# GOLDER

**DATE** November 08, 2019 **Project No.** 1899291 (13000)

**TO** Melanie Humphrey
Michigan Department of Environment, Great Lakes and Energy

**CC** David Anderson, Aquila Resources Inc. and Steve Donohue, Foth Infrastructure & Environment, LLC.

**FROM** Kebreab Habte and Ken Bocking **EMAIL khabte@golder.com**

**RE: BACK FORTY PROJECT - MINING PERMIT AMENDMENT APPLICATION (MP 01 2016) – RESPONSE TO OCTOBER 23, 2019 REQUEST FOR ADDITIONAL INFORMATION AND CLARIFICATION ON THE TAILINGS MANAGEMENT FACILITY**

On October 16, 2019 Aquila Resources Inc. (Aquila) and its consultants (Golder Associates Ltd. (Golder) and Foth Infrastructure & Environment, LLC, (Foth)) presented the Back Forty Project Tailings Management Facility design concept to the staff of the Water Resource Division (WRD), Materials Management Division (MMD), and Oil, Gas, and Minerals Division (OGMD) of the Michigan Department of Environment, Great Lakes, and Energy (EGLE). The presentation materials are provided in Attachment A.

On October 23, 2019, EGLE requested additional information and clarification regarding the design, construction and monitoring of the Tailings Management Facility (TMF). This letter provides the response to the five questions requested. EGLE's questions are provided in italics. Golder's responses to the questions are provided following each question.

Aquila is anticipating that original permit conditions under MP 01 2016, Special Permit Conditions (SPC) F and K will be continued in the amended permit with minimal revision. Section K addresses additional monitoring requirements pertaining to the TMF.

1. *A conceptual level geotechnical exploration/monitoring plan outlining the following:*
    a. *Frequency and depth of soil borings and other exploration to be completed before construction of each berm lift.*
    b. *Spacing and locations of monitoring devices (including piezometers, inclinometers, settlement plates, etc.) that would be used to track conditions of foundation materials and berm lifts.*
    c. *Provisions for periodic monitoring/construction progress reports to be submitted to EGLE for review throughout the construction process*

Response to Question 1

1a. As shown in Figure B1 in Attachment B, a total of 31 boreholes and 17 test pits have been completed within the footprint of the proposed TMF. Considering the relatively uniform sand and gravel overburden across the TMF site, it is considered that the current geotechnical information is sufficient to characterize the subsurface condition underlying the TMF site  Therefore, no further geotechnical investigation is proposed to characterize the subsurface soils during detailed design and construction of the TMF start-up perimeter walls (i.e. founded on overburden soils).

Following the start-up construction, the TMF perimeter walls will be raised over deposited tailings. Prior to the construction of each perimeter wall raise, electronic Cone Penetration Tests with pore water pressure measurement (CPTu) will be carried out in the tailings to determine the state of the tailings foundation.

The CPTu tests will be used to profile the tailings by soil behaviour classification, to measure pore water pressures, to identify dilative and contractive zones (i.e. potentially liquefiable zones), and to estimate the undrained shear strength of the tailings deposit.

The following CPTu tests will be carried out prior to each of the following perimeter wall raises:

- Raise to El. 250 m: One CPTu in tailings at approximately the mid-way point of each of the sides of the TMF (total of four).
- Raise to El. 262 m: One CPTu in tailings at approximately the mid-way point of the north and south side of the TMF (total of two).

The CPTu tests will be carried out from the surface of the tailings to 3 m above the liner (to prevent accidental punctures).

The proposed locations of the CPTu tests are shown in Figure C1 in Attachment C.

1b. Vibrating wire piezometers (VWP) and Vibrating Wire Liquid Settlement System (VWLSS) will be installed in the tailings for performance monitoring.

Multi-point VWP strings will be installed at the following locations prior to each of the following perimeter wall raises:

- Raise to El. 250 m: One multi-point VWP will be installed at approximately the mid-way point on each side of the TMF (total of four).
- Raise to El. 262 m: One multi-point VWP will be installed at approximately the mid-way point on the north and south side of the TMF (total of two).

The piezometer strings of each multi-point VWP will be spaced apart along the cable to create a pore water pressure profile at the installation location.

The VWP cables will be protected and run through the Transition layer at the base of each TMF perimeter wall raise.  The VWPs will be connected to data loggers to enable continuous recording of pore pressures at the installation location. The monitoring data will be downloaded and reviewed on a regular schedule as part of the TMF operational procedures.

Vibrating Wire Liquid Settlement System will be installed at the following locations following each stage of TMF perimeter wall construction:

- Raise to El. 250 m: One VWLSS will be installed at the bottom of the perimeter wall raise (at Elev. 240 m) at approximately the mid-way point of each of the sides of the TMF (total of four).
- Raise to EL 262 m: One VWLSS will be installed at the bottom of the perimeter wall raise (at Elev. 250 m) at approximately the mid-way point on the north and south side of the TMF (total of two).

The VWLSS cable will be protected and run through the Transition layer at the base of each TMF perimeter wall raise. The VWLSS will be connected to data loggers to enable continuous recording of settlements at the installation location. The monitoring data will be downloaded and reviewed on a regular schedule as part of the TMF operational procedures.

The proposed locations of the VWPs and VWLSSs are shown in Figure C1 in Attachment C.

1c. During construction, the following two types of reports will be submitted to EGLE:

- Annual inspection reports; and
- As-built reports.

The annual inspection report will be submitted annually following inspection of the TMF by the Engineer of Record. This report will address the monitoring of the TMF during construction of the perimeter wall raises and will include:

- Visual inspection of the physical condition of the TMF;
- Summary of visual inspection reports completed during the year by Aquila;
- Documentation of any repairs to monitoring devices and new installations;
- Summary of data collected from monitoring devices (i.e. settlement plates and VW piezometers);
- Identification of any areas of concern based on the monitoring data;
- Summary of recorded waste rock and tailings quantities stored in the TMF;
- Review of tailings deposition strategies and development plans;
- Review of monitoring procedures;
- Compilation of a formal list of deficient items (if any);
- Recommendations for improvements to construction monitoring procedures or instrumentation (if any).

As-built reports for each TMF perimeter wall raise will be submitted to EGLE following the completion of each raise (i.e., the starter wall including the base liner system, the Elev. 250 m raise, the Elev. 262 m raise and the closure cap). The as-built reports will document the construction progress and will include:

- Parties involved in the construction and responsibilities;
- Construction schedule;

- Description of construction methods;
- Description of design changes made (if any);
- As-built drawings showing as-built conditions;
- Photographs of key construction activities and milestones;
- All documentation of Quality Control and Quality Assurance (QA/QC) programs;
- Summary of QA/QC results; and
- Compilation of a formal list of deficient items (if any) to be corrected.

2. *Additional conceptual detail/explanation of the feasibility/appropriateness of a granular filter to be constructed between the tailings and waste rock interfaces including the following:*
   a. *Potential migration of fine-grained tailings materials into the waste rock penetrating layers, crushed rock transition layers, overburden soil filtration layers, and/or non-woven geotextile layers.*
   b. *Potential for fouling of the non-woven geotextiles.*
   c. *Potential impacts on berm/foundation stability if filters and separation layers do not perform as designed.*

<u>Response to Question 2</u>

2a. The TMF will consist of a rockfill perimeter wall with upstream transition and filter zones. The filter zone is designed to act as a filter for the tailings to prevent migration of fines while still allowing for the dissipation of any excess porewater pressure through seepage. The transition zone is designed to prevent migration of fines from the filter zone into the rockfill.

The transition and filter zone gradation envelopes were developed using procedures outlined by NRCS (2017). This method is commonly applied in the design of filters for embankment dams and similar guidelines have been published by the US Army Corps of Engineers and the US Bureau of Reclamation.

Attachment D presents the expected tailings and waste rock material gradations and resulting transition and filter zone gradation envelopes. Each specific step taken to develop the gradation envelopes are also outlined in Attachment D.

2b. Geotextile fouling can be caused by a number of factors. One mechanism for fouling is due to biological clogging. This is uncommon in tailings facilities which contain no organic material. It is more common with landfills. Since there will be no organic material in the TMF, the risk for biological fouling is very low. Chemical precipitation is another possible mechanism for fouling. Chemical fouling requires time for the chemical precipitates to occur that could result in clogging the geotextiles. Given the short life span of the TMF the risk for clogging due to chemical precipitates is very low. This issue will be addressed further if limestone amendment is required in the perimeter wall as a condition of the permit. If fouling of the geotextile were to occur, the most likely mechanism would be due to physical clogging. There are different methods of assessing the potential for physical clogging. Attachment E presents the physical clogging potential assessment completed using the criteria recommended by Luettich et.al. (1992) and Canadian Foundation

Engineering Manual (2006). The assessment confirmed that the proposed 340 g/m$^2$ nonwoven geotextile will not be prone to physical clogging.

2c. The perimeter wall of the TMF is designed to be free draining, using filter and transition zones to prevent tailings infiltration into the waste rock shell. As discussed in Attachment D, Modern filter criteria, routinely used in embankment dams, were used to design the filter and transition zones in order to prevent tailings infiltration. However, in the unlikely event that the filter and transition zones do not perform as designed, the fines in the tailings could clog the filter and transition zones and impede drainage, potentially raising the phreatic surface in the TMF.

If a higher phreatic surface were to occur, the potential impact on the stability of the TMF was considered. The stability analysis was carried out using the GeoStudio 2019 software package (GEO-SLOPE International Ltd. 2018). The Factor of Safety (FoS) was computed using the Morgenstern-Price method for numerous potential failure surfaces and the lowest FoS that causes a deep-seated failure resulting in significant scale slope instability was reported as the critical FoS. For long-term static stability, a FoS of 1.5 is needed to show continued TMF stability. For pseudo-static stability, the minimum FoS of 1.1 demonstrates continued TMF stability.

The input parameters and the results of the stability analyses are presented in Figures F1 and F2 (Attachment F). For the TMF design under filter failure conditions, the long-term static stability achieves a FoS of 1.56, which is greater than the minimum static FoS design criteria. The pseudo-static stability achieved a FoS of 1.44, which is greater than the minimum pseudo-static FoS design criteria.

Therefore, acceptable FoS values would be attained even if the filter and transition zones were to become clogged. The perimeter walls are sufficiently robust to maintain an acceptable FoS even if clogging were to occur. The analysis demonstrates the TMF will remain stable even with higher phreatic surface conditions.

3. *Conceptual level construction specifications and Construction Quality Assurance (CQA) plans outlining the following:*
   a. *Level of onsite CQA that would be provided during subgrade preparation and liner installation.*
   b. *Construction sequence and processes for the drainage/buffer layers, initial berm construction and grading, and subsequent berm lift construction and grading. Please include berm lift thicknesses, and any CQA and monitoring that will take place during construction.*

Response to Question 3

3a. As per the conditions in the Part 632 Permit, the Construction Specifications and the Construction Quality Control and Quality Assurance Plan will be prepared during the detailed design stage of the Project. Templates showing the table of contents of these two documents are provided in Attachment G.

The level of onsite CQA that would be provided during construction is outlined as following:

- The QC Contractor will be responsible for providing Quality Control (QC). The QC program will be defined in the Specifications and systematically implemented to ensure the quality of the construction Work.
- Trained and qualified staff will carry out the QC work.
- The Owner will retain a third party to provide Quality Assurance (QA). The QA program will be defined in the Specifications and systematically implemented to provide adequate confidence to the Owner and various stakeholders that the QC program is being implemented effectively.
- The QA program will be directed by the QA Manager, the Engineer's full-time on-site representative who will be responsible for construction quality assurance.
- The QA Manager will be a registered Profession Engineer in Michigan with sufficient practical, technical, and managerial experience to successfully implement the CQA plan. The QA Manager will direct trained and qualified staff to carry out QC work.
- The Specifications will be prepared referencing accepted standard Specifications such as ASTM (American Society of Testing Materials) and GRI (Geosynthetics Research Institute).
- All Manufacturer QA/QC certifications and Contractor QC testing equipment certifications and calibration records will be reviewed and documented.

The CQA provided for the subgrade preparation would include:

- Full-time QC and QA monitoring during placement and compaction of lifts during cut to fill grading. Monitoring includes checking lines and grades conform to the Drawings, ensuring unsuitable materials (e.g. organics, frozen soil, snow, ice, etc..) are removed and ensuring lift thicknesses are placed and compacted as specified.
- The following CQA tests will be performed at specified intervals on the fill material at specified intervals to confirm compaction:
  - Grain size distribution
  - Standard Proctor
  - In-situ Density, and
  - Moisture content.

The CQA provided for the geosynthetics installation would include:

- Review of Geosynthetic Manufacturer's QA/QC certifications and documentation to verify all geosynthetic materials meet the minimum properties defined by the Specifications.
- Inspection of all received geosynthetic materials to verify the rolls are received in good condition, wrapped in protective covers and clearly marked with identifying information matching the Manufacturer's QA/QC documentation.

- Inspection of material handling and storage locations to verify Manufacturer's procedures for storage and handling requirements are followed.
- Inspection and written approval of prepared subgrade and/or installation surface immediately prior to deployment of geosynthetic materials.
- Care will be taken to avoid damaging the geosynthetics following deployment. Strict adherence to the following procedures will be enforced:
  - No mechanical equipment or vehicles will be allowed to traffic on the surface except approved by the Engineer.
  - Only approved cutting tools will be used.
  - No smoking, no petroleum products and no damaging shoes will be permitted on the geosynthetic surface.
  - Geosynthetics will be sufficiently ballasted and anchored to prevent wind uplift.
- Full-time QC and QA representatives will monitor and document the geosynthetic deployment, field seaming and repairs.
- Upon completion of each component installation, a visual inspection will be completed and written approval will be issued by the QA Manager prior to covering or installation of a subsequent geosynthetic layer.

Geotextile installation will have the following QA/QC requirements:

- Geotextile will be overlapped and seams will be sewn or heat bonded using a method approved by the Engineer.
- Any defects will be repaired by sewing and heat bonding a geotextile patch with a minimum overlap as specified.

Geomembrane installation will have the following QA/QC requirements:

- Trial welds will be conducted every four hours of operation or when environmental conditions change. No welding equipment or welder will be allowed to perform production welds until equipment and welders have successfully completed trial welds passing peel strength and shear strength tests.
- Non-destructive tests will be conducted on every seam of the installed liner and on every extrusion weld patch.
- Destructive tests (i.e. samples cut from the installed liner) will be collected at specified intervals and tested for peel and shear strength tests. Failed welds will be tracked until a passing weld is encountered.
- Failed seams and patches will be patched and/or replaced as per the Specifications.
- Geomembrane covering will only take place when the geomembrane wrinkles caused by heat expansion are below a height defined by the Specifications.

- The cover must be built up to a minimum specified thickness prior to approved equipment and vehicles being allowed to traffic on the cover.

Geocomposite installation will have the following QA/QC requirements:

- The geocomposite will be composed of a geonet with geotextile heat bonded to both sides of the geonet.
- The geocomposite panels will be overlapped, the geonet will be tied together, the geotextile will be heated bonded or sewn using a method specified or approved by the Engineer.
- Any geonet defects will be repaired by tying a geonet patch with a minimum overlap as specified.
- Any defects to the upper geotextile will be repaired by sewing and heat bonding a geotextile patch with a minimum overlap as specified

Geosynthetic clay liner (GCL) installation will have the following QA/QC requirements:

- The GCL panels will be overlapped and granular bentonite will be placed between the panels with a minimum coverage width and rate specified or approved by the Engineer.
- Any defects will be repaired by a GCL patch with a minimum overlap, secured with approved adhesive and seamed with bentonite as specified.
- GCL will be covered on the same day as installation by either permanent cover or waterproof material to prevent hydration.

Throughout construction there will be hold points, whereby the Contractor will submit relevant information to the QA/QC Site Manager and other relevant parties for approval prior to commencing with the next stage of the Works. The hold points are summarized in the table below.

| Hold Point Description | Action Required | By whom |
|---|---|---|
| Submission of construction program | Review and approval | Engineer and Construction Manager |
| Characterization of borrow materials, including aggregates | Receipt of laboratory testing results and approval | Engineer, QA/QC Site Manager |
| Manufacturer Quality Assurance testing | Receipt of laboratory testing results and approval | Engineer, QA/QC Site Manager |
| Submission of samples of geomembrane liners, GCL, geocomposite, and geotextile to designated laboratory | Testing by laboratory and approval | Engineer, QA/QC Site Manager |

| Hold Point Description | Action Required | By whom |
|---|---|---|
| Completing of survey of natural ground surface | Receipt of contour and approval | Engineer, QA/QC Site Manager |
| Setting-out structures and elements of structures | Receipt of setting-out points and approval | Engineer, QA/QC Site Manager |
| Completion of clearing and grubbing | Inspection of cleared areas and approval | Engineer, QA/QC Site Manager |
| Completion of stripping | Inspection of stripped areas and approval | Engineer, QA/QC Site Manager |
| Placing, moisture conditioning, and compaction of each fill layer to prepare the base grades, and perimeter berms of the TMF and WRFs | Receipt of quality control test results, inspection of compaction achieved and approval | Engineer, QA/QC Site Manager |
| Excavation of perimeter ditches and LLCSs of the TMF and WRFs | Inspection of final profiles and approval | Engineer, QA/QC Site Manager |
| Placing, moisture conditioning, and compaction of the liner bedding of the TMF, WRFs and LLCSs | Receipt of quality control test results, inspection of compaction achieved and approval | Engineer, QA/QC Site Manager |
| MQA testing of geosynthetic materials | Receipt of laboratory testing results and approval | Engineer, QA/QC Site Manager |
| Geomembrane liners, GCL, geocomposite and geotextile installation and field testing. | Inspection of installation and field testing | Engineer, QA/QC Site Manager |
| Excavation of liner anchor trench | Inspection of final profiles and approval | Engineer, QA/QC Site Manager |
| Backfilled and compacted liner anchor trench | Inspection of backfill compaction | Engineer, QA/QC Site Manager |
| Leak location survey of geomembrane liners | Receipt of survey results and approval of defects repair | Engineer, QA/QC Site Manager |
| Placement of drainage layer | Receipt of laboratory testing results and approval | Engineer, QA/QC Site Manager |

| Hold Point Description | Action Required | By whom |
|---|---|---|
| Leak location survey of geomembrane liners | Receipt of survey results and approval of defects repair | Engineer, QA/QC Site Manager |
| Placement of liner protection layer | Inspection of final profiles and approval | Engineer, QA/QC Site Manager |
| Placing, moisture conditioning, and compaction of each fill layer of the Perimeter Wall of the TMF | Receipt of quality control test results, inspection of compaction achieved and approval | Engineer, QA/QC Site Manager |
| Completion of final survey and production of as-built drawings | Receipt and Approval | Engineer, QA/QC Site Manager |

3b. A brief description of the construction sequence of the TMF and WRFs is described below.

The TMF and WRFs will be constructed in stages over the life of mine as summarized in the table below.

| Stage | TMF | WRFs |
|---|---|---|
| 1 | Prepare base grade and install liner system of the initial footprint area of the TMF and LLCS 1. Construct perimeter wall of first cell to elevation 237 m. | Prepare base grade of the South WRF and install liner system on the initial footprint area of the South WRF and prepare the based grade and install liner system of LLCS 2. |
| 2 | Construct perimeter wall of first cell of TMF to elevation 240 m. | Install liner system of the remaining footprint area of the South WRF. |
| 3 | Prepare the remaining based grade and install liner system of the ultimate TMF footprint area. Construct perimeter wall of second cell of the TMF to elevation 240 m. | Prepare base grade and install liner system of the initial footprint area of the North WRF and LLCS 3. |
| 4 | Raise perimeter walls of the TMF in 2m lifts to elevation 250 m. | Prepare base grade and install liner system of the remaining footprint area of the North WRF and LLCS 4. |
| 5 | Raise outer perimeter walls of the TMF in 2m lifts to elevation 262 m. | N/A |
| 6 | Decommission decant area and place waste rock crown on top of TMF | Remove waste rock from North WRF for use in the construction of the TMF crown |

| Stage | TMF | WRFs |
|---|---|---|
| 7 | Place closure cover of the TMF and decommission the LLCS 1. | Relocate the remaining waste rock from the South WRF and North WRFs to the open Pit. Remove liner system, decommission LLCSs 2 to 4 and revegetate the footprint areas of the WRFs and LLCSs 2 to 4. |

The General Scope of Work for the TMF, WRFs and LLCSs construction is as follows:

- Surveying of the ground surface of construction area and setting out of the foundation preparation limits, lines and grades;
- Clearing and grubbing of vegetation cover within the construction areas and hauling to designated stockpile areas;
- Stripping of all organic and unsuitable materials within the construction areas and hauling to designated stockpile areas;
- Base grade preparation of the TMF and WRFs by cut to fill operation;
- Excavation of LLCSs and perimeter leachate and leak collection ditches;
- Construction of the perimeter berms of the TMF, WRFs and LLCSs;
- Placement of 9.5 mm minus overburden soil (liner bedding) in 150 mm layer over the footprint areas of the TMF, WRFs, and LLCSs;
- Installation of the base liner system of the TMF, WRFs and LLCSs.
- Installation of perforated HDPE pipes to collect leachate and leak at the base of the TMF, WRFs and LLCSs;
- Excavation of liner anchor trenches and backfilling at the TMF, WRFs, and LLCSs perimeter berms.
- Placement of the perimeter wall of the TMF, which consist of the following materials:
  - 500mm minus waste rock (Zone 1)
  - 150mm minus crushed waste rock (Zone 2)
  - 9.5mm minus filter (screened overburden) (Zone 3)

The following table outlines the lift thickness, compaction method (if any) and geotechnical testing requirements for each earthworks material.

| Item | Compaction | | Testing |
|---|---|---|---|
| | Maximum Loose Lift Thickness | Compaction Method | Type of Testing |
| Zone 1 Random Waste Rock | 1.0 m | smooth drum, vibratory roller and compactor | Visual inspection |
| Zone 2 Transition | 0.5 m | smooth drum, vibratory roller and compactor | Gradation |
| | | | Visual inspection |
| Zone 3 Filter | 0.3 m | Nominal compaction | Gradation |
| | | | Visual inspection |
| Zone 4 Random Overburden | 0.3 m | smooth drum, vibratory roller and compactor | Moisture Content |
| | | | Density |
| | | | Standard Proctor |
| | | | Visual inspection |
| Zone 5 Liner Bedding | 0.2 m | smooth drum, vibratory roller and compactor | Gradation |
| | | | Moisture Content |
| | | | Density |
| | | | Standard Proctor |
| | | | Visual inspection |
| Zone 6 Drainage Protection Soil | 0.3 | None, low ground pressure bulldozers (<5.0 psi) | Gradation |
| | | | Moisture Content |
| | | | Visual inspection |
| Zone 7 Coarse Aggregates | 0.5 | None, low ground pressure bulldozers (<5.0 psi) | Gradation |
| | | | Visual inspection |
| Zone 8 Rip Rap | 1.0 | Nominal compaction | Visual inspection |

4. *The application materials and subsequent responses provide very little detail of how leachate will be collected and transported from the liner catchment to treatment facilities. Provide further explanation of conceptual level plans of leachate collection and transportation in order to ensure that phreatic surface within the basin does not impact stability of the tailings or rock berms and so that escapement does not occur.*

Response to Question 4

4a. The base grade and the perimeter ditch of the TMF will slope downward from southeast corner to the northwest corner at a minimum gradient of 1%. Leachate and run-off from the downstream slope of the perimeter wall will flow to the perimeter ditch and eventually to LLCS 1 by gravity. Four HDPE pipes, each 800 mm diameter, and an open trapezoidal trench will be provided to convey the contact water collected by the perimeter ditch into LLCS 1 as shown in Figure H1 (Attachment H). Similarly, the leakage collected from the TMF will be conveyed to LLCS 1 using a 250 mm diameter HDPE pipe.

A pumping system will be provided in the LLCS 1 to convey the contact water collected to the Contact Water Basin. Additionally, the sump will have an emergency spillway that will convey extreme events into the open pit.

5. *Summarize analysis completed to date for conceptual/feasibility design phase of the TMF and describe analysis and plans to be completed as part of the final design phase.*

Response to Question 5

5a. The following analyses were completed as part of the feasibility design of the TMF:

- Monthly water balance for various climatic conditions
- Staged tailings deposition plan
- Thermal analysis to determine the minimum depth required to protect the perimeter leak and leachate collection pipes from frost penetration
- Filter compatibility analysis (between the following materials: tailings-filter; filter-transition, and geotextile-protection soil)
- Liquefaction stability analyses (static and seismic)
- Tailings consolidation analysis
- Seepage analysis to determine the volume of seepage water reporting to the base of the TMF with time
- Slope stability analysis
- Closure cover veneer stability analysis
- Post-closure drawdown seepage analysis to estimate the seepage water that will report to the base of the TMF post closure

- Hydraulic analysis of closure chutes and spillway

The following will be completed prior to construction of the TMF as per the conditions in the Part 632 Permit:

- Detailed design
- Issued for Construction (IFC) drawings
- Technical specifications
- Construction Quality Control and Quality Assurance (CQC/CQA) plan
- Operations, Maintenance and Surveillance (OMS) Manual
- Instrumentation and monitoring plan

Sincerely,

**Golder Associates Ltd.**

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*Principal*

KBH/KAB/jl

https://golderassociates.sharepoint.com/sites/27531g/technical work/12-egle response/ss/egle response_ rev 0_8nov19.docx

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**ATTACHMENT A**

# Presentation

# Design of Back Forty Tailings Management Facility

**BACK FORTY PROJECT, MICHIGAN**

Presentation by:
Kebreab Habte
Ken Bocking
David List

Prepared for:
EGLE, Lansing

October 16, 2019

# Mine Waste Material Balance

The mine will generate the following waste streams over the Life-of-Mine

- Tailings – 8.95M t (4.90M $m^3$ / 6.41M $yd^3$)
- Waste Rock – 48.81M t (24.96M $m^3$ / 32.65M $yd^3$)

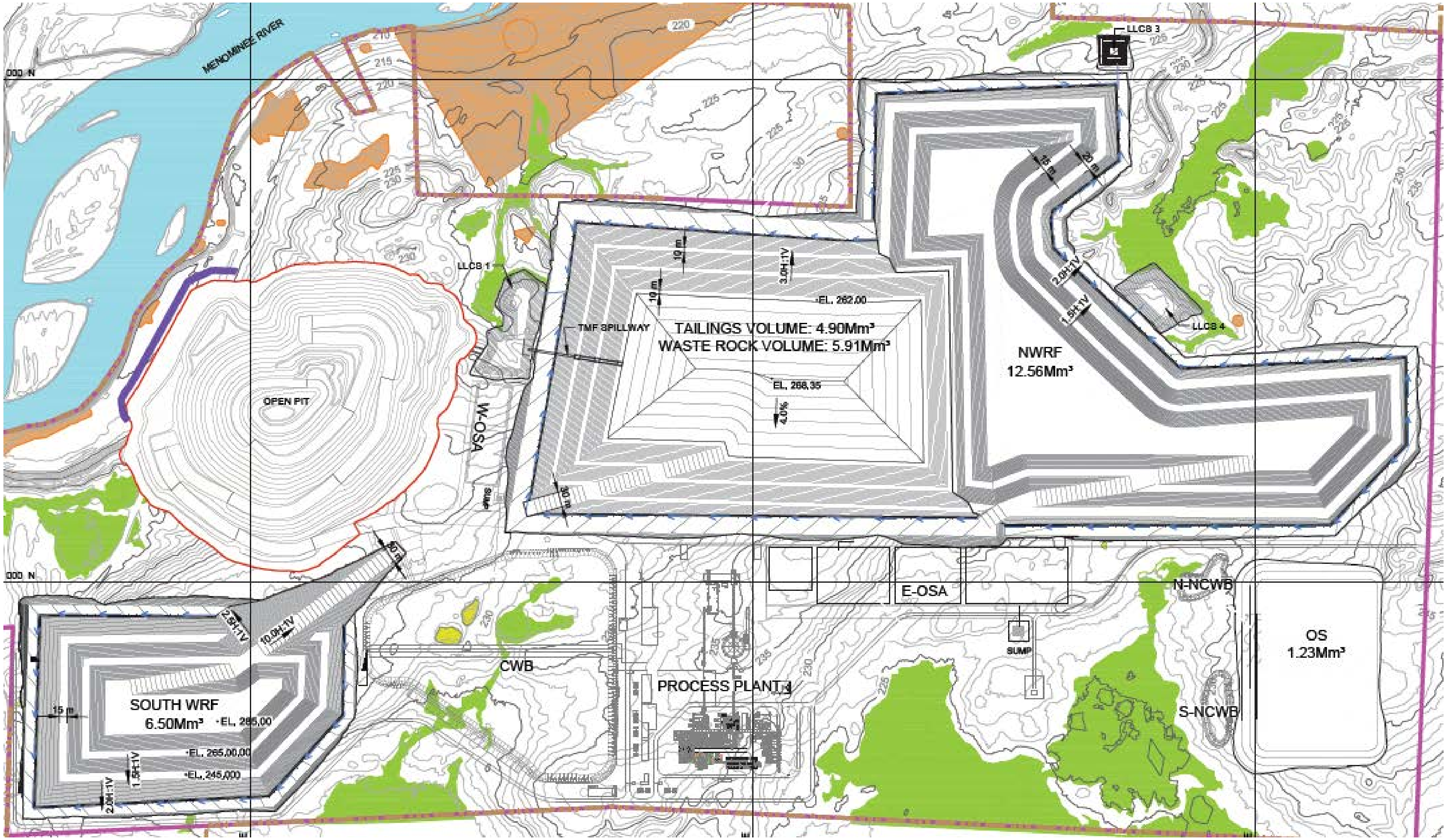
As per the mine permit commitment, backfilling the open pit at the end of operation will require 19.05M $m^3$ of waste rock

The TMF is therefore designed to deposit the following waste streams that will remain on surface:

- Remaining waste rock – 5.91M $m^3$
- Total tailings – 4.90M $m^3$

The TMF is a zoned co-disposal facility, containing more waste rock than tailings

# TMF General Arrangement Plan




- Footprint area of TMF is 50.2 ha (124 acres)

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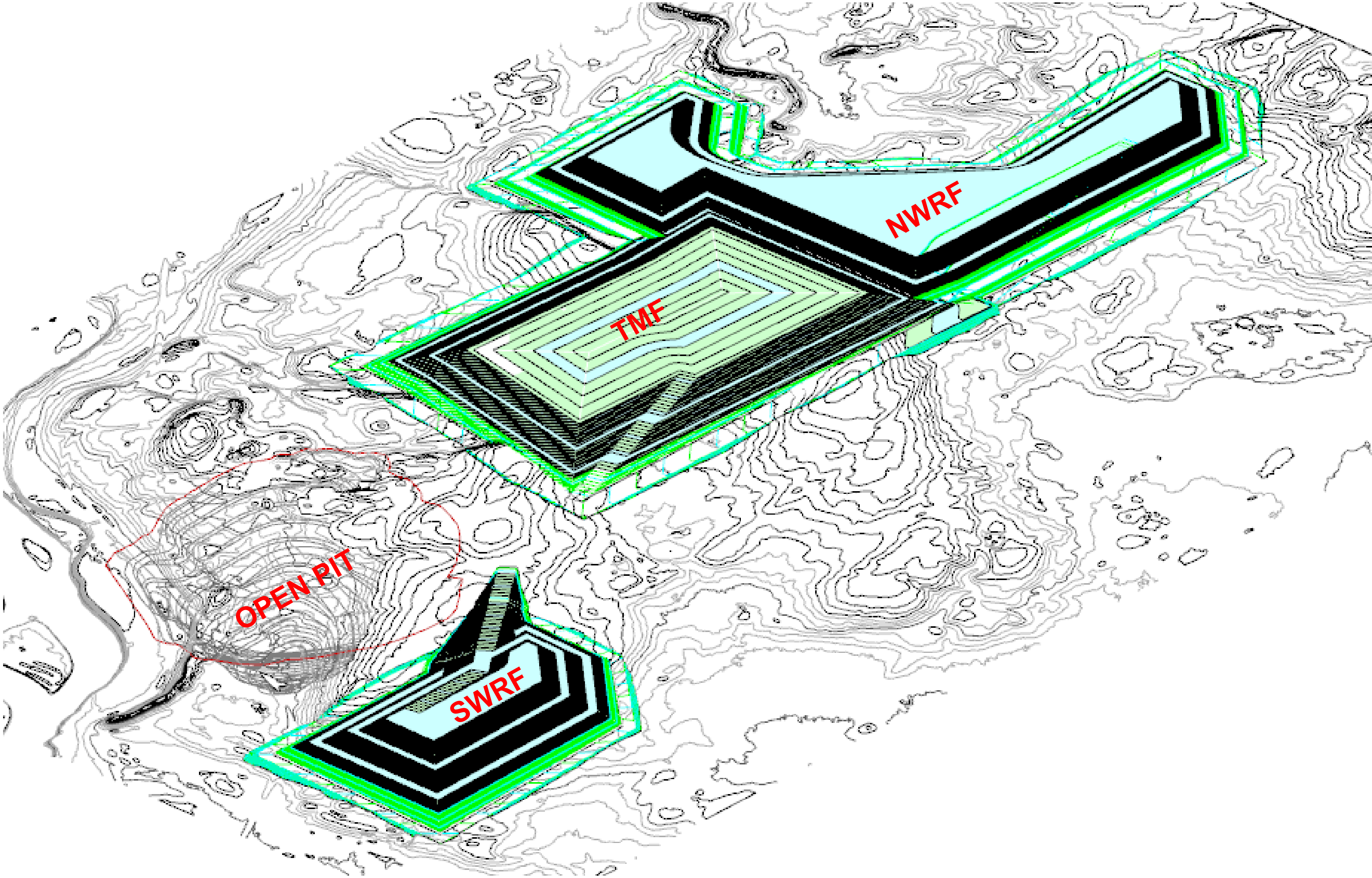
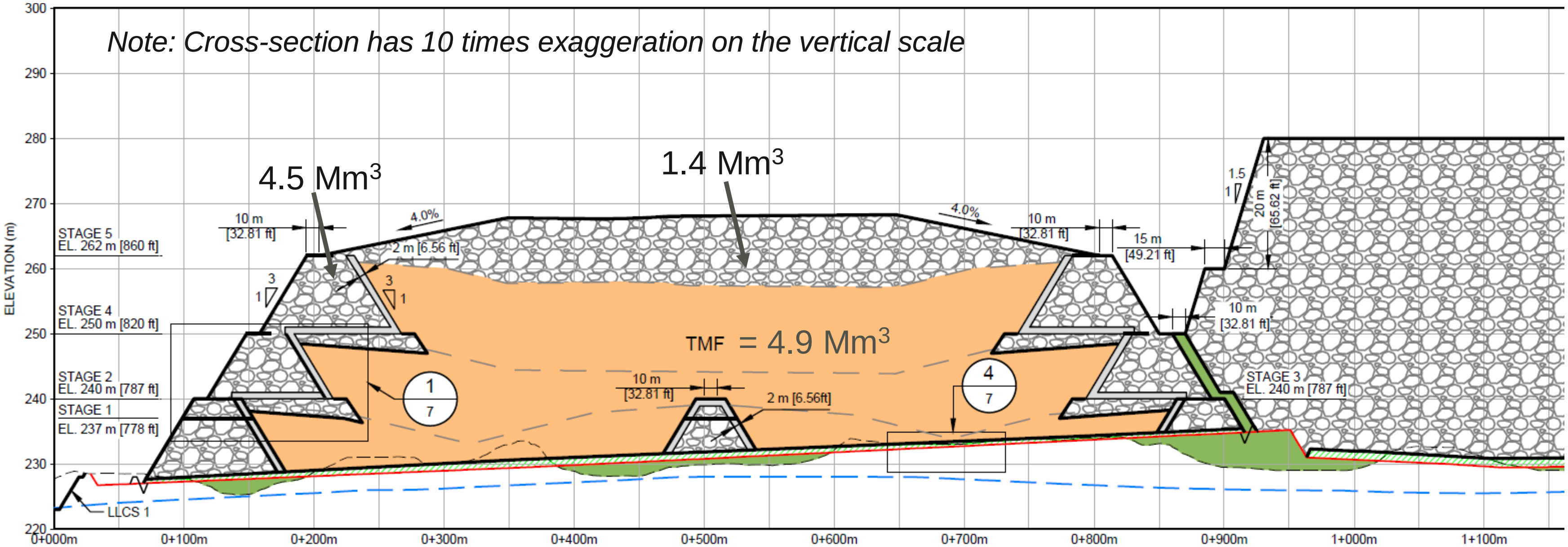
# TMF General Arrangement Plan Cont..



# TMF Cross-Section




The TMF has:

- A gently sloped base (~1%)
- A free draining waste rock perimeter wall (4.5M $m^3$)
- A double liner system that extends under the perimeter wall
- A waste rock crown at top of the facility (1.4M $m^3$)
- An overburden separator from the NWRF (10 m wide)

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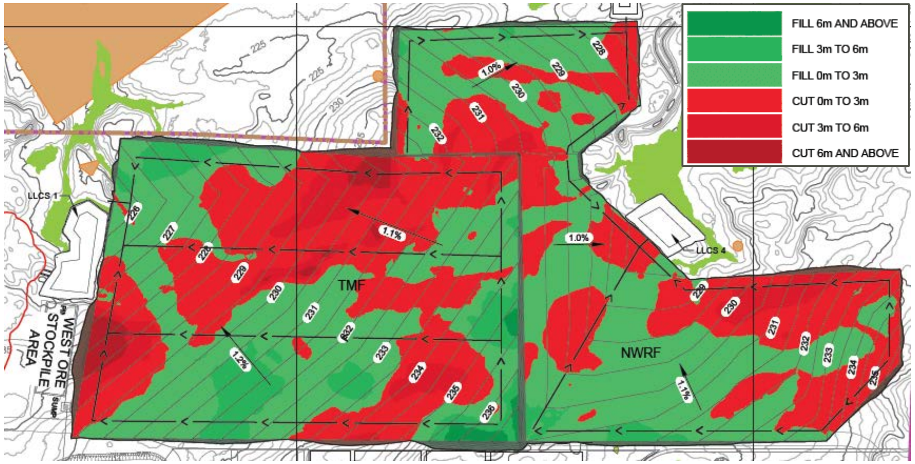
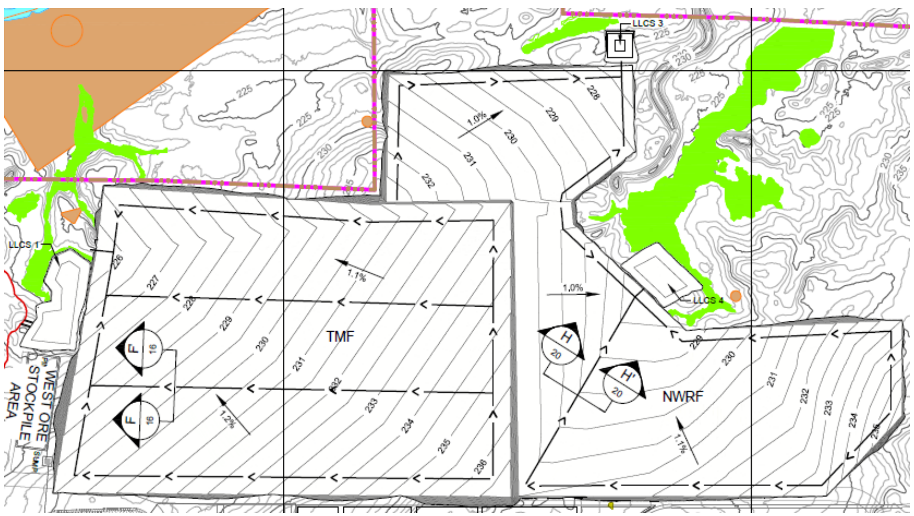
# The TMF is Designed to High Standard

- Tailings, dewatered to 65-76% solids content, is discharged in the facility
- Perimeter structure contain three waste rock dykes (each dyke is about 10 m high, 36 m crest width, 3H:1V side slopes)
- The perimeter dyke is competent frictional waste rock material
- A granular drainage is provided under the entire footprint of the facility
- Supernatant water will be pumped out actively
- Most of the tailings will be unsaturated except just below the pond area, phreatic surface will be only under the pond
- The facility will have an emergency spillway
- The wide waste rock perimeter structure and lower phreatic surface significantly increase the factor of safety for stability

# TMF Base Grade



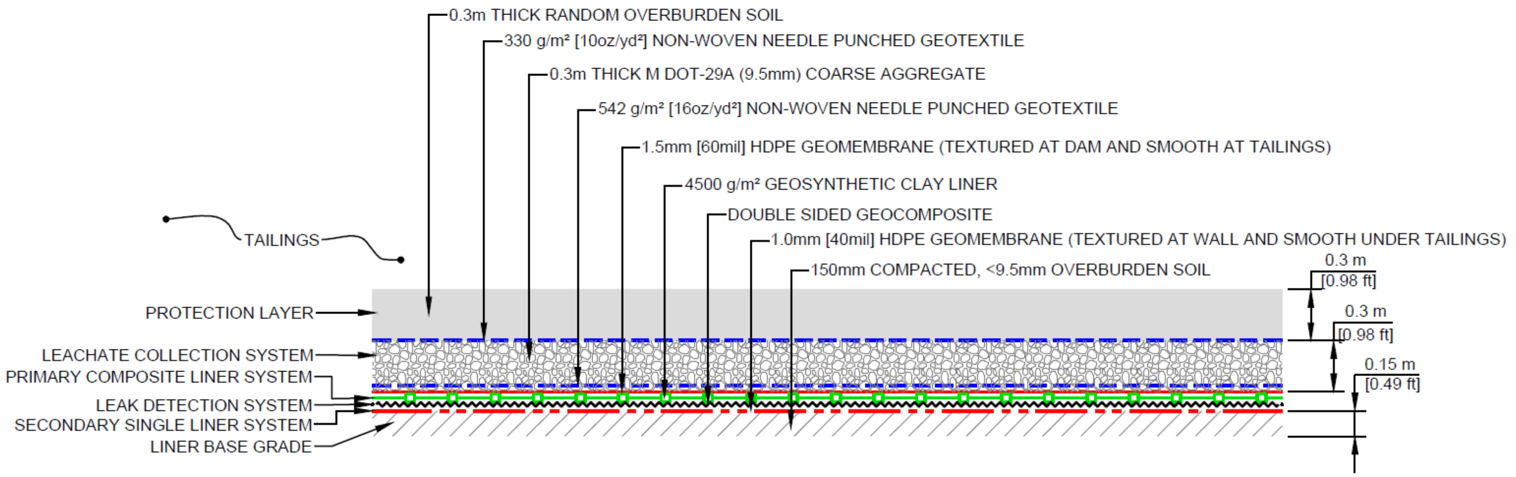

Cut and fill




Base Grade

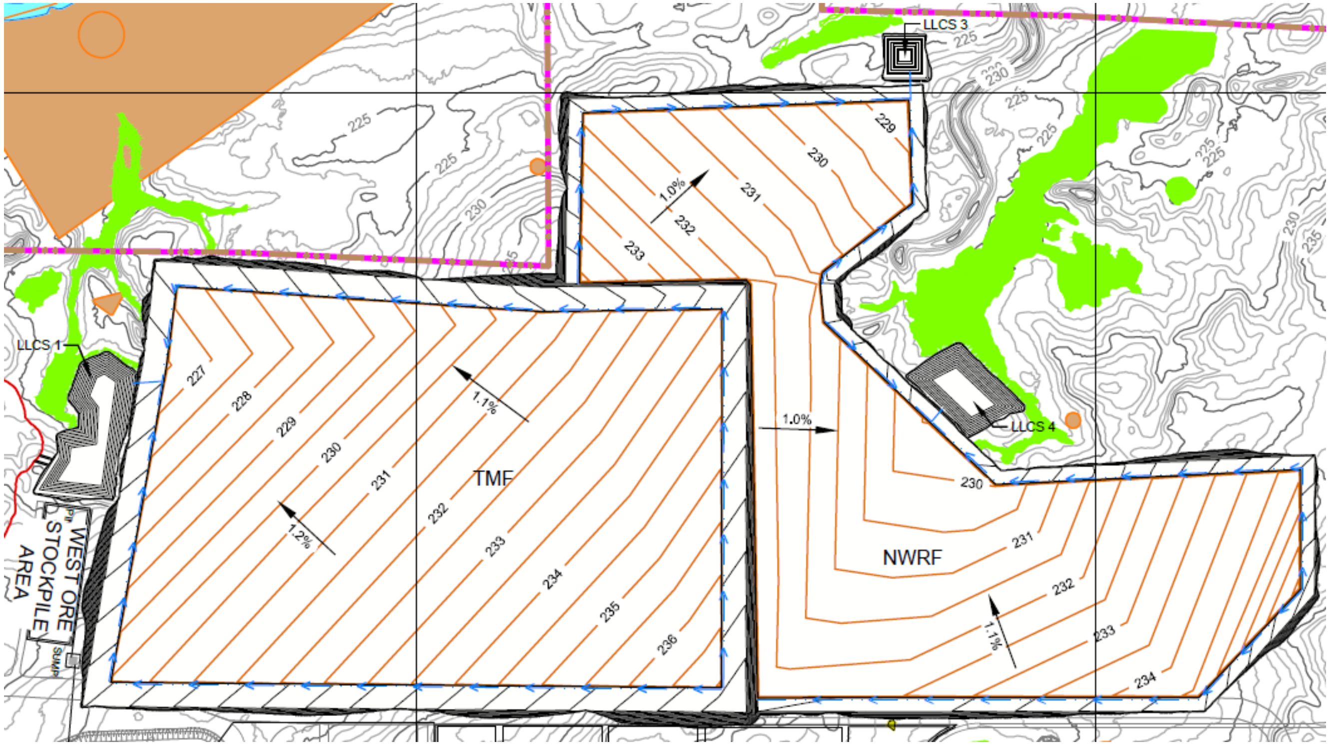
- The base of the facility is graded to the northwest to convey seepage and any leakage by gravity into an external sump
- The base grade of the facility will be prepared by cut and fill
- The subsurface soil is silty sand, sand to sand and gravel – strong foundation soil

# TMF Base Liner System




- The double liner system of the facility includes the following, from top to bottom:
  - 0.3 m (1.0 ft) thick random overburden soil protection layer
  - 330 g/m$^2$ (10 oz/yd$^2$) Non-woven filter geotextile
  - 0.3 m (1.0 ft) thick 9.5 mm (0.37 in) aggregate (MDOT-29A) leachate collection layer
  - 542 g/m$^2$ (16 oz/yd$^2$) Non-woven cushion geotextile
  - 1.5 mm (60-mil) HDPE primary liner (textured below perimeter wall and below tailings)
  - 4.5 kg/m$^2$ (0.92 lb/ft$^2$) Geosynthetic Clay Liner (GCL)
  - Geocomposite leak detection and collection layer
  - 1.0 mm (40-mil) HDPE secondary liner (textured below perimeter wall and below tailings)
  - 150 mm (5.9 in) compacted < 9.5 mm (0.37 in) overburden soil

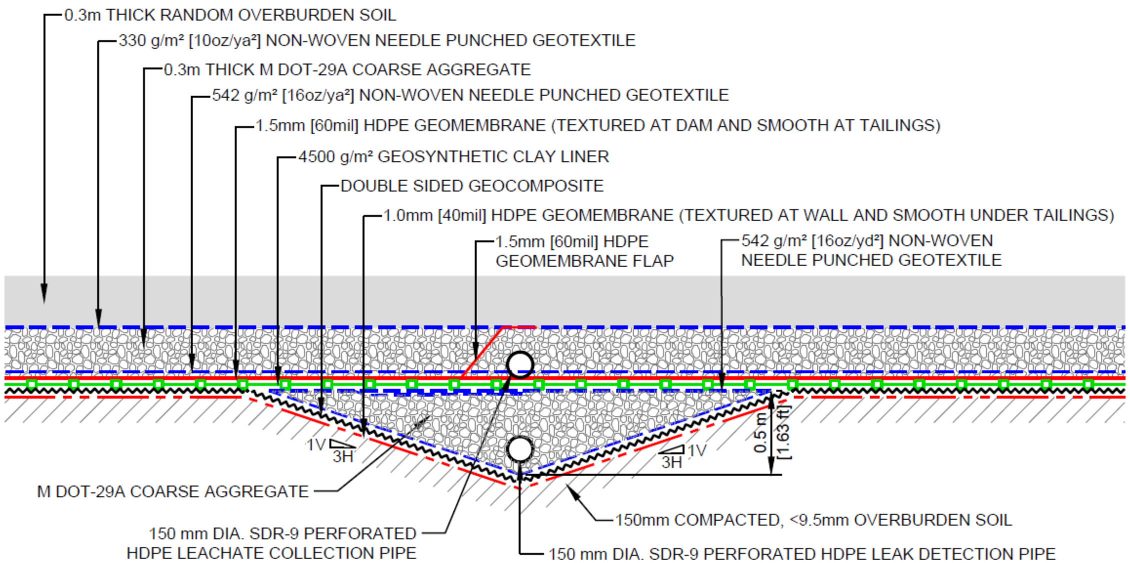
# TMF Top of Liner Grade




Top of protection layer

- Top of the liner is approximately 0.6 m above the base grade, containing 0.3 m drainage layer and 0.3 m overburden protection layer
- The drainage layer will limit the head of leachate over the liner, reducing risk to groundwater contamination

# Leachate and Leak Collection Systems

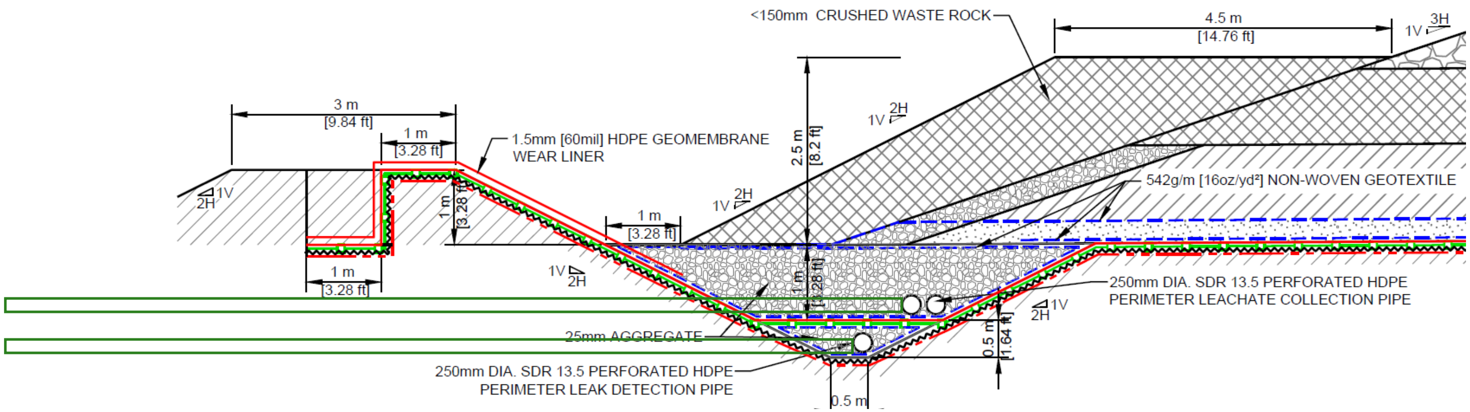



TYPICAL CROSS-SECTION OF TMF BASE LEACHATE COLLECTION AND LEAK DETECTION PIPES

SCALE 1:25 m [1"=2.1'] F 2

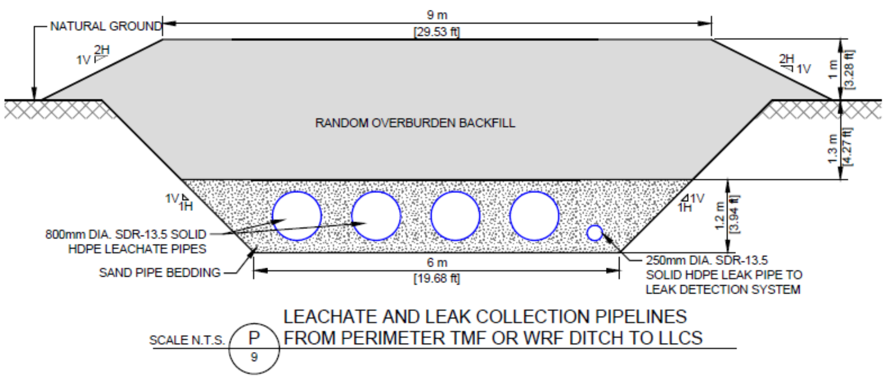

- The Leachate Collection System includes a blanket of coarse aggregate, two interior perforated pipelines, and two perimeter pipelines
- The Leak Collection System includes a geocomposite, two interior perforated pipelines, and one perimeter pipeline

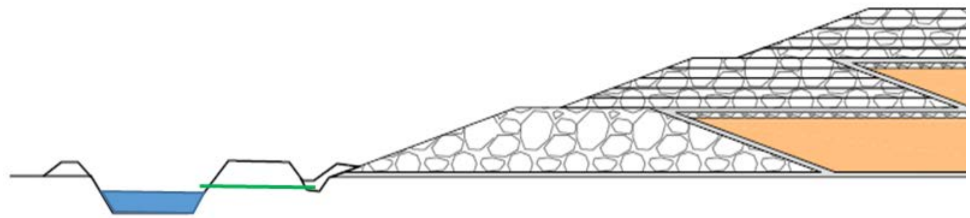
# TMF Perimeter Liner Anchor Berm



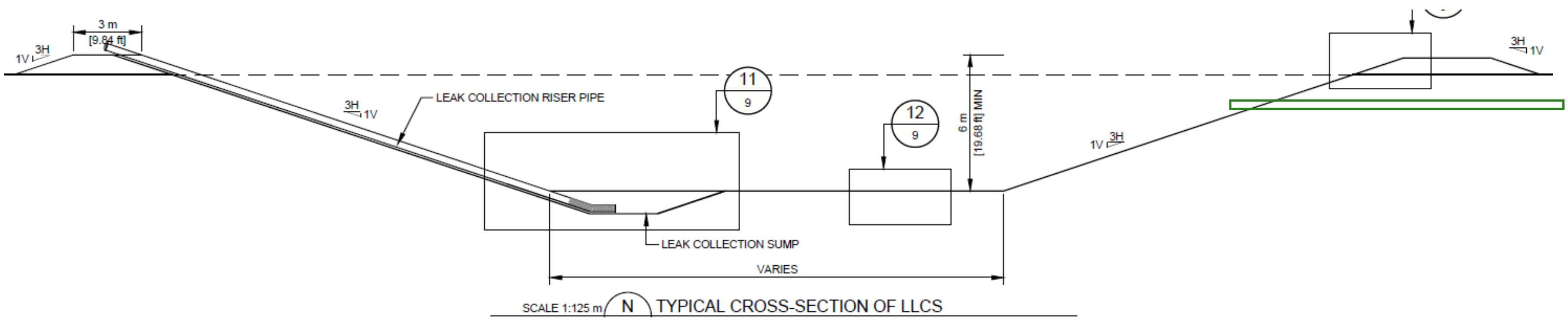

- A 1 m (3.3 ft) high perimeter berm is proposed for anchoring the base liner system of the facility and also for creating a perimeter ditch
- The perimeter ditch is designed to convey the 100-year, 24-hour storm event
- The ditch will discharge into the external sump
- A thermal cap is provided to protect the perimeter seepage and leak collection pipelines against freezing
- Pipe boots will be provided where the perimeter seepage and leak collection pipes penetrate the liner system to convey flow to the external sump
- The pipelines that penetrate the liner system will be insulated

# Leachate and Leak Collection System



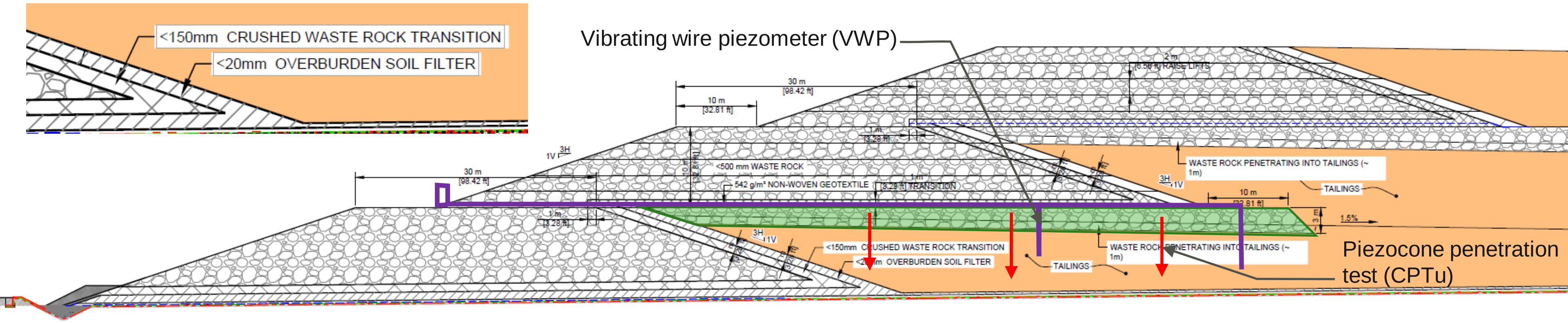



- Thermal cover is provided over the seepage and leak collection pipelines discharging into the external sump



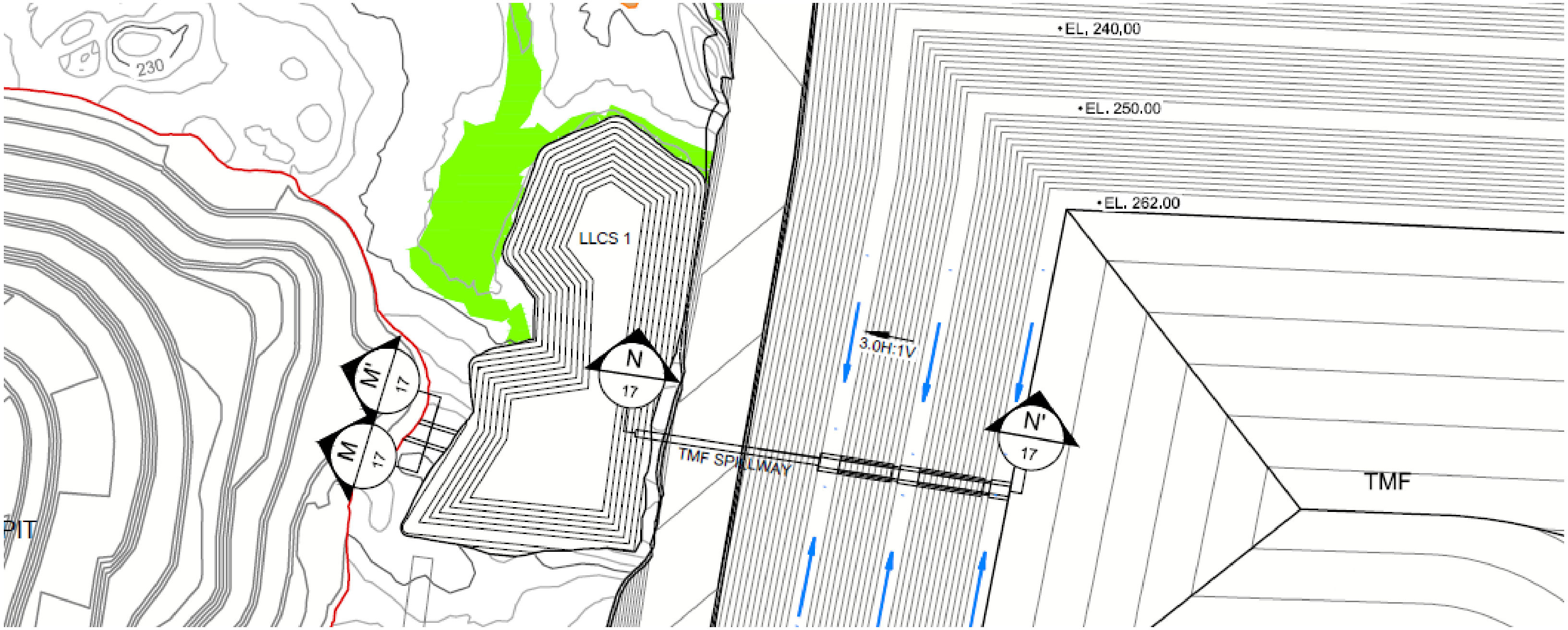

- The external sump will have a double liner system

# TMF Perimeter Dyke



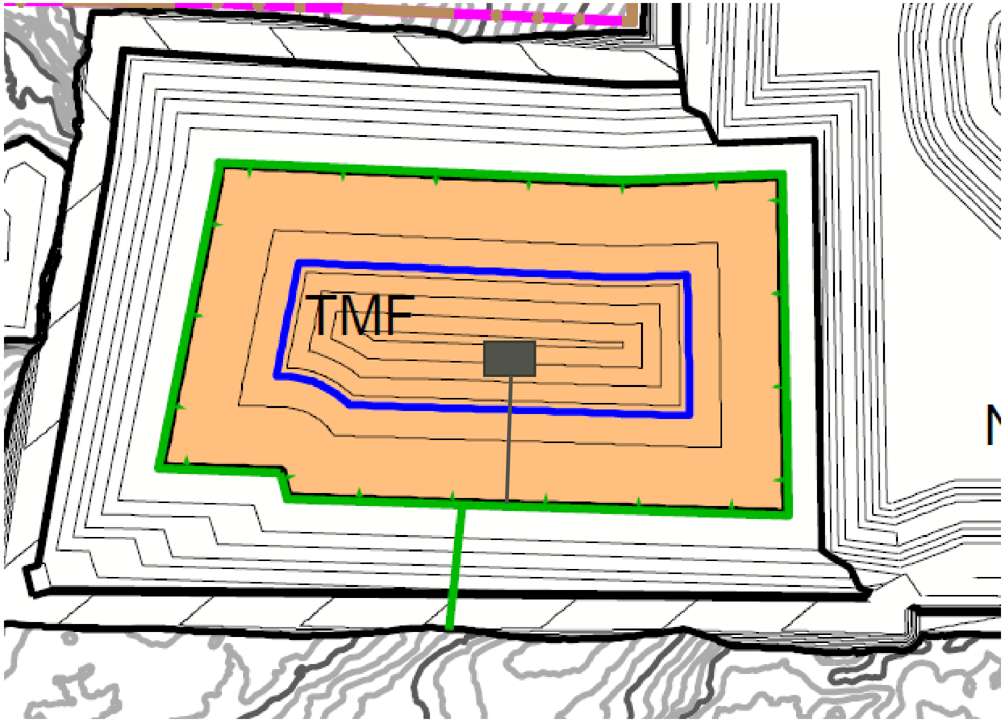

- Perimeter wall is free draining constructed of waste rock to a maximum elevation of 262 m (859.6 ft), maximum height of about 35 m (115 ft)
- The wall will have about 36 m (118 ft) wide crest and 3H:1V side slopes
- Upstream face of the wall will have crushed rock transition and overburden filter
- A 542 g/m$^2$ (16 oz/yd$^2$) non-woven geotextile will be used as a filter between the raises
- Tailings foundation will be in-situ tested (e.g. CPTu) prior to dyke raise
- VWPs will be installed to monitor tailings foundation performance
- After the 10 m high start-up dyke, the perimeter wall will be raised in 2 m lifts

# TMF Emergency Spillway




- Emergency spillway is provided to convey storm events up to PMP to the open pit via LLCS 1
- The emergency spillway will eliminate the risk of overtopping
- Emergency spillway includes riprap lined channels and pipe culverts

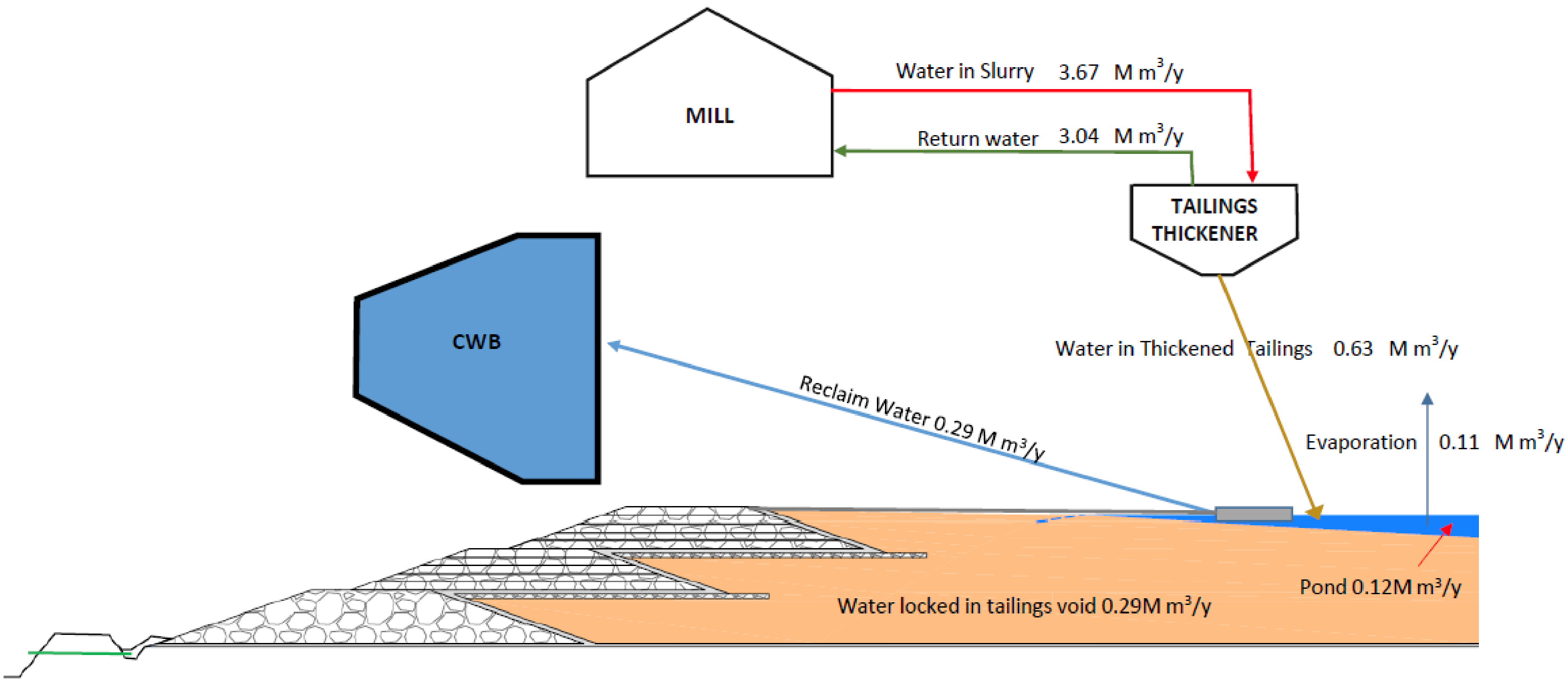
# TMF Distribution and Decant System




- Tailings will be discharged from perimeter spigot points, located about 50 m (164 ft) apart
- Floating pump barge will be used to pump the water accumulated at the top of the facility

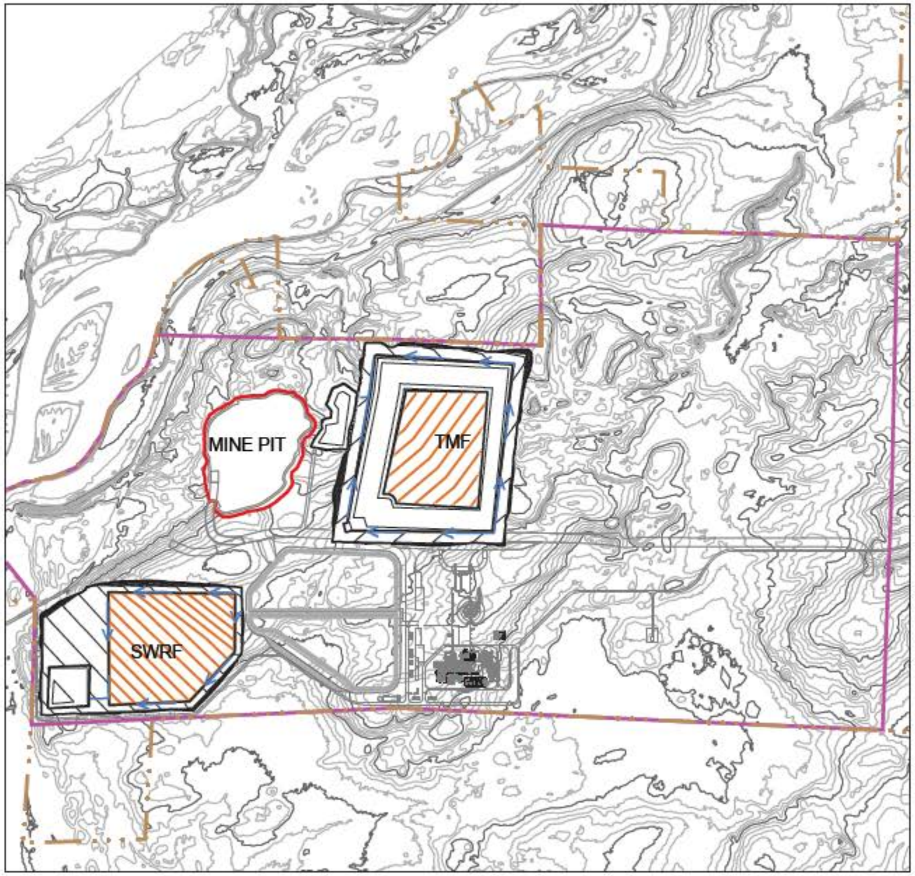
# TMF Water Management

- Supernatant and consolidation tailings water will be drained through the perimeter wall, bottom leachate collection system and floating pump barge
- Tailings thickening to 65-76% solids content in the mill will eliminate about 3.04M $m^3$ of water from coming to the TMF

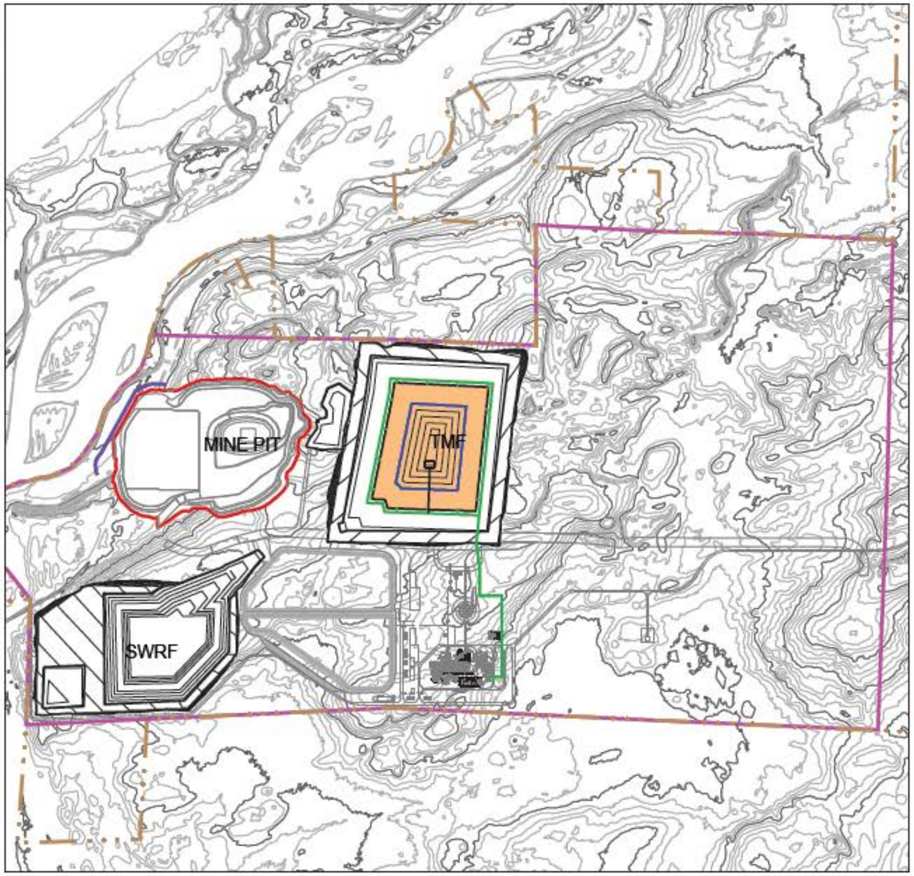



GOLDER

# TMF Stage Developmental Plan

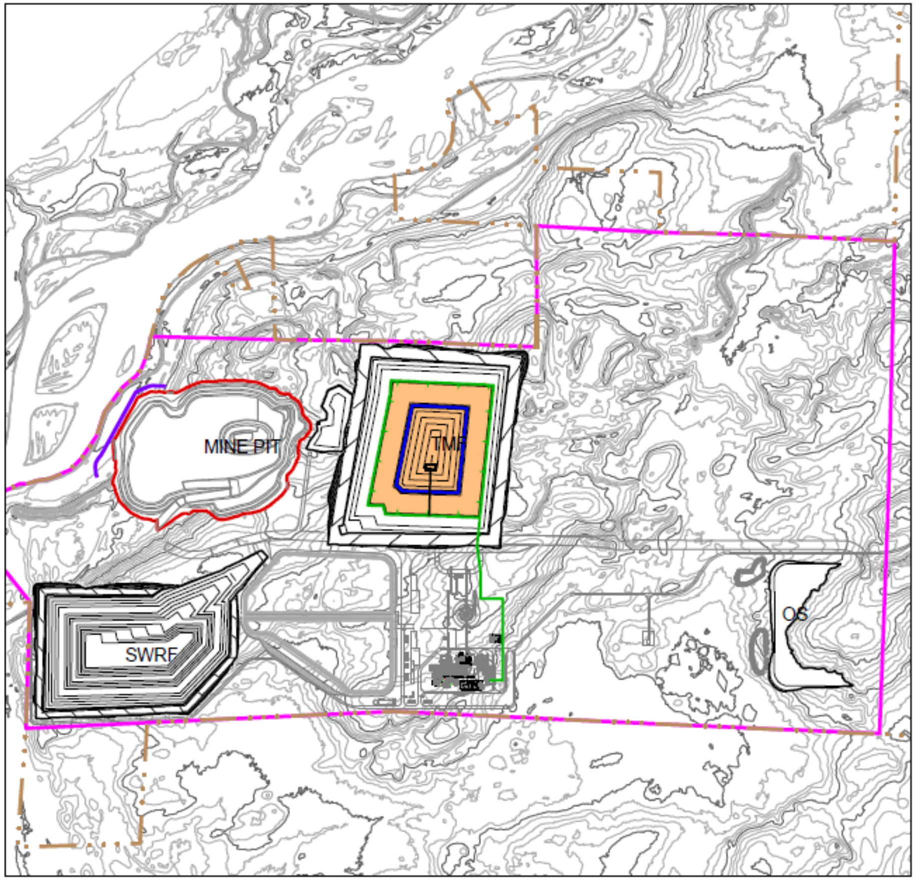



END OF START-UP CONSTRUCTION

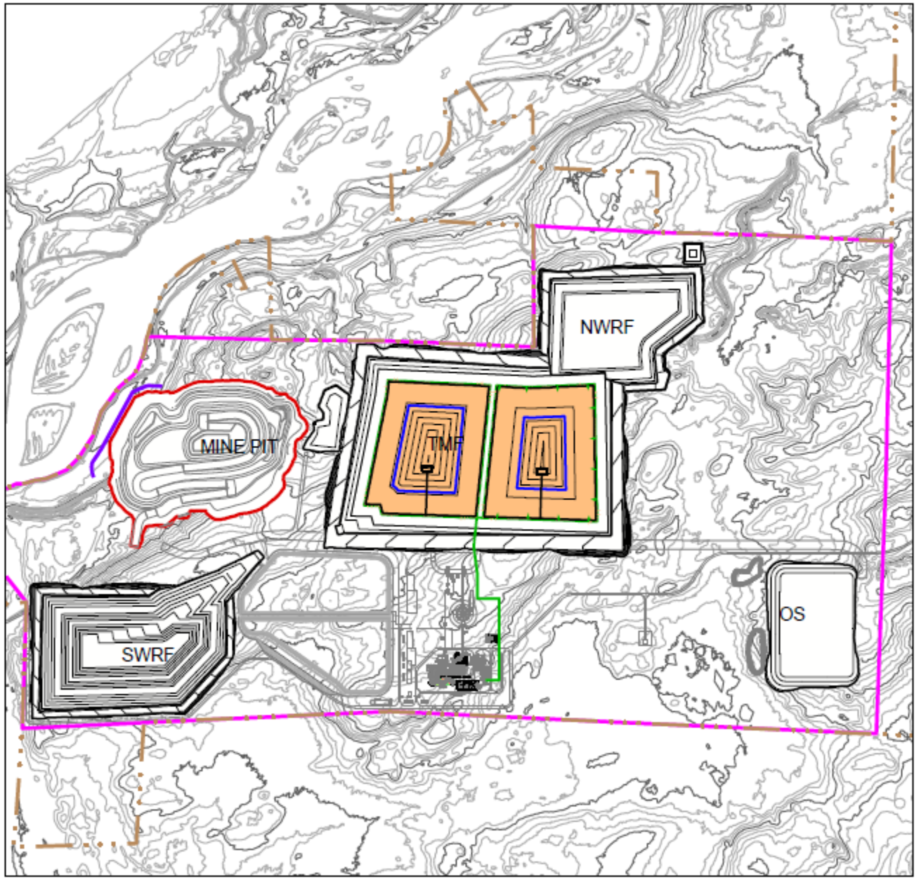



STAGE 1 CONFIGURATION AT 10 MONTHS

# TMF Stage Developmental Plan Cont…

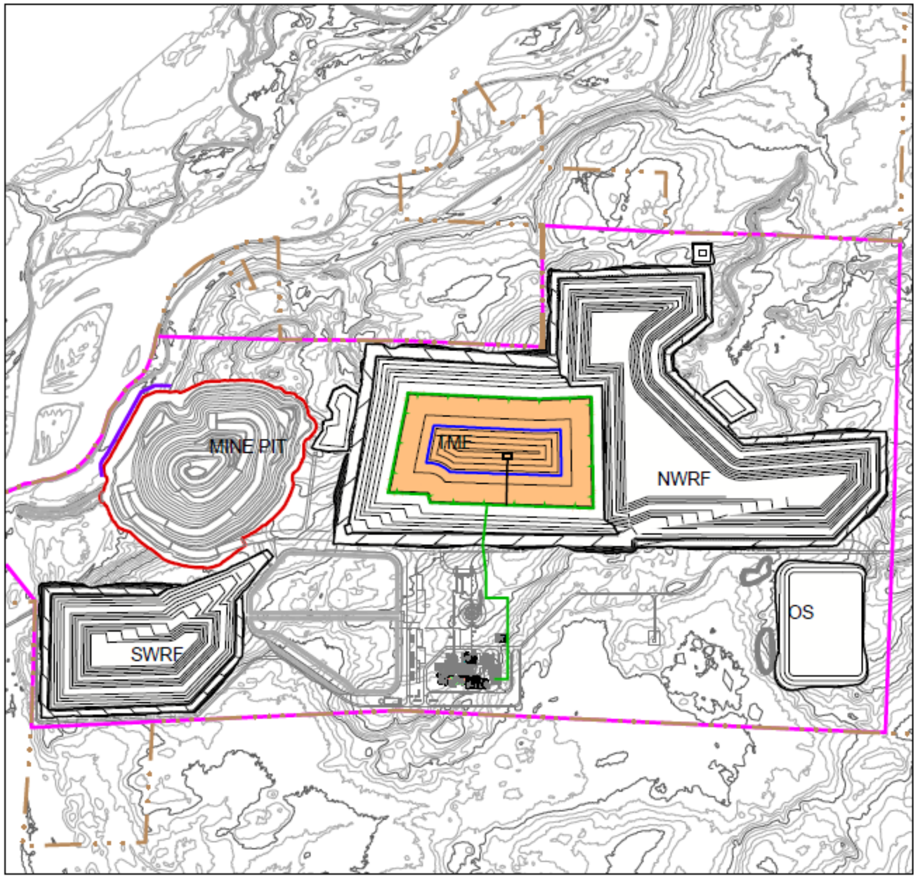



STAGE 2 CONFIGURATION AT 16 MONTHS

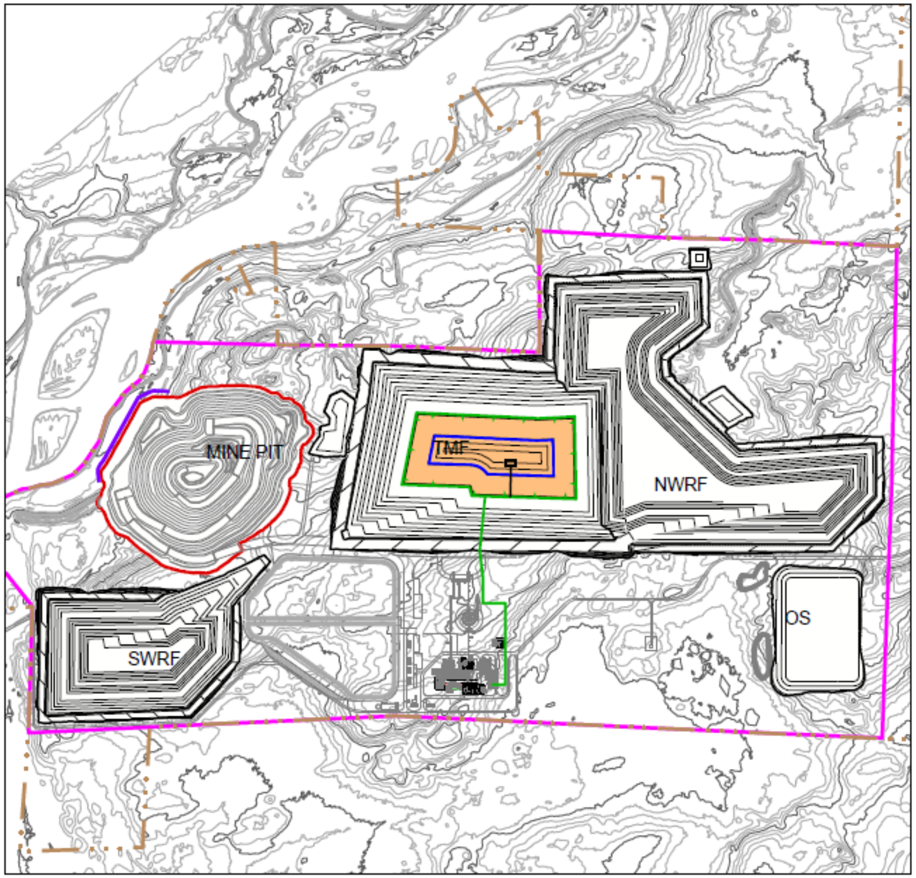



STAGE 3 CONFIGURATION AT 24 MONTHS

# TMF Stage Developmental Plan Cont…



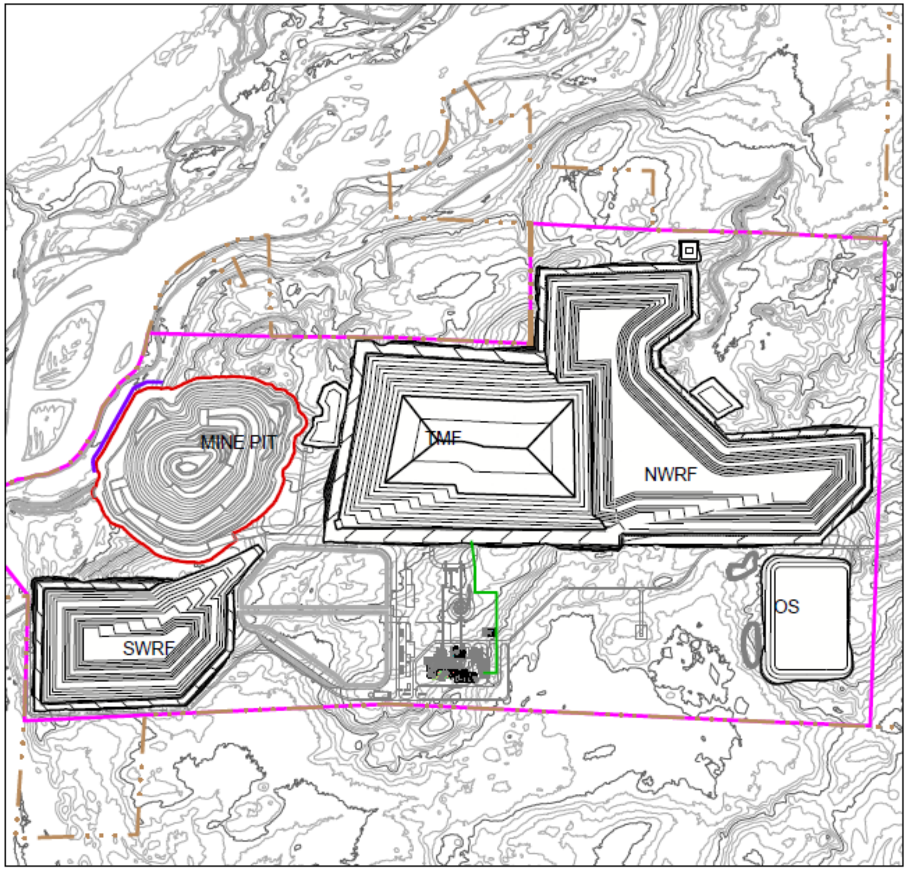

STAGE 4 CONFIGURATION AT 50 MONTHS



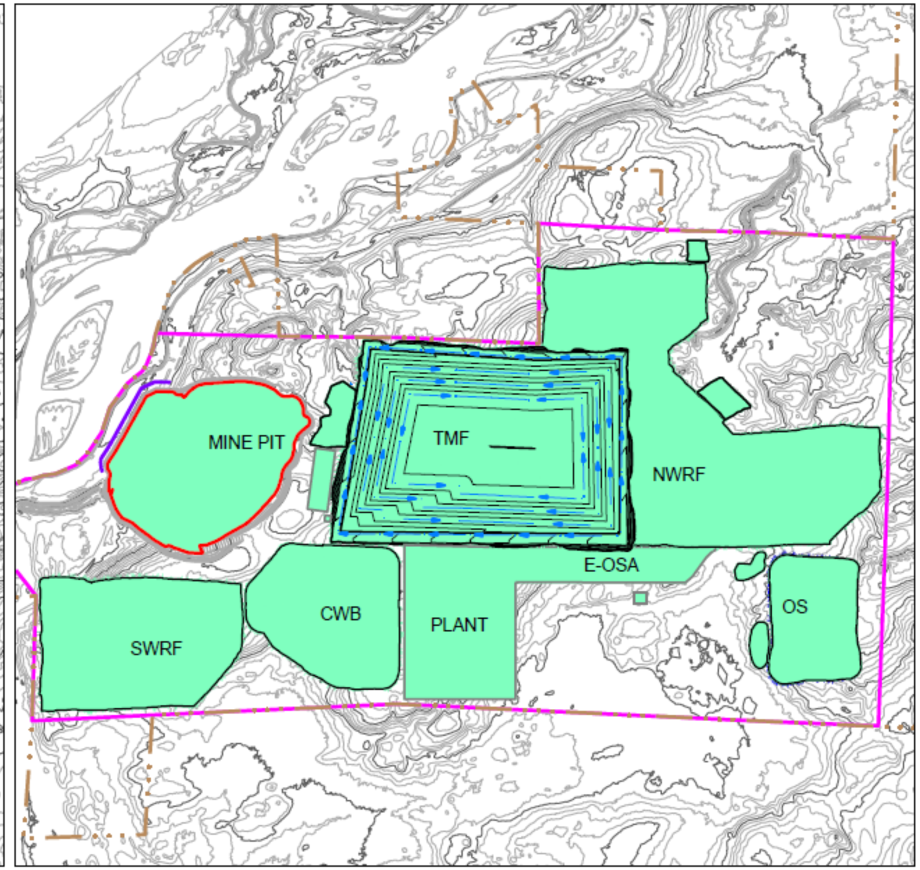

STAGE 5 CONFIGURATION AT 78 MONTHS

GOLDER

# TMF Stage Developmental Plan Cont…



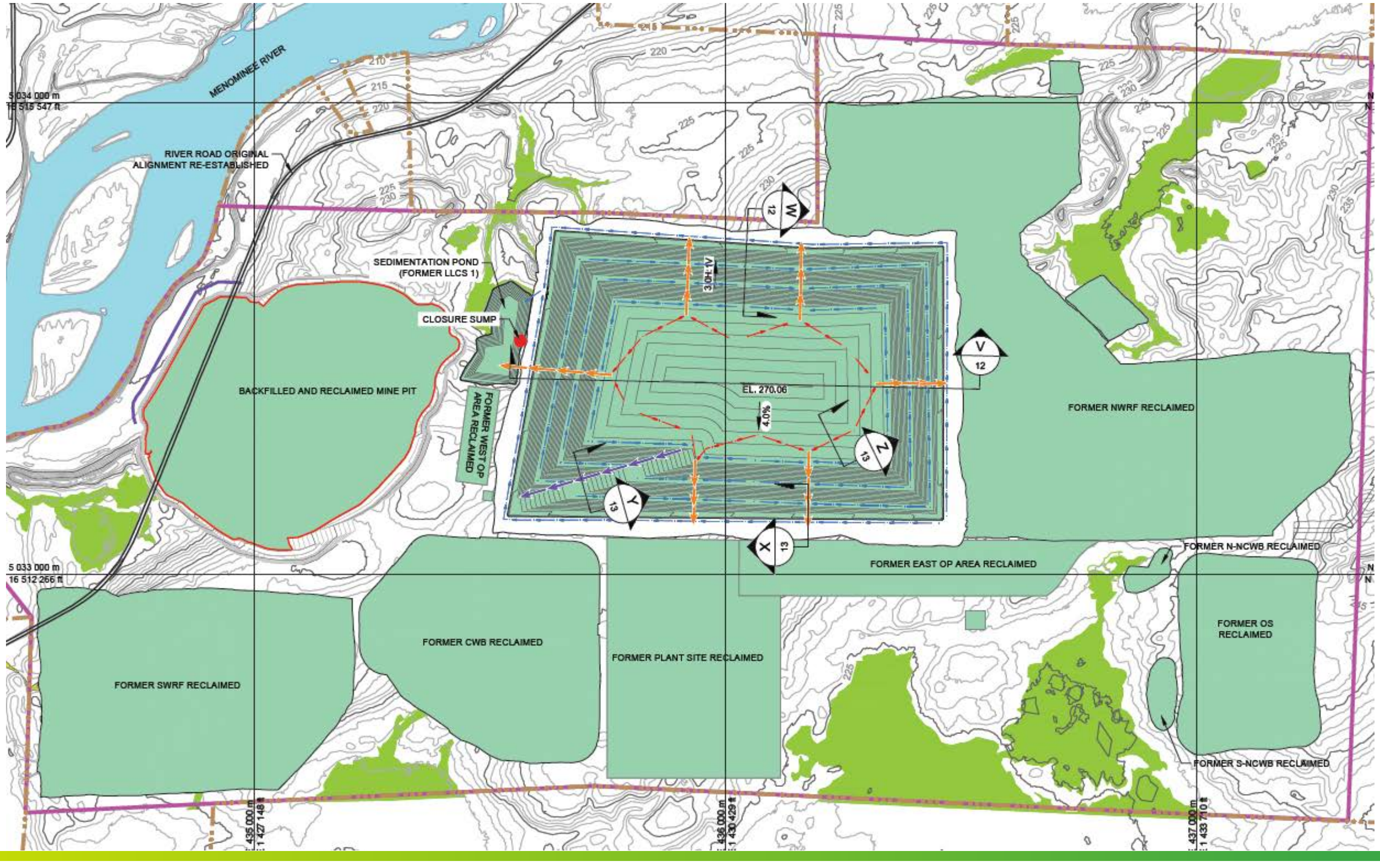

STAGE 6 CONFIGURATION AT ULTIMATE




CLOSURE CONFIGURATION

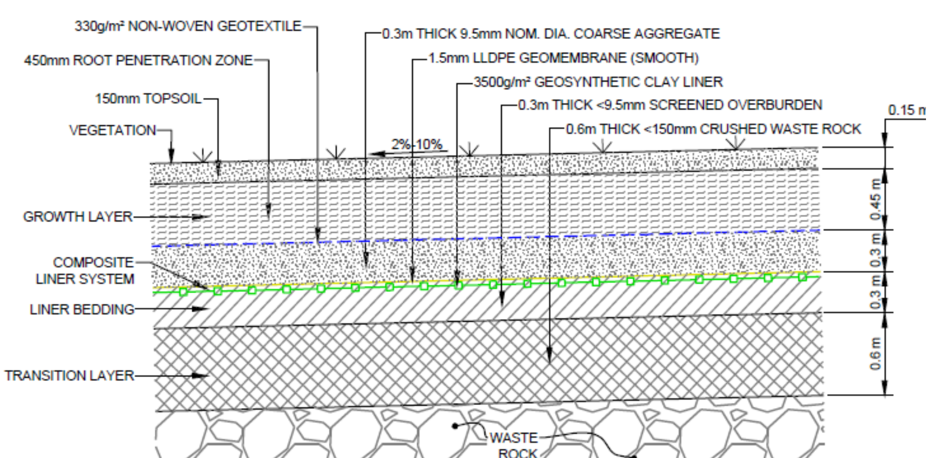
# TMF Closure

- Waste rock will be removed from the NWRF and placed on top of the TMF to form a stable post-closure landform that will easily shed-off runoff water
- The remaining material on the NWRF and the SWRF will be used for backfilling the open pit

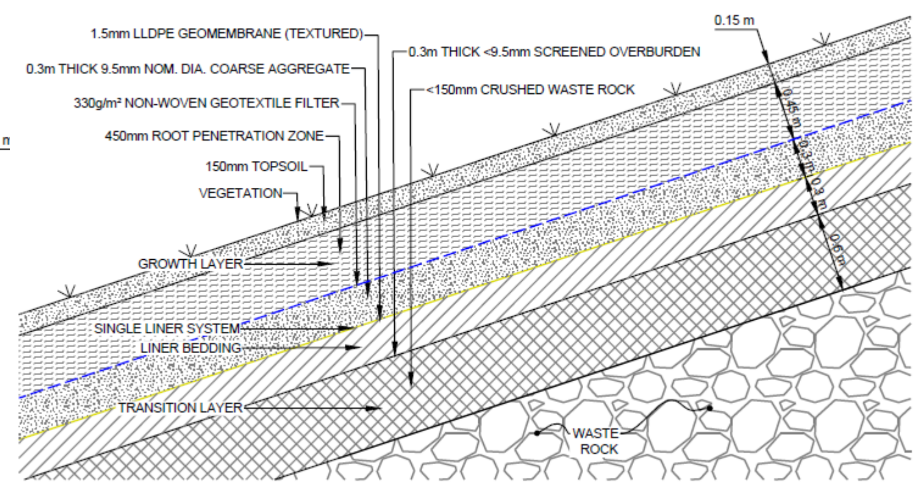


# TMF Closure Cont...

- Closure cover on benches and crown of the TMF will include a multilayer composite liner system containing the following, from top to bottom:
  - 0.6 m transition layer
  - 0.3 m liner bedding
  - 3.5 kg/m$^2$ (0.92 lb/ft$^2$) Geosynthetic Clay Liner (GCL)
  - 1.5 mm (60-mil) LLDPE liner
  - 0.3 m (1.0 ft) thick 9.5 mm (0.37 in) aggregate (MDOT-29A) drainage layer
  - 330 g/m$^2$ (10 oz/yd$^2$) non-woven filter geotextile
  - 450 mm (17.7 in) growth layer
  - 150 mm (5.9 in) topsoil
- Closure cover on side slopes (3H:1V) will include all the multilayers above except for GCL



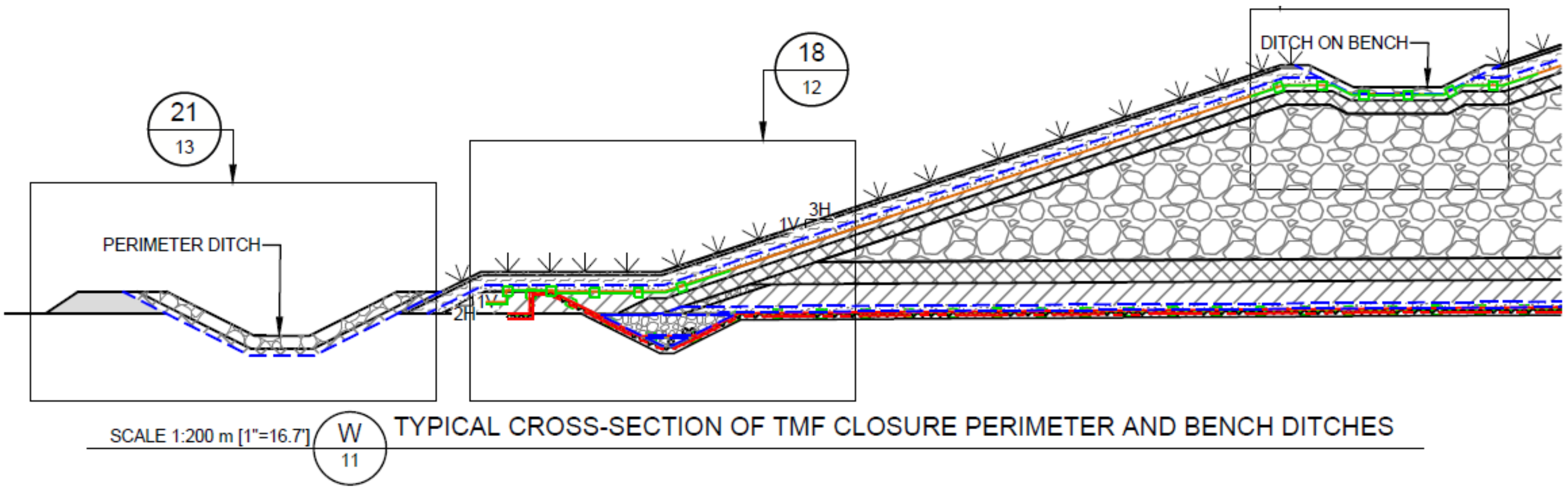

SCALE 1:25 m 15/22 TMF CLOSURE COVER DETAIL ON TOP CROWN



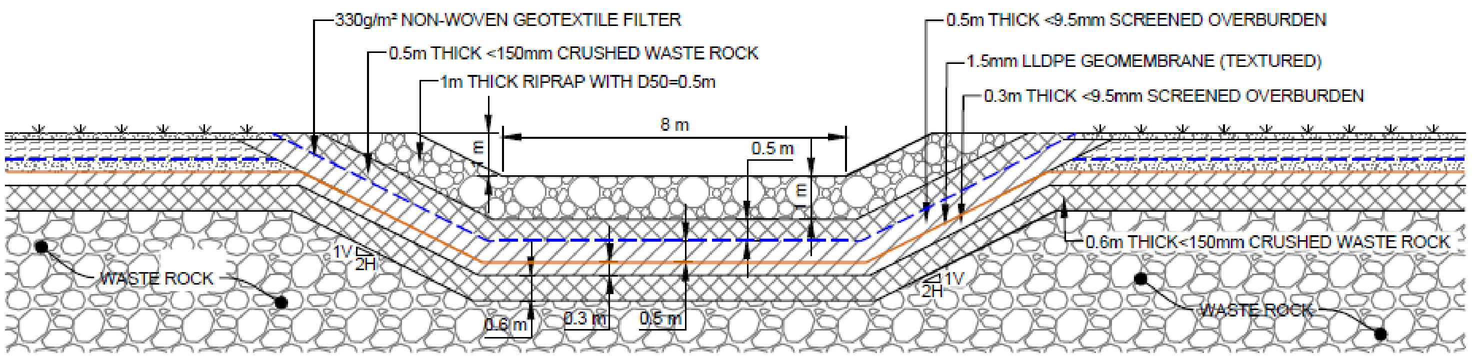

SCALE 1:25 m 18/22 TMF CLOSURE COVER DETAIL ON SIDE SLOPES

# TMF Closure Cont…

- Chutes and drainage ditches (designed for PMP) will be provided to manage the post closure drainage




SCALE 1:200 m [1"=16.7'] W 11 TYPICAL CROSS-SECTION OF TMF CLOSURE PERIMETER AND BENCH DITCHES




SCALE 1:100 m [1"=8.3'] A2 TYPICAL CROSS-SECTION OF TMF CLOSURE CHUTE ON SIDE SLOPES

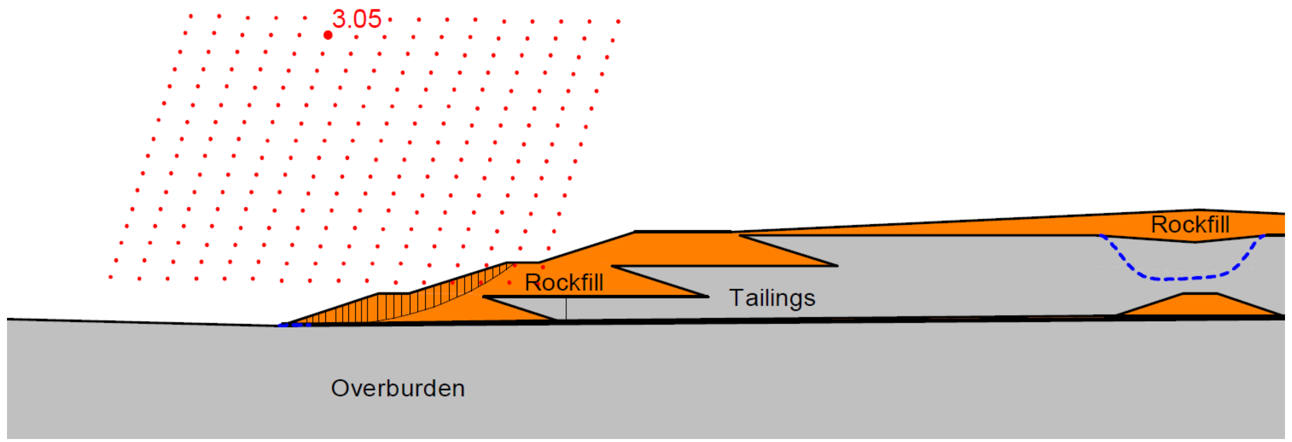
# Design Analyses Completed

The following analyses have been completed to support the design of the TMF:

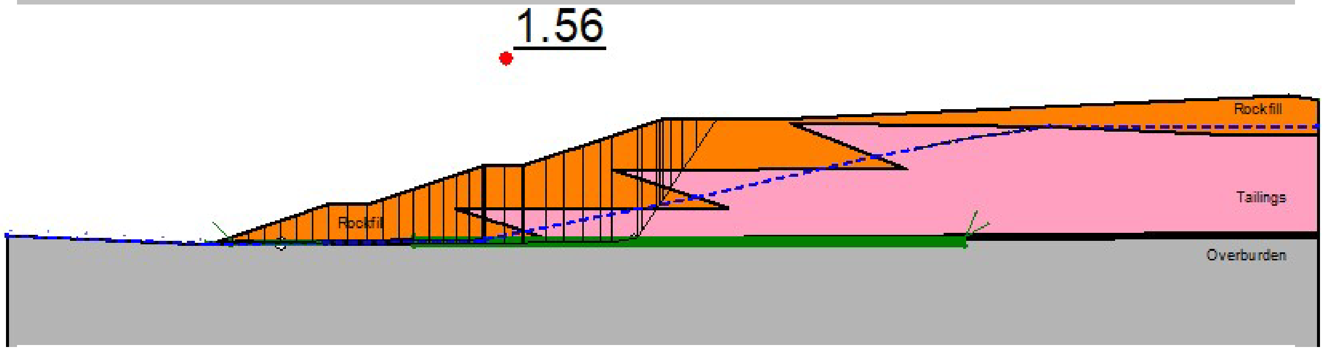
- Material balance
- Monthly water balance for various climatic conditions
- Staged tailings deposition plan (Goldtail and AutoCAD Civil 3D)
- Thermal analysis (TEMP/W)
- Filter compatibility analysis (NRCS 2017)
- Liquefaction analyses
  - Static (Sadrekarimi 2014 and 2016)
  - Seismic (SHAKE2000 and Boulanger and Idriss 2014)
- Consolidation analysis (CONDES0)
- Seepage analysis (SEEP/W)

# Design Analyses Completed Cont…

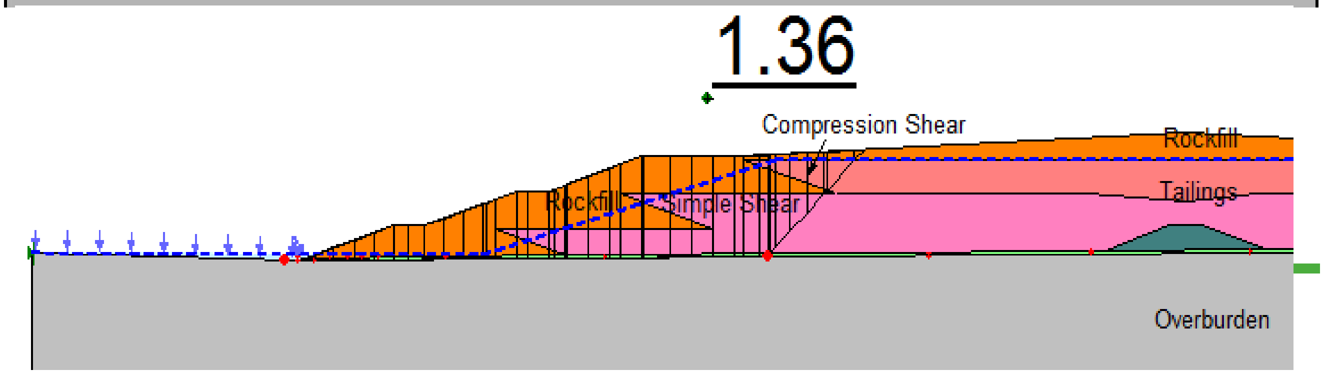
- Stability (static and pseudo-static) analysis (SLOPE/W): e.g.:




Static Slope Stability (good drainage)




Static Slope Stability (conservatively assumed high water level- due to poor drainage)




Static Liquefaction (conservatively assumed high water level- due to poor drainage)

# Design Analyses Completed Cont...

- Liner tests
  - GCL chemical compatibility (Swell Index, ASTM D5890, and Fluid Loss, ASTM D5891)
  - Geomembrane hydrostatic puncture test (ASTM D5514)
- Closure Analyses
  - Veneer stability analyses (static unsaturated, static saturated, pseudo-static unsaturated, and static unsaturated & low ground pressure)
  - Cover infiltration (HELP model)
  - Post-closure drawdown seepage (SEEP/W transient)
  - Hydraulic analysis of chutes and spillway - PMP

# Detailed Design

The following will be completed per the conditions in the Part 632 Permit:

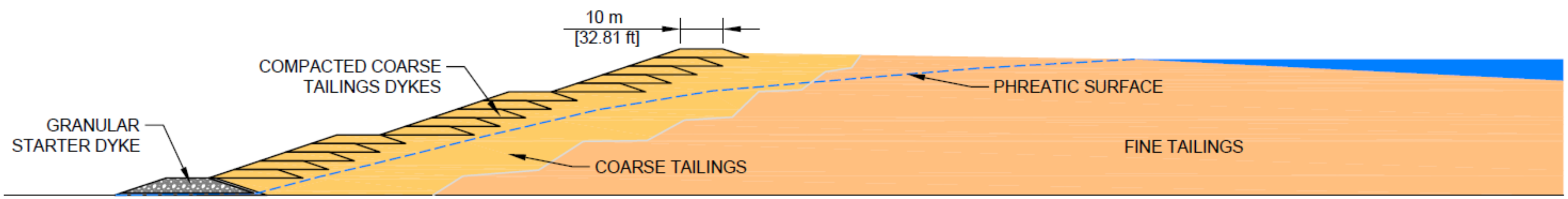
- Detailed design
- IFC drawings
- Technical specifications
- CQC/CQA plan
- Operations, Maintenance and Surveillance (OMS) Manual
- Instrumentation and monitoring plan

# Traditional Upstream Tailings Management Facilities vs Zoned Tailings and Waste Rock Co-Disposal Facilities

CONCEPTS AND EXAMPLES

October 16, 2019

# Zoned Co-disposal vs Traditional Upstream Raised TMF




Traditional Upstream Raised TMFs

The following are characteristics of typical upstream TMFs:

- Starts with a free draining low starter dyke
- Tailings discharged at around 30% solids content by weight
- Tailings segregate during deposition
- Coarse tailings and high specific gravity tailings settle near discharge location
- Fine tailings and low specific gravity slimes settle away from discharge location
- Coarse tailings excavated from tailings beach are used to construct the subsequent dam raises

# Zoned Co-disposal vs Traditional Upstream Raised TMF Cont..

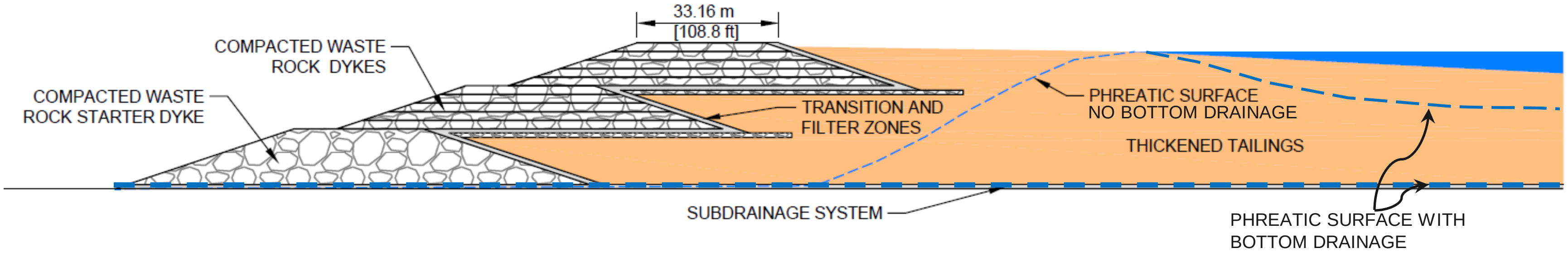
The following photos show how a typical upstream TMF is constructed:

Coarse starter dyke

Tailings excavation during upstream dyke raise

After upstream dyke raise is complete

# Zoned Co-disposal vs Traditional Upstream Raised TMF Cont…




Back Forty Zoned Co-disposal TMF

The Back Forty TMF design mitigated the known risks of traditional upstream TMFs:

- Perimeter dyke - Constructed of waste rock 36 m wide crest (strong, free draining, non-liquefiable and erosion resistant)
- Transition and filter zones of dyke - Allow tailings consolidation water to easily drain out of the facility while eliminating the risk of tailings migration into the perimeter wall
- Underdrain system - A granular drainage layer beneath the entire base of the tailings facility which is graded for gravity drainage
- Tailings solids content - Tailings will be thickened to 65-76% solids content in the mill reducing 3M $m^3$ of water from coming to the TMF

# Zoned Co-disposal vs Traditional Upstream Raised TMF Cont…

- Phreatic surface - Free draining underdrain and perimeter wall as well as pumping of bleed water from decant area will result a very low phreatic surface
- Dyke raise foundation - The dyke will be raised over high density and high strength consolidated thickened tailings
- Emergency spillway - It will safely convey extreme storm events up to the Probable Maximum Precipitation, thus preventing overtopping
- Slope stability analysis - Placement of very wide competent frictional waste rock material as perimeter structure and placement of a drainage layer at the bottom of the facility that lowers the phreatic surface within the facility significantly increase the factor of safety for stability
- Liquefaction analysis - Conservative seismic and static liquefaction analyses carried out assuming elevated water table confirmed the stability of the facility
- Performance review - The facility will be monitored closely during construction and operations to ensure that the design intent is being satisfied

# Operating TMFs with Similar Features to Back Forty TMF

## 1. Canadian Malartic Mine, Quebec

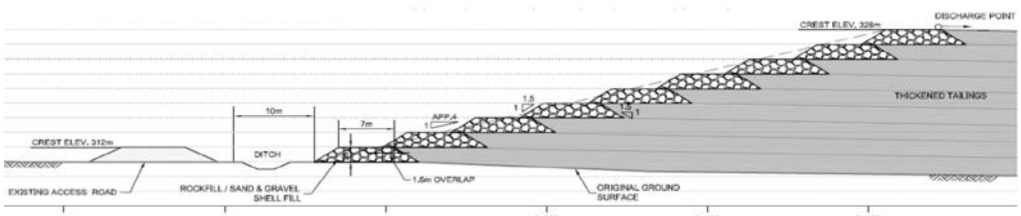

- Open pit gold mine
- The perimeter waste rock fill berms are raised by the upstream method
- Tailings are deposited at 60% to 68% solids content

# Operating TMFs with Similar Features to Back Forty TMF Cont…

## 2. Musselwhite Mine, Ontario


Sand and gravel over soft tailings

- Underground gold mine
- Thickened tailings at 63% to 68% solids content) deposited over previously slurry tailings facility
- Perimeter wall is sand and gravel

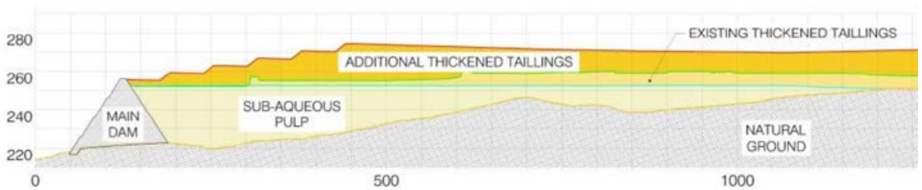



Sand and gravel over thickened tailings

# Operating TMFs with Similar Features to Back Forty TMF Cont…

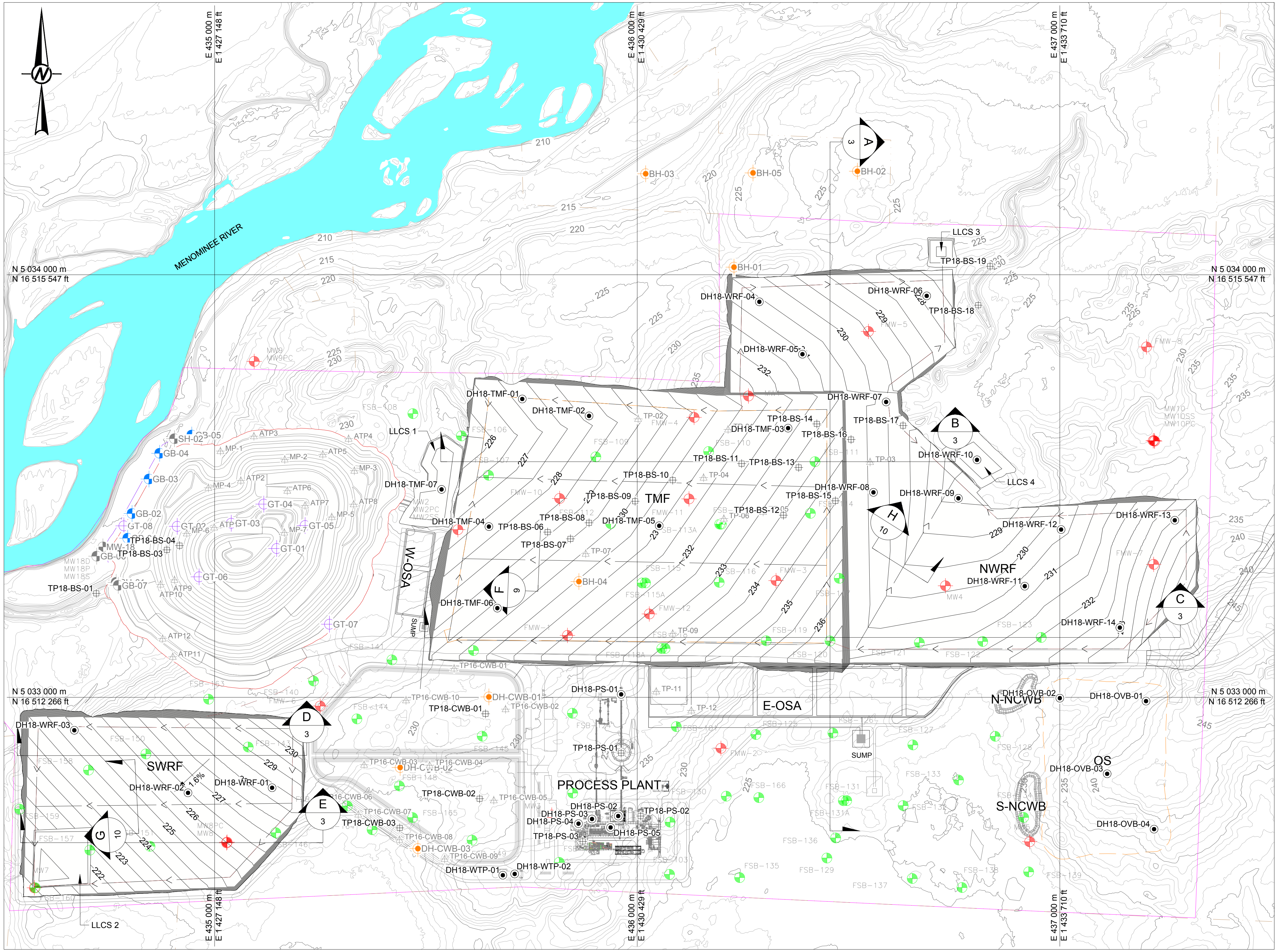
## 3. Neves Corvo Mine, Portugal


- Underground copper and zinc mine
- Thickened tailings disposed over subaqueous slurry tailings
- Interior of the facility partitioned using waste rock berms



**ATTACHMENT B**

# Geotechnical Investigation




**LEGEND**

PROJECT BOUNDARY
MINERAL PROPERTY BOUNDARY
220 NATURAL TOPOGRAPHY
230 TOP ELEVATION OF LINER BASE GRADE
CUT-OFF WALL
MINE PIT OUTLINE
TAILINGS MANAGEMENT FACILITY (TMF) OUTLINE
WASTE ROCK FACILITY (WRF) OUTLINE
OVERBURDEN STOCKPILE (OS) OUTLINE
LEACHATE COLLECTION AND LEAK DETECTION PIPES
MW MONITORING WELLS
GB CUT-OFF WALL BOREHOLES
GT MINE PIT BOREHOLES
FSB HISTORICAL GEOTECHNICAL BOREHOLES
BH 2016 GEOTECHNICAL BOREHOLES
HISTORICAL TEST PIT
2018 GEOTECHNICAL BOREHOLE
2018 TEST PIT

**NOTE(S)**

1. LOCATION OF HISTORICAL BOREHOLES AND TEST PITS WERE SUPPLIED BY KNIGHT PIÉSOLD ON OCTOBER 26, 2017.
2. LOCATION OF 2018 BOREHOLES AND TEST PITS WERE SUPPLIED BY KNIGHT PIÉSOLD ON NOVEMBER 2, 2018.

1:5,000 0 200 400 METRES
1"=416.7' 0 656 1,312 FEET

CLIENT
AQUILA RESOURCES

CONSULTANT
GOLDER

| | |
|---|---|
| YYYY-MM-DD | 2019-05-10 |
| DESIGNED | KBH |
| PREPARED | FZG |
| REVIEWED | KBH |
| APPROVED | KAB |

PROJECT
BACK FORTY PROJECT

TITLE
**GEOTECHNICAL INVESTIGATION PLANS**

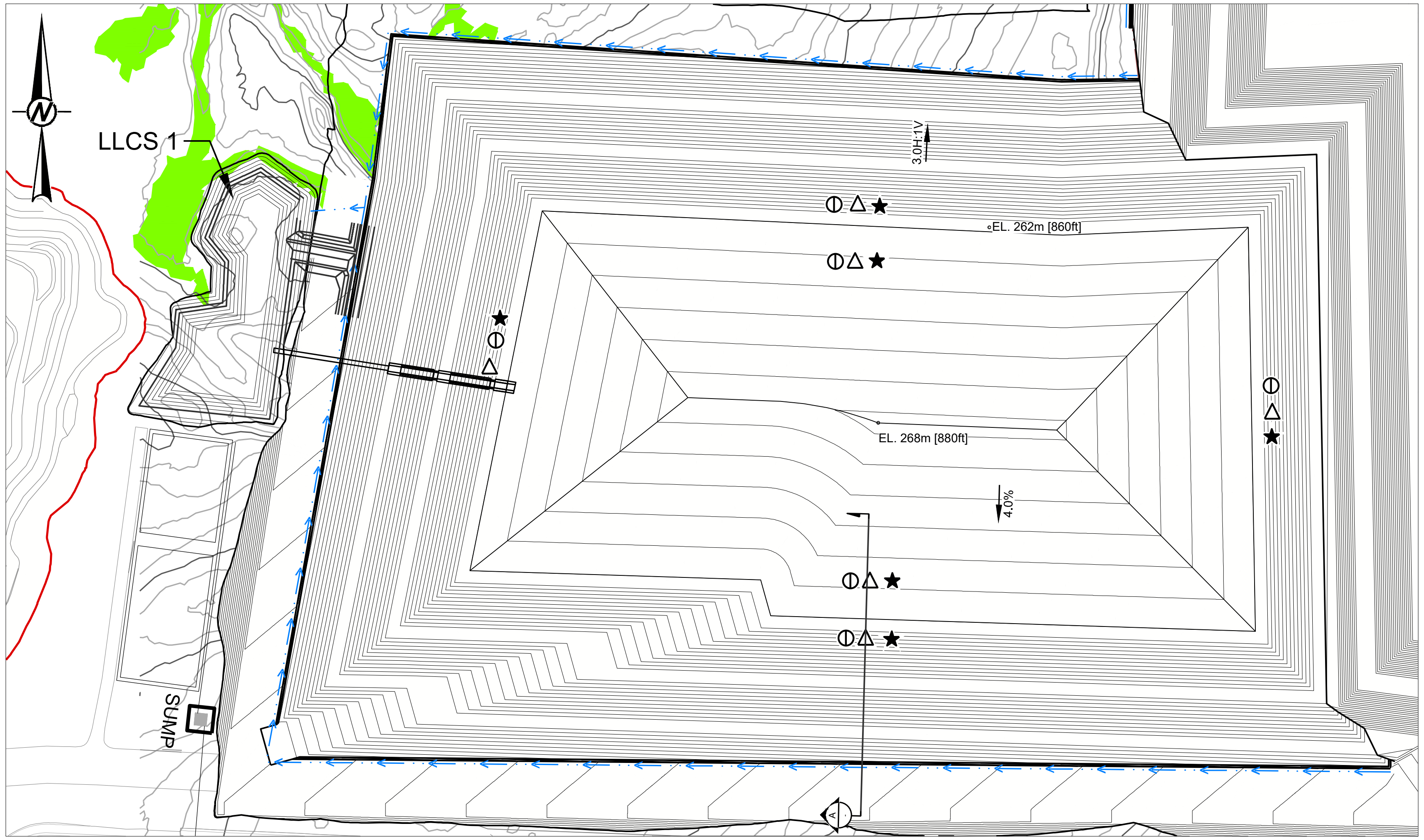
| PROJECT NO. | CONTROL | REV. | FIGURE |
|---|---|---|---|
| 1899291 | 12000 | | B1 |

Path: \\golder.gds\GAL\Mississauga\SIM\Clients\Aquila_Resources\Back_Forty\99_PROJ\1911770740_PROD\0004_LowerThroughput\ | File Name: 19117707-0004-CM-0002.dwg

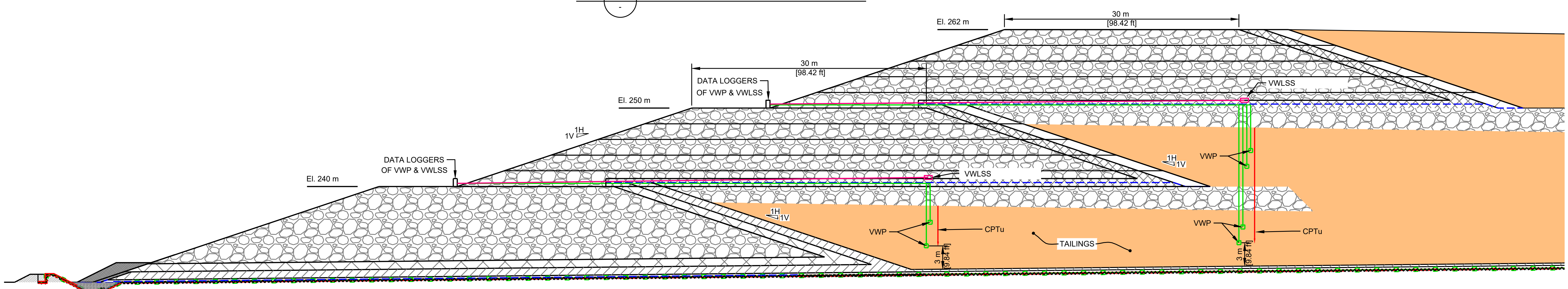
25 mm IF THIS MEASUREMENT DOES NOT MATCH WHAT IS SHOWN, THE SHEET SIZE HAS BEEN MODIFIED FROM: ANSI D

**ATTACHMENT C**

# Instrumentation Location




1:2,500 1 - PLAN VIEW OF TMF INSTRUMENTATION




1:250 A - CROSS SECTION OF TMF PERIMETER WALL INSTRUMENTATION

**LEGEND**

- VIBRATING WIRE PIEZOMETER (VWP)
- VIBRATING WEIR LIQUID SETTLEMENT SYSTEM (VWLSS)
- CONE PENETRATION TEST (CPTu)

0 10 20 30
SCALE 1:250 METRES

0 100 200 300
SCALE 1:2,500 METRES

CLIENT
AQUILA RESOURCES

CONSULTANT
GOLDER

| | |
|---|---|
| YYYY-MM-DD | 2019-11-07 |
| DESIGNED | KBH |
| PREPARED | JAF |
| REVIEWED | KBH |
| APPROVED | KAB |

PROJECT
BACK FORTY PROJECT
TAILINGS MANAGEMENT FACILITY

TITLE
**PLAN VIEW OF TMF INSTRUMENTATION**

| PROJECT NO. | PHASE | REV. | FIGURE |
|---|---|---|---|
| 1899291 | 12000 | 0 | C1 |

ATTACHMENT D

# Filter Analysis

# 1.0 INTRODUCTION

The proposed Tailings Management Facility (TMF) of the Back Forty Project consists of a waste rock perimeter wall with upstream transition and filter zones. The bulk of the perimeter wall will be constructed using 500 mm minus waste rock. The perimeter wall is required to allow flow of seepage water while preventing migration of fine particles. To ensure this, filter compatibility analyses were carried out between the following zones of the perimeter wall:

- Tailings and filter zone; and
- Filter zone and transition zone.

The filter compatibility analyses were carried out to comply with the following general criteria:

- Retention criteria – The voids of the filter material should be small enough to prevent particles of the base soil from penetrating or washing through it.
- Permeability criteria – The filter material should have significantly higher permeability (hydraulic conductivity) than the base soil. This ensures that the filter will accept seepage without excessive pore pressure build-up.
- Gap graded criteria – Gap graded materials should not be used as a filter. Gap graded soils can be internally unstable; that is the coarse fraction of the soil does not serve as a filter to the fine fraction, and the fine fraction can be piped out through the coarse fraction (i.e. suffusion).
- Segregation criteria – The filter material should not segregate during processing, handling, placing, spreading or compaction. The susceptibility to segregation increases with range in grain size, and the maximum particle size.
- Thickness criteria – The filter should be sufficiently thick to ensure a representative gradation throughout, providing compensation for potential segregation and contamination during construction. The minimum thickness is strongly influenced by the size of the larger grains. Furthermore, the filter must be thick enough that cracks cannot extend through the filter zone during any possible differential movements. The suggested minimum thickness for a filter is 0.3 m.

The purpose of this attachment is to present the results of the filter compatibility analyses.

# 2.0 METHOD

The design of the filter and transition material was carried out following the procedures outlined in NRCS (2017). A summary of the procedure is presented below.

- Step 1: Plot the gradation curve (grain-size distribution) of the base soil material.
- Step 2: Determine if the base soil has particles larger than the No. 4 sieve (4.75 mm) or has less than 15% passing the No. 200 sieve. If so, identify if the soil is gap-graded and re-grade according to the next step.
- Step 3: Prepare adjusted gradation curves for base soils that have particles larger than the No. 4 sieve (4.75 mm) sieve, or on a smaller sieve if the soil has is gap-graded curve. Soils with less than 15 percent fines do not ordinarily require regrading.
- Step 4: Place the base soil in a category based on the percent passing the No. 200 (0.075 mm) sieve from the regraded gradation curve data. As displayed below in Table D1, the NRCS (2017) identifies four base soil categories.

**Table D1: Base Soil Categories**

| Base Soil Category | Percent finer than 0.075 mm sieve | Description |
|---|---|---|
| 1 | >85 | Fine silt and clays |
| 2 | 40–85 | Sands, silts, clays, and silty sands |
| 3 | 15–39 | Silty and clayey sands and gravels |
| 4 | <15 | Sands and gravels |

- Step 5: Determine the maximum allowable $D_{15}$ size for the filter in accordance to Table D2. This satisfies the filtering (i.e. retention) criteria, preventing fines in the base filter from infiltrating the filter material.

**Table D2: Filtering (Retention) Criteria**

| Base Soil Category | Filtering – Maximum D15 |
|---|---|
| 1 | The maximum $D_{15}$ should be ≤ 9 × $d_{85}$ of the base soil, but not less than 0.2 mm, unless the soils are dispersive. Dispersive soils in category 1 require a filter with a maximum $D_{15}$ that is ≤ 6.5 times the $d_{85}$ of the base soil size, but not less than 0.2 mm. |
| 2 | The maximum $D_{15}$ should be ≤ 0.7 mm unless soil is dispersive, in which case the maximum $D_{15}$ should be <0.5 mm |
| 3 | The maximum $D_{15}$ should be: $\leq \left[\frac{40 - A}{40 - 15}\right][(4 \text{ x } d_{85}) - 0.7 \text{ mm}] + 0.7 \text{ mm}$ A = percent passing No. 200 sieve after regrading (when 4 × $d_{85}$ is less than 0.7 mm*, use 0.7 mm*). |
| 4 | The maximum $D_{15}$ should be ≤ 4 × $d_{85}$ of base soil after regrading |

- Step 6: In order to meet the permeability criteria, the minimum $D_{15}$ for the filter must be the greater of 0.1mm or one-fifth of the maximum $D_{15}$ Filter.
- Step 7: This step establishes control points on the filter band to avoid specifying gap-graded and segregation prone filter material. The minimum and maximum $D_{60}$ sizes for the filter should be developed to maintain a filter limit band size of 5. Furthermore, a coefficient of uniformity ($C_u$=$D_{60}$/$D_{10}$) equal to or less than 6 is required to prevent gap-grading.
- Step 8: The maximum allowable particle size for the filter is 50 mm and the maximum percentage passing the No. 200 sieve is 5 percent. These standards are meant for sand size filters only to maintain sufficient permeability and limit the broadness of the filter band gradation.
- Step 9: To prevent the tendency of broadly graded filters to segregate easily during construction, the relationship between the maximum $D_{90}$ and the minimum $D_{10}$ is limited by Table D3 below.

**Table D3: Segregation Criteria**

| Base Soil Category | If minimum $D_{10}$ is: (mm) | Then, maximum $D_{90}$ is: (mm) |
|---|---|---|
| All Categories | <0.5 | 20 |
| | 0.5-1.0 | 25 |
| | 1.0-2.0 | 30 |
| | 2.0-5.0 | 40 |
| | 5.0-10 | 50 |
| | >10 | 60 |

- Step 10: Develop a filter band using standard sieve sizes by connecting the control points developed from Steps 5 to 9 and extrapolating outside of the control points.

## 3.0 RESULTS

Figure D1 shows the expected gradations for the tailings and waste rock as well as the developed gradation envelopes for the transition and filter zones based on the NRCS (2017) procedure outlined above.

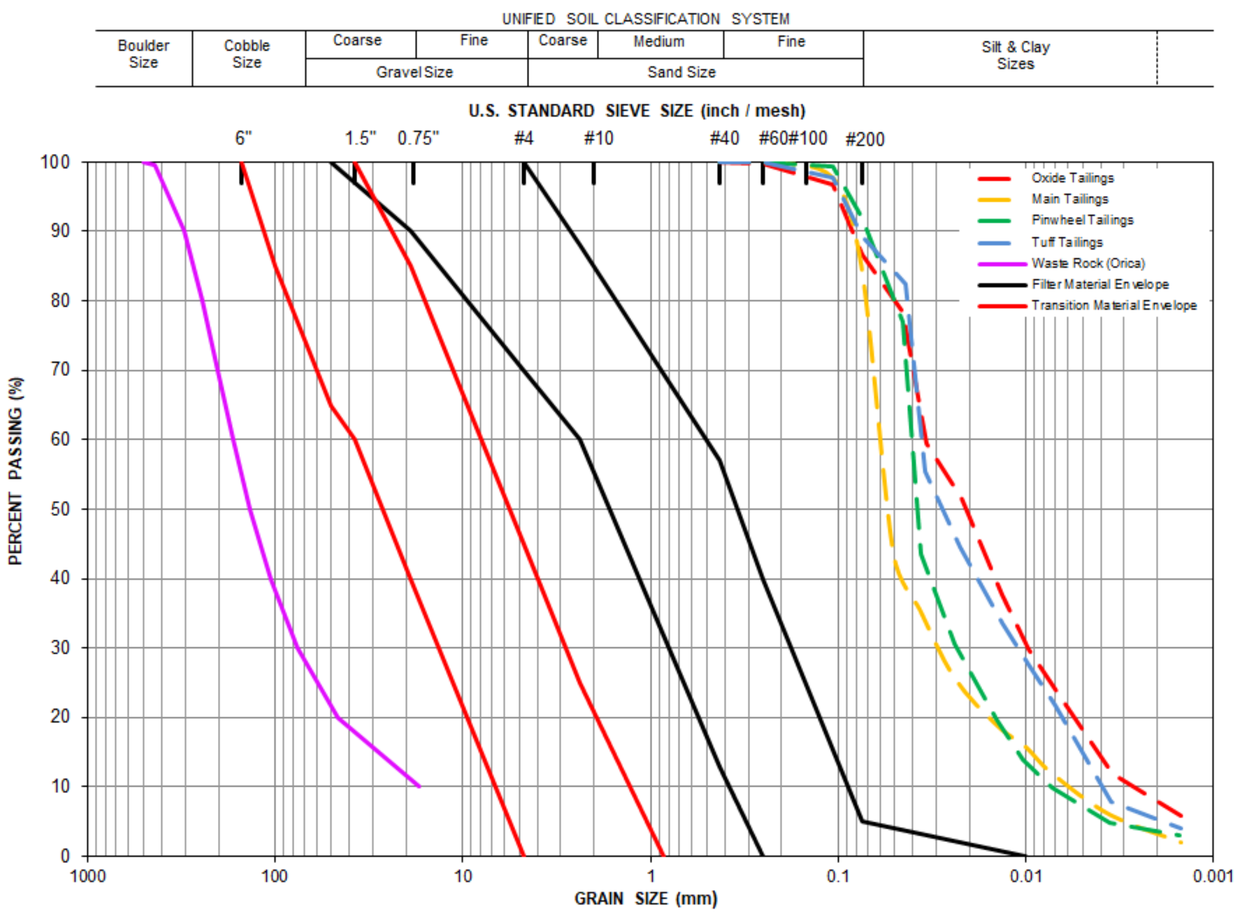



**Figure D1: Summary of Material Gradations**

## 3.1 Filter Material Gradation Envelope

The soil gradation curve of the Tailings shows 85 to 92 percent passing the 0.075 mm (No. 200) sieve. Therefore, all the Tailings are Base Soil Category 1 – Fine silt and clays. A gradation envelope of the four tailings types was developed and the fine limit of the envelope was used for the filter compatibility analysis.

The results of the NCRS procedures used to the design the filter material envelopes are presented in Figure D2 and Table D4. Figure D2 presents the control points developed by each separate step outlined in the NCRS (2017) procedures.

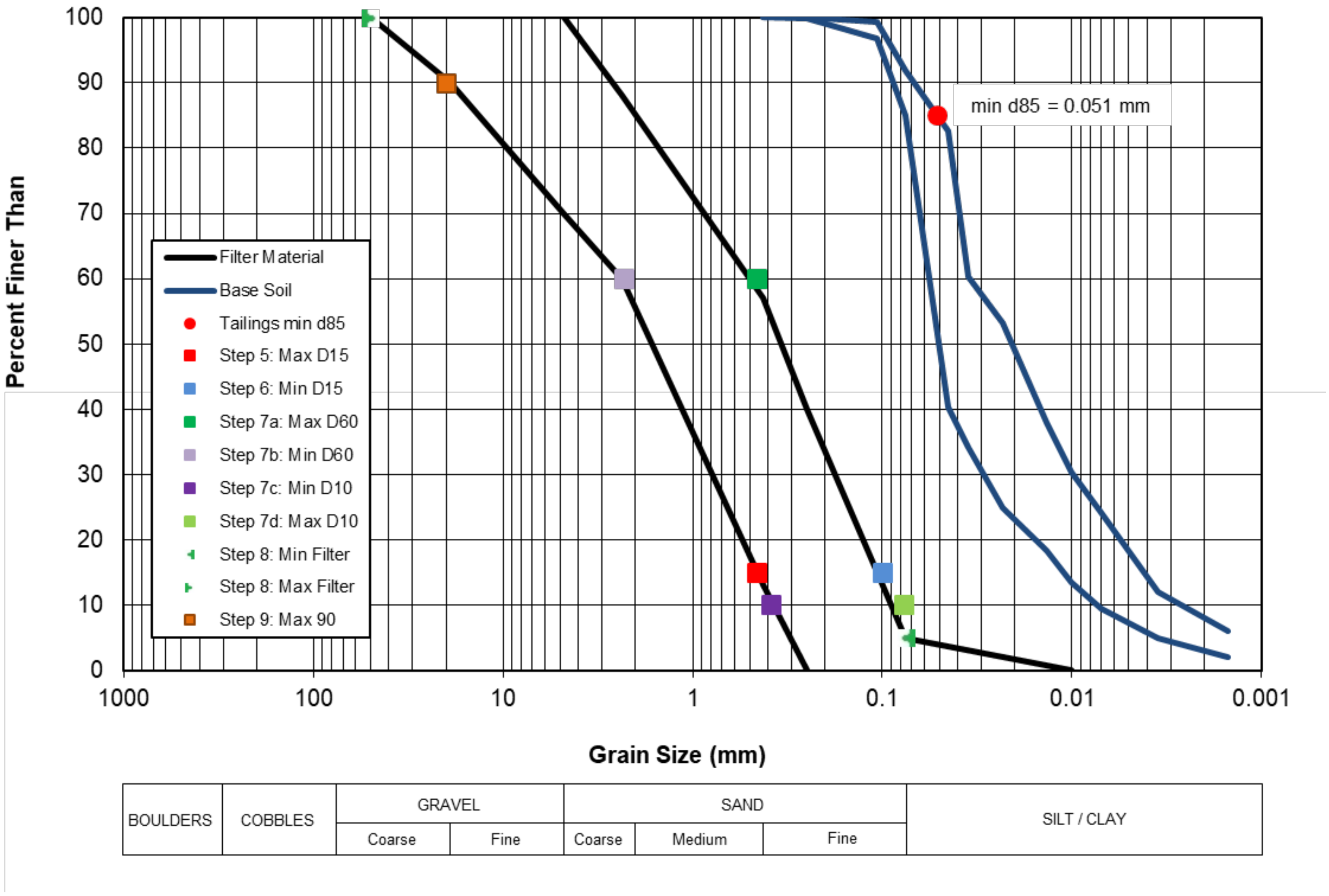



**Figure D2: Filter Zone Envelopes and Control Points**

**Table D4: Filter Zone Design Envelope**

| Sieve Size (mm) | Coarse Limit Passing (%) | Fine Limit Passing (%) |
|---|---|---|
| 50 | 100 | |
| 19 | 90 | |
| 4.75 | 70 | 100 |
| 2.36 | 60 | 88 |
| 0.425 | 13 | 57 |
| 0.25 | 0 | 40 |
| 0.075 | | 5 |

## 3.2 Transition Material Gradation Envelope

The fine limit of the Filter material gradation envelope was used for the filter compatibility analysis. The fine limit completely passes 4.75 mm sieve size therefore no re-grading was necessary. The Filter material is Base Soil Category 4 – Sand and gravels.

The results of the NCRS procedures used to the design the transition material envelopes are presented in Figure D3 and Table D5. Figure D3 presents the control points developed by each separate step outlined in the NCRS (2017) procedures. Steps 8 and 9 are not applicable.

**Table D5: Transition Material Design Envelope**

| Sieve Size (mm) | Coarse Limit Passing (%) | Fine Limit Passing (%) |
|---|---|---|
| 150 | 100 | |
| 100 | 85 | |
| 50 | 65 | |
| 37.5 | 60 | 100 |
| 19 | 40 | 85 |
| 4.75 | 0 | 45 |
| 2.36 | 0 | 25 |
| 0.85 | | 0 |

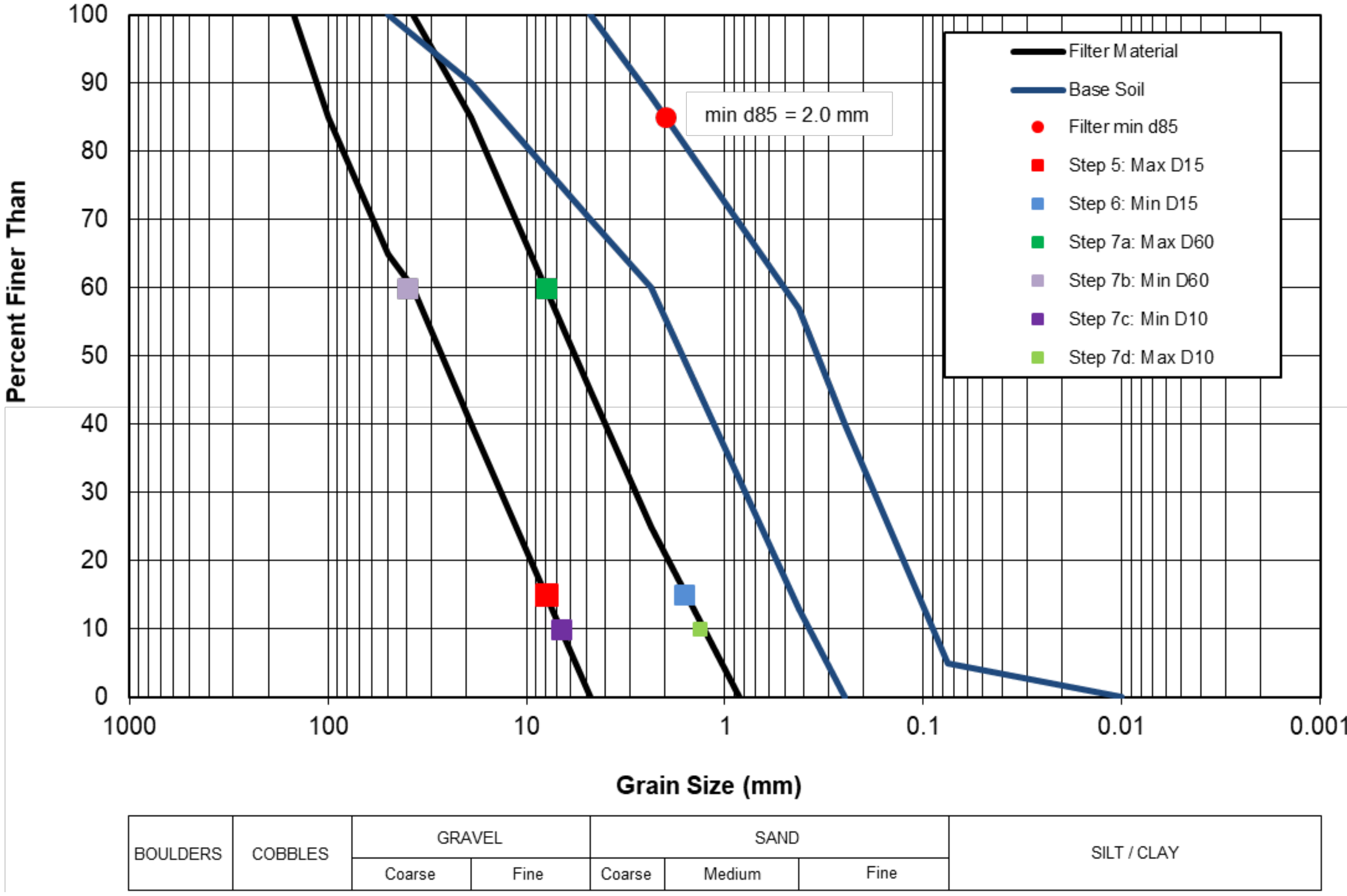



**Figure D3: Transition Material Design Envelope and Control Points**

## 4.0 CONCLUSION

The Filter was designed to act as a filter to the tailings in the TMF based on the expected gradation of the tailings to be deposited in the TMF. The Filter meets all criteria to retain the tailings fines and also to allow sufficient dissipation of porewater pressures. The Transition was designed to act as a filter to the designed Filter, to prevent washing into the rockfill and to allow seepage through to the rockfill. The Transition meets all filter criteria.

All the construction materials are physically stable. The filter material is expected to be produced from local borrow sources which are chemically inert. The transition material is expected to be produced from crushed and screened non-sulphide bearing waste rock for durability.

Both the filter and transition materials have design thicknesses of 1.0 m. The field construction quality control and quality assurance should ensure the proper placement and compaction of all materials to minimize segregation.

## REFERENCE

U.S. Department of Agriculture, National Resources Conservation Service (NRCS) (2017). Chapter 26 - Gradation Design of Sand and Gravel Filters. Part 633 Soils Engineering National Engineering Handbook, 210-VI-NEH, August 2017.

**ATTACHMENT E**

# Geotextile Physical Clogging Assessment

# 1.0 INTRODUCTION

The proposed Tailings Management Facility (TMF) of the Back Forty Project will have a double liner system. A granular drainage layer will be provided above the double liner system to collect tailings consolidation water reporting to the base of the TMF. The drainage layer will be protected by a nonwoven geotextile, overlain by a 0.3 m (1.0 ft) thick protection layer of overburden soil.

The purpose of this attachment is to present the results of the analyses carried out to evaluate the physical clogging potential of the geotextile due to the overlying protection layer of overburden soil.

# 2.0 OVERBURDEN SOIL PROTECTION LAYER

The overburden soil on site consists of silty sand to sand and gravel. The overburden soil is non-plastic and non-dispersive. The protection layer will be selectively borrowed or processed overburden soil. The proposed grain size envelope of the protection overburden soil will be as shown in Table G1.

**Table G1: Gradation Limits for Protection Overburden Soil**

| Sieve Size | Percent Passing |
|---|---|
| 50 mm (2 in) | 100 |
| 19 mm (3/4 in) | 87 - 100 |
| 4.75 mm (No.4) | 68 - 100 |
| 2.36 mm (No.8) | 59 - 100 |
| 1.18 mm (No.16) | 50 - 100 |
| 0.6 mm (No.30) | 27 - 100 |
| 0.425 mm (No.40) | 14 - 90 |
| 0.3 mm (No.50) | 0 - 78 |
| 0.075 mm (No.200) | 0 - 35 |
| 0.03 mm | 0 - 10 |
| 0.002 mm | 0 - 5 |

# 3.0 FILTER COMPATIBILITY BETWEEN GEOTEXTILE AND OVERBURDEN SOIL PROTECTION LAYER

The filter compatibility between the geotextile and the overlying protection soil was evaluated following the procedure recommended by Luettich et.al. (1992). The geotextile is required to retain the fines of the protection layer while allowing flow of tailing water to the granular drainage layer.

The flowchart developed by Luettich et.al. (1992) for soil retention criteria under steady state flow conditions is shown in Figure G1. The evaluation was carried out using the fine end of the grain size envelope for the overburden soil protection layer as shown in Figure G2. The path followed in the evaluation is shown in Figure G1. The evaluation shows that the geotextile apparent opening size required to retain the fines in the protection soil is less than 0.2 mm (loose condition). The proposed 340 g/m$^2$ (10 oz/yd$^2$) needle punched nonwoven geotextile have an apparent open size of 0.15 mm. Therefore, this nonwoven geotextile is adequate to filter the fines of the overburden soil protection layer.

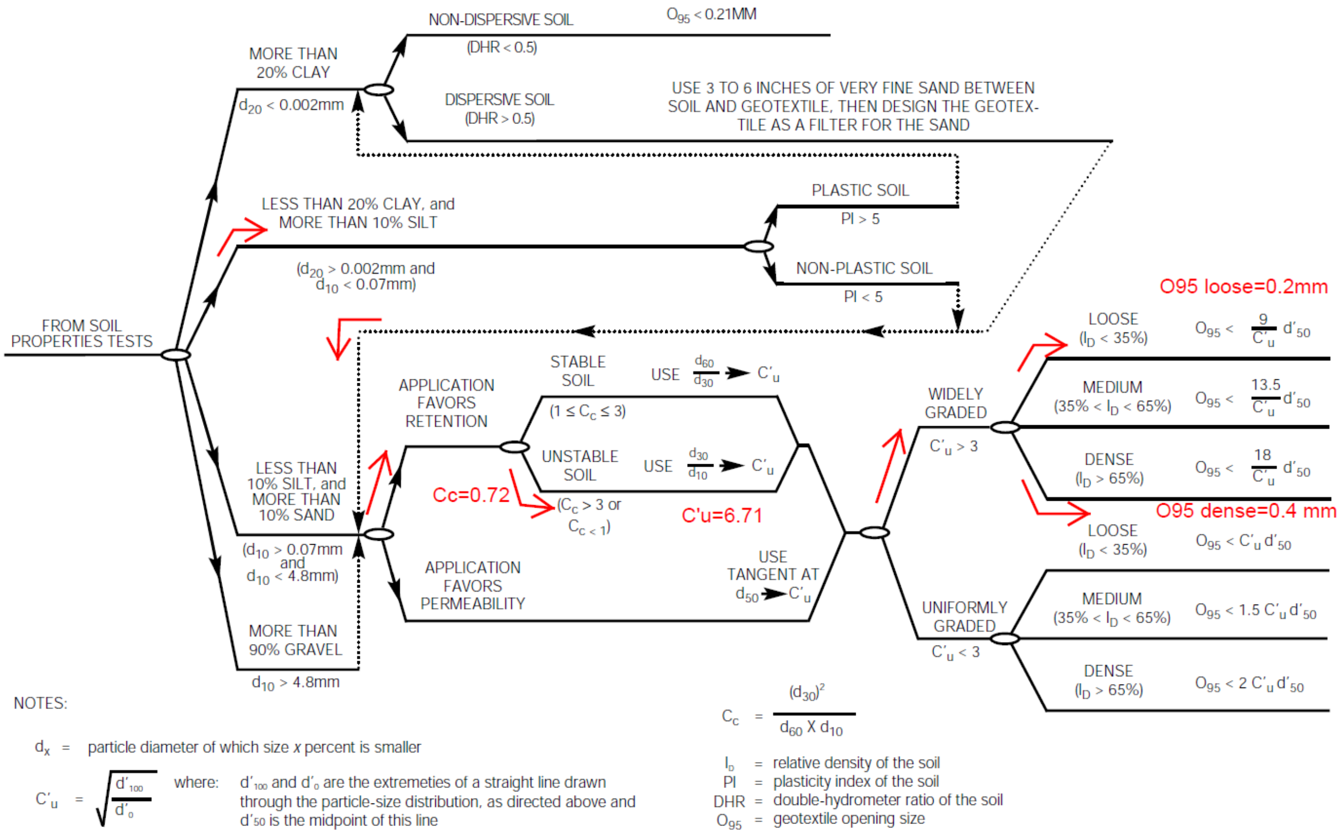



Figure G1: Flowchart for evaluation of soil retention criteria of geotextile under steady state flow conditions

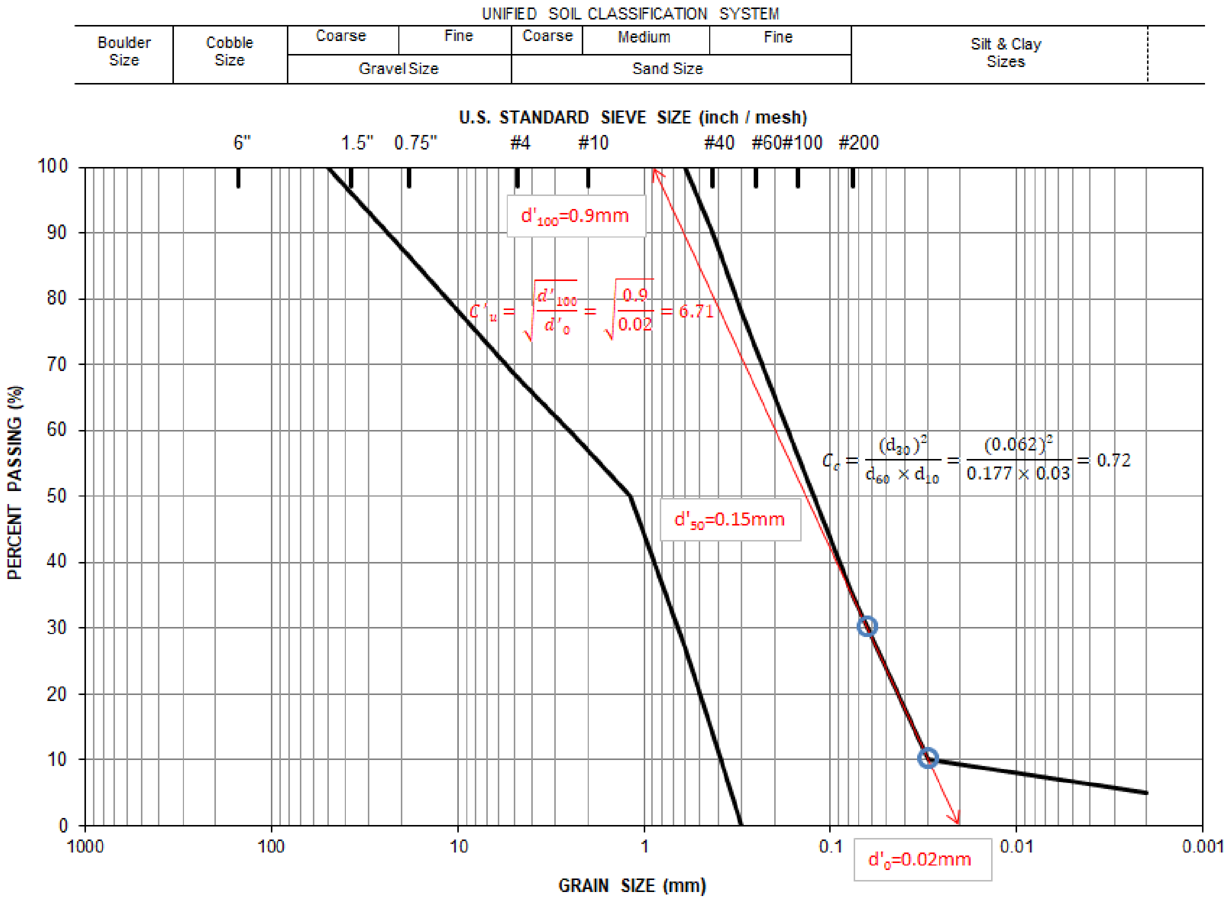



Figure G2: Gradation limits of overburden soil protection layer

## 4.0 GEOTEXTILE CLOGGING RESISTANCE

Geotextile fouling can be caused by a number of factors. One mechanism for fouling is due to biological clogging. This is uncommon in tailings facilities which contain no organic material. It is more common with landfills. Since there will be no organic material in the TMF, the risk for biological fouling is very low. Chemical precipitation is another possible mechanism for fouling. Chemical fouling requires time for the chemical precipitates to occur that could result in clogging the geotextiles. Given the short life span of the TMF the risk for clogging due to chemical precipitates is very low. This issue will be addressed further if limestone amendment is required in the perimeter wall as a condition of the permit. If fouling of the geotextile were to occur, the most likely mechanism would be due to physical clogging. During the detailed design, the physical clogging potential of the proposed geotextile will be tested using the Hydraulic Conductivity Ratio Test (ASTM D5567) and the Gradient Ratio Test (ASTM D5101).

The Canadian Foundation Engineering Manual (CFEM, 2006) recommends using the following criteria to reduce the risk of clogging of nonwoven geotextiles:

- For well graded or uniform soils with Coefficient of Uniformity ($C_u$) greater than 3 and low hydraulic gradients under steady state flow conditions, the apparent opening size (AOS) of the geotextile should be more than three times the minimum $d_{15}$ of the protection soil.

- The porosity of the nonwoven geotextile should be more than 50%;

Based on the first criterion, the nonwoven geotextile is required to have a minimum AOS of 0.105 mm to reduce the risk of clogging . The proposed 340 g/m$^2$ nonwoven geotextile meets this criterion as its AOS is about 0.15 mm. The porosity of the proposed nonwoven geotextile was estimated to be about 70%. Therefore, the proposed geotextile meets the criteria recommended by CFEM (2006).

## 5.0 CONCLUSION

The geotextile selected for the project is filter compatible with the protection overburden soil. The filter compatibility evaluation was completed based on the procedure developed by Luettich et.al. (1992). The geotextile selected is not anticipated to be prone to clogging by soil fines from the overlying soil protection layer. This was confirmed using the criteria recommended by CFEM (2006). Additional confirmatory laboratory tests will be carried out during detailed design of the project.

# REFERENCE

CFEM, (2006). Canadian Foundation Engineering Manual: 4th Edition. Canadian Geotechnical Society, Altona, MB.

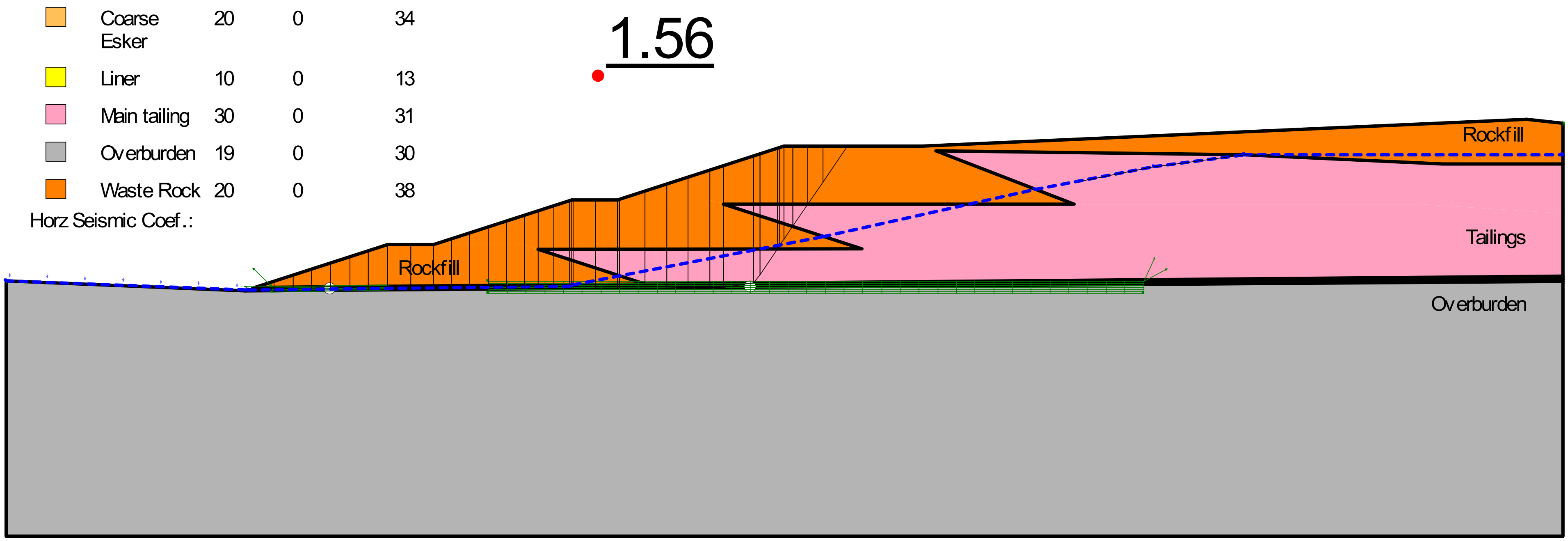
Luettich, S., Giroud, J. P., and Bachus, R. C., 1992. Geotextile Filter Design Guide, Journal of Geotextiles and Geomembranes, Vol. 11, No. 4-6, pp. 19-34.

**ATTACHMENT F**

# Stability Analysis

| Color | Name | Unit Weight (kN/m³) | Cohesion' (kPa) | Phi' (°) |
|---|---|---|---|---|
| | 6mm crushed stone | 20 | 0 | 34 |
| | Coarse Esker | 20 | 0 | 34 |
| | Liner | 10 | 0 | 13 |
| | Main tailing | 30 | 0 | 31 |
| | Overburden | 19 | 0 | 30 |
| | Waste Rock | 20 | 0 | 38 |

Horz Seismic Coef.:




1. Conservative phreatic surface assumed if underdrainage layer is non-functional.
2. Slip surfaces restricted to liner.
3. Minimum static factor of safety during operation and closure = 1.5

CLIENT

AQUILA RESOURCES

CONSULTANT

GOLDER

| | |
|---|---|
| YYYY-MM-DD | 2019-11-02 |
| DESIGNED | CEC |
| PREPARED | CEC |
| REVIEWED | KBH |
| APPROVED | KAB |

PROJECT

**BACK FORTY PROJECT**
**STABILITY ANALYSES OF TMF**

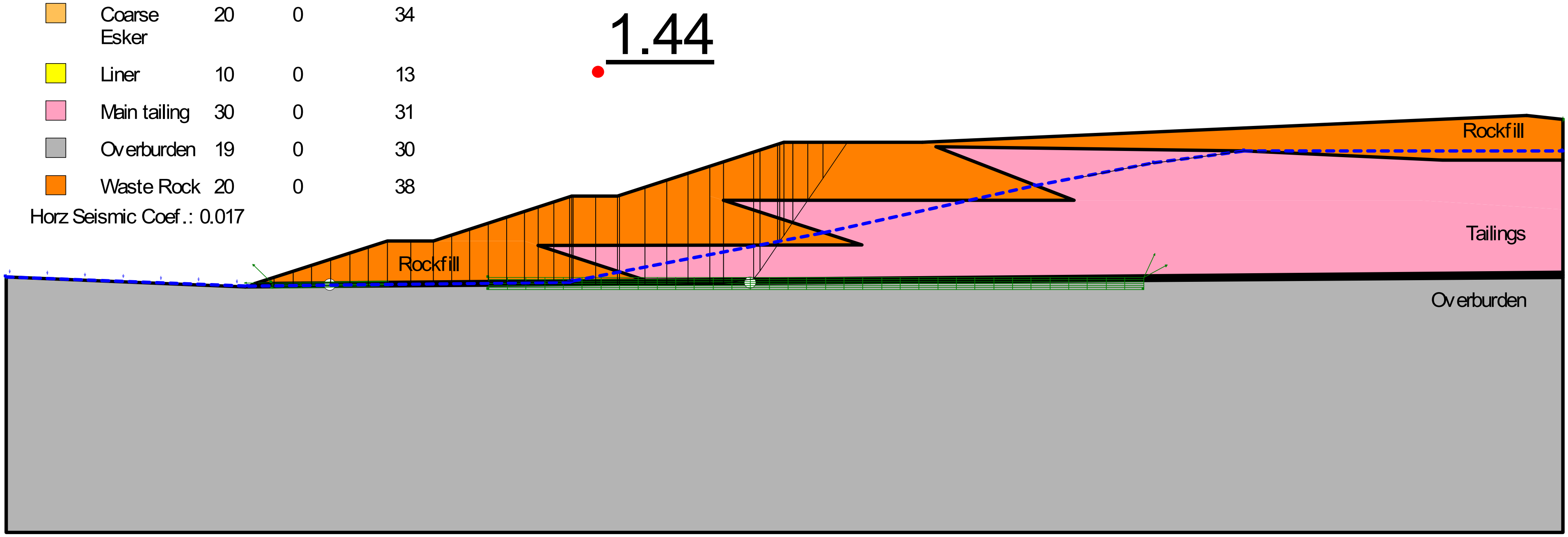
TITLE

**Ultimate TMF Static Stability Analysis**
**Grid-and-Radius**

| TITLE | PHASE | REV | FIGURE |
|---|---|---|---|
| 1899291 | | | F1 |

| Color | Name | Unit Weight (kN/m³) | Cohesion' (kPa) | Phi' (°) |
|---|---|---|---|---|
| | 6mm crushed stone | 20 | 0 | 34 |
| | Coarse Esker | 20 | 0 | 34 |
| | Liner | 10 | 0 | 13 |
| | Main tailing | 30 | 0 | 31 |
| | Overburden | 19 | 0 | 30 |
| | Waste Rock | 20 | 0 | 38 |

Horz Seismic Coef.: 0.017




1. Conservative phreatic surface assumed if underdrainage layer is non-functional.
2. Slip surfaces restricted to liner.
3. Minimum pseudostatic factor of safety = 1.1
4. Estimated PGA for 1:2,475 year return period = 0.034g according to the USGS - 2015 National Earthquake Hazards Reduction Program.
5. PGA reduction factor of 0.5 applied (Kramer 1996).

CLIENT

AQUILA RESOURCES

CONSULTANT

GOLDER

| | |
|---|---|
| YYYY-MM-DD | 2019-11-02 |
| DESIGNED | CEC |
| PREPARED | CEC |
| REVIEWED | KBH |
| APPROVED | KAB |

PROJECT

**BACK FORTY PROJECT**
**STABILITY ANALYSES OF TMF**

TITLE

**Ultimate TMF Pseudo-Static Stability Analysis**
**Grid-and-Radius**

| TITLE | PHASE | REV | FIGURE |
|---|---|---|---|
| **1899291** | | **A** | **F2** |

**ATTACHMENT G**

# Construction Specifications

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# Construction Quality Assurance Plan

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REPORT

# TMF and WRFs Construction Specifications

*Back Forty Project, Michigan*

Submitted to:

**Aquila Michigan Inc.**

E807 Gerue Street, Stephenson
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Submitted by:

**Golder Associates Ltd.**

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November 8, 2019

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GOLDER

**REPORT**

# TMF and WRFs Construction Quality Assurance Plan

*Back Forty Project, Michigan*

Submitted to:

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November 8, 2019

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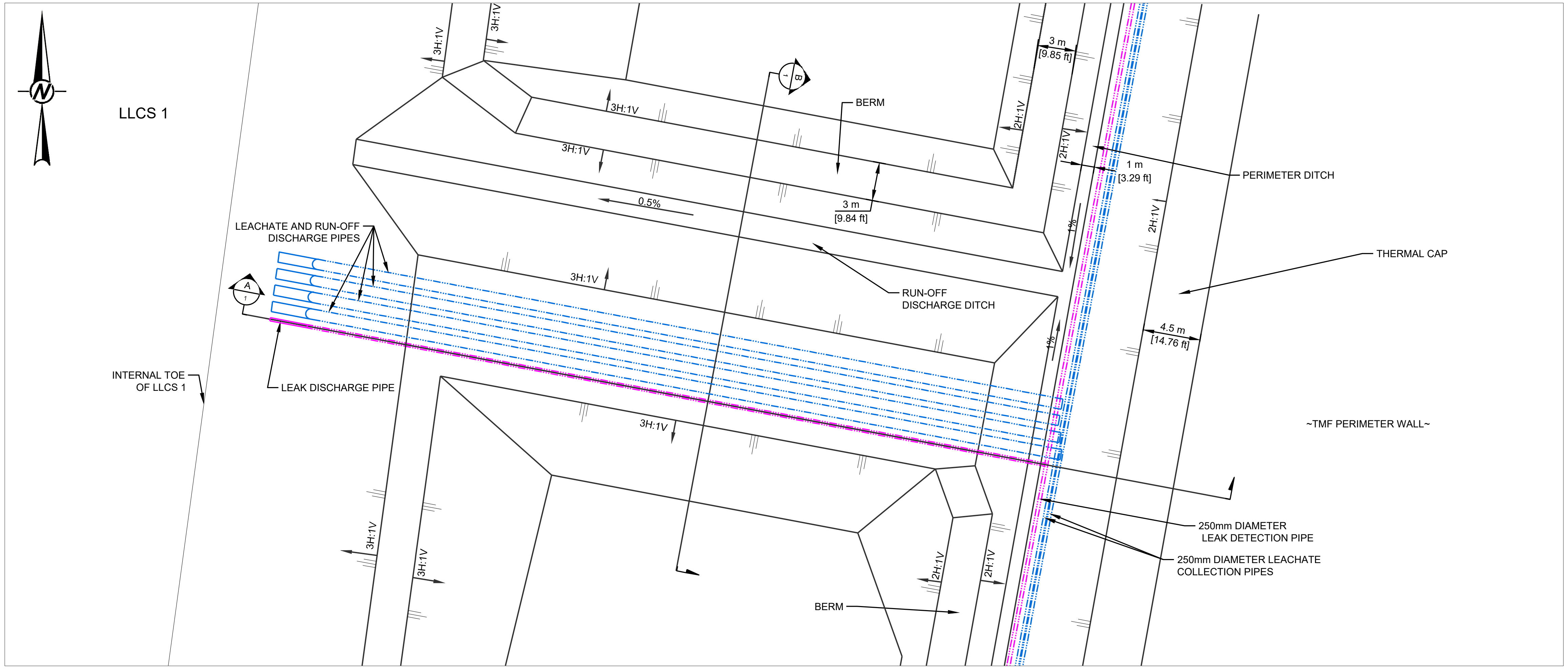
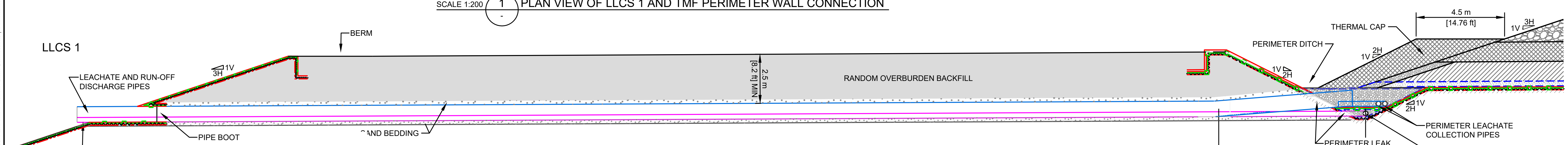
**ATTACHMENT H**

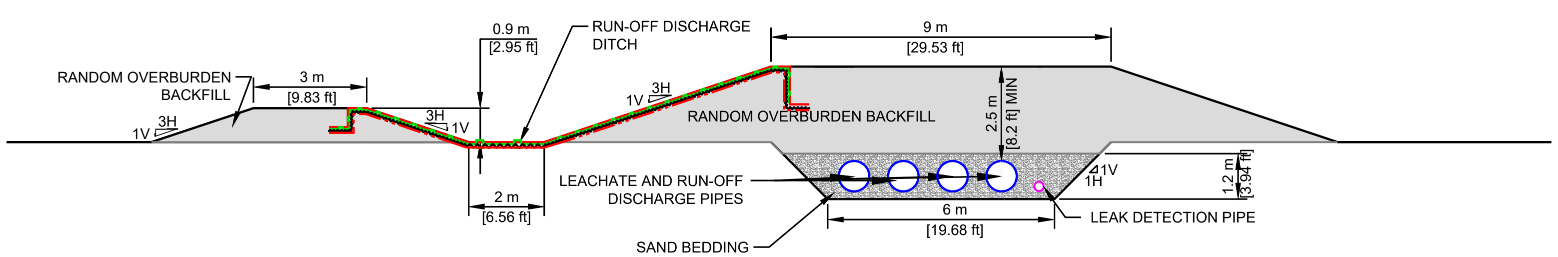
# Details of LLCS 1 and TMF Perimeter Ditch Connection




SCALE 1:200 1 PLAN VIEW OF LLCS 1 AND TMF PERIMETER WALL CONNECTION




SCALE 1:100 A CROSS SECTION OF LLCS 1 AND TMF PERIMETER WALL CONNECTION




SCALE 1:100 B CROSS SECTION OF LEACHATE AND LEAK COLLECTION PIPELINES FROM PERIMETER TMF TO LLCS 1

**LEGEND**

- NON-WOVEN NEEDLE PUNCHED GEOTEXTILE
- 1.5mm HDPE GEOMEMBRANE
- GEOSYNTHETIC CLAY LINER
- DOUBLE SIDED GEOCOMPOSITE
- 1.0mm HDPE GEOMEMBRANE
- LEACHATE COLLECTION/DISCHARGE PIPE
- LEAK COLLECTION/DISCHARGE PIPE

0 10,000 20,000
1:200 MILLIMETRES

0 5,000 10,000
1:100 MILLIMETRES

CLIENT
AQUILA RESOURCES

CONSULTANT
GOLDER

| | |
|---|---|
| YYYY-MM-DD | 2019-11-07 |
| DESIGNED | KBH |
| PREPARED | JAF |
| REVIEWED | KBH |
| APPROVED | KAB |

PROJECT
BACK FORTY PROJECT
TAILINGS MANAGEMENT FACILITY

TITLE
**PLAN AND CROSS SECTION OF LLCS 1 AND TMF PERIMETER DITCH CONNECTION**

| PROJECT NO. | PHASE | REV. | FIGURE |
|---|---|---|---|
| 1899291 | 12000 | 0 | H1 |

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