Capping and Closing Deep Fine Tailings Deposits

Alexander Hyndman

Richard Dawson

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Topics

• Background on FFT and pond behaviour
• FFT processes & deposit types
• Deep fines-dominated deposits
  – Characteristics & challenges
• Capping approaches
• Mine closure summary
Cell & Beach Tailings Dam Construction

Cell Construction
Tailings Pipeline
Sand Dyke
Bedrock
Bedrock

Beach Above Water
Beach Below Water
Recycle Water
MFT
Mudline

Courtesy Shell Canada
Courtesy Syncrude
Distinct layers of settled particle types

Clay Activity Chart

Surface Areas of Clays:

- Kaolinite: 10 - 20 m²/g
- Illite: 65 - 100 m²/g
- Smectite: 700 - 840 m²/g

Settling Pond: MFT Solids % and Clay Concentration (Clay Content by Methylene Blue)
FFT Management Goals

1. To eliminate fluid containment dams in the closure landscape.
2. To establish a stable closure landscape, with sustainable and diverse ecosystems, within a reasonable time after cessation of mining.
3. To develop sustainable surface drainage including a functional lake system.
4. To facilitate progressive reclamation (i.e., the reclamation of mine areas, to the extent practical during mine life, to reduce post-closure liability).
5. To optimize full life-cycle costs and minimize life-cycle environmental impacts without compromising reclamation and closure objectives.
6. To understand technical uncertainties and appropriately manage their associated residual risks.*

Surface Oil Sands Ore Body Properties

Note: Fines content for Aurora N, Aurora S and MLX W are adjusted down to reflect full dispersion for fines analysis.

Green symbols indicate sites with Clearwater clay-dominated overburden.
Deposit Types (COSIA Guides)

Thin-lift dewatering (e.g., for drying)
Fines-enriched sand deposits (e.g., CT)
Deep fines-dominated (cohesive) deposits
Water-capped fines
Pit Geometry, Mining Sequence & Foundation Influences In-Pit Timing & Deposit Volumes
Cost and Area Requirement

Cost
$/tonne
Fine
Solids

Area Requirement

Drying Methods
(MFT-C, TLD/AFD)
Higher Cost
Land Intensive

Lower Cost
Less Land
Intensive
(In-Pit ADW, TT, CT)

Rapid strength attained using large area at high $cost
Oil sands fines ≈15-25% of mineral

Fluid fine tailings segregate during deposition

MFT at 30% solids requires a 50% reduction in water content to reach soft tailings boundary.
TT Consolidation

Deposit Height (m)

Total Solids Content (%)

Year 1
Deposit Completed

Year 5

Year 10

Year 15
Capping Completed

Year 22

Year 30

Year 85

Shell Cell 1 Parameters
13% clay 0.8 SFR

Deposition at 2.9 t/m²
(1.61 t/m² fines)
Deposit Consolidation Behaviour

Solids Content with Time

Strength with Time

Pore Pressure Dissipation
Deposit Settlement and Density Increase with Time (75m deposit – 50% Clay)
Deep Fines-Dominated Deposit

In-Pit Fines Deposit

Final Pit Wall

In-Pit Dyke

Base of Ore

Active Mine Area

(Future in-pit deposit and/or pit lake)
Containment Barrier

Consider 2-3% gradient as screening guidance through \textit{in situ} material. Still requires site-specific assessment.
Water Quality Approaches

• Densify FFT before water capping
  – Slow consolidation = low upward seepage

• Surface desiccation
  – Eliminate fines re-entrainment
  – Requires out-of-pit water storage pending transfer

• Salt reduction
  – Dilution through controlled discharge
  – Augmented inflow
In-Pit Water Capped Sequestration

- Drainage in through wetland
- Water cap lake
- Undisturbed *in situ* land
- No Strength Requirement
- Sand tailings
- Fine tailings
- Drainage out through wetland
- Water Quality Requirement
In-Pit Sequestration Below Grade

Emergent surface water body will appear over the deep zone of a high-clay deposit.

Drainage in through wetland

Undisturbed in situ land

Sand & soil cap

Fine tailings

Sand tailings

Drainage out through wetland
Water Cap
Deposit Capping

A solid cap may be applied to a deposit to:

• Add a surcharge load to enhance consolidation
• Provide a foundation for application of surface materials and vegetative plantings
• To provide a robust barrier at the base of a water cap to prevent fines upwelling during thermal lake turnovers.
Capping Methods

Conventional Methods

• Sand spray (from a floating barge)
• Surface desiccation
• Frozen surface access
• Hydraulic sand placement
• Mechanical spreading (of sand or overburden)
• Wick drains

Developmental Methods

• Coke capping
• Sodium silicate (e.g., Particlear®)
• Electrokinetic dewatering
# Failure Modes

<table>
<thead>
<tr>
<th>FAILURE MODE</th>
<th>BEARING CAPACITY</th>
<th>EDGE STABILITY</th>
</tr>
</thead>
<tbody>
<tr>
<td>PUNCHING/</td>
<td></td>
<td></td>
</tr>
<tr>
<td>SHEARING</td>
<td></td>
<td></td>
</tr>
<tr>
<td>BENDING/</td>
<td></td>
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<tr>
<td>SQUEEZING</td>
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</tr>
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Particlear®-Treated Fines
- Strength Increase with Dewatering
Electro-kinetic Dewatering

Long electrodes: 80% of the field is uniform and parallel.

Cross-sectional View

Cathodes sink with mudline

Neutral buoyancy cathodes floating on mudline

Sinking tethered anodes

Commercial Deployment
Summary
Mine Closure Essentials

Sustainable Settlement

In-Pit Fines Deposit

In-Pit Dyke

Water Quality

Extensive / natural barrier (no dam)

Robust drainage outlet

Suitably situated in the closure landscape & surface hydrology for a sustainable surface water feature
Summary

• Future surface mining will see high-fines ore bodies

• In-pit, fines-dominated deposits will be common in closure landscapes – Geotechnical security, small footprint
Summary

High clay content deposits minimize disposal volume and final deposit volumes

- Clay-rich deep deposits will settle for centuries

- Upland design for such deposits is very challenging
  - Capping, long-term care, elevation amendment, drainage control may go on for many decades or more
Summary

Deep Clay-rich deposits are suited to open water surfaces

- Deposit surface treatment for prevention of fines upwelling – no load bearing
- Methods are available for terrestrial wetland surface reclamation
  - More costly & technically challenging
  - Emergent lake may appear after settlement of deep deposit sections
Summary

Deep In-Pit Deposits

• Geotechnical security
  – no dam at closure
• Small footprint
• Adequate inflow drainage area (5:1 → 10:1?)
  – Early closure planning
  – Position deposits for adequate inflow
Collect and use clay data in planning
Extra Slides
## Plan Constraints & Drivers

<table>
<thead>
<tr>
<th>Deposit Types</th>
<th>In-Pit</th>
<th>External</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin-Layered Fines-Dominated Deposits</td>
<td>?</td>
<td>*</td>
</tr>
<tr>
<td>Deep Fines Dominated Deposits</td>
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<td>?</td>
</tr>
<tr>
<td>Fines Enriched Sand and Sandy Fines Deposits</td>
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<td>Water Capped Deposits</td>
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**In-Pit vs External Deposition**

**Regulatory:**
- Closure Plan commitments
- MFT D-85 inventory limits

**Physical**
- Ore body geometry
- Lease boundary
- Waterways
- Foundation geology

**Mine Planning**
- Infrastructure locations
- Waste and Ore quantities
- Ore and waste release schedule
- Ore body **clay** content
SUB-AERIAL PIPELINE DISCHARGE
CT prototype
Water In Tailings
Fluid Volume

Example Case Basis:
- Mine capacity 123 M t/y
- 23.6% Fines
- 68% beach fines capture
- FFT centrifuge capacity added in years 7 & 12

- Condition 1 FFT: Water Released for Re-Use or Discharge
- Condition 2 FFT: Deposition of Centrifuge Cake
- FFT that has Progressed to Solid
- Continuing Consolidation
- FFT Produced (without treatment)
Coke Cap Bearing Capacity

Ultimate Bearing Capacity, kPa

B/H (Bearing Area/ Cap Thickness)

Coke over CT
Coke over MFT
Design for capping

• Density & strength
• Normal terrestrial reclamation
• Water capping
• Hydraulic sand capping
  – Raining in
  – Beaching
• Floating cap
• Soft ground capping
Summary

• Deep in-pit fines-dominated deposits will be a common feature of mine closure landscapes
  – Geotechnical security, small footprint
• Long-term settlement/surface subsidence
  – Favours wetland or water-feature surface
  – Surface hydrology is key to landform design
• Capping methods available reclaim deposits
• Desiccation or frozen surface
  – Provides a useful low-cost starting point
• Engineering tools are available
  – To complete capping and closure
Summary

• Future surface mining will see deposits with higher fines content
  – FFT management and closure plans must account
• FFT clay content is the dominant volume generator
  – Efficient volume storage = high clay content (≥70%) MFT
• Much of the FFT will need to be sequestered in deep deposits
  – Small area footprint, energy-efficient, cost-effective
  – In-pit deposits used for geotechnical integrity – decommission dams
• Centuries of settlement times for such deposits
  – Upland design for such deposits is very demanding
    - capping, long-term care, amendment of elevations and drainage may go on for decades or more
• Water capping most straight-forward for very deep deposits
  – Surface desiccation could rapidly stabilize the surface water
  – Off-deposit water storage needed during drying/freeze-thaw activity
• Wetland surface may make sense in some situations
  – Requires more robust capping strategy
  – Emergent lake for deeper part of deposit
Managed Drainage Outlet Placeholder

• Slide to come from Richard