NORTHERN MINERALS LTD
BROWNS RANGE RARE EARTH PROJECT



TAILINGS STORAGE FACILITY SUMMARY

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NORTHERN MINERALS LTD

BROWNS RANGE RARE EARTHS PROJECT

TAILINGS STORAGE FACILITY

SUMMARY REPORT

KP Job No. PE801-00241/01

CONTRACT
PROJECT CONTRACT

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CONTENTS **PAGE**

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CONTENTS **PAGE**

1. INTRODUCTION

The Tailings Storage Facility (TSF) and associated infrastructure for the Browns Range Project will form an Integrated Waste Landform (IWL) with the mine waste from open pits. The TSF will contain the comingled tailings from the beneficiation and hydrometallurgical processing plant at an approximately 90% to 10% split respectively. The location and embankment alignment of the proposed facility has been selected to make efficient use of natural topography and local mine waste availability while remaining remote from the majority of mining infrastructure.

Over the life of the operation, a total of approximately 6.3 Mt of tailings is expected to be produced over 10 years. The tailings will be thickened and then transferred via slurry pipeline at a range of 50 – 55% solids. Tailings will be deposited into the purpose built two celled paddock TSF where the solids will settle out, and excess water expelled during settling and rainfall runoff will be returned to the process plant for reuse subject to suitability of water quality. The facility will contain the 1 in 100 year Average Return Interval (ARI) 72 hour rainfall event with the decant not operational and still maintain adequate freeboard. The facility will be built in stages with the first stage designed to contain 1 year of tailings production at an embankment level of 455 m RL or approximately 8 m high. Future raises will be performed on a yearly or two yearly cycle to the final elevation of 470 m RL or 23 m high (similar to the maximum height of the natural topography on the south side). The TSF is classified as having a “Medium” hazard rating according to the Department of Mines and Petroleum (DMP) Code of Practice and was defined as Category 1 due to the maximum embankment height in accordance with the DMP Code of Practice – Tailings Storages in Western Australia (DMP, 2013). The TSF is classified as being a “High C” Consequence Category according to the ANCOLD Guidelines on Tailings Dams (May 2012).

2. DESIGN CRITERIA

The design objectives for the TSF are as follows:

- Permanent and secure containment of all solid waste materials.
- Maximisation of tailings densities using sub-aerial deposition.
- Removal and reuse of free water.
- Minimisation of seepage.
- Containment of extreme storm events within the TSF.
- Ease of operation.
- Rapid and effective rehabilitation.

A summary of the key policies and guidance documents used for the design of the TSF are summarised as follows:

- DME (now DMP) Guidelines on the Safe Design and Operating Standards for Tailings Storage, May 1999;
- DME (now DMP) Guidelines on the Development of an Operating Manual for Tailings Storage, October 1998;
- ANCOLD Guidelines on Tailings Dams, Planning, Design, Construction, Operation and Closure. May 2012;
- ANCOLD Guidelines on The Consequence Categories for Dams. October 2012;
- DMP Code of Practice – Tailings Storage Facilities in Western Australia 2013.

Design criteria and parameters adopted for the study are summarised in Table 2.1.

Table 2.1: TSF design criteria

DESIGN STANDARDS	
Storm Events:	**Design Application**
1:2 yr	Temporary diversion structures during construction.
100 yr/72 hr	Diversion channel erosion protection.
100 yr/72 hr	Diversion channel capacity.
100 yr/72 hr in addition to the maximum operating volumes for average climatic conditions	TSF stormwater storage capacity.
1:10,000 yr/72 hr storm event	Emergency spillway, if required.
A PMP intensity and 72 hr volume	TSF permanent spillway structure at closure.
EMBANKMENT STABILITY/EARTHQUAKE CRITERIA	
Earthquake Loading - Operating Basis Earthquake (OBE) - Maximum Design Earthquake (MDE)	• 0.03g (500yr event) • Maximum Credible Earthquake (MCE)
Stability Factors of Safety - Static - Seismic (OBE) - Seismic (MDE)	• 1.5 (minimum) (ANCOLD Guidelines (2012)) • 1.1 (minimum) (ANCOLD Guidelines (2012)) • Damage and deformation allowed (<freeboard allowance) - No release of tailings or water
WATER MANAGEMENT	
Supernatant Pond	• Minimum operating pond (target pond size) of 10,000 m^3 • TSF not designed to accommodate external water flows. Any additional flows require review of water management impacts prior to discharge.
OPERATIONS	
Capacity - Final - Starter	6.3 Mt of dry tails over 10 years. 0.63 Mt of dry tails – 12 months initial capacity.
Production Rate	0.63 Mtpa.
Production Days/Year	7800 hr/yr (89% availability).
Slurry Characteristics	50% - 55% solids by weight SG = 2.7. Final slurry settled density = 1.4 t/m^3. Permeability of: 1×10^{-7} m/s.
Facility Description	Two Cell facility (approximately 14 Ha per cell crest to crest) located at Site Option 4.
Fluid Management	Basin underdrainage system reports (via gravity) into a collection sump, pumped to supernatant pond. Decant tower removal of supernatant solution and surface runoff via pipeline to a tank at the plant. Rate of water return will depend on water quality to ensure that plant performance not affected. Decant tower located in centre of each basin area. A temporary decant tower may be located in the basin to expedite process water recycle during the first year of operation.

Table 2.1 (cont): TSF Design Criteria

DESIGN STANDARDS	
EMBANKMENTS (both cells)	
Construction	Upstream cut-off trench and toe drain. Zoned starter embankment constructed of mine waste and local borrow (sourced from within TSF basin where possible) with low permeability zone on upstream face. 8 m typical crest width (8 m for Stage 1).
Construction Materials	Remove unsuitable foundation soils from entire embankment footprint for use as embankment fill (if suitable). Low permeability material (Zone A) from borrow areas located within TSF basin where possible. Zone C from mine waste. Erosion Protection (Zone E) and coarse rockfill (Decant Zone G) may be sourced from screening of mine waste stockpiles. Other drainage material (e.g. filter sand (Zone F)) imported from off site.
TAILINGS BASIN	
Basin Liner	Geosynthetic Liner over entire TSF basin, to achieve overall average target seepage rate of less than 4 kL/ha/day for average operating conditions. Liner comprises the following: Compacted soil subgrade, comprising primarily in situ soils, scarified and re-compacted throughout the basin area to form a 150 mm thick soil subgrade. Where in-situ materials are unsuitable for subgrade, low permeability material (Zone A) will be won from basin area to provide the soil subgrade. 1.5 mm smooth HDPE geomembrane liner installed throughout the basin area to achieve overall seepage performance of less than 4kL/ha/day.
Tailings Underdrainage System	Main collector drains, branch drains and finger drains throughout TSF basin area, will collect seepage water from the tailings mass and discharge it to a lined collection sump to be pumped to the supernatant pond. Main Collector Drains - Corrugated, perforated tubing (with filter sock), surrounded by sand (Zone F1), wrapped in geotextile (continuously seamed or heat welded). Branch Drains - Corrugated, perforated tubing (with filter sock), surrounded by sand (Zone F1) and wrapped in geotextile (continuously seamed or heat welded).
Operation	Discharge from main embankment to form supernatant pond centrally. Recycle rate of supernatant water subject to water quality being suitable for plant operation. Excess supernatant water to be evaporated within TSF basin or used for other operational purpose where suitable. Underdrainage recovery pumped to tailings surface or operational purpose where suitable to improve tailings consolidation.
Monitoring	Monitoring bores downstream of embankment to monitor groundwater level and quality. Piezometers in embankments to monitor stability.
Closure	Tailings surface to be designed as store and release cover. Embankments to be progressively rehabilitated. Permanent structure designed to accommodate PMP event.

3. SITE DESCRIPTION

The following sections describe the site characteristics of the area with a focus on items which influence TSF site selection, design, operation and closure.

3.1 SITE LOCATION AND TOPOGRAPHY

The topography of the site comprises a series of sharply rising ridges and rock outcrops within an otherwise gently sloping area of approximately 1% gradient. The location of the proposed TSF slopes down gently from the east to the west and is remote from any distinct drainage features. Topography ranges from the lower flatter areas at R.L. 445 m up to localised peaks around R.L. 470 m. The proposed TSF is located in close proximity to the ore bodies, the process plant and proposed camp sites with a facility centroid of approximately latitude 18.90°S, longitude 128.95°E.

3.2 CLIMATE

Climate information for the project was obtained from a previous study report by Golder Associates. The site is located in a semi-arid climate with monsoonal influence being approximately 430 km inland from the coast. Rainfall is highly variable due to the influence of periodic summer cyclones but is on average 410 mm per annum. Peak rainfall occurs in the summer months of December to March with about 80% of the annual rainfall occurring. The highest annual rainfall recorded was 1107 mm and a minimum of 101 mm.

Short term intensity-frequency-duration (IFD) relationships for the location were obtained using the online model developed by Australian Bureau of Meteorology (BOM) and are a function of latitude and longitude. The rainfall from 100 year ARI 24 hour and 72 hour events were calculated as 210 mm and 291 mm respectively. A full data set is provided in Figure 3.1

The estimation of Probable Maximum Precipitation (PMP) at the site location and specific for the TSF catchment size was developed from publications produced by BOM. The PMP event is greater than a 1 in 100,000 year event. The rainfall for PMP 24 hour and 72 hour events were calculated as 1,037 mm and 1,888 mm respectively.

Evaporation isopleth maps of Australia are provided by BOM for both annual and monthly average evaporation. The data were interpolated from gauging stations with more than 10 years of record of Class A evaporation pan data.

The average annual and monthly rainfall and evaporation used in the design are presented in Table 3.1 and presented graphically in Figure 3.1. The data indicate that the site is water negative at all times of the year.

Table 3.1: Rainfall and evaporation data.

Month	Mean monthly rainfall (mm)	Mean monthly evaporation (mm)
January	98.4	278.6
February	112.0	225.6
March	55.8	241.7
April	14.7	224.7
May	10.0	189.1
June	5.3	157.8
July	5.9	174.0
August	3.1	218.9
September	3.6	269.1
October	14.8	320.2
November	26.3	314.5
December	60.3	301.2
Total	**410.2**	**2915.4**

3.3 WIND

The wind frequency analysis of the site based on the BOM station at Halls Creek Airport (station number 02012) shows a prevailing wind direction from the east. Design wind speeds for the area were estimated from AS1170.2 Structural Design Actions - Wind Actions based on location and wind direction. The Browns Range area is categorised as Region A4 (AS 1170.2 Figure 3.1) with resulting wind speeds based on a 3 second gust of 40.8 m/s.

3.4 SEISMICITY

The selected design peak horizontal ground acceleration adopted for the study at this stage was based on the 2012 Australian Earthquake Hazard Map developed from Geoscience Australia. The site is located in an area of low seismicity as shown in Figure 3.2. The assigned OBE value for seismic acceleration coefficient applicable to the site is approximately 0.03 g for a return period of 500 years. A general site assessment will be conducted in the next phase of design to determine the Maximum Design Earthquake (MDE) for closure and long term stability requirements.

3.5 HYDROLOGY

The project area is characterised by several small ephemeral streams that form part of the Sturt Creek drainage system. The Sturt Creek catchment ultimately drains into the Lake Gregory system located approximately 220 km south-west of the project. Streamflows in the region are generally ephemeral which are highly dominated by wet season storm flows with dry season flows contributing little to no flow to annual volumes. No significant drainage paths were identified for the TSF as it will be located at the head of the catchments with minor perimeter drainage required to manage sheet flow around the toe of the facility.

3.6 HYDROGEOLOGY

A groundwater study of the area was conducted by Klohn Crippen Berger (KCB). No groundwater was reported in the shallow testpits conducted as part of the site investigation by Golder. KCB indicated that groundwater levels around the Gambit Pits (east, central and west) located slightly to the north of the TSF range from R.L. 422 m to R.L. 448 m (depth from natural surface to groundwater level is typically 7 – 14 m with some areas at depths of up to 28 m).

3.7 REGIONAL AND LOCAL GEOLOGY

The Gordon Downs sheet of the 1:250,000 Geological Series published by the Geological Survey of Western Australia describes the geology surrounding the Browns Range site. The map indicates that the site is underlain by meta-arkoses and meta-sandstones of the Archaean-Early Proterozoic age as well as granitic gneisses and muscovite schists. Ultramafic intrusions are understood to occur within the metamorphic rocks. The map also indicates that the lower topography areas of the site are generally described as:

- Sand and silt, mainly aeolian and sheet wash deposits;
- Alluvium comprising sand, silt, gravel and clay in channels and on flood plains.

3.8 FLORA AND FAUNA

The vegetation in the region is mostly open grassy woodlands comprising Spinifex grassland, sparse bush and small trees. Vegetation becomes denser around drainage lines and creeks. The Lake Gregory system is located approximately 220 km south-west of the project and contains wetlands of national importance and is a significant site for domestic and migratory waterbird species.

3.9 HERITAGE

Two surveys have been conducted across the general area to date, primarily targeting areas associated with exploration activity for Browns Range. A detailed heritage survey of the area will be conducted prior to construction and the TSF will avoid “no-go” areas identified in consultation with the traditional land owners.

4. OPTION STUDIES

4.1 SITE SELECTION

A site selection study for the TSF was undertaken by Golder Associates in April 2013. A number of potential TSF sites were considered, taking into account existing infrastructure, lease boundaries and environmentally sensitive areas. The tailings disposal options considered:

- Paddock disposal on relatively flat areas;
- Side valley disposal in topographically appropriate valleys and ridgelines;
- Central thickened discharge on relatively flat areas.

In pit storage of tailings was not considered viable at this stage as the mineralisation continues below the current pit depths.

For the site selection study, four sites were evaluated as shown in Figure 4.1. Site 4 was selected as the preferred area for the TSF. This was based on consideration of surface conditions, haulage and pumping distance from the plant, constructability, proximity to other proposed infrastructure (while remaining downstream from a dam break perspective), wind direction and potential for expansion.

The location of the embankments is proposed to be optimised within the Site 4 area to form an integrated waste landform (IWL) with the local waste dumps and to avoid the rock outcrops on the southern extents of Site 4. As a result, a fully downstream embankment configuration was selected for the study with 3 sides buttressed against waste dumps. A nominal offset of 500 m from pits has been assigned for both blasting and stability purposes, while also remaining close enough for construction material sources and providing a localised sink for any groundwater seepage.

4.2 TAILINGS THICKENING CRITERIA

As discussed in the tailings characterisation section, various degrees of thickening of

- Paste tailings. Dewatered in a deep cone thickener to produce a “non bleeding” paste and transported with displacement pumps.

The paste option was eliminated due to both high capital costs and high operating costs as well as requiring a much larger footprint area to manage the deposition and surface water runoff control in the TSF. The embankment layouts, infrastructure and cost difference between conventional thickening and ultra-thickening was marginal, however conventional thickened tailings was the selected option due to more operational flexibility. An operational range of 50 – 55 % solids was selected.

5. HAZARD CLASSIFICATION

As part of the calculation of the hazard/consequence category of any facility, an assessment of the Population at Risk (PAR) needs to be undertaken for the selected location (ANCOLD, May 2012). There are a number of factors impacting the PAR calculation from water storage potential, tailings capacity, downstream topography, structures and their frequency of usage. A high level PAR value was determined for the selected location based on proximity of pits, plant site and village and a nominal dam break direction downstream. A PAR range of >1 to 10 was selected on the basis that only the proposed Gambit West Pit would be in the potential flow path from a dam break, but it would be protected by mining waste.

5.1 DMP HAZARD RATING

The TSF classification was assessed by the methods set out in the DMP Code of Practice for Tailings Storage Facilities in Western Australia (2013) to determine the category of the facility over the life of the project. The storage category was determined as >15m as the maximum final embankment height is 23 m, as a result, the facility is considered a “Category 1” facility.

5.2 ANCOLD CONSEQUENCE CATEGORY

An assessment was made of the severity level of impacts from a large scale failure of the facility. The severity table is obtained from ANCOLD (2012 Table 1) and presented in Table 5.1.

Table 5.1: ANCOLD Guideline on Severity Level

Damage Type	Severity Level
Infrastructure	Medium
Business Importance	Major
Public Health	Minor
Social Dislocation	Minor
Impact Area	Medium
Impact Duration	Medium
Impact on Natural Environment	Medium

Based on the PAR of >1 to 10 and the 'Major" severity level, the facility would be rated as High C. The PAR may need to be reassessed if the project design and construction develops to incorporate any new infrastructure or highly trafficked roads located downstream.

6. SITE INVESTIGATION

The subsurface conditions of the proposed TSF site were investigated as part of a site wide investigation presented in Golder Associates' report "Preliminary Geotechnical Investigation Report – Stage 1" Feb 2014. During the geotechnical investigation, a total of 5 test pits were excavated within the footprint of the proposed TSF location of which 3 were tested for soil properties. A summary of the test locations and laboratory results are presented in table 6.1.

Table 6.1: TSF Test Pit Laboratory Data.

Testpit ID	Sample Depth (m)	Soil Description	USCS	Particle Size Distribution (%)			Atterberg Limits	
				Gravel	Sand	Fines	LL (%)	PI (%)
TSF4TP-01	1.0 – 1.5	Clayey SAND	SC	0	74	26	15	8
TSF4TP-17	0.7 – 1.2	Clayey SAND	SC	0	70	30	17	9
TSF4TP-26	1.0 – 1.5	Clayey SAND	SC	31	44	25	23	13

The subsurface conditions can generally be summarised as follows:

- Silty SAND (SM) – fine to coarse grained, approximately 20% liquid limit from the ground surface to about 0.2m depth;
- Clayey SAND (SC) – fine to coarse grained, low plasticity clay, generally becoming weakly iron cemented with depth. Medium dense to very dense extending to depths ranging from 0.9 m to 2.1 m;
- GRAVEL/Sandy Clayey GRAVEL (GP/GC) – not encountered in all test pits. Fine to coarse grained low plasticity weakly to moderately cemented, very dense extending to a maximum depth investigated of 2.0 m.

7. TAILINGS CHARACTERISTICS

7.1 GENERAL

Preliminary physical and geochemical test work of tailings samples have been undertaken with the results reported in the following documents:

- "Browns Range Project – Preliminary Geochemical Assessment & Tailings" June 2014, Golder Associates;
- "Browns Range Project – Tailings Management Concepts * - Appendix B - * Tailings Geotechnical and Rheological Laboratory Testing" Dec 2013, Golder Associates.

The following interpretation of the tailings properties and associated liner requirements are based on the test data provided in these reports.

7.2 GROUNDWATER CONDITION

Information on groundwater water quality was obtained from boreholes in the site area. The water quality measurements are from sampling in 2013.

A comparison of the groundwater movements to Australian drinking water and stock water standards was made. Table 7.1 lists groundwater elements which exceed drinking water and/or stock water standards.

Table 7.1: Groundwater quality

Element	Average Value (mg/L)		Times Level of Exceedance			
			Drinking Water		Stock Water	
	Average	Median	Average	Median	Average	Median
TDS	2130	790	3.6	1.3*	0.54	0.20
Sulphate	367	79	1.5	0.3	-	
Aluminium	0.61	0.11	3.1	0.5	-	
Iron	0.96	0.31	3.2	1.03	-	
Manganese	0.16	0.020	1.6	0.20	-	
Uranium	0.023	0.003	1.8	0.15	-	

*Exceedance compared to median value.

Thus the average groundwater quality exceeds drinking water standards for 6 elements but only TDS is slightly exceeded for stock water standards.

The ground water quality assessment is that the ground water is generally suitable for ANZECC beef cattle standards but the quality does not meet drinking water standards.

7.3 TAILINGS PHYSICAL PROPERTIES

The tailings will consist of 90% flotation tailings and 10% hydromet tailings. Physical testing of a combined sample was undertaken by Golder (December, 2013). The testing included:

- Particle size distribution;
- Specific gravity;
- Settling tests;
- Air drying tests;
- Viscosity and thickening tests.

The sample was tested at 45% solids. The current disposal option is to discharge the tailings slurry at 50-55%% solids and where required the parameters have been adjusted.

The results used for design are summarised in Table 7.2.

Table 7.2: Tailings Physical Characteristics (at 51-53% solids)

Property	Estimated / Measured Value
SG solids (combined tailings)	2.67
P_{80} Flotation Tailings Hydromet Tailings	31 µm 68 µm
Plasticity Index (Combined Tailings)	14%
Supernatant Production (%) - Average - Range	 15 9 - 26
Maximum Underdrainage (%)	25
Achieved Density in Facility (t/m^3) - Drying Beach - Under Pond Area	 1.40 1.0
Permeabilities (m/s) - Dry Beach - Pond Area	 1×10^{-8} 1×10^{-7}

7.4 GEOCHEMICAL AND RADIOLOGICAL PROPERTIES

Geochemical and radioactivity measurements were evaluated separately for the flotation and hydromet samples. The primary results are as follows:

The geochemistry of the tailings was tested by Golder Associates (June 2014). The data was reviewed and demonstrates that:

i. The mixed tailings is not likely to be acid generating.

ii. The tailings solids have some elevated element concentrations.

iii. The tailings liquor is marginally poorer than ANZECC livestock standards.

On the basis of these points, it is concluded that the mixed tailings liquor may cause a marginal deterioration in the overall groundwater quality if released to the environment.

Measurements of radioactivity for various radionuclides were undertaken by ANSTO and assessed by JRHC. A summary of the radionuclide concentrations in the tailings solids are provided in Table 7.3.

Table 7.3: Radioactivity assessment – Solids (Bq/g)

Radionuclides	Calculated Bene Tailings Value	Calculated Hydromet Tailings Value	Combined (Ratio 90:10) *	Radioactive Classification Criteria **
Uranium 238	0.3	0.6	0.3	1
Thorium 230	0.3	1.9	0.4	
Radium 226	0.3	3.1	0.6	
Lead 210	0.3	3.1	0.6	
Thorium 232	0.1	0.3	0.1	
Radium 228	0.1	0.6	0.1	
Thorium 228	0.1	0.3	0.1	
Uranium 235	0.02	0.02	0.02	

* Refers to a final tailings mixture of 90% beneficiation (bene) tailings and 10% hydrometallurgical plant tailings.

** Note that for a material to be classified as “radioactive”, the combined head of chain activity (Uranium 238, Thorium 232 and uranium 235) must exceed 1Bq/g. Where material is not in secular equilibrium, a mixture method is recommended by ARPANSA. The classification criteria shown here refers to the head of chain criterion.

The combined tailings stream does not exceed the criterion for being defined as a radioactive material and is therefore classified as not radioactive.

7.5 SUMMARY OF TAILINGS ASSESSMENT

On the basis of the tailings properties the tailings facility should be design to achieve an overall seepage rate of 4 kL/ha/day or less. In order to achieve this performance standard it is envisaged that the insitu soils will be scarified and recompacted to form a 150 mm thick liner subgrade. HDPE liner will be installed above the soil liner throughout the basin area and underdrains will be constructed within the basin area so that the overall seepage performance standard is achieved.

At closure a suitable cover will be required to prevent loss of solids.

8. FACILITY DESCRIPTION

The TSF will be combined with waste rock from some of the open pits to form an integrated waste landform (IWL). The facility will consist of a two cell multi-zoned downstream perimeter embankment, forming a total footprint area of approximately 28.0 ha for the Stage 1 TSF increasing to 36.4 ha for the final TSF (internal crest area of 23.5 ha Stage 1 to 30.1 ha Final TSF). General arrangements for the TSF (Stage 1 and Final) are shown on Drg. No. 801-241-C001-006 Rev A.

The facility will comprise of two square shaped paddock storage cells located on a naturally sloping basin. The Stage 1 embankment and subsequent stages will be constructed downstream with 3 embankments located against mine waste dumps. The embankments will be zoned with an upstream low permeability zone and downstream structural zone.

The Stage 1 embankment will provide for 1 year of deposition between two cells, and the embankments will typically be raised every year or two years depending on mine waste production.

The embankment will have an 8 m crest, upstream slope of 1V:2H and a downstream slope of 1V:3H. The zones in the embankment consist of an upstream low permeability zone (Zone A) and a downstream structural zone (Zone C). The design is based on Zone C being placed directly from the open pit mining operations. For Zone A, lifts will be constructed out of local borrow, winning from mine waste stockpile or utilising mine waste directly.

A soil subgrade will be constructed over the entire TSF basin area comprising insitu soils scarified and recompacted. An HDPE geomembrane liner will be installed in the basin area to meet the overall seepage rate objective. The low permeability soil liner will comprise 150 mm depth of low permeability soil (reworked in-situ material). The liner system will be constructed to achieve a target seepage rate of less than 4 kL/ha/day.

The design incorporates a basin underdrainage system over the entire TSF basin to reduce pressure head acting on the basin liner, reduce seepage, increase tailings densities, and improve the geotechnical stability of the facility. The underdrainage system comprises a network of finger, branch and collector drains. The underdrainage system drains by gravity to a collection sump.

Some supernatant water will be removed from the TSF by natural evaporation or via submersible pumps located within the decant tower (constructed and raised during operation). Solution recovered from the decant system will be pumped back to the plant for re-use in the process circuits, subject to process water quality requirements. The rate of removal will be controlled to ensure it is suitable for the plant and excess water will be evaporated from the TSF.

9. WATER MANAGEMENT

A high level water balance was conducted to demonstrate the facility remains in negative balance and that the facility is designed to contain the 100 year ARI 72 hour rainfall event without the risk of overtopping.

9.1 WATER BALANCE

The process plant requires approximately 72.7 tph of makeup water in order to generate the tailings slurry to 52% solids w/w. Of this, approximately 15% of the water in the slurry reporting to the TSF is expected to be released and available for recycle back to the plant. An average decant rate of 11 tph is expected with higher values experienced during the wet season and potentially zero return in the dry season. On a monthly basis, the evaporation potential exceeds rainfall by at least double, indicating only short term storm events with the decant not operational will cause a short term increase in the supernatant pond.

A design storm of 100 year ARI and 72 hour duration results in approximately 44,000 m^3 of runoff in each cell. The storage capacity on the tailings surface for each cell ranges from 70,000 m^3 in stage 1 to 90,000 m^3 in the final stage as the facility increases in size. The storm storage assessment assumes the waste dump does not contribute runoff to the TSF.

9.2 STORM EVENT STORAGE CAPACITY AND SPILLWAY

During operation sufficient freeboard will be provided to hold the PMP 24 hour event. Thus no operational spillway is required.

After closure and placement of the cover layers the facilities will operate with a store and release cover. A PMF capacity spillway will be provided to discharge any longer duration events or longer term accumulation of water either to the environment or to the open pits.

9.3 SURFACE WATER

The TSF is located to ensure that no upstream ponding will occur due to natural creek flow or surface water runoff from the hills to the south. Runoff will be channelled along the southern embankment to discharge into the original catchment to ensure minimal disruption to total flows downstream.

10. CONSTRUCTION

Construction for each stage of the embankment will be conducted by a dedicated earthworks contractor and will utilise mining operations for material source and delivery. A dedicated construction management team, technical supervision and quality assurance/quality control (QA/QC) will be carried out for each stage of construction to ensure the facility is constructed as the design intent and in accordance with DMP requirements. The construction materials required are summarised in Table 10.1.

Table 10.1: Summary of Construction Materials

TYPICAL ZONE SPECIFICATION SUMMARY		
ZONE TYPE	ZONE DESCRIPTION	COMPACTION SPECIFICATION
ZONE A	LOW PERMEABILITY FILL FROM BASIN OR MINE WASTE	98% SMDD -2% <OMC < +3% 150 - 300mm LAYERS
ZONE B	TRANSITION FILTER ZONE (IF REQUIRED BETWEEN A AND C)	95% SMDD -2% <OMC < +2% 300mm LAYERS
ZONE C	MINE WASTE	95% SMDD -2% <OMC < +2% 500 mm LAYERS
ZONE D	RANDOM FILL	92% SMDD 700mm LAYERS
ZONE E	EROSION PROTECTION	D_{MAX} = 300mm % FINES <5
ZONE F(SAND)	DRAINAGE MEDIUM (SAND OR FINE GRAVEL)	UNIFORM DENSITY FREE FROM CAVITIES
ZONE G	SELECTED ROCKFILL	D_{MAX} = 500mm % FINES < 5 D_{AVG} = 50 mm
CLEAN GRAVEL	SELECTED FILL	D_{MAX} = 50mm % FINES < 5
EMBANKMENT FOUNDATION	IN-SITU MATERIAL AS APPROVED BY THE ENGINEER	95% SMDD -1% <OMC < +3%
WEARING COURSE	SELECTED GRAVEL	95% SMDD -3% <OMC < +2% 150mm LAYERS
BASIN SOIL SUBGRADE	LOW PERMEABILITY FILL FROM BASIN AREA	98% SMDD -2% <OMC < +3% 150 - 300mm

The majority of Zone A low permeability material will be sourced from the basin or delivered to a stockpile from the open pit mine waste. Zone C material will be hauled directly from the open pit to the embankment by the mining fleet. A summary of the construction sequence is:

- Zone A will be used for the embankment cutoff trench backfill and TSF perimeter embankment upstream low permeability zone. Material will be paddock dumped by the mining fleet and spread, moisture conditioned and compacted by the TSF construction civil contractor or won from borrow/stockpiles.
- TSF basin low permeability subgrade will be scarified, moisture conditioned and re-compacted basin material by the TSF construction civil contractor.
- TSF decant materials will be stockpiled by the mining fleet as close as possible to the final locations, and won, placed, spread, moisture conditioned and compacted by the TSF construction civil contractor.
- Zone C will be paddock dumped, spread and traffic compacted by the mining fleet, with a compactor used within the 20 m width directly adjacent to Zone A.

11. OPERATION

11.1 DEPOSITION OBJECTIVES

The tailings deposition strategy is designed and will be managed throughout the life of the facility to meet the following objectives:

- Maintenance of freeboard against the upstream embankment face;
- Deposition to improve sub-aerial deposition and consolidation of tailings;
- Deposition to effectively utilise the net available storage capacity;
- Effective management of the size and location of the supernatant pond;
- Reduce the volume of water stored on the facility at any time;
- Reduce the operating costs of the tailings distribution system;
- Reduce down time by providing operational flexibility;
- Facilitate the implementation of the storage closure strategy;
- Reduce potential for dust generation.

11.2 DEPOSITION TECHNIQUES

The deposition of tailings into the facility will be sub-aerially from the perimeter embankments into two facility cells. The tailings delivery pipeline will run from the Plant Site to the TSF perimeter embankment crest in a bunded trench. Deposition will occur from multiple spigots inserted along the tailings line. The deposition location(s) will be moved progressively along the delivery line as required to control the location of the supernatant ponds. After initial establishment of the tailings beaches, a suitable cycle time will be determined in order to evenly deposit the tailings around the facility, thereby maintaining the supernatant ponds at the decant tower.

A degree of segregation of the tailings will occur against the embankment, promoting de-watering of the tailings through the toe drain and thus enhancing stability, consolidation and reducing basin drainage. Tailings deposition will then be moved either side of this initial point to line the basin area whilst controlling the location of the supernatant pond.

The proposed tailings deposition method is the sub-aerial technique. Sub-aerial deposition allows for the maximum amount of water removal from the facility by the formation of a large beach for drying and draining. Together with keeping the pond size small, sub-aerial deposition should increase the settled density of the tailings, and hence improve the storage potential and efficiency of the facility.

The tailings will generally be deposited from along the distribution pipeline in such a way as to encourage the formation of beaches over which the slurry will flow in a laminar non-turbulent manner. The solids will settle as deposition continues and water will be released to form a thin film on the surface of the tailings.

Deposition of the tailings will be conducted on a cyclic basis with the tailings being deposited over one area of the storage until the required layer thickness has been built up. Deposition will then be moved to an adjacent part of the storage to allow the deposition layer to dry and consolidate, thus facilitating maximum storage to be achieved over the entire area.

12. MONITORING

Monitoring will be conducted during operations in accordance with a documented tailings operation strategy. This monitoring will comprise three basic types. These are:

- Operation monitoring/ planned observations.

This will include items such as spigot offtake location, whether pipe joints are leaking, supernatant pond location etc. This monitoring is directed at ensuring that the facility is operating smoothly.

- Compliance monitoring.

This includes items such as checking survey pins for movement, monitoring bores for contamination, piezometer levels etc. This monitoring is required to ensure that the project is meeting all its commitments in regard to a safe and secure operation.

- Performance monitoring.

This will include items such as tailings level surveys, all critical flow measurements, water balance calibrations etc. This monitoring is necessary to assess the performance of the facility and refine future embankment lift levels and final extents.

As per Western Australian regulation, the facility will require annual audits by a suitably qualified geotechnical engineer to ensure that the facility is operating in a safe and efficient manner. The audit should include a review of the above monitoring compliance and compare them to the design to ensure selected parameters are validated during operation.

13. REHABILITATION AND CLOSURE

At the end of the operation of the TSF, the downstream faces of the TSF perimeter embankment will have a maximum slope of 3H:1V (18°). The adopted downstream profile will be geotechnically stable under both normal and seismic loading conditions, will provide a stable drainage system, and will allow for re-vegetation.

During the operation, deposition will occur from the perimeter embankments with the low point on the tailings surface being at the centre of each cell at the decant location. After decommissioning the operating plant the underdrainage system will need to continue to operate for some time to drain excess water from the tailings deposit. The quantity of water recovered from the underdrainage system will reduce with time and experience with similar facilities suggests that water recovery may continue for a period of several years following closure. During this time, water from the underdrainage will be pumped back onto the tailings surface for evaporation.

The final shape of the tailings surface will be two conical depressions. It is envisaged that the cover design will comprise a store and release cover underlain, if required, by a capillary break. The proposed capping configuration will be reviewed during operation based on the in-situ tailings characteristics and available materials on site.

The nominal design of the cover is as follows:

- A base layer placed to facilitate access to the surface. For the bulk of the tailings surface it is anticipated that when fully dried the tailings will have sufficient strength to support equipment over this cushion layer. A nominal allowance of 500 mm of clayey sand material has been assumed;
- A capillary break layer of coarse gravel / rockfill material to block migration of any salts etc from the tailings into the upper layer of the cover. If the grading of the base layer is suitable this layer could work as a capillary break.
- A store and release layer. Based on the low rainfall and high evaporation a relatively thin store and release layer will be required. Thus an allowance of between 500 mm and 1000 mm is considered suitable. Suitable mine waste will be selected which is both erosion resistant and provides suitable storage characteristics;
- A growth medium surface layer. The upper 150 mm would be lightly ripped topsoil reclaimed from stockpiles to form a rock mulch and promote vegetation growth.

14. REFERENCES

1. Browns Range Project – Preliminary Geotechnical Investigation Report – Stage 1” February 2014, Golder Associates.

2. Browns Range Project – Tailings Management Concepts, February 2014 Golder Associates.

3. Browns Range Project – Tailings Geotechnical and Rheological Laboratory Testing, December 2013, Golder Associates.

4. Institute of Engineers Australia – National Committee for Water Engineering. “Australian Rainfall and Runoff – A Guide to Flood Estimation”, Volume 1 and 2, 1987.

5. Guidelines on the Safe Design and Operating Standards for Tailings Storage - DME, May 1999

6. Guidelines on the Development of an Operating Manual for Tailings Storage - DME, October 1998

7. Guidelines on Tailings Dams, Planning, Design, Construction, Operation and Closure – ANCOLD, May 2012

8. Guidelines on The Consequence Categories for Dams – ANCOLD , October 2012

FIGURES

DRAWINGS

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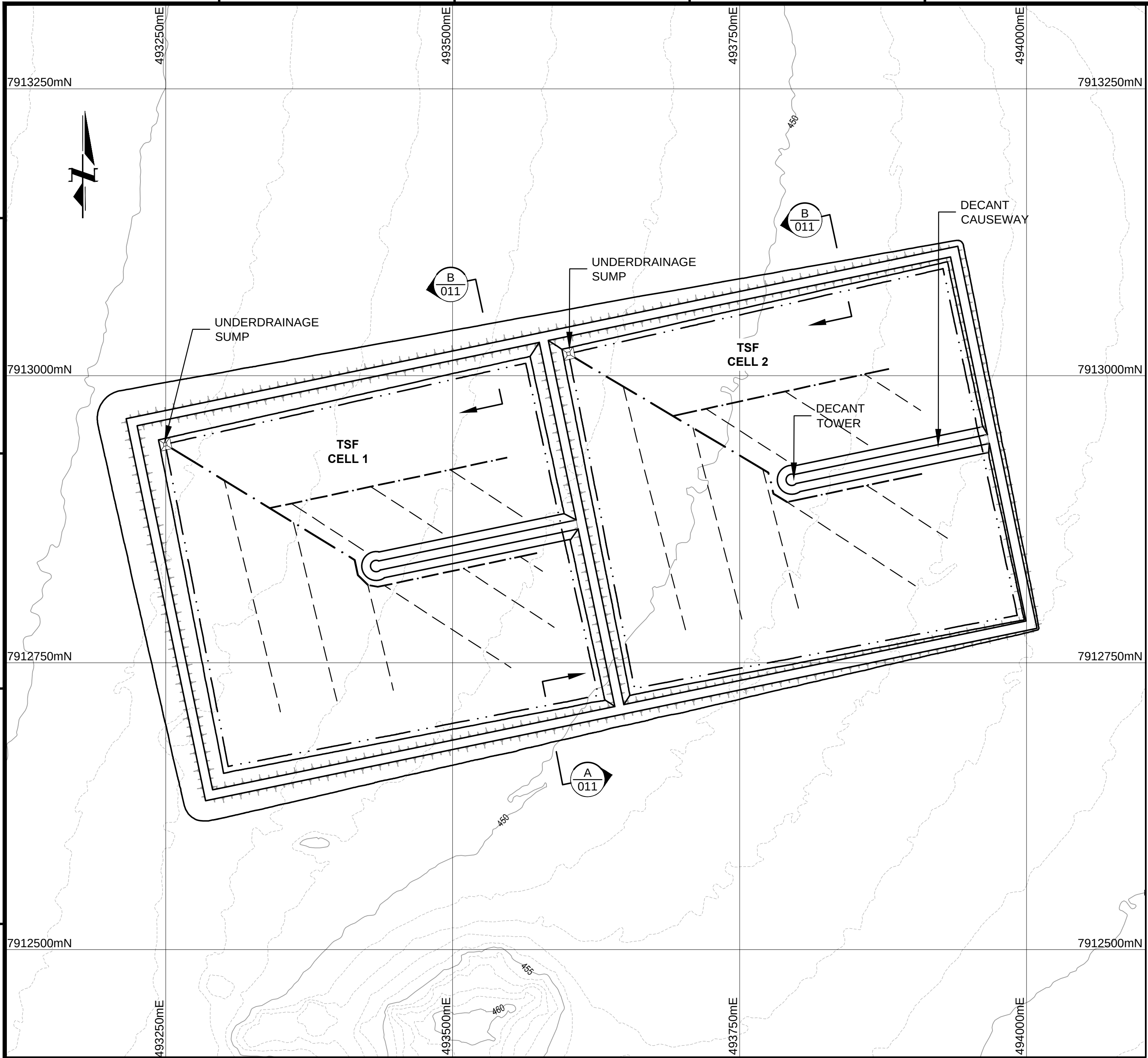
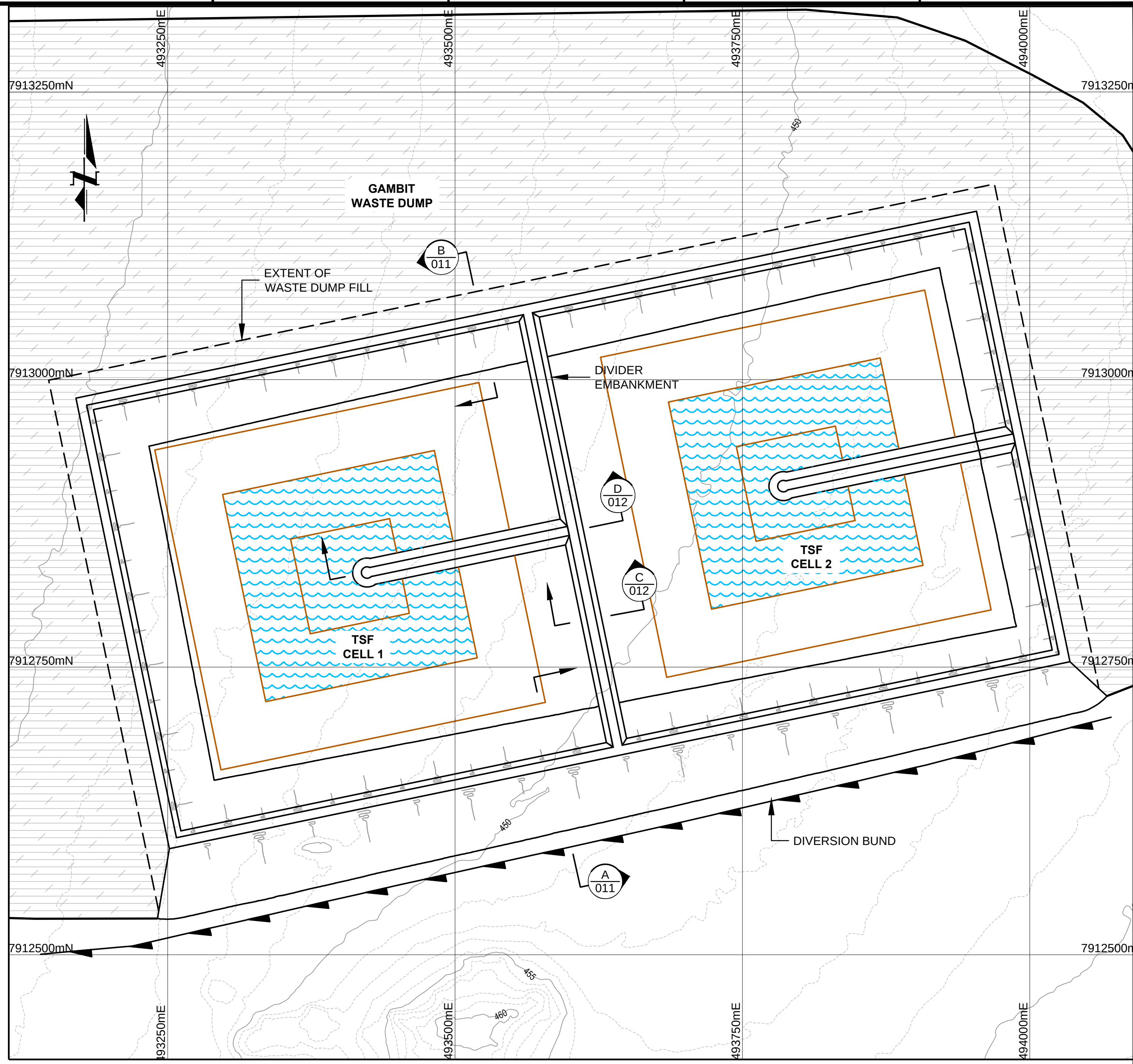


STAGE 1 GENERAL ARRANGEMENT

SCALE 1:5,000



FINAL STAGE GENERAL ARRANGEMENT

SCALE 1:5,000

NOTES:

1. PRELIMINARY SITE LAYOUT PROVIDED BY NML SHOWN AND IS SUBJECT TO CHANGE.
2. UNDERDRAINAGE LAYOUT INDICATIVE ONLY.
3. 1m CONTOUR INTERVALS SHOWN. CONTOURS PROVIDED BY NML.

LEGEND:

- TOE DRAIN
- MAIN COLLECTOR
- BRANCH DRAIN
- FINGER DRAINS
- TAILINGS BEACH CONTOURS
- SUPERNATANT POND
- SURFACE WATER BUND

SCALE (METRES) 100 75 50 25 0 50 100 150 200 1:5,000 (A3)

SHEET SIZE A3

REFERENCES	
801-241-C0001-011	TYPICAL SECTIONS AND DETAILS - SHEET 1
801-241-C0001-012	TYPICAL SECTIONS AND DETAILS - SHEET 2
DRAWING No.	DRAWING TITLE

REV	DATE	DESCRIPTION	DRN	CKD	DESIGN	APP	CLIENT APP
A	25/03/2014	ISSUED FOR REVIEW	PRK	DSS	DSS	DJTM	
B	04/04/2014	ADDED LABELS, REVISED TSF	PAN	DSS	DSS	DJTM	
C	06/04/2014	REVISED TSF DRAINS	PAN	DSS	DSS	DJTM	
D	07/04/2014	REVISED TSF AND WASTE DUMP EXTENT	JJT	DSS	DSS	BAS	
E		REVISED NOTES	PAN				

ORIGINAL STAMPED IN RED

DATE	CHECKED	DESIGNED	APPROVED	CLIENT APP'D

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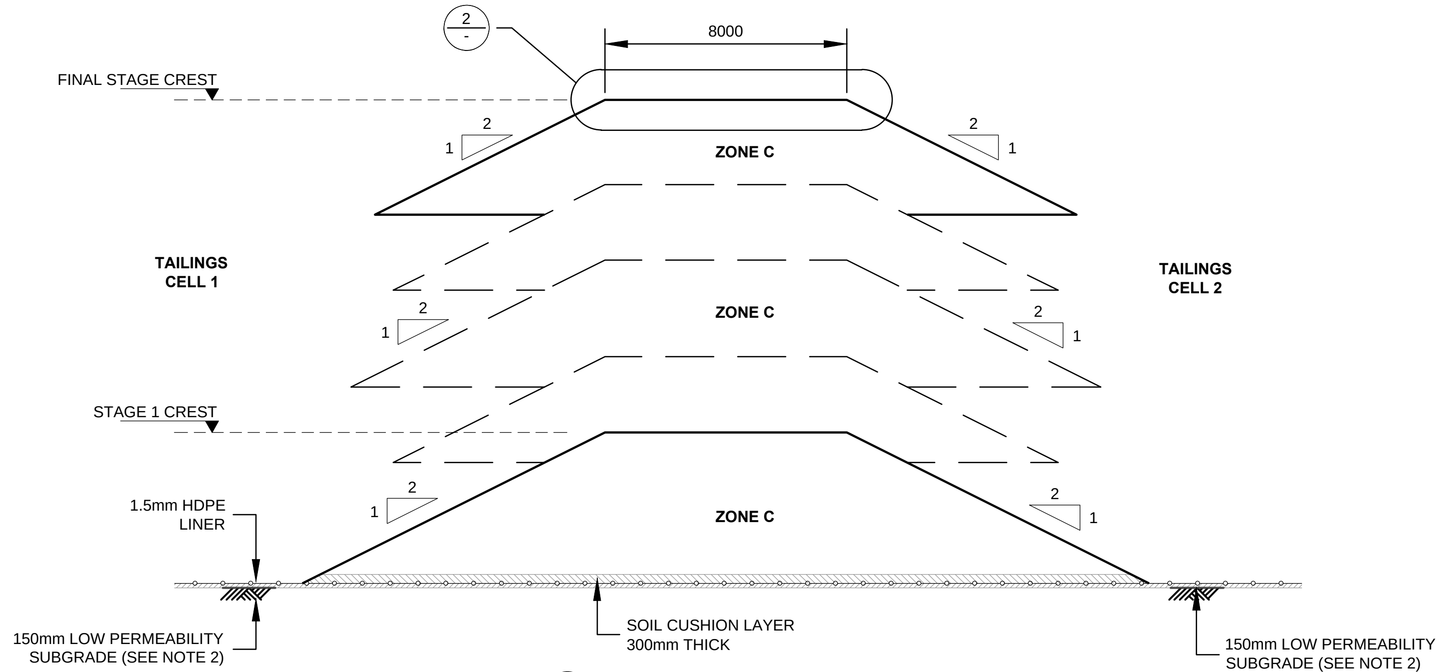
THIRD ANGLE PROJECTION

NORTHERN MINERALS LTD.
BROWNS RANGE PROJECT
TAILINGS STORAGE FACILITY
STAGE 1 AND FINAL GENERAL ARRANGEMENT

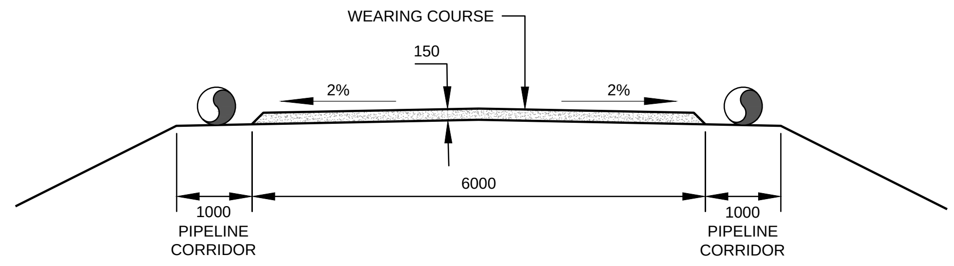
SCALE 1:10,000
STATUS IFR
DRAWING NUMBER **801-241-C001-006**
REV **E**

NOTES:

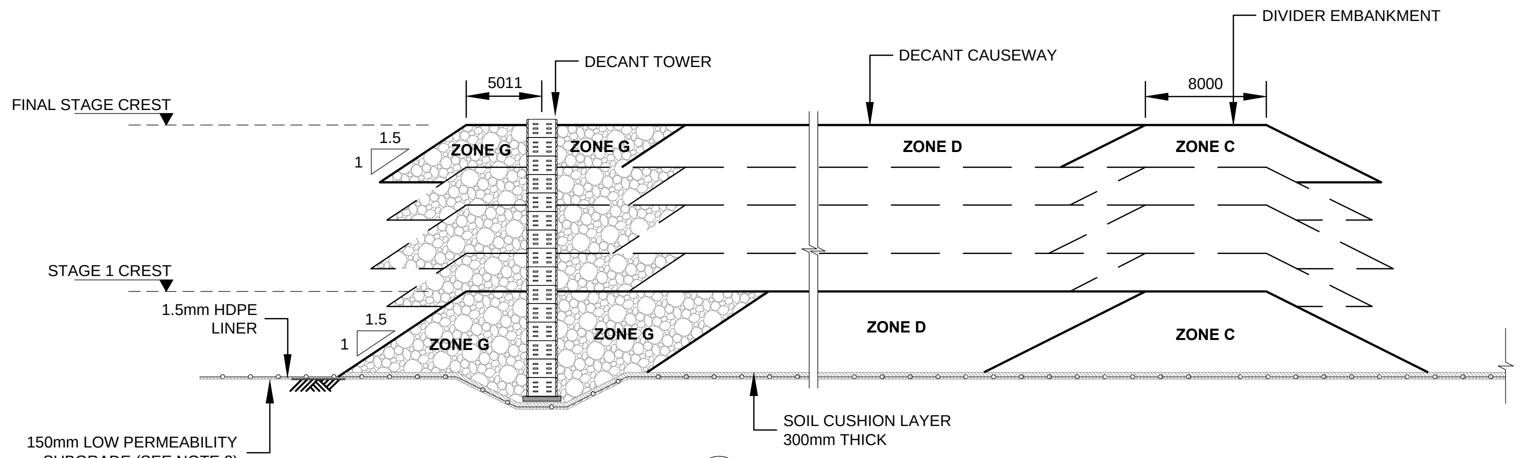
1. BREAKS IN SAFETY BUND AT 50m CENTRES (TO ALLOW DRAINAGE OF RAINFALL RUNOFF).
2. LOW PERMEABILITY SUBGRADE IN TSF BASIN AREA CONSISTS OF IN-SITU MATERIAL RE-WORKED TO COMPACT TO 150mm DEPTH.



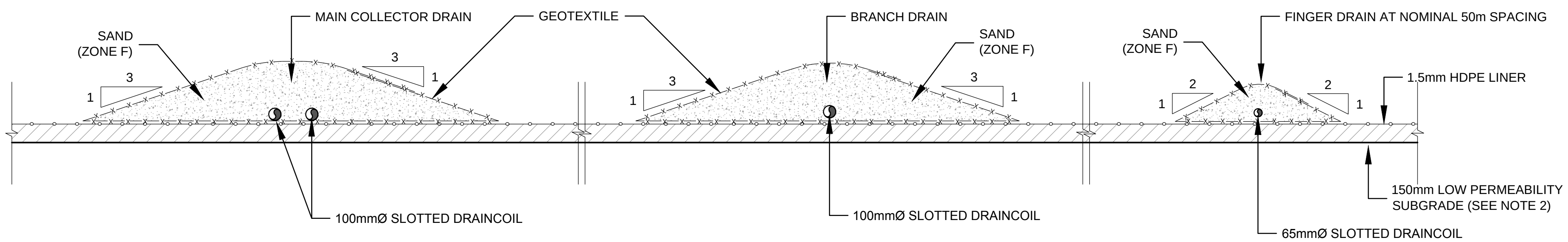
SECTION C/006 TYPICAL TSF DIVIDER EMBANKMENT
SCALE 1:250



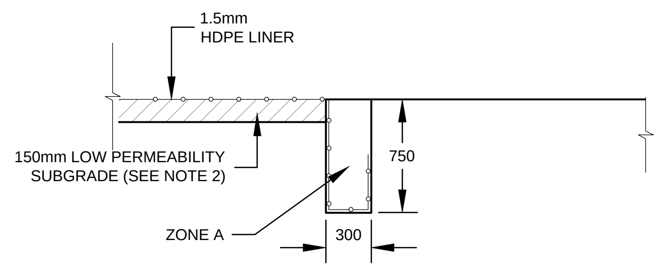
DETAIL 2/- TYPICAL DIVIDER EMBANKMENT CREST
SCALE 1:100



SECTION D/006 DECANT TOWER AND CAUSEWAY
SCALE 1:500



DETAIL 1/- BASIN LINER (HDPE)
SCALE 1:50



DETAIL 3/- HDPE LINER ANCHOR TRENCH
SCALE 1:50

FOR INFORMATION ONLY
ORIGINAL STAMPED IN RED

DATE	CHECKED	DESIGNED	APPROVED	CLIENT APP'D

REFERENCES DRAWING No.	DRAWING TITLE
801-241-C001-006	STAGE 1 & FINAL GENERAL ARRANGEMENT

REVISIONS

REV	DATE	DESCRIPTION	DRN	CKD	DESIGN	APP	CLIENT APP
A	25/03/2014	ISSUED FOR REVIEW	PRK	DSS	DSS	DJTM	
B	04/04/2014	ISSUED FOR PRE-FEASIBLITY SUBMISSION	AZ				
C	07/04/2014	REVISED DETAILS 3, 4 & 5	PAN				
D		REVISED LINER DETAILS	PAN				

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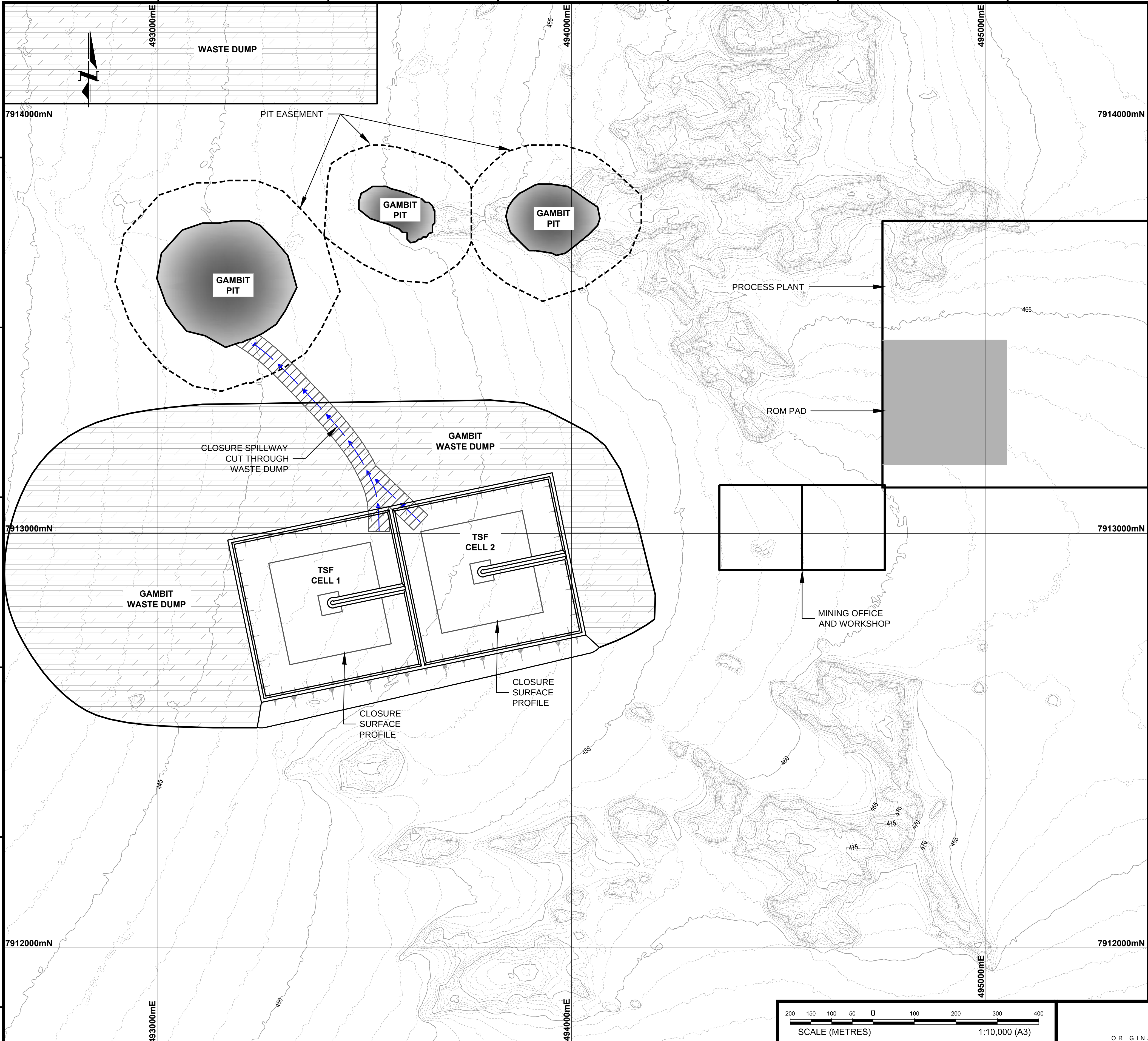
THIRD ANGLE PROJECTION

NORTHERN MINERALS LTD.
BROWNS RANGE PROJECT
TAILINGS STORAGE FACILITY
TYPICAL SECTIONS AND DETAILS - SHEET 2

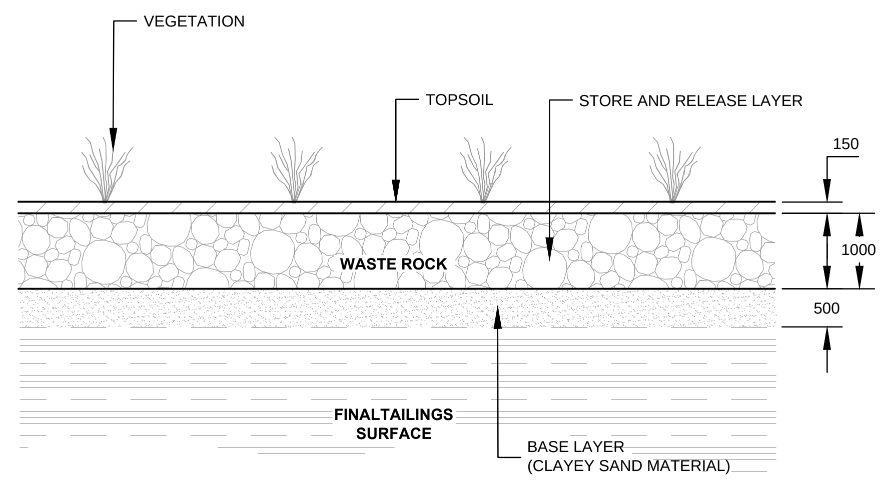
SCALE AS SHOWN
STATUS IFR
DRAWING NUMBER **801-241-C001-012**
REV **D**

SHEET SIZE A3



NOTES:

1. PRELIMINARY SITE LAYOUT SHOWN AND IS SUBJECT TO CHANGE.



TYPICAL CLOSURE CAPPING
SCALE 1:100

REV	DATE	DESCRIPTION	DRN	CKD	DESIGN	APP	CLIENT APP
A	25/03/2014	ISSUED FOR REVIEW	PRK	DSS	DSS	DJTM	
B	04/04/2014	ADDITIONAL LABELS	PAN	DSS	DSS	DJTM	
C	06/04/2014	REVISED TSF AND WASTE DUMP EXTENT	JJT	DSS	DSS	BAS	

DRAWING No.	DRAWING TITLE

SHEET SIZE A3 — REFERENCES

DATE	CHECKED	DESIGNED	APPROVED	CLIENT APP'D

ORIGINAL STAMPED IN RED

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THIRD ANGLE PROJECTION

NORTHERN MINERALS LTD.
BROWNS RANGE PROJECT
TAILINGS STORAGE FACILITY
CLOSURE GENERAL ARRANGEMENT

SCALE AS SHOWN
STATUS IFR
DRAWING NUMBER **801-241-C001-008**
REV **C**