Knight Piésold CONSULTING

MEMORANDUM

To:	**Venturex Resources Pty Ltd**	**Date:**	22 January 2020
Attn:	Piers Goodman	**Our Ref:**	PE20-00063
		KP File Ref.:	PE801-00300/12-A sjs M20002
cc:	Brad Walker	**From:**	Simon Smith

RE: SULPHUR SPRINGS ZINC-COPPER PROJECT – TAILINGS STORAGE FACILITY PRELIMINARY CONCEPT DESIGN REV. 1

1. INTRODUCTION

A number of options for management of the tailings and excess de-watering water streams have been considered by different proponents during the course of the project history. The Definitive Feasibility Study (DFS) (Ref. 1) tailings storage facility (TSF) is located in the valley north of the plant infrastructure and was designed to store 8.48 Mt of tailings and 5.31 GL of excess de-watering water over the life of the project.

Following meetings with the Environmental Protection Authority (EPA) and the Department of Mines, Industry Regulation and Safety (DMIRS) during the last quarter of 2019, Venturex engaged Knight Piésold Pty Ltd (KP) to carry out a concept design for an alternative TSF location occupying the catchment to the south-east of the proposed open pit.

This memorandum presents a preliminary concept design for the alternative TSF location and supersedes memorandum PE20-0042 dated 17th January 2020.

2. TSF CONCEPT DESIGN

2.1 GENERAL

The project site lies within three surface water catchments, Sulphur Springs Creek (SSC), Minnieritchie Creek (MRC), and Six Mile Creek (SMC). Each of these catchments were de-lineated into sub-catchments (as part of previous phases of work), SSC1 to 8, MRC1 to 7, and SMC1 to 6. In addition, the catchments contributing directly to the open pit, Pit Shell Catchments PSC1 to 6, were de-lineated. The proposed open pit intersects the drainage course of Sulphur Springs Creek and is situated at the foot of the Sulphur Springs Creek catchment (PSC5).

The DFS infrastructure design incorporated a pit diversion dam directly to the south-east of the pit shell to intercept rainfall run-off from the upstream catchment as a means to reduce the risk of flooding the open pit workings during operations. The alternative TSF concept uses the PSC5 catchment as a tailings storage facility, in effect replacing the pit diversion dam and the requirement to actively manage the catchment diversion post-closure.

2.2 TSF CONSEQUENCE/HAZARD ASSESSMENT

A significant failure of any of the TSF embankments would result in a release of tailings and/or water, though the extent and magnitude of the release would depend on the location of the breach, its size and the cause. For the alternative TSF location a breach of the main embankment would result in a tailings flow slide into the open pit whilst a breach of the southern saddle dam (based on the assessment carried out for the DFS) would likely result in a flow slide predominantly to the east into the Minnieritchie Creek catchment and then flowing to the north.

The hazard rating of a facility is derived by considering the potential impacts of a significant embankment breach and resulting release of tailings slurry in terms of safety, environmental and economic factors. The assessment presented herein is an initial assessment only and will need to be developed in more detail during subsequent design phases to confirm the assigned hazard rating.

In accordance with the DMIRS Code of Practice, “Tailings storage facilities in Western Australia” (Ref. 2), the TSF is classified as “Category 1” regardless of its hazard rating, on the basis that the facility will reach a final embankment height in excess of 15 m. This categorisation requires specific supporting documentation, design approach, construction control, operating procedures and rehabilitation approach to ensure it is safe, stable, erosion-resistant and non-polluting throughout its lifecycle.

A high level assessment of consequence category has been carried out with reference to the ANCOLD “Guidelines on the Consequence Categories for Dams” (Ref. 3). The severity of damage and loss resulting from the dam failure together with the assessed population at risk and probable loss of life are used to determine the consequence category. The severity level impact is assessed to be Major due to a potentially Severe to Crippling impact on the business as a result of a dam failure into the open pit. In addition the Population at Risk (PAR) is estimated to be >10-100 based on an estimated 20-35 persons working in the open pit at any time. It is understood that the access portal to the underground workings will originate in the process plant valley and therefore the PAR will be limited to those personnel working in the open pit up to cessation of open pit mining in Year 5.

A summary of the consequence/hazard assessment and derivation of the facility consequence categories is presented in Table 2.1. On the basis of the assessment provided the TSF is rated as a ‘High B’ consequence category facility. The design criteria applicable to this category are drawn from the ANCOLD “Guidelines on Tailings Dams” and are summarised in Table 2.2.

Table 2.1: Assessment of consequence category (PAR) (ANCOLD 2019)

Embankment	Population at Risk (PAR)	Severity of Damage and Loss			
		Minor	Medium	Major	Catastrophic
North Embankment	≥10 < 100	High C	High C	**High B**	High A

Table 2.2: ANCOLD design criteria summary

Guideline Requirement	Description of requirements – High B*	Guideline Reference
Extreme storm storage	1 in 1,000 year AEP 72 hour duration storm with no release, evaporation or decant.	ANCOLD 2019 Table 4
Contingency freeboard	Wave run-up associated with a 1:50 AEP wind velocity and an additional freeboard of 0.5 m	ANCOLD 2019 Table 5
Spillway capacity	1 in 100,000 year Annual Exceedance Probability (AEP) design flood with freeboard allowance to suit wave run-up for 1:10 AEP wind velocity or PMF	ANCOLD 2019 Table 6
Design earthquake loading	OBE 1 in 1,000 AEP SEE 1 in 5,000 AEP Post Closure MCE	ANCOLD 2019 Table 7
Stability minimum factor of safety	Long term drained 1.5 Short term undrained • Downstream 1.5 • Upstream 1.3 Post Seismic 1.0 – 1.2	ANCOLD 2019 Table 8
Dam safety/ inspection frequency	Comprehensive inspection by Dams Engineer and Specialist (where relevant) after first year of operation, then every 2 years Intermediate inspection by Dams Engineer annually. Routine inspections – daily to 3 times per week by operations personnel/inspector.	ANCOLD 2019 Tables 9 and 10

*consequence category

3. DESIGN PARAMETERS

The total ore production from open cut and underground is 12.5 Mt. The proposed plant throughput rate is 1.25 Mtpa. Copper and Zinc transition ore will be processed for the first 2.5 years with proposed concentrate extraction of 7% and 12% respectively giving a tailings production rate ex plant of 1.135 Mtpa. Subsequently, fresh ore will be processed with proposed concentrate extraction of 18% giving a tailings production rate ex plant of 1.025 Mtpa for the remainder of the mine life. During the underground production phase some tailings, estimated as a total tailings tonnage of 0.21 Mt, may be used for mine backfill. However, this has not been confirmed and is disregarded for the purposes of the TSF design. The TSF design was based on the production data as detailed in Table 3.1. The design criteria and standards adopted for design of the TSF are presented in Table 3.2.

De-watering, mining, processing, and operation of the TSF will commence at different times and operate for different periods. Table 3.3 summarises the timing of each project component.

Table 3.1: TSF process design criteria

DESIGN COMPONENT/VALUE	PERIOD		TOTAL
PROCESSING DATA	Year 0 to 2.5	Year 2.5 to 10	
• Ore Production (Mt)			12.5
Copper/Zinc transition	3.1	-	3.1
Fresh	-	9.4	9.4
• Plant throughput (Mtpa)	1.25	1.25	
• Concentrate extraction (%)	7-12	18	
• Mine backfill (Mt)	0	0.21^	-
• Tailings production (Mtpa)	1.135	1.025	-
TSF			
Storage Capacity - Final (10.53 Mt of dry tails over 10 years)	2.84	7.69	10.53
- Starter (1.14 Mt of dry tails – 12 months capacity)	-	-	1.14
Production Rate (t/day of dry tails)	3,110	2,808	-

^disregarded

Table 3.2: TSF design criteria

PROJECT OPERATIONS	
Tailings Storage - Final - Starter	• 10.53 Mt. • 1.14 Mt.
Slurry Characteristics	• 50/55% solids by weight – Zinc/Copper transition ore. • 60% solids by weight – Fresh ore. • Slurry settled density – 1.9 – 2.0 t/m^3. • Supernatant release – 50-60%. • Potentially acid forming (PAF) tailings.
Fluid Management	• Partial basin drainage system drains by gravity to sump and is then pumped into the supernatant pond. • Decant removal of supernatant solution via a pumping system and pressure pipeline back to the plant.
HYDRAULIC DESIGN	
TSF storm storage capacity	• 1:1,000 AEP, 72 hour flood
TSF emergency spillway	• PMF
EMBANKMENT STABILITY/EARTHQUAKE CRITERIA	
Earthquake Loading - Operating Basis Earthquake (OBE) - Safety Evaluation Earthquake (SEE)	 • 1 in 1,000 year ARI • 1 in 5,000 year ARI
Stability Factors of Safety - Long term drained - Short term undrained (potential loss of containment) - Short term undrained (no potential loss of containment) - Post seismic	 • 1.5 • 1.5 • 1.3 • 1.0 - 1.2

Table 3.2 (cont'd): TSF design criteria

FACILITY CONSTRUCTION AND OPERATION	
General	• Deposition from north and south embankments. • Minimum tailings freeboard of 0.5 m. • The supernatant pond will form towards the centre of the facility. Decant facilities will be provided at all stages to enable removal of water from the pond.
Construction	• Upstream cut-off trench and toe drain. • Zoned starter embankment constructed from mine waste and/or local borrow, comprising an upstream low permeability zone and downstream structural zone. • 10 m crest width.
Materials	• Remove unsuitable foundation soils from embankment footprint. Structural fill won from mine waste and/or local borrow. • Low permeability material won from selected local borrow areas.
TAILINGS BASIN	
Basin Lining	• Imported soils, scarified, moisture conditioned and compacted to form a partial soil liner.
Basin Underdrainage	• Partial basin underdrainage system comprising main collector drains along part of the basin spine.

Table 3.3: Scheduling of operational components

Month	De-watering	Mining	Process	TSF
1		Mining starts – pre-strip for construction		
12	De-watering commences		Process plant commissioned	TSF commissioned
13				TSF fully operational
132	De-watering ends	Mining ceases	Process plant ceases operation	TSF ceases operation

4. TAILINGS CHARACTERISTICS

4.1 PREVIOUS TESTING

4.1.1 Report Review

A number of historical reports were reviewed during the DFS to establish the scope and findings of previous tailings testing:

1. Bankable Feasibility Study Report, Sulphur Springs Project, 06641103-R01-Rev F, Golder Associates, November 2006;
2. Sulphur Springs Bankable Feasibility Study, Tailings Storage Facility, Design Document, P7209.01-AC Design Rev 2, Coffey Geosciences, November 2006; and
3. Panorama Project, Geochemical Characterisation of Process-Tailings Sample (Static Testwork), Implications for Process-Tailings Management, Graeme Campbell and Associates, April 2002;

A review of these reports indicated that:

- tailings test work was performed in 2002;
- the TSF design adopted a settled density of 1.5 t/m^3;
- the TSF design adopted a tailings permeability of 1 x 10^{-7} m/s;
- the Coffey design report references the geochemical testing carried out by Graeme Campbell & Associates in 2002. The geochemical assessment indicated that the tailings are potentially acid forming as a consequence of the high pyrite content. It was noted that neutral pH should prevail on the tailings beaches for deposition cycle times of up to 4 to 5 weeks during operation of the TSF. However, if left exposed for an extended period, the surface zone tailings are likely to develop a pH of 3 to 4. In practice, cycle times less than 4 to 5 weeks would be expected during normal operations;
- lime dosing of the decant pond was noted as a possible control measure to manage acid formation in the decant pond;
- it was recommended that further physical and geochemical characterisation (including kinetic testing) be carried out on the tailings; and
- the scope and findings of any tailings physical testing was not sighted.

4. Panorama Copper-Zinc Project, Geochemical Assessment of Tailing: Letter Report, Depyritised Tailing Samples GS3412 and GS3696, RGS Environmental, May 2009;

A review of this letter report indicated that:

- two samples of depyritised tailings materials were characterised using static geochemical tests and kinetic leach column tests;
- the objective of the kinetic leach tests was to investigate the real-time geochemical behaviour of the tailing materials over an initial period of six months in order to provide an indication of the ongoing quality of run-off/ seepage and therefore determine any implications for environmental management at the proposed TSF;
- surface run-off and leachate from the depyritised tailing materials is likely to be acidic and contain elevated concentrations of some soluble metals and salts;

- in comparison, surface run-off and leachate from the limestone amended depyritised tailing material is likely to be pH neutral and contain much lower concentrations of soluble metals; and
- following crushed limestone addition and exposure to oxidising conditions for six months, the only soluble metal with a concentration in leachate likely to be greater than the ANZECC/NEPM water quality guideline criteria is Selenium.

5. Pilbara Cu/Zn Project, Tailings Management, Conceptual Design Report, DE Cooper & Associates, February 2013; and
6. Pilbara Copper-Zinc Project: Geochemical Characterisation of Process-Tailings Slurry Samples (Sulphur Springs and Mons Cupri Deposits) – Implications for Process – Tailings Management, Graeme Campbell & Associates, November 2012.

A review of these reports indicated that:

- the tailings storage concept for the Panorama Project, under the ownership of CBH Sulphur Springs, proposed a conventional slurry tailings storage with decant system. The DE Cooper proposed concept comprised filtering of the tailings and compaction in a purpose built facility to form a dense mass;
- tailings physical testing comprised Rowe Cell, permeability, compaction and Atterberg Limits tests. These tests yielded the following parameters:
  - Maximum dry density – 2.33 t/m^3;
  - Optimum moisture content – 10.2%;
  - Permeability – 1.5 x 10^{-7} m/s;
  - Liquid limit – 20.5%;
  - Plastic limit – 15.5%;
  - Cohesion – 0 kPa; and
  - Angle of internal friction – 37 degrees.
- the tailings solids was characterised as follows:
  - a Sulphide-S value of 24.4%;
  - an Acid Neutralisation Capacity value of 5 kg H_2SO_4/tonne;
  - a Net Acid Generation value of 380-400 kg H_2SO_4/tonne and a NAG pH value of 1.6;
  - variously enriched in Zinc, Cadmium, Copper, Lead, Silver, Arsenic, Bismuth, Antimony, Selenium, Molybdenum, Mercury and Chromium;
  - pyrite and quartz were major components with sub-ordinate K-feldspar; and
  - classified as Potentially Acid Forming (PAF) through pyrite oxidation.
- the tailings slurry water sample was alkaline (pH 11.0-11.5) and of brackish salinity. At this pH value the concentration of minor elements were close to or below their respective detection limits;
- the kinetic testing indicated that the tailings-pore fluids within the surface zone tailings on a dormant beach within the active TSF should be circum-neutral (pH = 6 approximately) for about 2 weeks. However, during this period the pore fluid Zinc concentrations could increase to within 50-100 mg/L; and
- although difficult to project accurately, any seepage fluid within the sub-surface should have a pH value above approximately 3.

4.2 TAILINGS PHYSICAL TESTING

4.2.1 General

Tailings physical testing was carried out on two samples as part of the DFS, a Copper transition composite and a Zinc transition composite, to determine density and water release design parameters. The following information was provided by Lycopodium regarding the physical properties of the two tailings samples:

- Copper and zinc transition composites for bulk flotation;
- Target grind size is 63 µm;
- Copper Transition Composite target %solids w/w = 55%;
- Zinc Transition Composite target %solids w/w = 50%; and
- Transition ore representative of first 2.5 years of production.

The following tests were carried out on the samples:

- Classification tests to determine:
  - Particle size distribution of the tailings;
  - Supernatant liquor density and pH;
  - Tailings solids particle density; and
  - Atterberg limits of the tailings solids.
- Undrained and drained sedimentation tests;
- Air drying tests;
- Permeability tests; and
- High strain consolidation tests.

The results and recommendations associated with the physical testing programme are reported in detail in the DFS report. The main findings are presented in the following sections.

4.2.2 Water Production

The release of supernatant/underdrainage following deposition can be estimated based on the climatic conditions, particle size distribution and permeability of the tailings, and the results of the undrained and drained sedimentation tests. The rate of supernatant release will also affect the potential decant recovery.

The testing indicated that the rate of supernatant release for the Zn Tails was quick, with the majority of water released in under a day. The expected water release would be around 55 – 65% of the water in slurry, not accounting for rainfall and evaporation but considering the loss of water to re-saturate lower tailings layers.

Comparatively, the testing indicated that the rate of supernatant release for the Cu Tails was also relatively quick but slower than the Zn Tails, with the majority of water released in 1 - 2 days. The expected water release would be around 45 – 55% of the water in slurry, not accounting for rainfall and evaporation but considering the loss of water to re-saturate lower tailings layers.

4.2.3 Tailings Density

The settled dry density deposited into a tailings storage facility can be predicted from the laboratory test work, facility design and site climatic conditions. It has been observed over a number of years that densities achieved in the field are generally lower than those obtained in the laboratory. In addition, field densities achieved are dependent on the area available for drying and the thickness of deposited layers.

The tests provided final dry density values as follows:

Zn Tails

- Undrained test 1.64 t/m^3;
- Drained test 1.74 t/m^3; and
- Air drying test 2.15 t/m^3.

Cu Tails

- Undrained test 1.44 t/m^3;
- Drained test 1.70 t/m^3; and
- Air drying test 2.15 t/m^3.

The test work indicated that for the Zn Tails, there is a moderate difference in the density achieved between tailings based on settlement and tailings exposed to air drying. With suitable air drying of the tailings slurry a settled density of approximately 1.95 to 2.05 t/m^3 is expected in the facility.

For the Cu Tails there is a considerable difference in the density achieved between tailings based on settlement and tailings exposed to air drying. With suitable air drying of the tailings slurry, a settled density of approximately 1.9 to 2.0 t/m^3 is expected in the facility.

For both samples, the air drying test achieved a high density primarily associated with the high solids particle density. Assuming that the fresh ore is consistent with the high SG of the two transition ores it is recommended that the TSF filling model be modified to match the physical tailings testing results.

4.3 TAILINGS GEOCHEMICAL TESTING

4.3.1 General

Geochemical testing of the Copper and Zinc composite transition solids and supernatant was carried out, also as part of the DFS, to assess the acid generation potential, element enrichment and supernatant/seepage water quality against reference standards. The results and recommendations associated with the geochemical testing programme are reported in detail in the DFS report. The main findings are presented in the following sections.

4.3.2 Acid Forming Potential

The tailings samples are considered Potentially Acid Forming (PAF) based on extremely high NAPP values and acidic NAG pH values. The ANC values are very low and, as such, the lag time to acid generation is likely to be very short. Based on these results there is considered to be an extreme risk of acid generation within the tailings storage facility without adequate controls.

The most effective technique to eliminate acid generation is to operate the tailings facility sub-aqueously with a permanent water cover. However, this is unlikely to be sustainable based on the climate at the project site. Therefore, it is recommended that the tailings deposition be managed in such a way to prevent the tailings saturation levels from falling below 100%. Towards the end of the operating life pH amendment via lime addition should be conducted prior to tailings discharge to prevent the top surface of the tailings generating acid following cessation of sub-aerial deposition and prior to construction of the closure cover.

The closure cover presented in the DFS comprised a multi-layered cross-section designed to reduce infiltration into the tailings and lower the potential for acid generation from the tailings stored and incorporated a barrier layer (low permeability material/HDPE) overlain by a well-graded granular non-acid forming (NAF) layer to store and release retained moisture. The cross-section description adopted for the DFS included the following layers:

- A low permeability compacted sub-base layer (200 mm);
- A 1.0 mm or 1.5 mm HDPE liner;
- An HDPE protection layer (150 mm) consisting of silt, sand or rounded gravel materials;
- A NAF waste rock layer won from the waste dumps; and
- A topsoil cover equivalent in thickness to the topsoil removed from the basin area.

As part of an independent review of the DFS it was recommended that an additional layer of crushed limestone be incorporated into the closure cover. This layer would be constructed over the final tailings surface and would underlie the other closure cover layers with the purpose of providing additional neutralising capacity to any seepage permeating through the closure cover.

For the alternative TSF location, any seepage from the facility is expected to report to and be contained by the mine pit. Consequently the TSF cover design may not warrant inclusion of an HDPE liner.

4.3.3 Multi-Element Enrichment

The samples recorded a high number of element enrichments, with the level of enrichment tending to vary from significant to high. Of particular note was Zinc which was recorded above the upper bound limit of detection of 50,000 mg/kg (5%) in one of the samples. As such, the TSF should be designed to contain all solids and appropriate operational controls will be required to limit dusting.

The multi-element concentrations also pose a risk to supernatant water quality unless the pH is adequately managed, as a reduction in pH would increase the solubility of several metals.

Comparison of the multi-element results to soil quality screening criteria indicates that the TSF will require a closure cover system that prevents plant uptake. However, in this case, the closure cover required to manage acid generation will also adequately manage the multi-element concentrations in the tailings solids.

4.3.4 Supernatant Water Quality

The supernatant was found to be reasonable, although several metals were detected above reference water quality guidelines.

5. TAILINGS DEPOSITION MANAGEMENT

5.1 INTRODUCTION

The design of the TSF incorporates both a density model and a site water management model. The density model is dependent on the throughput, site climatic data and the deposition plan developed for the facility.

5.2 DEPOSITION PLAN

A deposition plan was developed for the facility. The plan is based on the following requirements:

- The total storage capacity required.
- The throughput and resulting tailings beach slope.
- The proposed deposition concept.

The TSF design is based on the throughputs and storage capacity summarised in Table 3.1 and the design criteria summarised in Table 3.2. A tailings beach slope of 0.83% (1V:120H) was adopted, based on the tailings laboratory testing and measured tailings beach slopes at other sites for similar tailings blends.

The deposition of tailings into the storage facility will be primarily from the north and south embankments. The tailings delivery pipeline will be routed from the process plant up to the crest of the TSF embankments. The tailings distribution pipeline will be located on the embankment crests and will be raised with each stage. Deposition will occur from multiple spigots inserted along the tailings distribution line (nominally 4 to 5 at a time). The deposition locations(s) will be moved progressively along the distribution line as required to control the location of the supernatant pond.

The tailings deposition modelling was undertaken using the RIFT TD tailings modelling package (Ref. 4). Rift TD is an advanced three-dimensional Digital Terrain Model specifically developed to model tailings deposition. The program develops a model of the tailings beach based on the original topography, provided deposition point locations, beach slopes and tailings tonnages. Figures 1 to 4 show the approximate extent of the tailings beach at the end of Years 2, 5, 8 and 10 of operation.

The estimated tailings levels at the northern and southern embankments at the end of each year of operation are summarised in Table 5.1.

Table 5.1: Estimated life of mine tailings levels

Stage	Total Storage Capacity	Years of Capacity Per Lift	Tailings Level
	(Mt)	(Yrs)	(RL m)
1	1.135	1.0	1336.1
2	2.27	1.0	1342.3
3	3.35	1.0	1346.0
4	4.375	1.0	1348.8
5	5.40	1.0	1351.1
6	6.425	1.0	1353.2
7	7.45	1.0	1355.1
8	8.475	1.0	1356.8
9	9.5	1.0	1358.3
10	10.53	1.0	1359.7

6. WATER BALANCE

Management of water relating to the tailings storage facility is critical in terms of the facility design and decant return pumping requirements. The DFS water management model was amended for the alternative TSF concept design in order to estimate the flows of water entering and exiting the facility and to determine design embankment crest levels for the TSF. The model was run with a repeating sequence of average conditions and the water balance under average conditions is summarised in Table 6.1. Based on the modelling the following conclusions can be made:

- Water available for decant return is 3.6 GL and varies between 15,000 m^3 and 72,000 m^3 per month. The maximum decant return rate (and therefore the required water treatment rate) is 110 m^3/hr;
- The supernatant pond volume remains at the minimum (20,000 m^3) except for 1 or 2 months during each wet season;
- The facility experiences a total water shortfall of 4 GL under average climatic conditions and ranges from approximately 5,000 to 83,000 m^3/month. The average shortfall is approximately 34,000 m^3/month;
- The TSF recycle to the process plant varies from 27% to 100% of water in slurry during the operation and ranges from 15,000 to 72,000 m^3/month. The average recycle over the operating life is 48% of the water in slurry; and
- Development of the tailings level at the main embankments and pond level under average conditions are presented in Table 6.1. Of note, the pond level is consistently below the tailings level (at the main embankments).

Table 6.1: Summary of TSF water balance – average climatic conditions

Month		Water In Slurry (m³/month)	Additional Water to TSF (m³/month)	Decant Return (m³/month)	Excess for Evaporation (m³/month)	Water Lost in TSF (m³/month)	Shortfall (m³/month)	Pond Volume (m³)	Pond RL (RLm)	Tails RL at Emb. (RLm)
13	Nov	83004	0	23863	0	59141	83004	20000	1320.6	1320.6
14	Dec	85771	0	41150	0	44620	61908	20000	1321.4	1323.6
15	Jan	85771	0	39180	0	46590	44620	20000	1323.0	1325.7
16	Feb	77470	0	53861	0	23609	38290	20000	1324.2	1327.3
17	Mar	85771	0	43907	0	41864	31909	20000	1325.2	1328.8
18	Apr	83004	0	41341	0	41663	39097	20000	1326.2	1330.1
19	May	85771	0	40409	0	45362	44430	20000	1326.9	1331.3
20	Jun	83004	0	39398	0	43606	42595	20000	1327.7	1332.3
21	Jul	85771	0	40847	0	44924	46373	20000	1328.5	1333.4
22	Aug	85771	0	39161	0	46610	44924	20000	1329.4	1334.3
23	Sep	83004	0	35748	0	47256	43843	20000	1330.3	1335.2
24	Oct	85771	0	34536	0	51235	50023	20000	1331.2	1336.1
25	Nov	83004	0	32336	0	50668	48468	20000	1331.9	1336.8
26	Dec	85771	0	33890	0	51881	53435	20000	1333.0	1337.6
27	Jan	85771	0	40495	0	45276	51881	20000	1334.0	1338.2
28	Feb	77470	0	61177	0	16293	36975	20000	1334.6	1338.7
29	Mar	85771	0	46863	0	38908	24594	20000	1335.3	1339.2
30	Apr	83004	0	43514	0	39490	36141	20000	1335.7	1339.6
31	May	85771	0	40828	0	44943	42257	20000	1336.2	1340.1
32	Jun	83004	0	39407	0	43597	42176	20000	1336.7	1340.6
33	Jul	85771	0	41027	0	44743	46364	20000	1337.1	1341.0
34	Aug	85771	0	39184	0	46587	44743	20000	1337.6	1341.5
35	Sep	83004	0	35767	0	47237	43820	20000	1338.1	1342.0
36	Oct	85771	0	34546	0	51225	50004	20000	1338.4	1342.3
37	Nov	83004	0	32387	0	50617	48458	20000	1338.8	1342.7
38	Dec	85771	0	34095	0	51675	53384	20000	1339.1	1343.0
39	Jan	85771	0	42704	0	43066	51675	20000	1339.5	1343.4
40	Feb	77470	0	71427	0	6044	34766	20000	1339.8	1343.7
41	Mar	85771	0	50320	0	35451	14344	20000	1340.1	1344.0
42	Apr	83004	0	45655	0	37349	32684	20000	1340.4	1344.3
43	May	58037	0	23353	0	34683	12382	20000	1340.7	1344.6
44	Jun	56164	0	22112	0	34052	32811	20000	1341.0	1344.9
45	Jul	58037	0	23302	0	34735	35924	20000	1341.3	1345.2
46	Aug	58037	0	21391	0	36646	34735	20000	1341.5	1345.4
47	Sep	56164	0	18618	0	37546	34773	20000	1341.8	1345.7
48	Oct	58037	0	16924	0	41112	39418	20000	1342.1	1346.0
49	Nov	56164	0	15392	0	40772	39240	20000	1342.3	1346.2
50	Dec	58037	0	16637	0	41400	42644	20000	1342.6	1346.5
51	Jan	58037	0	26369	0	31667	41400	20000	1342.8	1346.7
52	Feb	52420	0	52420	0	0	26051	28916	1343.2	1346.9
53	Mar	58037	0	41191	0	16845	5616	20000	1343.3	1347.2
54	Apr	56164	0	29686	0	26478	14973	20000	1343.5	1347.4
55	May	58037	0	23561	0	34475	28350	20000	1343.7	1347.6
56	Jun	56164	0	22116	0	34048	32603	20000	1344.0	1347.9
57	Jul	58037	0	23385	0	34652	35920	20000	1344.2	1348.1
58	Aug	58037	0	21401	0	36635	34652	20000	1344.4	1348.3
59	Sep	56164	0	18626	0	37538	34763	20000	1344.6	1348.5
60	Oct	58037	0	16928	0	41109	39410	20000	1344.8	1348.7
61	Nov	56164	0	15413	0	40752	39236	20000	1345.1	1349.0
62	Dec	58037	0	16719	0	41318	42624	20000	1345.3	1349.2
63	Jan	58037	0	27264	0	30773	41318	20000	1345.5	1349.4
64	Feb	52420	0	52420	0	0	25156	33160	1345.9	1349.6
65	Mar	58037	0	45899	0	12138	5616	20000	1345.9	1349.8
66	Apr	56164	0	30633	0	25531	10266	20000	1346.1	1350.0
67	May	58037	0	23724	0	34313	27403	20000	1346.3	1350.2
68	Jun	56164	0	22120	0	34045	32441	20000	1346.5	1350.4
69	Jul	58037	0	23451	0	34585	35917	20000	1346.7	1350.6
70	Aug	58037	0	21409	0	36627	34585	20000	1346.9	1350.8
71	Sep	56164	0	18633	0	37532	34755	20000	1347.1	1351.0
72	Oct	58037	0	16931	0	41105	39404	20000	1347.2	1351.1
73	Nov	56164	0	15430	0	40734	39233	20000	1347.4	1351.3
74	Dec	58037	0	16791	0	41246	42606	20000	1347.6	1351.5
75	Jan	58037	0	28053	0	29984	41246	20000	1347.8	1351.7
76	Feb	52420	0	52420	0	0	24367	36915	1348.2	1351.9
77	Mar	58037	0	50101	0	7936	5616	20000	1348.2	1352.1
78	Apr	56164	0	31467	0	24698	6064	20000	1348.3	1352.2
79	May	58037	0	23868	0	34169	26570	20000	1348.5	1352.4
80	Jun	56164	0	22123	0	34042	32297	20000	1348.7	1352.6
81	Jul	58037	0	23510	0	34526	35914	20000	1348.8	1352.7
82	Aug	58037	0	21417	0	36620	34526	20000	1349.0	1352.9
83	Sep	56164	0	18638	0	37526	34748	20000	1349.2	1353.1
84	Oct	58037	0	16934	0	41102	39398	20000	1349.3	1353.2
85	Nov	56164	0	15446	0	40719	39230	20000	1349.5	1353.4
86	Dec	58037	0	16853	0	41183	42591	20000	1349.7	1353.6
87	Jan	58037	0	28731	0	29305	41183	20000	1349.8	1353.7

Table 6.1 (cont'd): Summary of TSF water balance – average climatic conditions

Month		Water In Slurry (m³/month)	Additional Water to TSF (m³/month)	Decant Return (m³/month)	Excess for Evaporation (m³/month)	Water Lost in TSF (m³/month)	Shortfall (m³/month)	Pond Volume (m³)	Pond RL (RLm)	Tails RL at Emb. (RLm)
88	Feb	52420	0	52420	0	0	23689	40129	1350.3	1353.9
89	Mar	58037	0	53719	0	4318	5616	20000	1350.2	1354.1
90	Apr	56164	0	32187	0	23977	2445	20000	1350.3	1354.2
91	May	58037	0	23992	0	34044	25849	20000	1350.5	1354.4
92	Jun	56164	0	22125	0	34039	32172	20000	1350.6	1354.5
93	Jul	58037	0	23562	0	34474	35911	20000	1350.8	1354.7
94	Aug	58037	0	21423	0	36614	34474	20000	1350.9	1354.8
95	Sep	56164	0	18644	0	37521	34741	20000	1351.1	1355.0
96	Oct	58037	0	16937	0	41100	39393	20000	1351.2	1355.1
97	Nov	56164	0	15460	0	40705	39228	20000	1351.4	1355.3
98	Dec	58037	0	16909	0	41127	42577	20000	1351.5	1355.4
99	Jan	58037	0	29348	0	28689	41127	20000	1351.7	1355.6
100	Feb	52420	0	52420	0	0	23073	43064	1352.1	1355.7
101	Mar	58037	0	57045	0	992	5616	20880	1352.0	1355.8
102	Apr	56164	0	33522	0	22642	0	20000	1352.1	1356.0
103	May	58037	0	24108	0	33928	24514	20000	1352.2	1356.1
104	Jun	56164	0	22128	0	34037	32056	20000	1352.4	1356.3
105	Jul	58037	0	23611	0	34425	35909	20000	1352.5	1356.4
106	Aug	58037	0	21429	0	36607	34425	20000	1352.6	1356.5
107	Sep	56164	0	18648	0	37516	34735	20000	1352.8	1356.7
108	Oct	58037	0	16939	0	41097	39388	20000	1352.9	1356.8
109	Nov	56164	0	15473	0	40691	39225	20000	1353.0	1356.9
110	Dec	58037	0	16965	0	41072	42563	20000	1353.2	1357.1
111	Jan	58037	0	29960	0	28077	41072	20000	1353.3	1357.2
112	Feb	52420	0	52420	0	0	22461	46000	1353.8	1357.3
113	Mar	58037	0	58037	0	0	5616	24230	1353.6	1357.4
114	Apr	56164	0	36774	0	19391	0	20000	1353.7	1357.6
115	May	58037	0	24225	0	33811	21263	20000	1353.8	1357.7
116	Jun	56164	0	22130	0	34034	31939	20000	1353.9	1357.8
117	Jul	58037	0	23660	0	34376	35906	20000	1354.1	1358.0
118	Aug	58037	0	21435	0	36601	34376	20000	1354.2	1358.1
119	Sep	56164	0	18653	0	37511	34729	20000	1354.3	1358.2
120	Oct	58037	0	16942	0	41095	39383	20000	1354.4	1358.3
121	Nov	56164	0	15487	0	40677	39223	20000	1354.5	1358.4
122	Dec	58037	0	17021	0	41015	42550	20000	1354.6	1358.5
123	Jan	58037	0	30586	0	27451	41015	20000	1354.8	1358.7
124	Feb	52420	0	52420	0	0	21835	49014	1355.2	1358.8
125	Mar	58037	0	58037	0	0	5616	27686	1355.1	1358.9
126	Apr	56164	0	40168	0	15996	0	20000	1355.1	1359.0
127	May	58037	0	24348	0	33689	17869	20000	1355.2	1359.1
128	Jun	56164	0	22133	0	34032	31817	20000	1355.3	1359.2
129	Jul	58037	0	23712	0	34324	35904	20000	1355.4	1359.3
130	Aug	58037	0	21442	0	36595	34324	20000	1355.6	1359.5
131	Sep	56164	0	18659	0	37506	34723	20000	1355.7	1359.6
132	Oct	58037	0	16944	0	41092	39378	36944	1356.0	1359.7
	Total	**7,648,363**	**-**	**3,643,041**	**-**	**4,005,322**	**4,026,891**			

7. TSF PRELIMINARY CONCEPT DESIGN

7.1 EMBANKMENT STAGING AND CONSTRUCTION

The TSF consists of a cross-valley storage that will be operated as a single cell facility. The facility will comprise a main embankment located upstream of the open pit with the final stage downstream toe outside the perimeter of the pit abandonment bund, and a primary saddle dam located along the ridgeline at the southern end of the catchment. Secondary saddle dams will be required later in the facility life (from Year 9) to contain the tailings beach and provide for the design storm storage capacity. Figure 5 presents a general arrangement plan of the facility.

The estimated main embankment and saddle dam levels at each stage are shown in Table 7.1. Preliminary calculations indicate that there will be of the order of 500,000 m^3 of storm capacity throughout the facility life, which is in excess of the 1 in 1,000 year 72 hour design storm capacity required for a High B consequence category facility.

Table 7.1: Preliminary embankment levels

Stage	Total Storage Capacity (Mt)	Years of Capacity Per Lift (Yrs)	Tailings RL (RL m)	Main/ Southern Saddle Embankment Level (RL m)	North-west Saddle Embankment Level (RL m)	West Saddle Embankment Level (RL m)
1	1.135	1.0	1336.1	1,337.0		
2	2.27	1.0	1342.3	1,343.0		
3	3.35	1.0	1346.0	1,346.5		
4	4.375	1.0	1348.8	1,349.5		
5	5.40	1.0	1351.1	1,352.0		
6	6.425	1.0	1353.2	1,354.0		
7	7.45	1.0	1355.1	1,356.0		
8	8.475	1.0	1356.8	1,357.5		
9	9.5	1.0	1358.3	1,359.0	1,358.0	1,356.0
10	10.53	1.0	1359.7	1,360.5	1,359.5	1,358.0

The embankments will be constructed as multi-zoned earth and rockfill dams, using downstream methods, and will consist of a 6 m wide low permeability zone (Zone A) won from local borrow or selected suitable mine waste. The downstream structural zone (Zone C) will be constructed of run of mine waste from the open pit or local borrow. A transition zone (Zone B) is designed to ensure filter compatibility been the Zone A and Zone C materials.

The initial embankments will have upstream and downstream slopes of 1V:3H with a crest width of 10 m. The same crest width will be adopted for subsequent stages. The design is based on all lifts being constructed using mine waste and local borrow. The embankment downstream face will comprise 1V:3H inter-bench slopes located at 10 m vertical intervals and with 5 m wide berms, producing an overall downstream slope of 1V:3.5H. Typical embankment sections and details are shown in figures 6 and 7.

Construction of the downstream stage raises would be scheduled so that there is adequate storage volume (storm and tailings) available throughout the operating life of the facility.

7.2 SEEPAGE CONTROL

Based on the premise that seepage from this catchment will report to the open pit, the alternative TSF could be either unlined or partially lined depending on the calculated seepage rates under operating and closure scenarios. The facility would incorporate an underdrainage system and an upstream toe drain designed to drain by gravity to a collection sump located at the toe of the main embankment.

A preliminary assessment of existing ground slope within the valley indicates that ground slopes of less than 1V:3H (typically the target maximum slope for HDPE lining) and between 1V:2H and 1V:3H (absolute maximum for HDPE lining) are predominant along the base and upper slopes of the valley (Figure 8). In acknowledgement of the valley terrain and recognising that the majority of seepage will tend to occur along the valley base particularly below the supernatant pond, a partial basin liner combined with an underdrainage system may provide adequate control of seepage from the facility. This will need to be assessed in greater detail by means of seepage modelling and hydrogeological modelling to confirm the flow rates and flow paths of seepage exiting the facility.

A geotechnical investigation and detailed engineering geological assessment of the proposed TSF site will be carried out to inform the detailed design of the facility and address the potential for hydraulic connection between the TSF and the open pit/ underground workings.

7.3 DECANT RECOVERY

Tailings would be discharged into the facility by sub-aerial deposition methods, via spigots spaced at regular intervals along the northern and southern embankment crests, driving the pond towards the centre of the valley. A series of decants would be used to recover water with the water pumped to a water treatment plant for acid neutralisation and heavy metal removal prior to its return to the process plant.

7.4 SPILLWAY

In the event that the storage capacity of the facility was exceeded, water which could not be stored within the facility would discharge via an engineered spillway. The emergency spillway during operation would be designed to convey run-off from the Probable Maximum Flood (PMF), assuming that the decant pond level is at the spillway invert level at commencement of the storm event. A new spillway would be constructed at each stage of construction.

8. TSF OPERATION

8.1 TAILINGS DEPOSITION SYSTEM

The deposition of tailings into the storage facility will be from the north and south TSF embankments. The tailings delivery pipeline will be routed from the process plant up to the crest of each of these embankments. The tailings distribution pipeline will be located on the embankment crest and will be raised with each stage.

Deposition will occur from single offtakes inserted along the tailings distribution pipelines. The deposition location will be moved on a daily basis to one of the deposition points, or as required to control the location of the supernatant pond.

8.2 DEPOSITION TECHNIQUE

Tailings deposition will be carried out using the sub-aerial technique in order to promote 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 to a minimum, sub-aerial deposition will increase the settled density of the tailings and hence maximise the storage potential and efficiency of the facility.

The tailings will be deposited into the facility in such a way as to encourage the formation of beaches over which the slurry will flow along the spine of the basin in a laminar non-turbulent manner. Limited settlement and water release will occur. The released water will form a thin film on the surface of the tailings. This water will flow to the supernatant pond from where it will be removed from the storage area via a decant tower. The Stage 1 decant tower will be located such that it will first receive water approximately 1 to 2 months after commissioning the facility.

Deposition of the tailings will be carried out 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. This will facilitate maximum storage to be achieved across the whole valley.

After deposition on a particular area of beach ceases and settling of the tailings has been completed, further de-watering will take place due partly to drainage into the underdrainage system, but mainly due to evaporation. As water evaporates and the moisture content drops, the volume of tailings will reduce to maintain a condition of full saturation within the tailings. This process will continue until interaction between the tailings particles negates volume reduction.

8.3 TSF MONITORING

8.3.1 Monitoring Programme

As part of the operation of the facility, extensive monitoring of all aspects of the operation should be undertaken. This monitoring falls into three basic categories:

- Short-term operation monitoring – this includes items such as offtake location, whether pipe joints are leaking, etc., which are part of ensuring that the facility is operating smoothly;
- Compliance monitoring – this includes items such as checking survey pins on embankment crests to monitor embankment movement, monitoring bores downstream of the TSF to monitor groundwater level and chemistry, and standpipe piezometers within each embankment to monitor the phreatic

surface, which are used to ensure that the project is meeting all of its commitments in regard to a safe, secure operation; and
- Long-term performance monitoring – this includes such items as tailings level surveys and water flow measurements, etc., which are used to monitor the long term performance of the facility and refine future embankment lift levels and final tailings extent.

If the monitoring programme indicated that potential problems were developing, an increase in monitoring frequency would be implemented and a response plan developed.

A detailed monitoring programme will be provided as part of the operating manual for the facility.

8.3.2 Seepage Monitoring

Six groundwater monitoring stations (bores MB1 to MB6) are proposed to be installed around the facility to facilitate early detection and remediation of any seepage which may occur due to operation of the facility. Each monitoring station will consist of one shallow hole, extending through approximately 5 - 10 m of the near surface horizon, and one deep hole terminating approximately 5 m below the groundwater table. The shallow bore is intended to detect any seepage from the TSF flowing within the surface sediment, whilst the deep bore will monitor any changes in the chemical composition of the groundwater. Each borehole will be cased and screened over an interval set in the field during installation and sealed back to surface with low permeability grout. It is recommended that the monitoring boreholes are constructed before commissioning the TSF to accumulate baseline data specific to the storage location.

8.3.3 Stability Monitoring

Pore water pressures should be monitored within the TSF embankments to ensure that stability is not compromised. To this end it is proposed that standpipe piezometers are installed at three locations on each of the main embankment crests. The base of the piezometers will be located within the embankment to ensure that the phreatic surface within the embankment fill is measured, as opposed to natural groundwater level. During each embankment raise the existing piezometers will be sealed with cement/bentonite grout mix. New piezometers will be established on the embankment crest at the end of raise construction.

Survey pins will be installed along the main embankment crests and downstream face to monitor any movement of the embankments. Any displacement which is considered excessive or ongoing may indicate embankment stability problems and would be assessed by a qualified geotechnical engineer.

8.3.4 Tailings Performance Monitoring

Tailings performance monitoring will include monitoring of the following parameters on a continuous basis:

- Solids tonnage to the tailings storage facility;
- Water volume to the tailings storage facility;
- Rainfall and evaporation at the facility;
- Water return from the facility; and
- Collection efficiency of the underdrainage system based on underdrainage sump pump monitoring.

Monitoring of tailings moisture contents and densities, and survey of the tailings beach and supernatant pond locations should be conducted four times a year.

8.3.5 Emergency Controls

Under normal operating conditions the following systems should be in place:

- The tailings pipelines will be located on the upstream crest of the embankments, which will have a minimum crossfall to the tailings beaches of 2%. Any leakage from the pipeline will therefore flow towards the tailings storage facility; and
- Between the plant site and the TSF, the tailings delivery pipeline and water return lines will be contained within a bunded easement or buried, and equipped with an automatic pressure drop cut-out. This will reduce the risk of uncontrolled release of tailings or supernatant in the event of a pipe burst.

These systems should greatly reduce the likelihood of uncontrolled spillages from the TSF.

9. TSF CLOSURE

9.1 CLOSURE CONCEPT

The closure concept for the facility is based on the following principles:

- The surface will be water shedding with no potential ponding;
- The surface will need to be erosion resistant; and
- The surface infiltration rate will need to be lower than the seepage rate out of the base of the facility.

9.2 COMPLETION CRITERIA

The following completion criteria apply to the closure design of the TSF:

- Final landform – the extent of erosion of the rehabilitated TSF embankments will be similar to that of the naturally occurring colluvial slopes in the project area;
- Vegetation and biodiversity – post-closure vegetation will be similar to the pre-mining vegetation in terms of cover, density, species diversity and weed occurrence;
- Water quality and quantity – there will be no significant impairment of the pre-mining beneficial uses of groundwater; and
- Soil quality – the chemical and physical condition of post-closure surface soils will not impede plant growth.

9.3 LANDFORM MODELLING

Long-term (1000 years) Landform Evolution Modelling was carried out for the DFS to assess the behaviour and performance of the TSF post-closure using the SIBERIA software developed by Telluric Research for landform modelling (Ref. 5). The modelling was carried out to:

- Confirm that the resultant landform is geomorphically stable;
- Identify those issues associated with the cover design that affect the landform performance;
- Identify any potential TSF design changes which may mitigate long-term erosion issues;
- Establish, within an order of magnitude, the likely changes in the TSF landform over a 1,000 year period; and

- Identify the subsequent information required to refine the model in the feasibility study.

The base case for the modelling was the TSF after closure with the barrier store and release cover system as described by O'Kane (Ref. 6). The cover system adopted by O'Kane has a multi-layered cross-section designed to reduce infiltration into the tailings and lower the potential for acid generation from the tailings stored. Achievement of this objective requires the development of a barrier layer (low permeability material/HDPE) over which a well-graded granular non-acid forming (NAF) layer is placed to store and release retained moisture. The cross-section description included the following range of dimensions:

- Low permeability soil liner – 200 mm;
- 1.0 or 1.5 mm HDPE liner;
- Protective sand layer –150 mm minimum;
- Well graded NAF layer – 1,560 mm to 2,650 mm; and
- Topsoil – nominal thickness.

This design was built into the digital terrain model which was then incorporated into the software for processing. Climate data used was drawn from the historic data collected in the period 1889 - 2017 and processed through the SILO data drill. A 1,000 year dataset was applied by taking the 100 year analysis and applying it 10 times in the SIBERIA model. The 1,000 year landscape evolution modelling was undertaken based on the DFS design of the TSF. There are three areas in which erosion effects occur as follows:

- On the surface of the cover area leading towards the spillway location;
- Around the perimeter of the cover where it interacts with the surrounding valley walls; and
- On the embankment face, in particular along the berm on the embankment face.

The following design modifications were incorporated into the DFS design to reduce or mitigate these effects as follows:

- Cover surface – the depth of erosion on the surface area is about 0.15 m up to a peak value of around 0.3 to 0.4 m. The cover design from O'Kane has an overall depth of 2 to 3 m and thus the expected level of erosion will not expose the HDPE liner within the cover. Notwithstanding this, some additional modifications to the cover design were recommended as follows:
  - Mix the topsoil layer into the surface zone of the growth medium layer;
  - Ensure that the surface zone (mixed topsoil/growth medium) has a base quantity (% of material) of gravel to cobble sized material present to improve erosion resistance; and
  - Restore the vegetation cover as soon as possible on completion of placement of the cover layers consistent with the existing moderately dense surface cover.
- Edge of the cover against the valley sides – the model has an assumed flat surface which meets the sloping valley hillside. This relatively sharp interface focuses water flow and thus results in a localised erosion issue. During construction of the cover the edges of the cover around the perimeter should be shaped to extend up and integrate into the hillside face. In addition, coarser material will be added in these areas to improve erosion resistance. The design concept is to draw the water away from the edge of the cover out onto the surface and also to reduce local erosion by increasing the erosion resistance in this area;

- Embankment face and berm – the berm on the downstream face of the embankment has been provided in accordance with the current embankment facility guidelines; however the berm does act as a focus point for erosion in the post closure condition. The following changes to the embankment were incorporated into the design:
  - The downstream face of the last stage of the embankment will consist of large size erosion resistant material to reduce the erosion potential. The topsoil will be mixed with this coarse material;
  - The profile of the berm should be sloped to the outside edge so it will act as a velocity inhibitor for rainfall run-off but not store any water on the berm itself;
  - The possibility of completely removing the berm as part of the post closure works should be assessed in more detail; and
  - Vegetation establishment on the face of the embankment consistent with vegetation established on existing steeper hill faces in the area should be incorporated into the embankment on completion of the final embankment lift.

It is expected that the issues associated with closure and changes in the landform associated with design of the alternative TSF will be very similar to those identified by the landform modelling of the DFS design. The conceptual closure design has considered and accounted for these factors. Detailed design of the TSF will need to verify the assumptions and findings of the landform modelling as they relate to the proposed alternative site.

9.4 TAILINGS STORAGE FACILITY CLOSURE

Based on the above principles the tailings storage facility will be closed in the following sequence:

- Drain the decant pond using the water treatment plant;
- Continue to drain the tailings mass by operating the underdrainage system;
- Shape the tailings profile to be water shedding. This will be relatively straightforward as the deposition profile will provide a tailings surface sloping towards the centre of the facility. The facility closure spillway will be cut through the west saddle;
- Cover the tailings surface with a multiple layer low infiltration, erosion resistant water shedding cover; and
- Shut down the underdrainage system and close out the facility.

Figure 9 shows typical details of the proposed closure capping.

10. DETAILED DESIGN

Detailed design of the alternative TSF will be carried out in accordance with the requirements of the Department of Mines, Industry Regulation and Safety (DMIRS formerly DMP) “Code of Practice, Tailings storage facilities in Western Australia” (Ref. 2) and the Australian National Committee on Large Dams (ANCOLD) “Guidelines on Tailings Dams, Planning, Design, Construction, Operation and Closure” (Ref. 3) and will augment the scope of work undertaken as part of the DFS design. The scope of work is expected to include:

i) Dam breach assessment and confirmation of the facility consequence category.
ii) Confirmation of the design criteria for the defined consequence category (storm storage, freeboard capacity, spillway capacity, design earthquake loading, stability factors of safety, dam safety/inspection requirements).
iii) Geotechnical investigation and detailed engineering geological assessment of the proposed TSF site to confirm the in situ ground conditions, to inform the detailed design of the facility and the potential for hydraulic connection between the TSF and the open pit/ underground workings, to confirm the geotechnical design parameters, and to establish potential sources of borrow material for construction.
iv) Siting of the TSF based on in situ ground conditions, topographical constraints and pit closure abandonment bund alignment.
v) Seepage analyses to evaluate seepage through the embankment and foundation of the TSF under normal operating conditions, a range of post closure conditions, and to approximate the phreatic surface and porewater pressures in the tailings and embankment.
vi) Stability modelling to assess the stability of the TSF embankments under static and post-seismic cases in order to confirm adequate factors of safety against the ANCOLD design criteria. A site specific seismic hazard assessment was carried out for the Sulphur Springs project site as part of the DFS. The assessment included probabilistic and deterministic seismic hazard analyses and provided recommended seismic design parameters.
vii) Water balance modelling for the TSF in order to understand and control the flow of water entering and exiting the facility and to determine design embankment crest levels for the TSF to cater for extreme storm events.
viii) Confirmation of TSF embankment levels and geometry incorporating storm storage, stability and spillway design analyses.
ix) Closure requirements to provide a landform that is geomorphically stable in the long term.

11. CONCLUSIONS

The key conclusions to arise from the preliminary assessment of the alternative TSF design concept are as follows:

- Storage of the projects' 10.53 Mt of tailings in the PSC5 catchment in accordance with requirements of the Department of Mines, Industry Regulation and Safety (DMIRS formerly DMP) "Code of Practice, Tailings storage facilities in Western Australia" and the Australian National Committee on Large Dams (ANCOLD) "Guidelines on Tailings Dams, Planning, Design, Construction, Operation and Closure is feasible;
- The facility is assessed to be a High B consequence category, primarily a function of the Population at Risk due to the facility location above the open pit. This category defines the design and operational criteria for the facility;
- Locating a facility in this valley offsets the requirement to construct and maintain a pit diversion dam during operations and post-closure;
- The storage is relatively inefficient in terms of storage capacity:embankment fill ratio;

- Constructing a TSF in this location will present specific challenges due to the terrain. Constructability will need to be assessed in greater detail, particularly with respect to any consideration of the installation of an HDPE liner;
- The type and extent of facility lining will need to be confirmed by means of detailed seepage analyses and hydrogeological modelling to confirm the quantity and flow path/s of seepage from the facility; and
- A detailed geotechnical investigation and assessment of the engineering geology of the proposed TSF site will be required to inform the detailed design of the facility and address the potential for hydraulic connection between the TSF and the open pit/underground workings. The investigation will be undertaken during the next phase of design work.

We trust that this memorandum meets with your requirements. Should you have any questions please do not hesitate to contact us.

Yours faithfully
KNIGHT PIÉSOLD PTY LTD

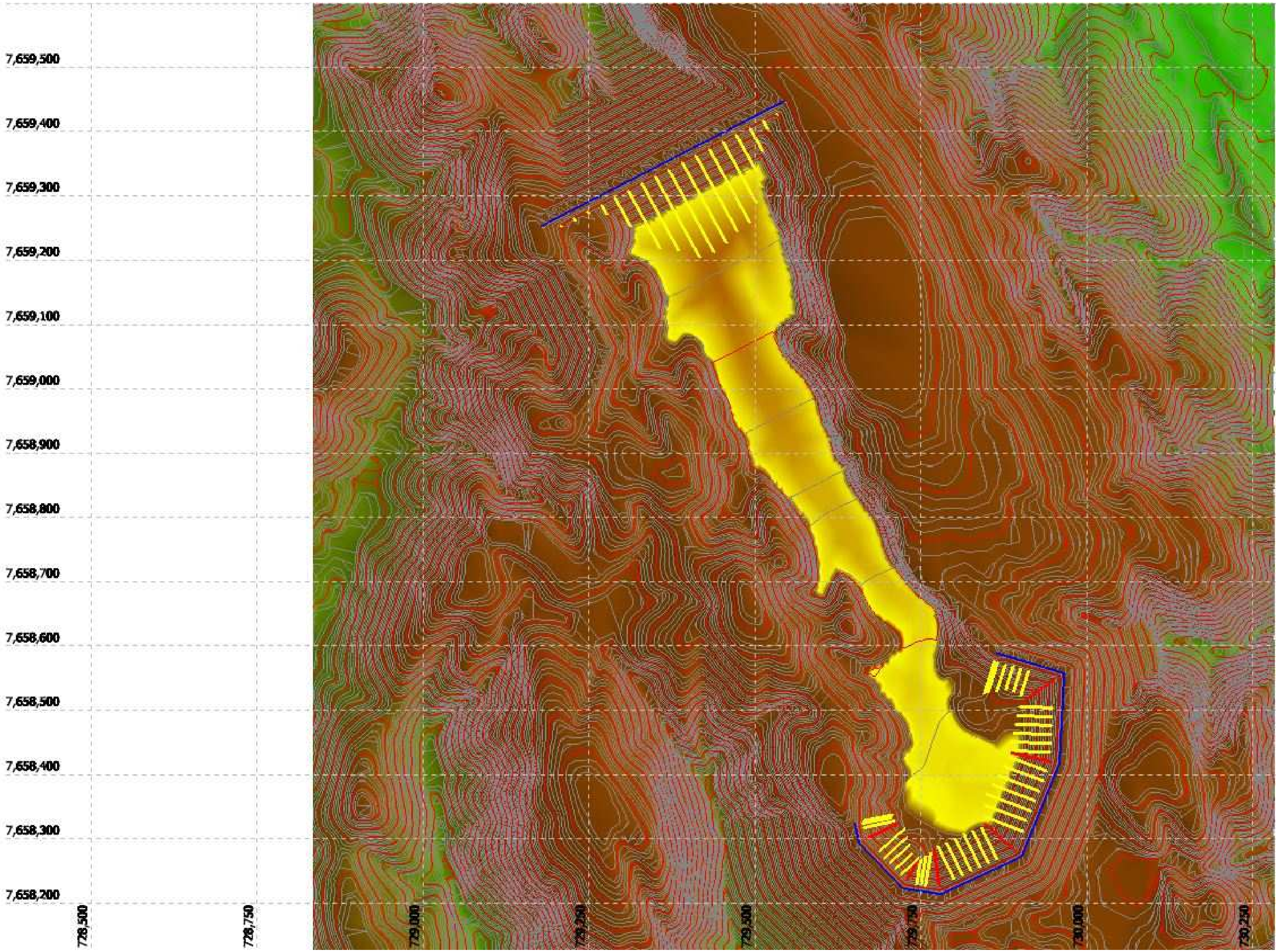
SIMON SMITH
Senior Engineer

DAVID MORGAN
Managing Director

REFERENCES

1. Tailings Management, Definitive Feasibility Study Rev. 0, Knight Piésold Pty Ltd, October 2018.
2. Department of Mines and Petroleum, Code of Practice, Tailings storage facilities in Western Australia, 2013.
3. Australian National Committee on Large Dams (ANCOLD), Guidelines on Tailings Dams, Planning, Design, Construction, Operation and Closure, Revision 1, July 2019.
4. RIFT TD, Rift Software (https://www.riftxone.com/), 2018.
5. "User Manual for Siberia (Version 8.30)" Prof. Garry Willgoose, Telluric Research, July 2005.
6. "Sulphur Springs Conceptual TSF Cover Design" Memorandum, O'Kane Consultants Pty Ltd, 8 May 2017.

FIGURES



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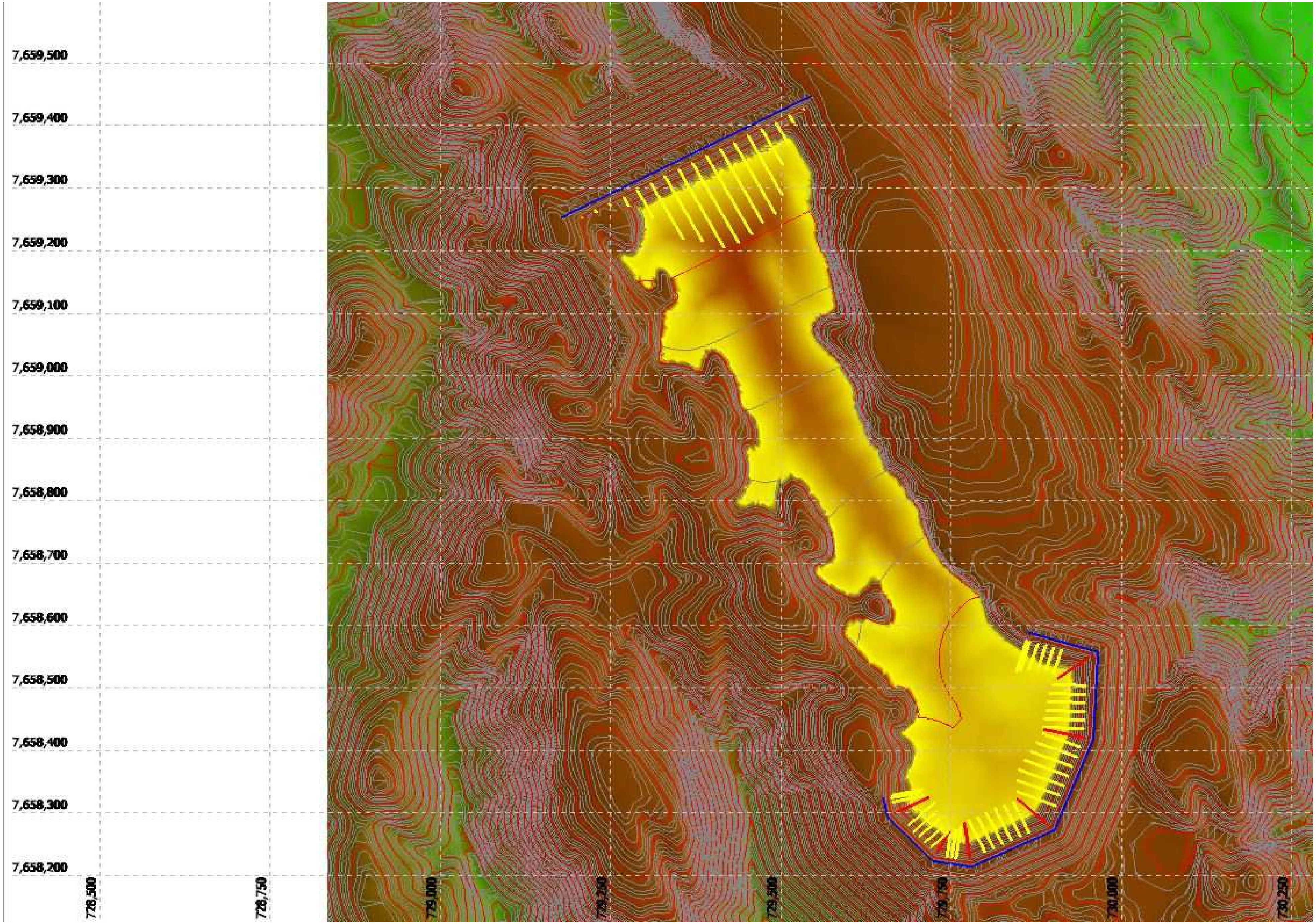
SULPHUR SPRINGS ZINC-COPPER PROJECT
ALTERNATIVE TAILINGS STORAGE FACILITY
TAILINGS DEPOSITION - YEAR 2

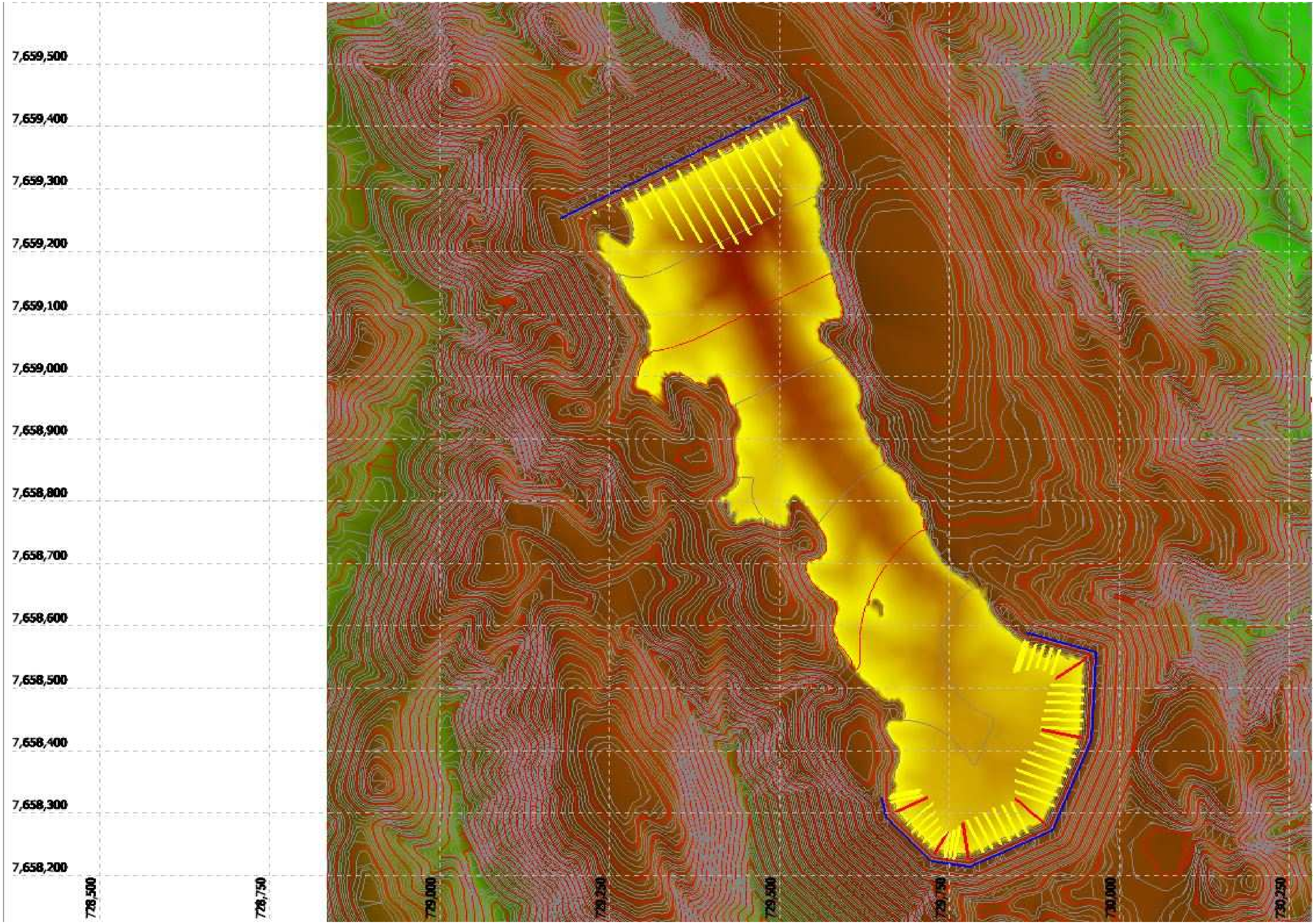
PE801-00300 M20002
Figure 1



Knight Piésold CONSULTING

SULPHUR SPRINGS ZINC-COPPER PROJECT
ALTERNATIVE TAILINGS STORAGE FACILITY
TAILINGS DEPOSITION - YEAR 5

PE801-00300 M20002
Figure 2



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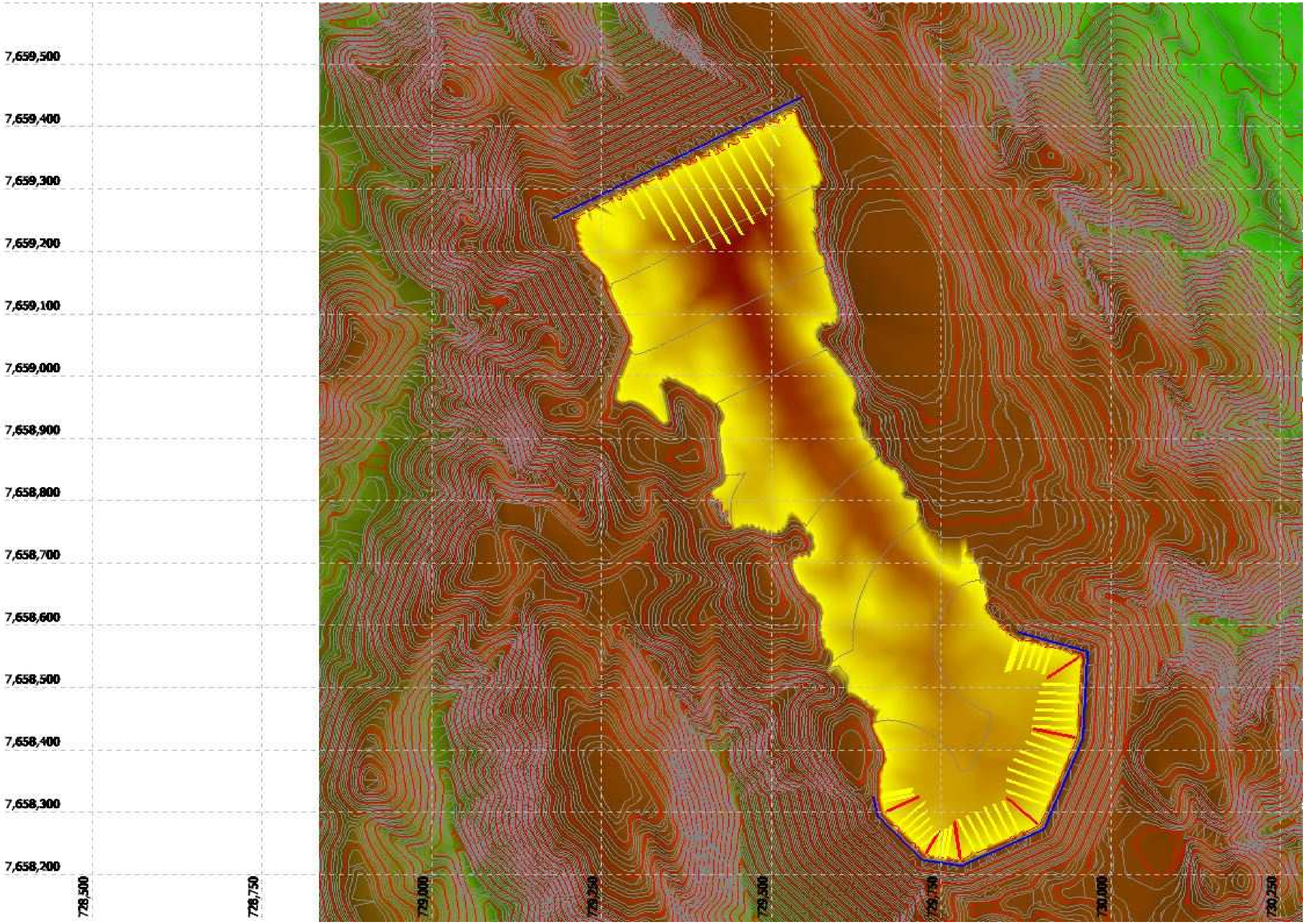
SULPHUR SPRINGS ZINC-COPPER PROJECT
ALTERNATIVE TAILINGS STORAGE FACILITY
TAILINGS DEPOSITION - YEAR 8

PE801-00300 M20002
Figure 3



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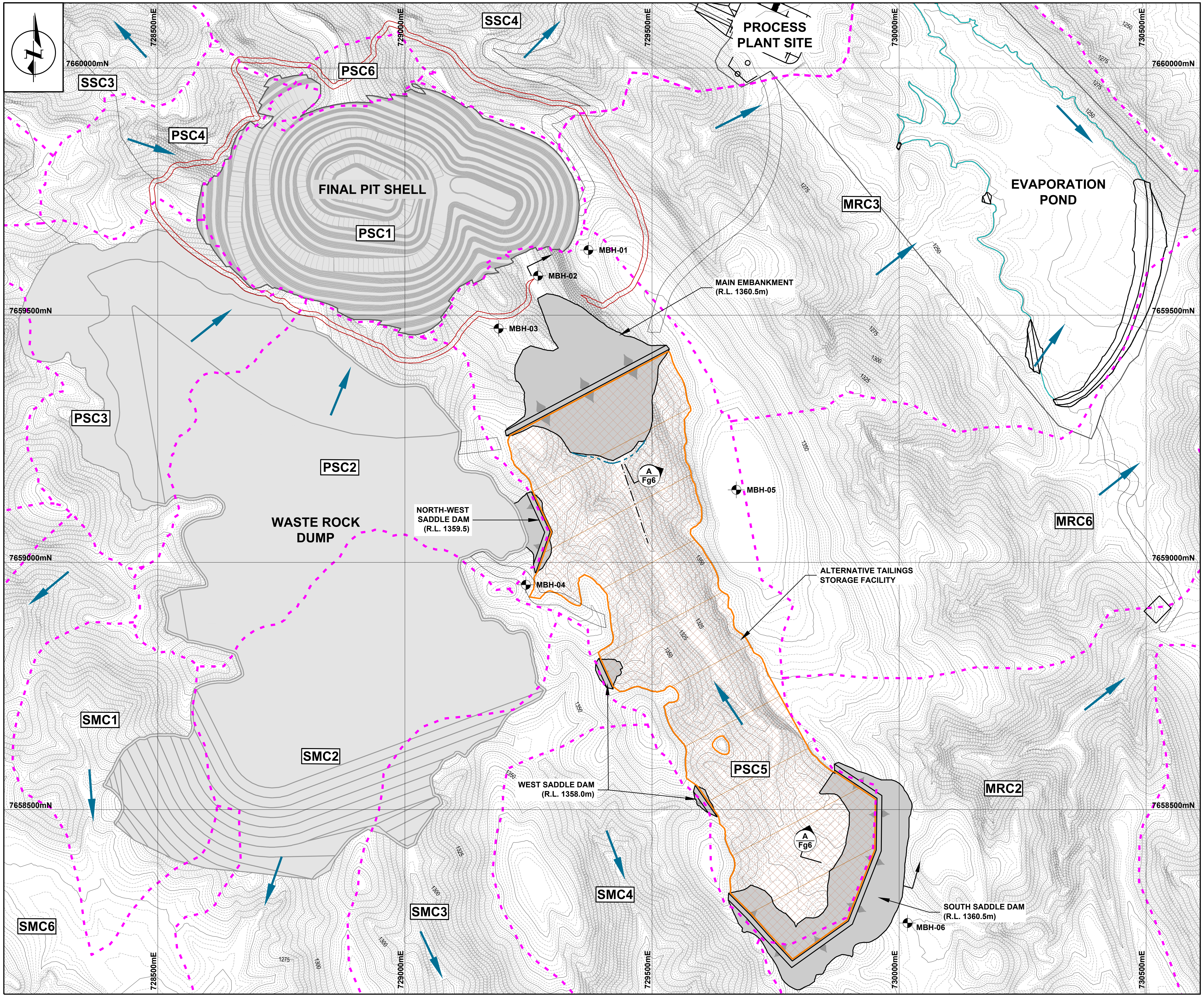
SULPHUR SPRINGS ZINC-COPPER PROJECT
ALTERNATIVE TAILINGS STORAGE FACILITY
TAILINGS DEPOSITION - YEAR 10

PE801-00300 M20002
Figure 4



NOTES:

1. 1m CONTOUR INTERVAL SHOWN. 2m CONTOUR INTERVAL TOPOGRAPHIC DATA PROVIDED BY VENTUREX RESOURCES LIMITED, AUGUST 2018.
2. PLANT SITE LAYOUT PROVIDED BY VENTUREX RESOURCES LIMITED, JANUARY 2020.
3. WASTE DUMP LAYOUT PROVIDED BY VENTUREX RESOURCES LIMITED, JANUARY 2020.
4. PIT SHELL AND PIT ABANDONMENT BUND PROVIDED BY VENTUREX RESOURCES LIMITED, JANUARY 2020.

LEGEND:

- PIT ABANDONMENT BUND
- NATURAL GROUND CATCHMENT BOUNDARY
- #### DRAINAGE CATCHMENT I.D.
- NATURAL CATCHMENT RUN-OFF DIRECTION
- TAILINGS BEACH EXTENT
- EMBANKMENT TOE DRAIN
- MAIN COLLECTOR DRAIN
- PROPOSED MONITORING BOREHOLE LOCATIONS

PROPOSED MONITORING BOREHOLE LOCATIONS

MBH I.D.	EASTING	NORTHING
MBH-01	729371	7659632
MBH-02	729269	7659580
MBH-03	729189	7659473
MBH-04	729245	7658954
MBH-05	729670	7659147
MBH-06	730017	7658270

100 50 0 100 200 300
SCALE (METRES) 1:7,500 (A3)

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SULPHUR SPRINGS ZINC-COPPER PROJECT
ALTERNATIVE TAILINGS STORAGE FACILITY
GENERAL ARRANGEMENT PLAN

PE801-00300 M20002
Figure 5

NOTES:

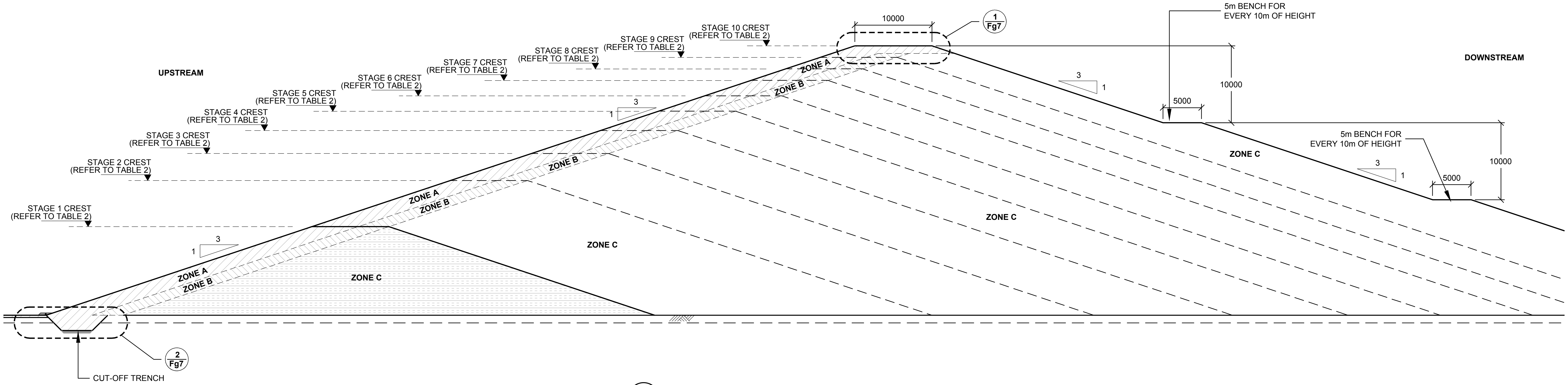
1. FOUNDATION PREPARATION SHALL EXTEND 5000mm BEYOND THE TOE OF THE EMBANKMENT.
2. CONSTRUCTION MATERIALS TO BE APPROVED BY THE ENGINEER.
3. PLACED CONSTRUCTION MATERIALS ARE TO BE TESTED FOR DENSITY AND MOISTURE CONTENT AND APPROVED BY THE ENGINEER PRIOR TO PLACEMENT OF SUBSEQUENT LAYERS.
4. ALL FILL MATERIAL TO BE PLACED AND COMPACTED IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION.
5. CUT-OFF TRENCH MINIMUM DEPTH OF 1.5m BELOW GROUND LEVEL AND A MINIMUM OF 1m INTO WEATHERED ROCK.
6. SAFETY BERM MATERIAL TO BE PLACED AND TRIMMED ONLY. NO COMPACTION REQUIRED.
7. FOR ZONE SPECIFICATIONS REFER TABLE 1.
8. FOR EMBANKMENT STAGE CREST ELEVATIONS REFER TABLE 2.

TABLE 1:
SOIL SPECIFICATIONS SUMMARY

ZONE TYPE	DESCRIPTION	COMPACTION SPECIFICATION
ZONE A	LOW PERMEABILITY FILL - WIN FROM BORROW	98% SMDD, -3%<OMC<+3% 300mm LAYERS
ZONE B	TRANSITION MATERIAL -WIN FROM BORROW / MINE WASTE	98% SMDD, -3%<OMC<+3% 300mm LAYERS
ZONE C	STRUCTURAL FILL - OXIDE MINE WASTE/WIN FROM BORROW	95% SMDD, -3%<OMC<+3% 500mm LAYERS
ZONE D	APPROVED GENERAL FILL	UNIFORM DENSITY FREE FROM CAVITIES
ZONE E	EROSION PROTECTION - COMPETENT WASTE ROCK	UNIFORM DENSITY FREE FROM LARGE CAVITIES
ZONE F	DRAINAGE MEDIUM - SAND OR FINE GRAVEL	UNIFORM DENSITY FREE FROM CAVITIES
ZONE G	SELECTED CLEAN ROCKFILL - NO FINES	UNIFORM DENSITY FREE FROM LARGE CAVITIES
RIPRAP	SELECTED ROCKFILL	UNIFORM DENSITY FREE FROM LARGE CAVITIES
EMBANKMENT FOUNDATION	IN-SITU MATERIAL AS APPROVED BY THE ENGINEER	WITHIN 5m OF THE CUT OFF TRENCH, 95% SMDD, -3%<OMC<+3%
CUT OFF TRENCH	LOW PERMEABILITY FILL (EQUIVALENT TO ZONE A)	98% SMDD, -1%<OMC<+3% 300mm LAYERS

TABLE 2:
EMBANKMENT CREST ELEVATION DETAILS

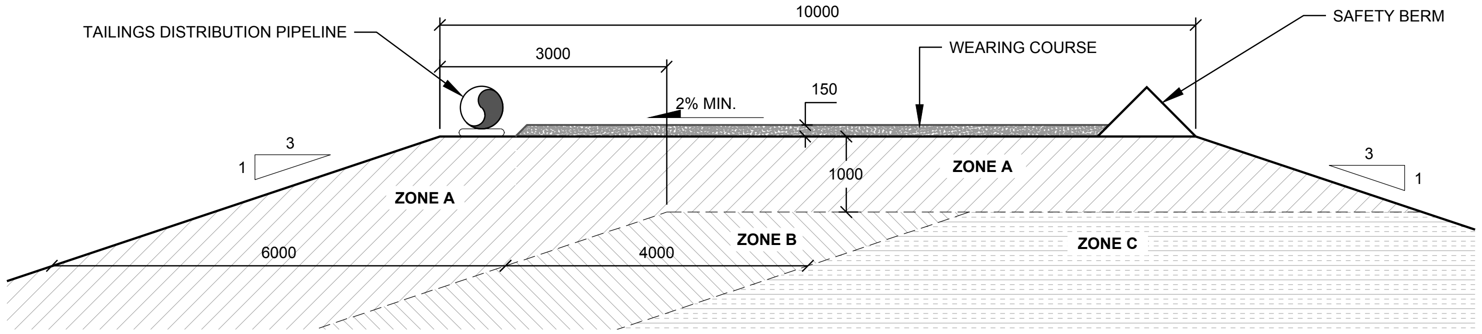
EMBANKMENTS	NORTH MAIN EMBANKMENT	SOUTH MAIN EMBANKMENT	NORTH-WEST SADDLE EMBANKMENT	WEST SADDLE EMBANKMENT	TOTAL STORAGE CAPACITY
STAGE	ELEVATION (m R.L.)	ELEVATION (m R.L.)	ELEVATION (m R.L.)	ELEVATION (m R.L.)	Mt.
1	1337.0	1337.0	-	-	1.135
2	1343.0	1343.0	-	-	2.27
3	1346.5	1346.5	-	-	3.35
4	1349.5	1349.5	-	-	4.375
5	1352.0	1352.0	-	-	5.4
6	1354.0	1354.0	-	-	6.425
7	1356.0	1356.0	-	-	7.45
8	1357.5	1357.5	-	-	8.475
9	1359.0	1359.0	1358.0	1356.0	9.5
10	1360.5	1360.5	1359.5	1358.0	10.53



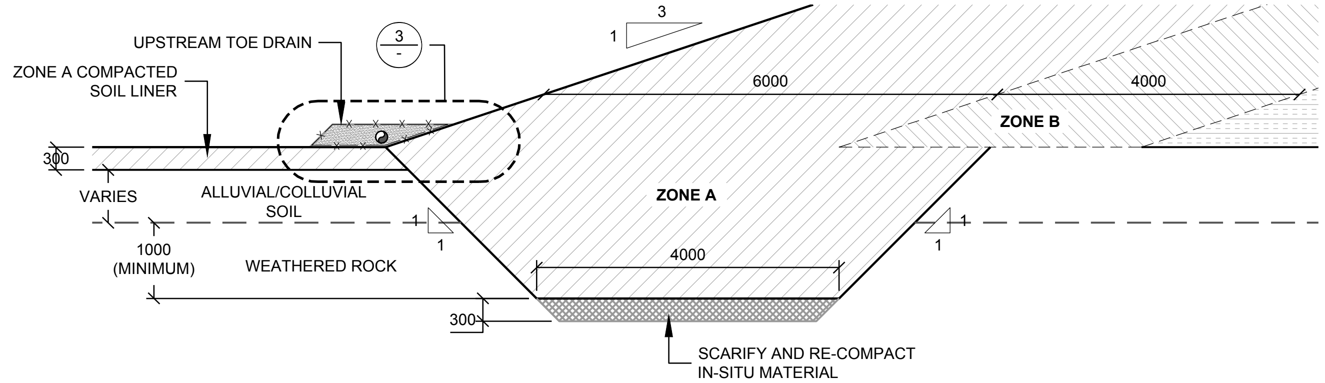
A Fg5 **TYPICAL FINAL EMBANKMENT SECTION**
1:500

NOTES:

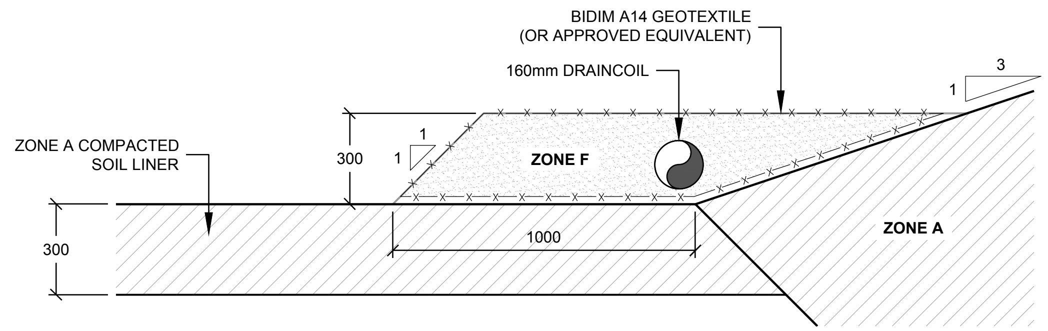
1. FOUNDATION PREPARATION SHALL EXTEND 5000mm BEYOND THE TOE OF THE EMBANKMENT.
2. CONSTRUCTION MATERIALS TO BE APPROVED BY THE ENGINEER.
3. PLACED CONSTRUCTION MATERIALS ARE TO BE TESTED FOR DENSITY AND MOISTURE CONTENT AND APPROVED BY THE ENGINEER PRIOR TO PLACEMENT OF SUBSEQUENT LAYERS.
4. ALL FILL MATERIAL TO BE PLACED AND COMPACTED IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION.
5. CUT-OFF TRENCH MINIMUM DEPTH OF 1.5m BELOW GROUND LEVEL AND A MINIMUM OF 1m INTO WEATHERED ROCK.
6. SAFETY BERM MATERIAL TO BE PLACED AND TRIMMED ONLY. NO COMPACTION REQUIRED.
7. FOR ZONE SPECIFICATIONS REFER TABLE 1, ON FIGURE 6.
8. FOR EMBANKMENT STAGE CREST ELEVATIONS REFER TABLE 2, ON FIGURE 6.



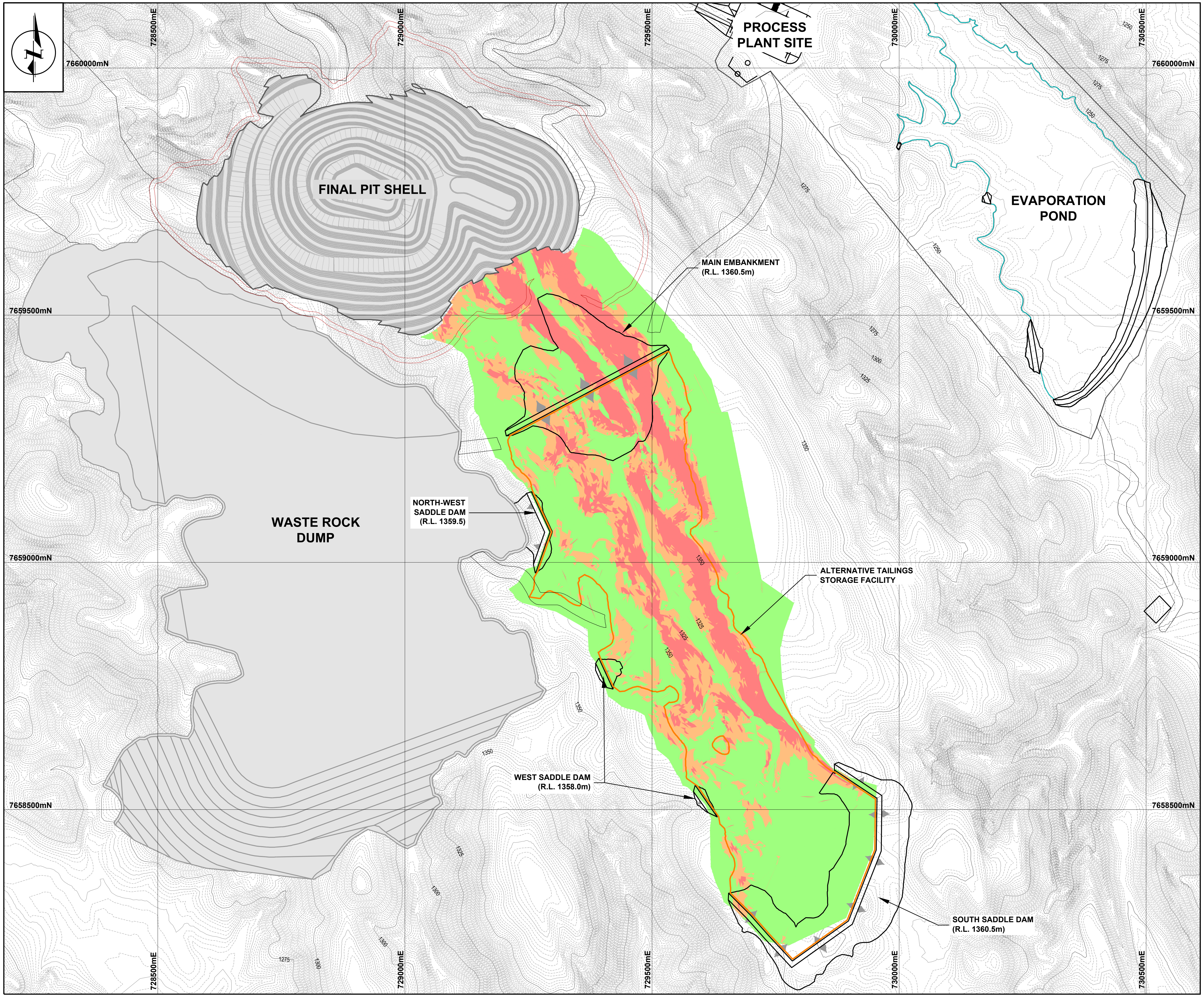
1 Fg6 **TYPICAL EMBANKMENT CREST DETAIL**
1:100



2 Fg6 **TYPICAL CUT-OFF TRENCH DETAIL**
1:100



3 - **TYPICAL UPSTREAM TOE DRAIN DETAIL**
1:25



NOTES:

1. 5m CONTOUR INTERVAL SHOWN. 2m CONTOUR INTERVAL TOPOGRAPHIC DATA PROVIDED BY VENTUREX RESOURCES LIMITED, AUGUST 2018.
2. PLANT SITE LAYOUT PROVIDED BY VENTUREX RESOURCES LIMITED, MARCH 2018.
3. WASTE DUMP LAYOUT PROVIDED BY VENTUREX RESOURCES LIMITED, SEPTEMBER 2018.
4. PIT SHELL AND PIT ABANDONMENT BUND PROVIDED BY VENTUREX RESOURCES LIMITED, AUGUST 2018.

LEGEND:

- PIT ABANDONMENT BUND
- EXISTING GROUND SLOPE ≤ 1(V) : 3(H)
- EXISTING GROUND SLOPE ≥ 1(V) : 3(H) ≤ 1(V) : 2(H)
- EXISTING GROUND SLOPE ≥ 1(V) : 2(H)

100 50 0 100 200 300
SCALE (METRES) 1:7,500 (A3)

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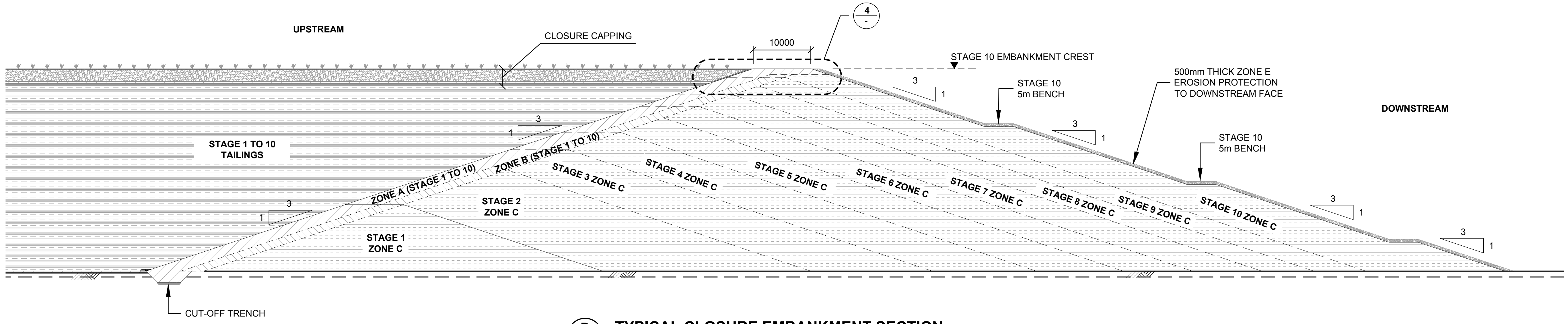
SULPHUR SPRINGS ZINC-COPPER PROJECT
ALTERNATIVE TAILINGS STORAGE FACILITY
EXISTING GROUND SLOPES

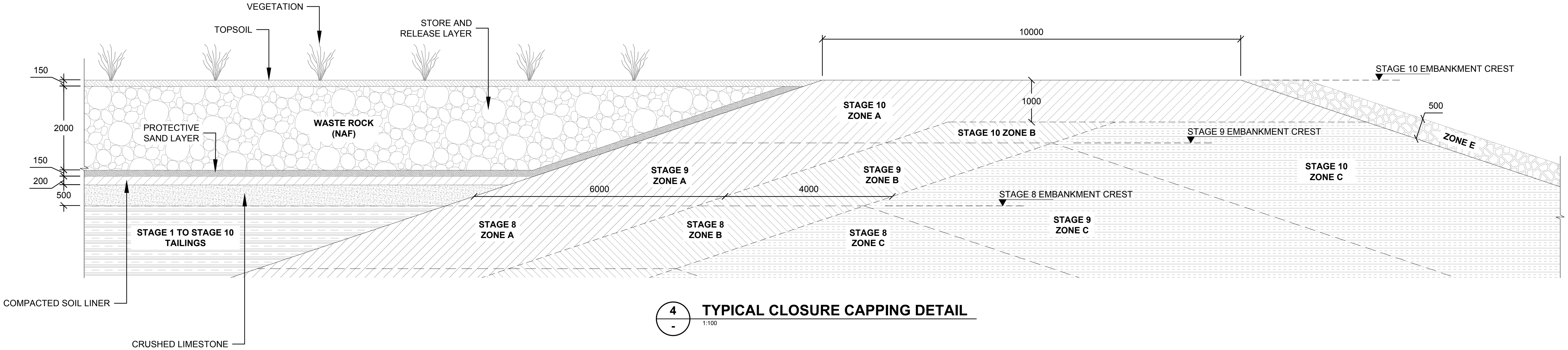
PE801-00300 M20002
Figure 8

NOTES:

1. CONSTRUCTION MATERIALS TO BE APPROVED BY THE ENGINEER.
2. PLACED CONSTRUCTION MATERIALS ARE TO BE TESTED FOR DENSITY AND MOISTURE CONTENT AND APPROVED BY THE ENGINEER PRIOR TO PLACEMENT OF SUBSEQUENT LAYERS.
3. ALL FILL MATERIAL TO BE PLACED AND COMPACTED IN ACCORDANCE WITH THE TECHNICAL SPECIFICATION.
4. SAFETY BERM MATERIAL TO BE PLACED AND TRIMMED ONLY. NO COMPACTION REQUIRED.



B
-
TYPICAL CLOSURE EMBANKMENT SECTION
1:500



4
-
TYPICAL CLOSURE CAPPING DETAIL
1:100