# “HARDROCK TAILINGS MANAGEMENT FACILITY, TMF DESIGN OVERVIEW” MEMO (AMEC 2018)

# TECHNICAL MEMORANDUM


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| Date | **January 10, 2018** | | |


**Subject** **Hardrock Tailings Management Facility**
**TMF Design Overview**

Wood/Amec has prepared this memo in response to comments on the Final EIS/EA and recent discussions with agencies to address key topics on the TMF design particularly the design measures addressing TMF dam stability, seepage through TMF dams, and contingency measures for seepage collection to mitigate potential seepage bypassing the seepage collection system.

This memorandum is being presented to further support of the TMF design with inherent safety measures to address failure risk and seepage mitigation measures.

## 1.0 TMF DAM DESIGN

In order to address the risk of potential dam failure, the TMF dams are designed for inherent safety. The proximity of the TMF to Kenogamisis Lake has been factored into every aspect of the design. The TMF is being designed, and will be built by the best available technology (BAT) and best available practices (BAP). The key TMF design considerations include the following:

- Geotechnical Investigations
- Dam design;
- Tailings deposition plan;
- Seepage mitigation and collection;
- Early pro-active establishment of an Independent Technical Review Board.
- Instrumentation and monitoring plan;
- Construction approach and QA/QC;
- Annual dam safety inspections and dam safety reviews

### 1.1 Geotechnical Investigations

Feasibility study level geotechnical investigations have been carried out along the TMF perimeter dam alignment footprint to characterize the subsurface conditions to facilitate implementation of adequate foundation design measures. The subsurface characteristics are typical of those encountered in northern Ontario. Additional investigations are planned for 2018 to support detailed engineering. The investigations to date included borehole drilling, test pitting, *in-situ* testing to determine the relative density of the foundation soils, groundwater conditions, hydraulic

conductivity of the soils and underlying bedrock and laboratory testing of soil samples to determine their index and strength properties. Cone penetration tests have been carried out to determine the soil types, in-situ strengths and pore pressure responses. The subsurface characterization has formed a key basis for the TMF dam design.

Additional geotechnical investigations have been planned this winter (Q1 2018) to further advance the detailed knowledge of sub surface conditions along the TMF dam footprints. This investigation will refine the spacing and number of investigation locations for verifying subsurface conditions and provide additional details in subsurface soil properties to support the detailed design. These extensive investigations provide assurance that all unsuitable soils will be identified and removed from the entire footprint of the dams, and the structures will then be constructed on competent subgrade soils or bedrock, to support the dams with adequate safety against any potential slope failures.

## 1.2 Dam Design

The TMF dams will be built out of robust mine rock with rockfill embankment dam design considerations to optimize the overall stability of the dam. The upstream slopes of the dams will include a low permeability glacial till core to mitigate seepage. Adequately designed filter and transition zones will be provided abutting the till core to prevent erosion of fines from the till core and also act as grade separators between various sized particles. A foundation filter is included in the design to prevent piping of the fines from the soil foundation into the downstream rockfill shells.

As stated previously all unsuitable soils will be removed from the entire footprint of the dams, and the structures will be constructed on competent subgrade soils or bedrock, to support the dams with adequate safety against any potential slope failures. A typical cross section of the dam is presented in the following Figure 1 indicating the upstream low permeability core, seepage cut-off system and downstream raise method of construction.

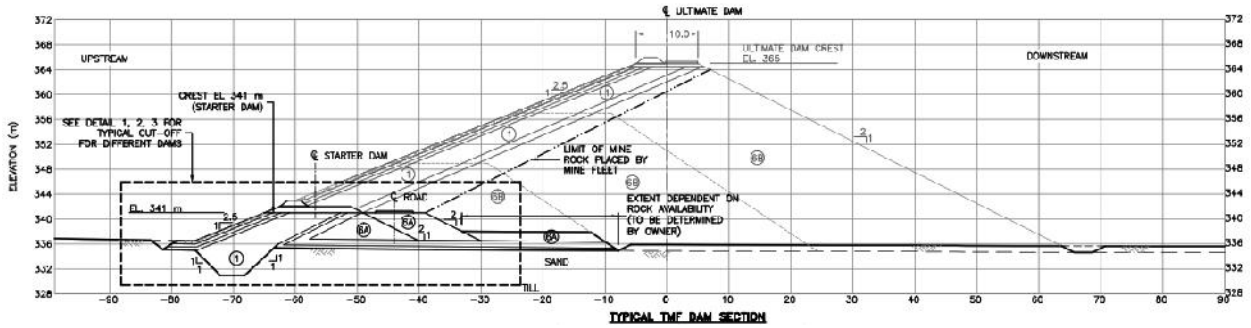


**Figure 1: Typical dam section showing the Starter and Ultimate dams**

## 1.3 Downstream Raising of dams

Recognizing the proximity to Kenogamisis Lake, the entire TMF perimeter dams will be raised over the Starter dam by “downstream raising” method using mine rock. In this method, the entire footprint of the perimeter dams will be founded on prepared/treated foundation surface unlike ‘centreline raise’ or ‘upstream raise’ tailings dams wherein part or entire raised footprint of the

dam is built over tailings. The downstream raising results in a robust structure and increases the stability of perimeter dams as there is full control on foundation preparation.

Construction of the dam by the downstream method is also of benefit with regard to demonstrating the environmental performance of the TMF dams. The upstream till core toe of the dam, will be about 350 to 400 m away from Kenogamisis Lake, with the downstream toe of the Starter dam being 250 to 300 m from the Lake Kenogamisis. Through raising, the downstream toe of the dam will move incrementally closer to Lake Kenogamisis ultimately to a point about 200 m from the Kenogamisis Lake. Instrumentation will be installed and monitored both during and following construction of the Starter dam and subsequent raises. Performance of the dam will be closely observed and assessed. The downstream raise method provides the flexibility to modify the design or construction approach for subsequent raises of the dam following performance review of the Starter dam.

## 1.4 Design as per LRIA and CDA Guidelines

As per Lakes and Rivers Improvement Act (LRIA) and Canadian Dam Association (CDA) guidelines the TMF dams are designed for probable maximum flood (PMF) and maximum credible earthquake (MCE) which is assumed to be close to 1:10,000 year annual exceedance probability. Essentially, the dams have been designed for ultimate flood and maximum credible seismic conditions. Following LRIA recommendation a site specific seismic hazard study is also in progress to assess the earthquake design ground motion (EDGM) for Hardrock project site.

The design of the TMF dams for stability exceeds the required target factors of safety in accordance with the LRIA criteria and the CDA guidelines.

### Emergency Spillways

Adequately designed emergency spillways will be constructed and maintained at every stage of dam raise designed to pass the PMF safely with required freeboard to the dam crest. This is provided as a dam safety measure to protect against any significant departures from the design intent, or water management associated with extreme storm events. The spillways will be inspected and maintained regularly for their functionality as a part of the maintenance and surveillance operations of the TMF dams.

## 1.5 Tailings Deposition Plan

The tailings deposition plan has been developed to enhance dam safety during operations and in the post-closure period while maintaining flexibility to adapt closure design to meet water quality objectives.

The tailings deposition plans have been developed in such way that the tailings pond is pushed to the natural ground on the west side of the TMF footprint such that pond water is not abutting the perimeter dam. Thus, the tailings pond will be located approximately 1,500 m from Kenogamisis Lake. This approach is due to the wide tailings beaches that separate the tailings pond from the perimeter dams. These measures further enhance the stability of the perimeter dams, reduce hydraulic gradients and seepage. The following figure provides end of mine tailings deposition plan.

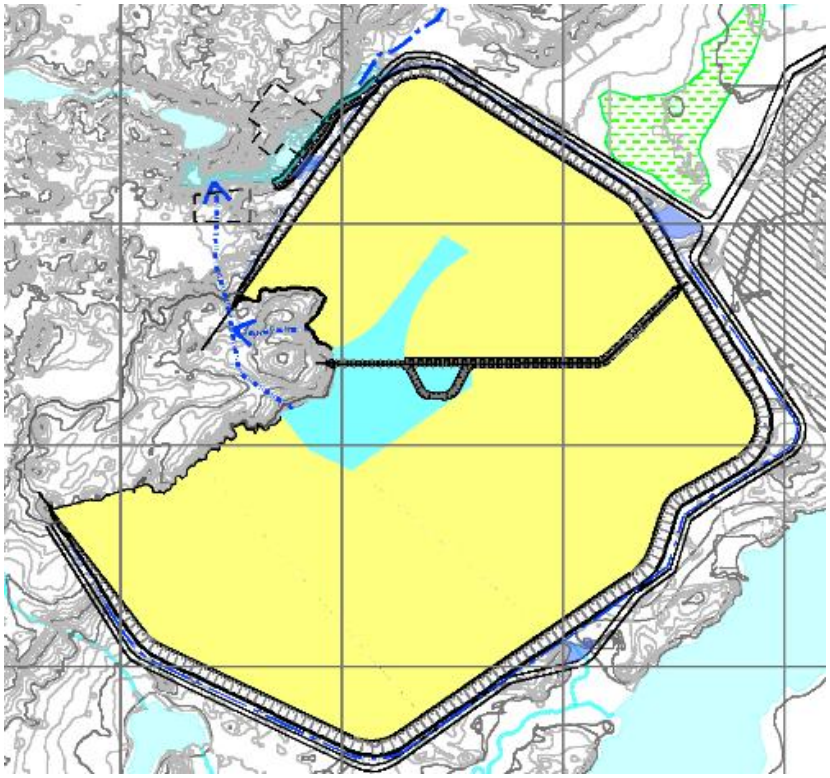

**Figure 2: Tailings Deposition Plan End of Mine Life**

### 1.6 Seepage Mitigation Measures

The TMF design includes a low permeability upstream till core, foundation seepage cut-off system along the upstream toe of the dam and seepage collection system.

The upstream till core will be sourced from a till borrow area close to TMF. Geotechnical investigations have been carried out in the borrow source area with sampling and laboratory testing of the native till deposit. The laboratory tests have confirmed that the till core will be low permeable, typical of compacted till material.

The foundation cut-off system in native overburden soils penetrates the upper relatively high permeability soils and will be tied into low permeability silt/silty clay or till. Where fractured bedrock is encountered consolidation grouting of the upper bedrock to a depth of 5 m will be carried out to seal the fissures.

During construction the entire foundation will be exposed as the construction progresses and the foundation conditions are required to be approved by the quality assurance engineer. The stringent QA/QC program which will be enforced during construction will ensure construction of foundation cut-off and all other construction procedure to progress diligently.

More than 500 m wide tailings beaches between the perimeter dams and tailings ponds further mitigate seepage through the dam body and foundation seepage.

### Seepage Collection System

The seepage collection system comprises perimeter ditches downstream of the ultimate toe of the dam and three seepage collection ponds. The seepage collection ditches and ponds will collect runoff from the downstream watershed area, from the crest of the dam to the ditch in addition intercepting seepage from the foundation and dam body. The collected seepage and runoff will be pumped back to TMF.

The seepage collection ponds will be maintained at levels lower than the ambient ground levels to create a positive hydraulic gradient to prevent seepage migrating from the seepage collection ditches and ponds.

### Contingency Seepage Collection Measures

The efficacy of the seepage collection system will be monitored with instrumentation during the early stage of operations. In the highly unlikely event of seepage bypassing the collection system presents adverse effects on Kenogamisis Lake, adequate space (more than 10 m) has been provided for deep groundwater collection wells that could effectively be established in the area between the seepage collection ditching and access/haul road.

## 1.7 Independent Technical Review Board

An independent technical review board(ITRB) has been established for the TMF consisting of independent experts in the field of tailings management. The first ITRB meeting was held between 11$^{th}$ to 15$^{th}$ December 2017 at Geraldton, Ontario. The establishment of an ITRB this early in the planning process is a global best practice that GGM has successfully implemented for the Project. The initial ITRB meeting will help shape the additional geotechnical work in 2018 to support detailed engineering.

## 1.8 Instrumentation and Monitoring Program

In order to monitor the performance of the dam an instrumentation and monitoring plan will be implemented. During Starter dam construction and subsequent raising of dams the instrumentation will provide information on pore pressure development if any, in the foundation units and would guide the rate of construction of the raises. Installed instrumentation during dam raising will also provide movements observed if any, so that remedial action by way of toe buttress/loading berms could be incorporated in the design.

The proposed instrumentation include nested vibrating wire piezometers, inclinometers and survey monuments.

## 1.9 Operation, Maintenance and Surveillance Manual

An Operations, Maintenance and Surveillance (OMS) Manual will be produced prior to operation of the TMF to assist with training new staff, clarify responsibilities, and explain the design and operation objectives, and set-out surveillance and monitoring procedures.

Surveillance and monitoring observations will be tailored to focus on potential dam failure modes. The OMS will include guidance for operators on how to respond to anomalous observations of monitoring data, with “trigger” and “alarm” levels set to engage management and the Engineer-of-Record, or initiate emergency response procedures, respectively.

The OMS manual will also indicate frequency of TMF inspections such as weekly, monthly, quarterly and annually. It will also indicate mill, engineering and environmental personnel and their roles and responsibilities including preparation of inspection reports detailing the performance of the TMF dams and complete photographic documentation.

Key performance indicators to demonstrate TMF operation according to the design intent include:

- Maintenance of a wide tailings beach.
- Raising of the rockfill shell in accordance with the dam raising schedule.
- Stable piezometric levels and embankment movement trends.
- Maintenance of pond volume tracking and water balance.

### 1.10 Dam Safety Inspections and Dam Safety Review

Dam safety inspections (DSI) are essential part of the TMF dam maintenance and will be carried out annually by a qualified geotechnical engineer. The inspection will include a thorough inspection of the TMF dams, review of the weekly, monthly, quarterly inspection reports prepared by the TMF management team. The inspection will highlight the performance of the dam over the year, any distress conditions noted and would recommend remedial measures as necessary.

Dam safety review(DSR) will be carried out periodically (currently scheduled for every 5 years). In this review, in addition to the dam safety inspection the TMF dam designs will be reviewed in relation to the hydrology and seismicity of the area. Hydro-meteorological database updated over the past five years will be reviewed in conjunction with the historic data to review and revise if necessary, hydrology and hydraulic design of the TMF. Impacts due to climate change are effectively addressed in the DSR.

Seismic database updated to include the data over the past five years on the observed seismic events in the vicinity will be considered for updating the seismic design of the dam.

## 2.0 CONSTRUCTION

A construction execution plan will be prepared for implementation during construction. The dam will be constructed by contractors according to technical specifications, quality control and quality assurance inspection procedures set by the Engineer-of-Record (EoR) and as-built reports will be prepared.

Each staged dam raise is based on the observed behaviour and environmental performance of the previous stage. If required, design revisions or changes are incorporated into the construction sequence based on operational performance monitoring data obtained during the dam construction program.

## 2.1 QA/QC During Construction

The Engineer-of-Record will deploy a qualified team for quality assurance and quality control so that the TMF dams are built in accordance with the design intent, construction drawings and technical specifications.

GGM will also deploy qualified geotechnical engineers on site during construction to ensure the construction proceeds as per the design. Periodic visits will be carried out by senior geotechnical engineers to inspect the construction.

## 2.2 Instrumentation During Construction

Foundation response monitoring forms an integral part of the construction program especially in fine grained soil foundations. Nested vibrating wire piezometers will be provided in the foundation units to measure change in pore pressures during construction. Additional monitoring locations will be provided as the footprint of the TMF dam increases during subsequent raises. The monitoring program will provide guidance to the rate of raise of the dams as well as to inform if design or construction modifications are required.

# 3.0 SUMMARY

The TMF designs have been carried out based on best available technology and best available practices. The following are the principal design features of the TMF are as follows.

- Feasibility level Geotechnical Investigations
- Robust Dam design following LRIA and CDA guidelines;
- Seepage cut-off and seepage collection system
- Wide tailings beaches between perimeter dams and tailings pond;
- Early pro-active establishment of an Independent Technical Review Board.
- OMS manuals;
- Instrumentation and monitoring plan;
- Construction approach and QA/QC during construction;
- Annual dam safety inspections and dam safety reviews.

In light of the above there is high degree of confidence in the TMF design approach and construction. Seepage issues have been adequately mitigated and failure risks are fully addressed.

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