Closure Landform Design for an Oil Sands External Tailings Facility

Tailings and Mine Waste 2017

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Outline

• Introduction
  o Project location
  o Background

• Overview of closure landform design surface

• Key aspects to the design approach

• Looking back at the design approach

• Looking ahead to the detailed design and construction
Project Location

Muskeg River Mine

- **2017 External Tailings Facility (ETF)**
  - Pond area approx. 316 ha

- **2017 South Expansion Area (SEA)**
  - Pond area approx. 30 ha

Athabasca River

Muskeg River
Background

- The perimeter ETF and SEA dykes were raised using hydraulically placed coarse sand tailings (CST) using cell construction techniques.
- The perimeter ETF dyke design includes a wide crest with a beach above water (BAW) zone adjacent to the cell sand, with fluid tailings accumulation in the central portions of the pond.
- During deposition, the sand segregates and settles out near the dyke crest and the fines are carried with the water to the centre of the facility.
- The fines settle to form fluid fine tailings (FFT) by releasing process affected water, which becomes part of the recycle water system.
Depositional History

- Tailings Solvent Recovery Unit (TSRU) deposition in the North Pool Deposit completed in October 2016
- TT deposition in the ETF completed in March 2017
- Future infilling of the ETF and SEA to be completed solely with CST

* Pipeline configuration current September 2017
Pre-Planning-Level Closure Work

- Closure strategy document for MRM Site
- Conceptual design of the geomorphic surface
- Geotechnical stability analysis using a base case over arching design and submitted for approval
- Geotechnical constraints map was developed with both the geotechnical and planning team
• The planning-level design is intended to:
  o Design to a level that allows a **reasonable base case** for comparison, development of a cost estimate for construction, and continuation of infilling operations
  o Identify risks and opportunities associated with the landform design and construction
  o Establish a path forward for the detailed design and subsequent construction
Design Approach: Setting the Goals and Objectives

• Overarching end goals of the closure design:
  o Delicensing
  o Reclamation certification

• Supporting objectives:
  o Safety of personnel and equipment during construction
  o Meet dam safety criteria for all stages of tailings infilling, stabilization, and reclamation
  o Create a safe and geotechnically stable landform that requires only minimal long-term maintenance
  o Control surface water such that water is safely conveyed off-landform
  o Integrate the landform with the lease-wide closure landscape

Existing reclaimed west slope of ETF
Design Approach: Predicting Conditions Post-infilling

• ETF:
  o CST infilling will displace the low density tailings (less than 55% solids by weight)
  o Tailings with densities greater than 65% will be captured
  o Some tailings with solids contents between 55 and 65% will remain in the northwest corner of the ETF for future treatment
  o Some tailings in the northeast corner will be capped in-place with CST

• SEA:
  o The fluid fine tailings are removed during construction and pumped to the ETF, leaving CST
  o Some entrapped pockets of FFT are expected to remain in the SEA

• For both the ETF and SEA, the plan is to track-pack the top 4 m of CST using dozers to create a compacted layer of trafficable sand
Design Approach: Determining the Main Design Constraints

• Maximizing waste placement within a specific topographic envelope
• Minimizing disturbance to already reclaimed areas
• Locating the ETF outlet to connect with channel designed in closure landscape plan
• Maximize the volume of water reporting to the end pit lake
Design Approach: Developing the Drainage Plan

- Defining the Perimeter Zone and Geotechnical Buffer Zone (adapted from CEMA (2014) Guidelines for Wetlands Establishment on Reclaimed Oil Sands Leases Wetlands Guide):
  - **Perimeter zone**: designed to eliminate ponding water and typically several hundred meters wide (adjacent to the dyke crest)
  - **Geotechnical buffer zone**: designed to avoid permanently flooded conditions, but may be inundated during extreme events
Design Approach: Developing the Drainage Plan

- Control surface water and direct it off-landform to the lease-wide surface water drainage system
- Precipitation is designed to sheet flow down the dyke slopes
- Precipitation that falls on the plateaus is directed into vegetated plateau channels
- Vegetated channels designed using Golder 2004 Vegetated Waterways Design Guidelines
- Central channel designed using guidance from 2014 CEMA wetland manual
Design Approach: Designing the Outlets

• OSTDC 2014: outlets require a robust design (hydraulically and geotechnically), as they are critical to both long-term performance and delicensing

• ETF and SEA outlets are designed to pass the PMF with minimal erosion.

• Designed for
  o Settlement
  o Potential beaver dams
  o Residual freeboard

• Outlet invert elevations based on:
  o Maximizing tailings storage
  o Maintaining a nominal gradient from the furthest channel to the outlet
  o Limiting the potential for backflooding into plateau channels, if outlet is blocked

• Designed as excavations into compacted dyke fill, to limit the potential for settlement

• Outlets are armoured with durable riprap to provide erosion control and help deter beavers from these critical areas
Design Approach: Creating Topographic Variation

• Approach used to guide the hummock design:
  o Review the current tailings deposit strengths
  o Develop reasonable geometry for hummocks
  o Limit-equilibrium slope stability analysis
  o Regular review and update following site investigation
  o Deformation analyses to support detailed design

• Hummock designs developed:
  o 2 to 5 m high
  o 10H:1V to 12H:1V slopes
  o 50 to 100 m offsets to channels
Design Approach: Planning for Settlement

• Post-reclamation settlements will be targeted:
  o Outlets < 1 m of settlement
  o Plateaus < 1 to 2 m of settlement

• Post landform construction:
  o Monitoring of the ongoing consolidation and landform performance is key
  o Observation of the landscape performance will help to understand the level of maintenance required/potential additional fill that may be required

• Infilling will displace much of the soft materials
  o Canadian Natural is developing a strategy for treatment of soft tailings left in the NW corner of ETF post-infilling
  o Canadian Natural is undertaking laboratory large-strain consolidation testing to refine predictions
  o Once refined, a strategy focused on detail landform design and final reclamation will be developed
Looking Back at the Design: Challenging the Design Constraints

• The closure topography for the ETF and SEA landforms are created through waste placement
  o A preliminary topographic envelope for waste was created by the dyke designers to maintain dyke stability
  o Preliminary closure landform designs followed this topographic envelope
    ▪ Limited the ability to drain the entirety of the ETF and SEA plateaus in toward central channels
    ▪ Required armoured channels down the dyke slopes to manage outward draining surface water

• To reduce costs and risk of downstream dyke erosion, the topographic waste placement envelope was revisited
  o Raising the dyke in specific locations was shown to be possible
  o Drainage from the dyke crests inwards to the main channels
  o Creates a more robust overall drainage plan
Looking Back at the Design:
When are the Outlets Required?

• Transitioning these tailings storage facilities
  o From ring dykes that manage storm events with large ponds during operation phase, with 3 m of freeboard
  TO
  o Landforms that pass storm events through outlets

• Freeboard assessments are required before the infilling process reduces the pond such that the design storm cannot be contained, AND

• The outlets need to be constructed to allow drainage to an environment that is ready to receive the surface flows from these landforms
Looking Back at the Design: Designing with Uncertainty

- Designing a landform on tailings substrates that do not yet exist is challenging
- Regulatory process to delicense a dam has not yet been formally applied to any structure
- Long-term maintenance requirements for the surface water drainage system
Looking Ahead

• The SEA infilling is scheduled to be completed in 2018. Next steps include:
  o Site investigation (CPTs, instrumentation, test excavations and test fills)
  o Detailed design
  o Use of the SEA design and construction process to learn for the ETF

• Continued ETF site investigations as infilling progresses include:
  o Revisiting the design as new information becomes available, and develop detailed designs for construction
  o Using annual site investigations for documenting as-built conditions

• The design process will continue to evolve as each of the over 30 oil sands tailings facilities in the region is closed and reclaimed
Progressive reclamation will commence earlier in the more easily accessed areas and where trafficability is sufficient to support reclamation activities (e.g. sand beaches, or sections of the dykes where permanent reclamation has already begun.)
Looking Ahead - MRM ETF Proposed Plan

Phase 1
Infilling & capping

Phase 2a
Landform construction (ETF South)

Phase 2b
Landform/Outlet Construction (ETF North)

Phase 3
Reclamation Activities

Phase 4
Monitoring (Active and Passive Care)

Reclamation Certification

Overburden capping design
Planning Level landform design

Geomorph Design

Engineering Studies:
- Environmental characterization of TSRU
- Consolidation & Settlement
- Treatment options
- Global/Internal Stability
- Infilling Strategy
- Site Investigations
- Instrumentation plan
- Risk Assessment
- Surface water Design
- Erosion Susceptibility Assessment

Design Check

Deposit Performance

Geomorph Design Update

Studies:
- Consolidation & Settlement update
- Liquefaction analysis update
- Seepage analysis update
- Performance monitoring
- Monitoring Plan
- Groundwater Update
- NPD Capping Requirements
- Outlet Design

Performance Check

Deposit Performance

Geomorph Design Update

Studies:
- Consolidation & Settlement update
- Liquefaction analysis update
- Performance monitoring
- Application of preferred treatment

Design Check

Deposit & Landform Performance

Geomorph Design Update

Stations:
- ETF Landform Reclamation Design
- Reclamation Design:
- Erosion control
- Reclamation cover designs
- Planting Prescriptions
- Wildlife habitat enhancements

• Annual Landform Performance Report
• Ground water and Water Quality monitoring
• Instrumentation Monitoring
• Annual survey and settlement monitoring
• Reclamation Performance Monitoring
• Vegetation Management

Progressive reclamation will commence earlier in the more easily accessed areas and where trafficability is sufficient to support reclamation activities (e.g. sand beaches, or sections of the dykes where permanent reclamation has already begun.)
For large tailings landforms: 
Design $\rightarrow$ construction $\rightarrow$ site investigation $\rightarrow$ repeat

Learnings from each phase of the project are applied in real time, allowing designs to be adjusted and optimized
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