Closure Planning and Implementation at Vale Inco’s Whistle Mine

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MEND MANITOBA WORKSHOP
Challenges in Acidic Drainage for Operating, Closed or Abandoned Mines
Winnipeg, MB – June 4-5, 2008
Presentation Outline

- Background
- Cover System Design Approach
- Cover Modelling
- Landform Evolution Modelling
- Sustainability of the Cover and Landform
- Key Construction Activities
- Performance Monitoring
Background

- ~60 km from Sudbury, ON
- Canadian Shield – numerous bedrock outcrops and lakes
- Open pit mining (nickel) between 1988-91 & 1994-98
- 6.4 Mt of waste rock on surface – 80% is mafic norite, avg. S of 3%
- Several acidic seeps developed
- Semi-humid climate – annual precip. of 900 mm (30% as snow) & PE of 520 mm
Background (cont’)

1.4 L/s
Not feasible to reclaim WRDs in-place

Based on available data, Inco decided to **relocate all waste rock to open pit** (with lime addition @ 2kg/tonne) and place a cover system

- Pit surface area – 10 ha

**Objectives of cover system:**
- reduce ingress of atmospheric \( \text{O}_2 \)
- reduce infiltration of meteoric \( \text{H}_2\text{O} \)
- growth medium for vegetation
Cover System Design Approach

Cover System Field Trials

Geochemical Modelling

Selection of Barrier Layer Material

Soil-Atmosphere Cover Design Modelling

Erosion and Landform Evolution Modelling

Slope Stability Analysis

Consideration of Processes Potentially Impacting on Sustainable Performance

Cover Design Criteria!
## Preliminary Cover Design Modelling

<table>
<thead>
<tr>
<th>Barrier Layer Thickness</th>
<th>Growth Medium Layer Thickness</th>
<th>Simulation</th>
<th>Degree of Saturation</th>
</tr>
</thead>
<tbody>
<tr>
<td>30 cm</td>
<td>90 cm</td>
<td>Initial conditions</td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Dry year – run 1</strong></td>
<td>78%</td>
</tr>
<tr>
<td>45 cm</td>
<td>90 cm</td>
<td>Initial conditions</td>
<td>92%</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Dry year – run 1</strong></td>
<td>82%</td>
</tr>
<tr>
<td>60 cm</td>
<td>90 cm</td>
<td>Initial conditions</td>
<td>93%</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Dry year – run 1</strong></td>
<td>85%</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Dry year – run 2</strong></td>
<td>78%</td>
</tr>
<tr>
<td>30 cm</td>
<td>120 cm</td>
<td>Initial conditions</td>
<td>93%</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Dry year – run 1</strong></td>
<td>83%</td>
</tr>
<tr>
<td>45 cm</td>
<td>120 cm</td>
<td>Initial conditions</td>
<td>98%</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Dry year – run 1</strong></td>
<td>94%</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Dry year – run 2</strong></td>
<td>90%</td>
</tr>
<tr>
<td></td>
<td></td>
<td><strong>Dry year – run 3</strong></td>
<td>86%</td>
</tr>
</tbody>
</table>
% Detailed Cover Design Modelling

% Topography
% Required Minimum $O_2$ Diff. Coeff. for Barrier Layer
% Final Barrier Layer $O_2$ Diff. Coeff.
% Initial Barrier Layer $O_2$ Diff. Coeff.

% Oxygen diffusion coefficient (m²/s)
% Distance (m)
% Elevation (m)
**Final Cover System Design**

- **Growth Medium / Protective Layer**
  - Non-compacted sandy-gravel till
  - 120 cm minimum on slope, with 8 cm of topsoil admixed to the near surface material
  - 60 cm minimum in the ponds

- **Barrier Layer**
  - Compacted Copper Cliff clay
  - 45 cm minimum on slope
  - 60 cm minimum in the ponds

- **Levelling Course**
  - Non-compacted sandy-gravel till (~10 cm thick)

- **Waste Rock**
Original Landform Design – Input to the SIBERIA Model
Original Landform Design – Output from the SIBERIA Model (after 100 yrs)

Significant Gully / Rill Development and Interill Erosion
Final Landform Design

WHISTLE MINE PIT COVER
ONE YEAR AFTER CONSTRUCTION
Sustainable Cover Performance

INITIAL PERFORMANCE

Physical Processes
- Erosion
- Slope Instability
- Wet/Dry Cycles
- Freeze/Thaw Cycles
- Consolidation/Settlement
- Extreme Climate Events
- Brush Fires
- Construction

Chemical Processes
- Osmotic Consolidation
- Dispersion/Erosion
- Dissolution/Precipitation
- Acidic Hydrolysis
- Mineralogical Consolidation
- Sorption
- Salinization
- Oxidation

Biological Processes
- Root Penetration
- Burrowing Animals
- Bioturbation
- Human Intervention
- Bacteriological Clogging
- Vegetation Establishment

LONG-TERM PERFORMANCE

(Adapted from INAP, 2003)
Design Elements Addressing Issue of Sustainable Performance

- Erosion control measures
- Revegetation plan
- Growth medium layer
  - Competent material
  - Thickness!
- Barrier layer
- Geotextile
- Performance monitoring system
Key Construction Activities
Key Construction Activities (cont’')
Key Construction Activities (cont’')
Key Construction Activities (cont’)

10/21/2005
Cover Performance Monitoring

- **Primary in situ cover monitoring sites (x 2):**
  - Automated
  - *Net percolation*
  - Suction / water content
  - Temperature
  - O$_2$ / CO$_2$ (manual)

- **Secondary in situ cover monitoring sites (x 13):**
  - Portable soil w/c probe & O$_2$ / CO$_2$ gas analyzer
  - Groundwater monitoring wells
  - Surface runoff (automated weirs)
  - Meteorological monitoring
Water Content Profiles
Measured in 2007

Vol. Water Content (cm³/cm³) at P-01

Vol. Water Content (cm³/cm³) at P-02

Depth from Surface (cm)

Depth from Surface (cm)
Degrees of Saturation for the Pit Cover Barrier Layer

- P-01 top of barrier (n=35%)
- P-01 bottom of barrier (n=31%)
- P-02 top of barrier (n=34%)
- P-02 bottom of barrier (n=34%)
# Pit Cover Water Balance

<table>
<thead>
<tr>
<th></th>
<th>2006 Value (mm)</th>
<th>% of Precip.</th>
<th>2007 Value (mm)</th>
<th>% of Precip.</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precipitation</td>
<td>765</td>
<td>-</td>
<td>584</td>
<td>-</td>
</tr>
<tr>
<td>Runoff &amp; interflow</td>
<td>475</td>
<td>62%</td>
<td>228</td>
<td>39%</td>
</tr>
<tr>
<td>Evapotranspiration</td>
<td>269</td>
<td>35%</td>
<td>332</td>
<td>57%</td>
</tr>
<tr>
<td>Net percolation</td>
<td>21</td>
<td>3%</td>
<td>16</td>
<td>3%</td>
</tr>
<tr>
<td>Change in storage</td>
<td>0</td>
<td>0</td>
<td>9</td>
<td>1%</td>
</tr>
</tbody>
</table>
Soil Temperature Profiles Measured in 2007

**In situ** Temperature (°C) at P-01

**In situ** Temperature (°C) at P-02

Depth from Surface (cm)

Data points for each month are plotted, showing temperature profiles at different depths.
Concluding Remarks

- **Cover design** – based on **site-specific** performance
  - Observations from test cover field trials
  - Geochemical predictions ... limit O₂ ingress most critical!
  - Cover performance on slope ... verified w/ 2-D model

- **Pit cover performing as expected** – **substantial reduction** in O₂ and H₂O ingress since construction
  - Net percolation will decrease as vegetation cover matures

- **Final landform** analogous to a **natural system** ... will aid in the sustainability of the pit cover

- Anticipated that Vale Inco will **walk-away** from site in **next 100 yrs**