Outline

• Introduction
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  – Sand Capping Rationale

• Field Trials
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  – 2016 Capping Trial
  – 2017 Winter Capping Trial

• Trial Observations

• Discussion
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Introduction – Canadian Natural Centrifuged Fine Tailings

• Centrifuge Product is placed into Jackpine Mine (JPM) Dedicated Disposal Area 1 (DDA1) as a component of fluid fine tailings management at JPM
  – One component of Canadian Natural’s Tailings Management Plan

• Centrifuge Product is typically:
  – 45% solids content
  – >90% fines

• Centrifuged material is deposited in DDA1 to create a deep deposit

• Centrifuge Deposit is investigated to characterize:
  – Deposit volume
  – Material properties (strength, solids, etc.)
  – Centrifuge Product and Thickened Tailings mix
  – Impact of dyke construction of sand on centrifuge deposit
  – Sand capping feasibility
Introduction – Sand Capping Rationale

• Sand capping goals include:
  1. Enhanced consolidation rates (additional load, release water management)
  2. Provide trafficability (allow access for additional cap placement or drain installation, etc)
  3. Provide a buffer between deposit and reclamation soils
  4. Aid in managing surface water and reclamation ground water
  5. Minimize acid mine or rock drainage by facilitating formation of water-capped deposits or end-pit lakes

• Canadian Natural identified hydraulic and mechanical sand capping as technical gaps to be addressed by operational opportunities:
  – Hydraulic capping of Centrifuge Deposit at JPM DDA1
  – Mechanical capping of Atmospheric Fines Drying (AFD) deep stack, and
  – 5m test cell capping

• Prior to full investigation of these situations, Canadian Natural capitalized on an unplanned overboard event in DDA1
JPM Site Overview

Centrifuge Plant

Centrifuge Deposit

Centrifuge Line 1/2

Centrifuge Line 3/4

Centrifuge Plant

DDA1
Capping Trials Overview

• 2015 Overboard event
  – Unplanned CST discharge onto/into Centrifuge Deposit
  – Post-event sampling indicated densification and strengthening of localized Centrifuge Deposit

• 2016 capping trial
  – CST discharged to NW corner of DDA1
  – significant mixing of CST into Centrifuge Deposit observed
  – mixing led to deposit strengthening

• 2017 winter capping trial
  – similar to 2016, but significantly larger CST volume
  – 0.5 m frozen ice/Centrifuge Deposit layer
  – larger CST volume led to larger-magnitude mixing and ‘localized’ capping of Centrifuge Deposit

<table>
<thead>
<tr>
<th>Event</th>
<th>Duration (hours)</th>
<th>CST Slurry Volume (m³)</th>
<th>Deposition Conditions</th>
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<tbody>
<tr>
<td>2015 Oct. 24</td>
<td>6</td>
<td>45,000</td>
<td>CST overboarding onto centrifuge deposit</td>
</tr>
<tr>
<td>2016 Aug. 24-25</td>
<td>7</td>
<td>54,000</td>
<td>CST multi-port outfall trial onto centrifuge deposit</td>
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<tr>
<td>2017 part I Mar. 21-22</td>
<td>14</td>
<td>107,000</td>
<td>CST spoon outfall trial onto ice-covered centrifuge deposit</td>
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<td>2017 part 2 Mar. 29</td>
<td>5</td>
<td>30,000</td>
<td>CST multi-port outfall trial onto ice-covered centrifuge deposit</td>
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Trial Sampling Overview

• All deposits sampled before and after capping events/trials
  – 2015: 2014 annual survey (pre) compared against 2015 annual survey (post)
  – 2016: 2015 annual survey (pre) compared against targeted post-trial sampling
  – 2017: 2016 survey compared against targeted post-trial sampling
2015 Overboard Event Representative Deposits

- Predominant behaviour: Involved displacement of Centrifuge Deposit by CST
- Key observations
  - Localized capping of Centrifuge Deposit by CST (high solids content, elevated fines content)
  - Localized occurrence of CST over densified Centrifuge Deposit/mixed Centrifuge Deposit/CST
2016 Capping Trial Representative Deposits

- Predominant behaviour: CST plunging and mixing with and displacing Centrifuge Deposit.
- Significant mixing zone above CST beach
  - mixing zone thickest near CST outfall, thinning basinward
  - mixed deposits stronger and denser than unmixed Centrifuge Deposit
- Numerical modeling indicated:
  - mixing patterns related to relative bulk density (CST vs. Centrifuge Deposit)
  - capping might be possible with denser Centrifuge Deposit (>65% solids)
2017 Winter Capping Trial Representative Deposits

• Predominant behaviour: Displacement of Centrifuge Deposit by CST
  – alternate layering of CST with densified/mixed Centrifuge Deposit
  – significantly deeper area in DDA1
  – no observed benefit from frozen layer

• Larger volume of CST (> 2x) led to wider CST distribution in DDA1
  – layering may reflect wider distribution of CST (periodic deposition)

• More widespread occurrence of densified/mixed Centrifuge Deposit
Deposit Comparison

• High-density CST streams generally displace Centrifuge Deposit via plunging and beach formation
  – sand mixing common at boundary between CST beach and Centrifuge Deposit
• Overall deposit geometry reflects local depth, CST volume, and outfall geometry
  – shallower basin → more advancement
  – larger CST volume → larger CST/mixed deposit
• ‘Localised’ capping occurs where local CST delivery is periodic
  – larger CST volume → larger beach → periodic delivery
  – CST/Centrifuge Deposit mixing zones capped by subsequent CST delivery
2017 Complex Capping Behaviour

• Larger CST volume & mixing area leads to more complex mixing/capping
  – alternate CST and quiescence lead to local mixing/strengthening before subsequent CST beach formation
• Resultant deposits show:
  – CST beach-like layers (high solids, low fines)
  – mixed layers (intermediate solids/fines)
  – densified Centrifuge Deposit layers (high fines & solids)
Summary

• No observed conventional ‘capping’ of Centrifuge Deposit with CST (widespread), localized capping did occur in 2017 event.

• ‘Conventional’ capping was not observed due to:
  – CST delivered too rapidly (7,700 tonnes/hr)
  – CST stream too dense (+/- 60%)
  – Centrifuge Deposit bulk density too low (40 – 50 % solids)

• Where CST/Centrifuge Deposit mixing occurred:
  – deposits were stronger and denser (higher solids)
  – mixed deposits often exceeded 10 kPa peak undrained shear strength, if CST sand dominated the mixture

• Mixing zone geometry was potentially related to
  – CST pour duration
  – Centrifuge Deposit initial strength
Summary

• Longer duration pours led to complex capping/mixing geometry
  – alternate layers of densified Centrifuge Deposit, mixed Centrifuge Deposit/CST, and CST beach occurred during longer pours
  – shorter-duration pours led to a simpler wedge-shaped mixing geometry

• Capping of Centrifuge Deposit should be possible via:
  – reduced density CST stream (either particle density, or solids content)
  – stronger Centrifuge Deposit deposit (e.g., dewatered), or
  – more careful, diffused management of CST onto the Centrifuge Deposit surface

• Mixed Centrifuge Deposit/CST deposits could potentially be more easily capped than pure Centrifuge Deposits
  – the 2017 long-duration pour showed that previously mixed deposits were capped by subsequent CST delivery
ACKNOWLEDGEMENTS

• Scott Martens, Canadian Natural
• Karsten Rudolf, Canadian Natural