Selection and Implementation of a Dry Cover System at Whistle Open Pit Mine

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Inco Ltd
Outline

- History/Background
- Description of background studies and modelling
- Selection of closure concept
- Dry cover trials
- Selection of barrier material
- Description of final cover design
- Current Progress

7 Mt of waste rock on surface - 80% is mafic norite, avg. S of 3%

Several acidic seeps developed

Whistle Mine ~60 km NW of Sudbury

Canadian Shield region - numerous bedrock outcrops and lakes
Whistle Mine Waste Rock Study 1997

MEND 1.41.4 – Conclusions

- The NE pile is constructed of very coarse waste rock (2.5% passing 2mm) and has a very high permeability (>10-2 cm/s)

- Porewater has low pH (3.8-4.1) and very high concentrations of sulphate (5,400-18,100mg/L), Al (166-878mg/L), Ni (438-954mg/L)

- Water quality in seepage discharging from the toe of the dump is generally more dilute (e.g. SO₄ 1,800-5,400 mg/L) due to contribution of runoff

- Majority of runoff from the site is surface water with ‘little’ groundwater seepage entering sensitive receiver
SENES Model 1997

**Lime Addition**

- **No Lime Addition**
  - Initial increase in sulphate and metals due to release of stored acidity
  - Neutral pH conditions reached after ~100 years

- **Lime Addition (1 kg/tonne)**
  - Lime addition maintains neutral pH conditions throughout 200 year modeling period
  - No significant improvement using higher lime addition

- **Similar long-term water quality for all three scenarios (0, 1, 2 kg/tonne)**
Closure Concepts

- Minimal options for closure due to proximity of Lake Wanapitei
  - 3 km East of mine
  - WFN
  - Post Creek
- Prominent environmental issues
  - Containment dam failure
- Remote location

Based on available data we decided to: Relocate all waste rock to the open pit and cap with an engineered dry cover
Closure Plan: Specifications and Objectives

- Mitigate environmental issues
  - Primarily associated with WR piles
- Mitigate safety issues
  - Open pit
- Closure plan submitted in 1998

- Engineered cover system will be on 20% slope, covering 9.7 ha
- Objectives of cover system:
  - reduce ingress of atmospheric $O_2$
  - reduce infiltration of meteoric $H_2O$
  - growth medium for vegetation
Whistle Cover Trials 2000 - 2004

Objectives of Study:
- Design/construct a WR platform with a seepage collection system
- Evaluate construction techniques and gain insight into potential QA/QC problems
- Monitor field performance
- Generate data for future modelling
Plot Design Details

TP#1
- N/C till (90 cm)
- GCL (1 cm)

TP#2
- N/C till (90 cm)
- Comp. sand-bentonite (45 cm)

TP#3
- N/C till (90 cm)
- Comp. silt/trace clay (60 cm)

TP#4 (control)

Waste Rock

- Fully instrumented
Cover Trial Conclusions

- Performance monitoring conducted by UWO
  - Runoff and interflow monitoring system
  - Density and permeability testing
  - Formal results forthcoming

- Intermediate Conclusions...
  - Frozen conditions in barrier layer
  - Poor vegetation success
  - Improved construction techniques
INAP Waste Rock Study 2001

- Conclusions
  - Coarse grained
  - Freely drained
  - Oxygen saturated
  - Still contained significant ANC and unoxidized sulphides
  - Greater than 50% water soluble oxidation products
Cover Scenarios evaluated:

- Without cover placement ARD generation in backfilled waste rock (above flood level) will result in poor pit water quality (low pH, high SO4 and metals)
- All three cover scenarios studied will control future ARD generation resulting in neutral pH and gradual decline of SO4 and metals in pit water
- Control of oxygen ingress is more critical than control of net percolation for cover design

<table>
<thead>
<tr>
<th>Cover Material</th>
<th>Cover Scenario</th>
<th>Volumetric Water Content</th>
<th>Porosity</th>
<th>Diffusion Coefficient (m²/s)</th>
<th>Net Percolation (% of precip.)**</th>
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<td>30cm sand/silt</td>
<td>1</td>
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<td>0.36</td>
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<td>45cm sand/bentonite</td>
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<td>0.38</td>
<td>0.40</td>
<td>2.60E-09</td>
<td>5</td>
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</tbody>
</table>
Selection of Barrier Layer Material

Preliminary Construction Cost Estimates

1) **GCL barrier cover** – $3.3M
   - Most economical
   - Poor oxygen diffusion barrier

2) **Silt/trace clay barrier (60 cm thick) cover** – $3.5M
   - Borrow source 40 km from site
   - Good oxygen diffusion barrier

3) **Sand-bentonite barrier (45 cm thick) cover** – $5.3M
   - Bentonite borrow source in Wyoming or Montana
   - Good oxygen diffusion barrier
Copper Cliff Clay

- Excavated & stockpiled as part of historic earthworks at Inco’s Copper Cliff operations
- Readily available

Key physical/hydraulic attributes:
- Inorganic clay of low to medium plasticity
- 25% clay-size particles
- Ksat ~ 5 x 10^-8 cm/sec
Original Landform Design

- Lateral berms used to direct runoff to drainage channels

- 100 Years Later…
  - Significant gully/rill erosion
  - Interrill erosion
  - Design change required
Preferred Final Landform Design
100 Years Later…
Important Construction Details
Cover Performance Monitoring System

- Primary in situ cover monitoring:
  - Automated
  - Net percolation
  - Suction / water content
  - Temperature

- Secondary in situ cover monitoring (portable moisture probe & O2 / CO2 gas analyzer)
- Groundwater monitoring wells
- Surface runoff (automated weirs)
- Meteorological monitoring
Growth Medium Layer/Revegetation
Where Are We Today?

- Wet summer forced delays
- Upper half of the cover has been completed
- Approx. half of the instrumentation was commissioned:
  - 8 of 13 secondary *in situ* monitoring sites
  - 1 of 2 lysimeters
  - Weather station installed
Thank You
Preferred Pit Cover System Design

- Non-compacted sandy-gravel till
  - 4 ft minimum on slope, with 3” of topsoil admixed to the near surface material
  - 2 ft minimum in the ponds

- Compacted Copper Cliff clay
  - 1.5 ft minimum on slope
  - 2 ft minimum in the ponds

- Non-compacted sandy-gravel till (~ 4” thick)
  - Overlaid with HDPE geotextile
Long Term Sustainable Performance

- Erosion control measures
- Revegetation plan
- Growth medium layer
  - Competent material
  - Thickness
- Barrier layer
- Geotextile
- Performance monitoring system
Cost Summary
Construction Details

- Test plot area was lined to direct runoff to a collection pond
- Each plot was instrumented to collect pertinent data
Waste Rock: Sample Results

Sulphur Content

- Range ⇒ 0.03 to 9.17%S.
- Average ⇒ 2%S.

Acid Neutralizing Capacity:

- Range ⇒ 0 and 56 kgH$_2$SO$_4$/t.
- Average ANC ⇒ 20 kgH$_2$SO$_4$/t.
Particle Size - Whistle

Dominance of cobble to boulder sized particles
Without cover placement ARD generation in backfilled waste rock will result in poor pit water quality.

All three cover scenarios studied will control future ARD generation resulting in neutral pH and gradual decline of SO4 and metals in pit water.

Control of oxygen ingress is more critical than control of net percolation for cover design.
Cover Trial Conclusion

- Instrumented with the following equipment:
  - Lysimeters
  - O₂/CO₂ gas measurement system
  - soil suction and temperature sensors
  - volumetric water content sensors
  - surface runoff / interflow collection and monitoring system
  - meteorological station
SENES Modelling

Objective:
- Evaluate benefit of lime addition during waste rock relocation