Delft3D modeling of Sand Placement on an Oil Sands Treated Tailings Deposit

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Outline

- Introduction and background
- Overview
- Modeling
  - Modeling approach
  - Assumptions
  - Results
- Summary
- Recommendations & path forward
Introduction and Background

- Centrifuge product is produced at Jackpine Mine (JPM) as part of Canadian Natural’s effort to reduce fluid fine tailings (FFT) inventory
- The centrifuge product has an average solids content of 45%, produced from fluid tailings (about 25% solids) dredged from a tailings pond at JPM
- The centrifuge product is currently being deposited at JPM DDA1
- Annual tailings investigations have been conducted since the start of operations in 2013 at JPM DDA1
Introduction and Background

- Understanding the feasibility of capping the centrifuge deposit at JPM DDA1 is a step towards reclamation activities and closure.

- The main goal of JPM DDA1 capping is to:
  - enhance consolidation (additional load, manage release water)
  - improve long and short term trafficability (access for additional capping, drain installation etc).

- To support the onset of reclamation activities for the DDA 1 centrifuge deposit, hydraulic sand placement was attempted to either:
  - cap the centrifuged FFT deposit or
  - potentially mix with the centrifuge deposit to allow future hydraulic sand cap placement.
Overview: Before 2016 Field Trial

- North Western corner of JPM DDA1 was identified as a good candidate to attempt hydraulic sand placement.

- Centrifuged deposit properties:
  - solids content = 40 – 50%
  - fines content > 90%

- Sampling and Testing:
  - pre-trial sampling and testing holes were available in this area.
Overview: After 2016 Field Trial

- Coarse sand tailings (CST) discharge:
  - Flow of: 7,700 m$^3$/hr.
  - Duration of: ~7 hours
  - End of pipe energy dissipation device

- Field observations:
  - flow tended towards western wall
  - majority of sand ‘plunged’ rapidly

- Sampling and Testing:
  - post trial sampling in area of CST deposit/mixing
Overview: Post-trial Field Observations

General trends:

- **CST beach:**
  - low fines, high solids

- **Mixed:**
  - variable fines, solids

- **Centrifuged FFT deposit:**
  - high fines, intermediate solids

- Solids decrease away from source
- Fines increase away from source
Conventional modeling tools were considered not appropriate:

- Newtonian flow: sand transport proportional to velocity/turbulence
- Non-Newtonian flow: sand settling proportional to velocity/turbulence

conventional modeling approaches were considered not suited for tailings slurries

Delft3D-slurry flow model

- Research version of Delft3D software that incorporates non-Newtonian flow behaviour including segregation behaviour was used. This is:
  - a physics-based numerical model of hydrodynamic and sediment behaviour
  - designed for flows with finite/variable yield stress

a secondary-level objective: would this modeled behavior compare well to observed results?
Modeling: Important Assumptions

- Delft3D-slurry software is still under development. Main assumptions to note for the present study are:
  - two-dimensional simulations (vertical, longitudinal)
  - no CST beach formation
  - post-depositional processes are not simulated (consolidation, dewatering)
  - centrifuged FFT deposit & CST properties constant in space and time

- Model is not capable of exact reproduction of field observations
- Intended as general tool to investigate CST mixing phenomena
### Modeling: Selected Simulations

<table>
<thead>
<tr>
<th>Simulation</th>
<th>Description</th>
<th>CST bulk density [kg/m³]</th>
<th>CST solids content [%]</th>
<th>Centrifuge bulk density [kg/m³]</th>
<th>Centrifuge solids content [%]</th>
<th>Centrifuge Yield Stress (τy) [kPa]</th>
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*Particle density = 1800 kg/m³

- **Constants:**
  - geometry (based on field x-section & 2015 field sampling)
  - CST discharge (7,700 m³/h) & trial duration (7 hours)
‘Wedge’ shaped mixing geometry:
- higher sand concentration near CST source

Centrifuge deposit yield stress controls sand distribution
- with weaker centrifuged deposit:
  • sand mixes for a farther distance
  • sand mixing zone is thinner
SFR illuminates some differences better than “sand content”

Sand concentration lower with weaker centrifuge deposit
- finite sand volume in 7 h trial
- with weaker centrifuge deposit, SFR < 1.1
- with stronger centrifuge deposit, SFR ~ 1.3
Modeling: Results of Reduced CST Sand Concentration

- Lower CST bulk density $\rightarrow$ smaller wedge
  - smaller total volume of sand delivered in 7 hours
  - smaller density contrast between CST and centrifuge deposit
    - shorter sand mixing distance
    - thicker sand mixing zone
Modeling: Comparison with Field Observations

Baseline sand simulations show wedge-shaped mixing region. Simulation SFR too low. Simulations overpredict runout (2D vs. 3D; CST conc. too high?)
3 capping scenarios:

- equal CST/centrifuge deposit bulk density
  - mixing throughout deposit column
- CST bulk density < centrifuge deposit bulk density
  - cap-like behaviour—mixing depth depends on relative density
  - centrifuged deposit solids content > 65%
- reduced density CST particles
  - similar solids content, lighter particles (eg. coke)

*bulk density contrast is the primary driver*
Summary

- Preliminary results suggest modeling interactions of CST/centrifuge deposit is possible
  - qualitatively similar depositional patterns & mixing magnitudes
  - certain important processes for refinement need to be included in future modeling such as:
    - beach formation, water release/densification/consolidation, three dimensions

- Sand/centrifuged deposit mixing controlled by CST density and centrifuge deposit properties
  - weaker/less dense centrifuged FFT deposit → more extensive mixing & wider sand distribution
  - denser CST → concentration of sand towards bottom of pond

- Capping may be considered under these conditions:
  - centrifuged FFT deposit solids content > 65% – assuming CST remains unchanged
  - capping may be possible with less dense CST (solids content or granular density)

  Considerations such as CST thickness limitations or how far such a cap may extend were not explored
Recommendations & Path Forward

- Modeling approach could be used to optimize mixing and/or capping
  - requires better characterization of both CST and centrifuge deposit
    - is CST density at shoreline same as in the pipe?
    - should centrifuge deposit spatial variability be included?
    - are there constraints on sand cap deployment approach?

- Additional validation of model performance needed
  - laboratory work would be valuable
    - what is the role of densification/dewatering during mixing?
    - how is mixing controlled by CST & centrifuge deposit density?

- Model development needed
  - important processes such as beach formation & post-depositional dewatering
Thank you for listening

- Acknowledgements:
  - Scott Martens, Adam Thompson and Karsten Rudolph, Canadian Natural;
  - Arno Talmon and Bas van Maren, Deltares; and
  - Ben Borree, Barr Engineering and Environmental Science Canada Ltd.

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