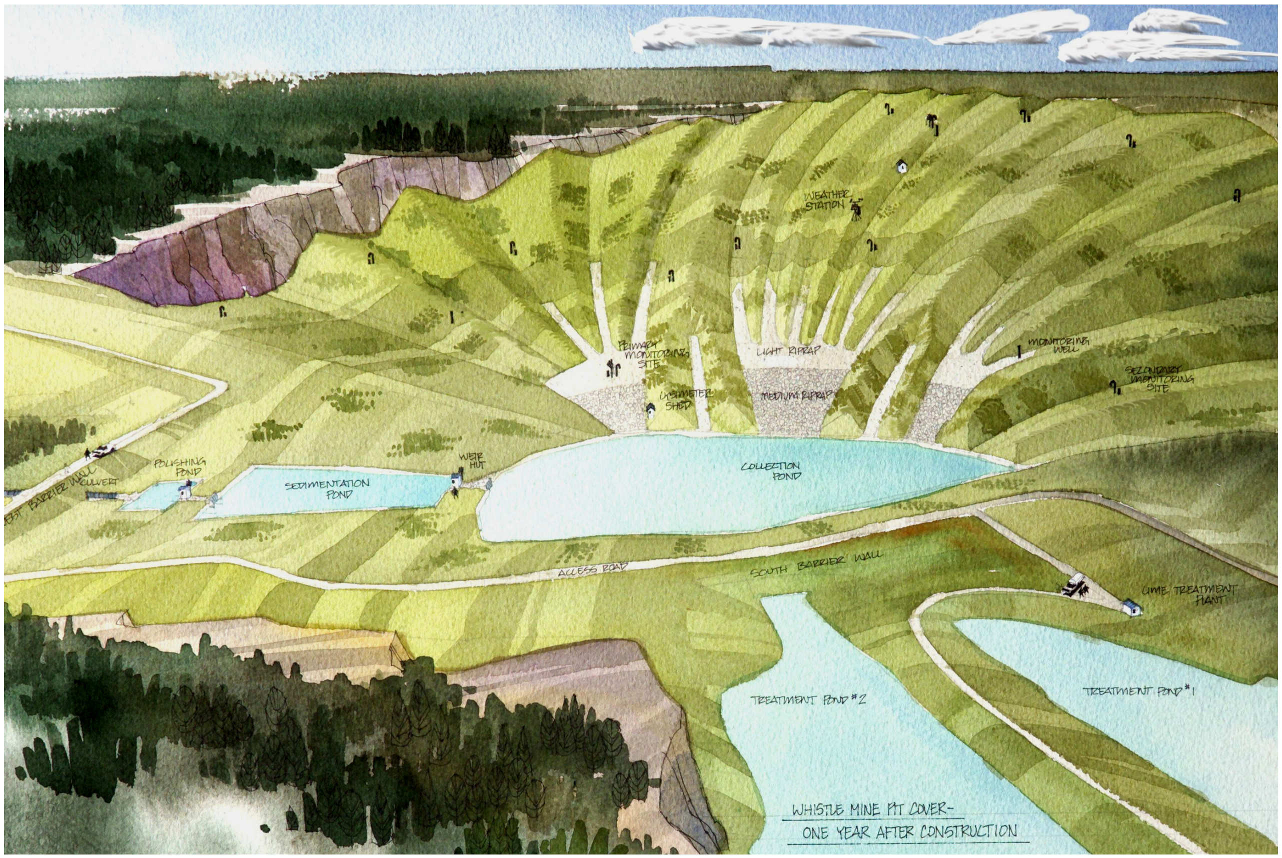
Selection and Implementation of a Dry Cover System at Whistle Open Pit Mine



Quentin Smith and Lisa Lanteigne

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

Background/History

- Whistle Mine ~60 km NW of Sudbury
- Canadian Shield region - numerous bedrock outcrops and lakes

- Open pit mining (nickel) between 1988-1991 and 1994-1998
- 7 Mt of waste rock on surface - 80% is mafic norite, avg. S of 3%
- Several acidic seeps developed

Whistle Mine Waste Rock Study 1997

MEND 1.41.4 – Conclusions

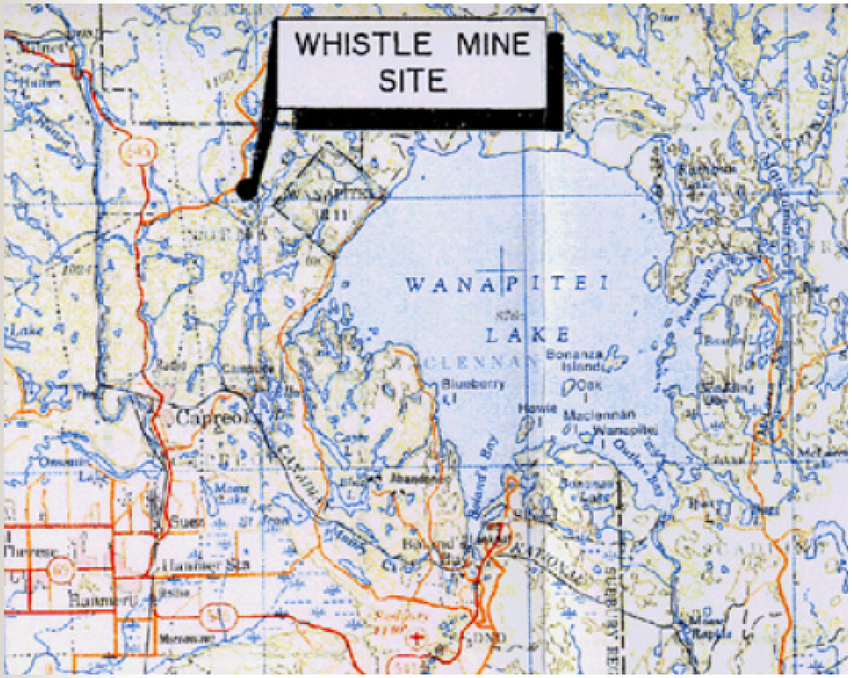
- The NE pile is constructed of very coarse waste rock (2.5% passing 2mm) and has a very high permeability (>10-2 cm/s)
- Porewater has low pH (3.8-4.1) and very high concentrations of sulphate (5,400-18,100mg/L), Al (166-878mg/L), Ni (438-954mg/L)
- Water quality in seepage discharging from the toe of the dump is generally more dilute (e.g. SO_4 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*

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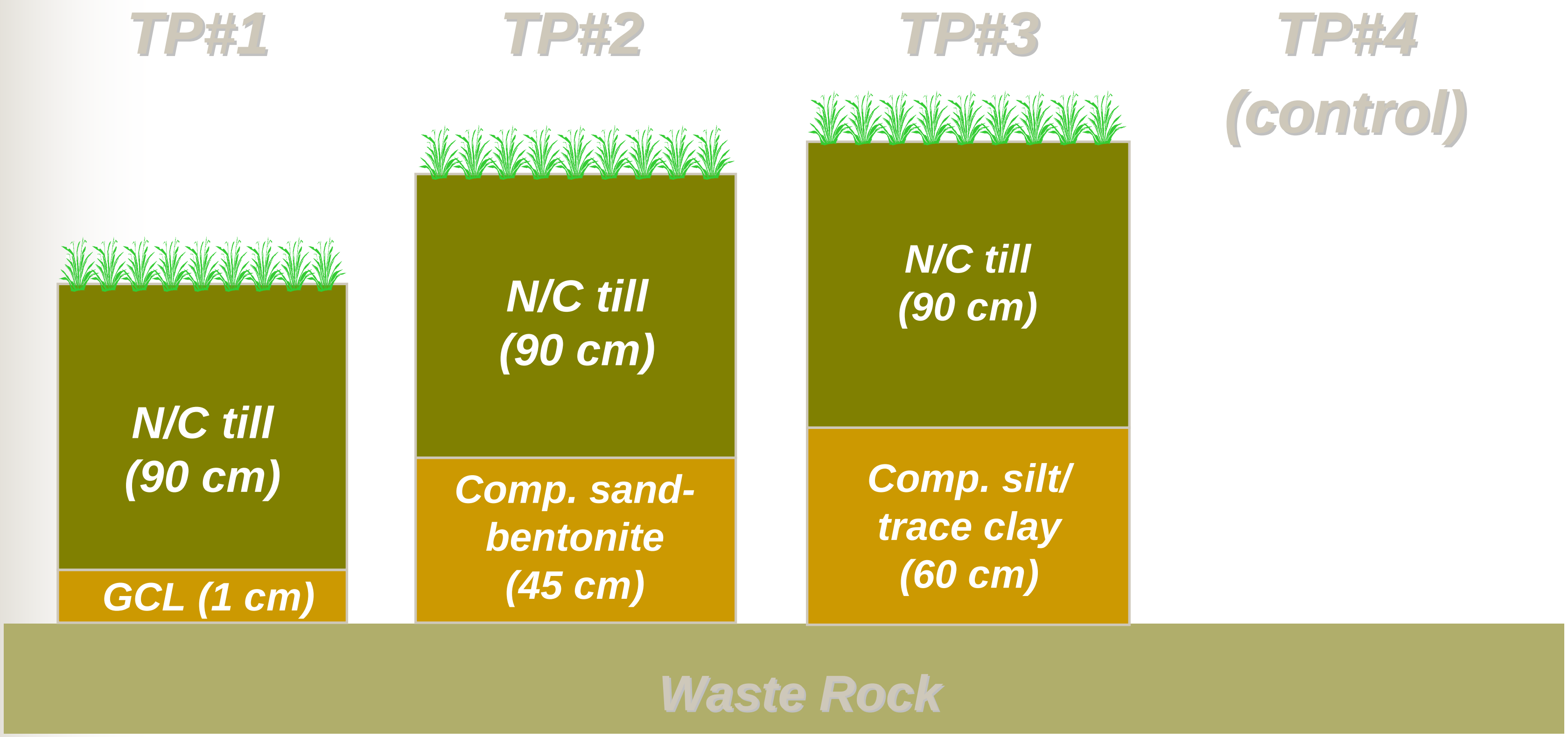
Whistle Cover Trials 2000 - 2004

- 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



- 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

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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

SENES Model 2003

- Cover Scenarios evaluated:

Cover Material	Cover Scenario	Volumetric Water Content	Porosity	Diffusion Coefficient (m^2/s)	Net Percolation (% of precip.)**
30cm sand/silt	1	0.34	0.36	7.47E-09	10
60cm sand/silt	2	0.32	0.36	1.51E-09	1
30cm sand/silt*	3	0.27	0.36	7.37E-08	20
45cm sand/bentonite	4	0.38	0.40	2.60E-09	5

- 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

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

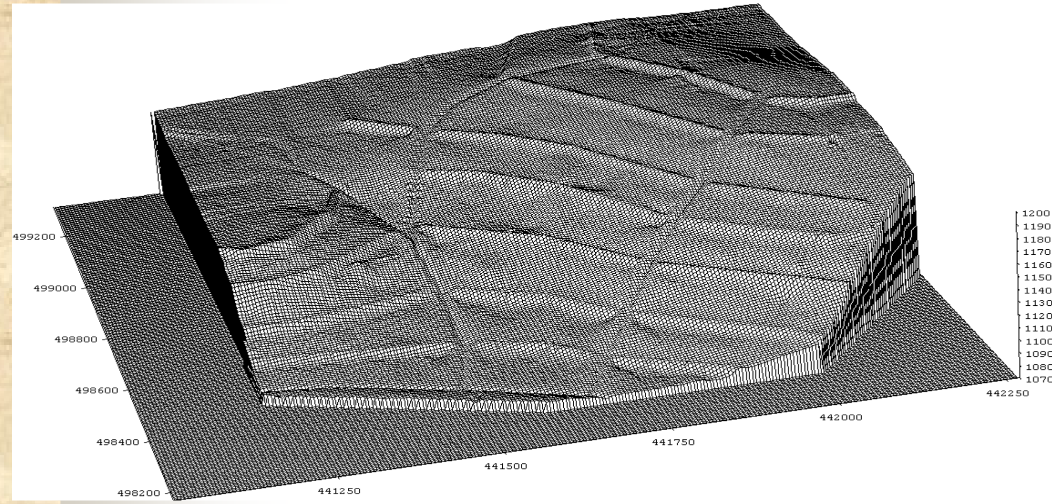
- Bentonite borrow source in Wyoming or Montana
- Good oxygen diffusion barrier

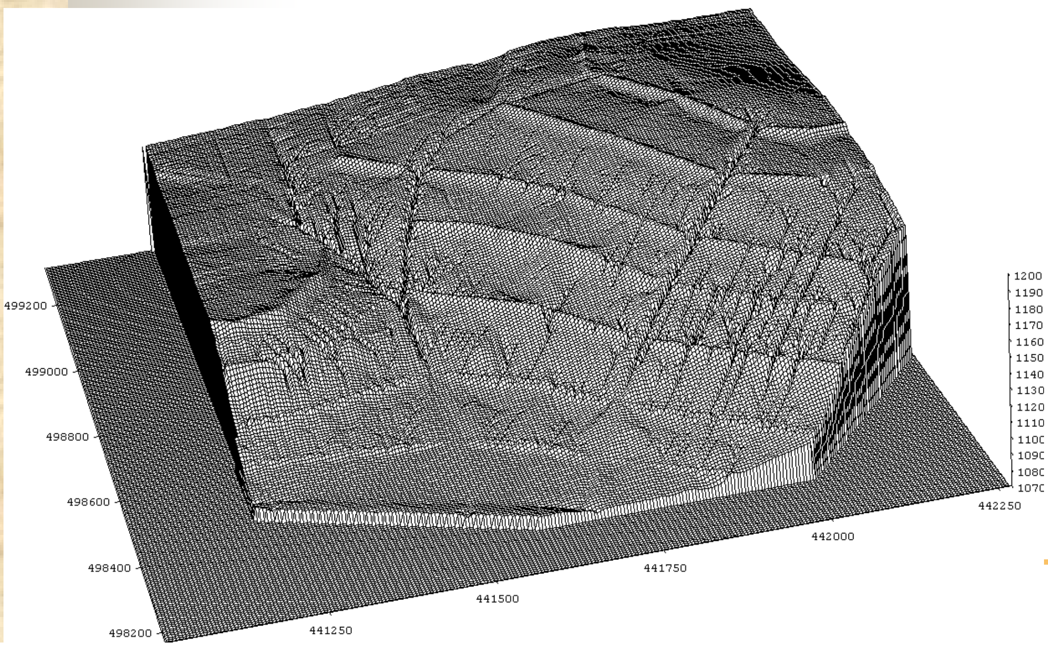
Copper Cliff Clay

- 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

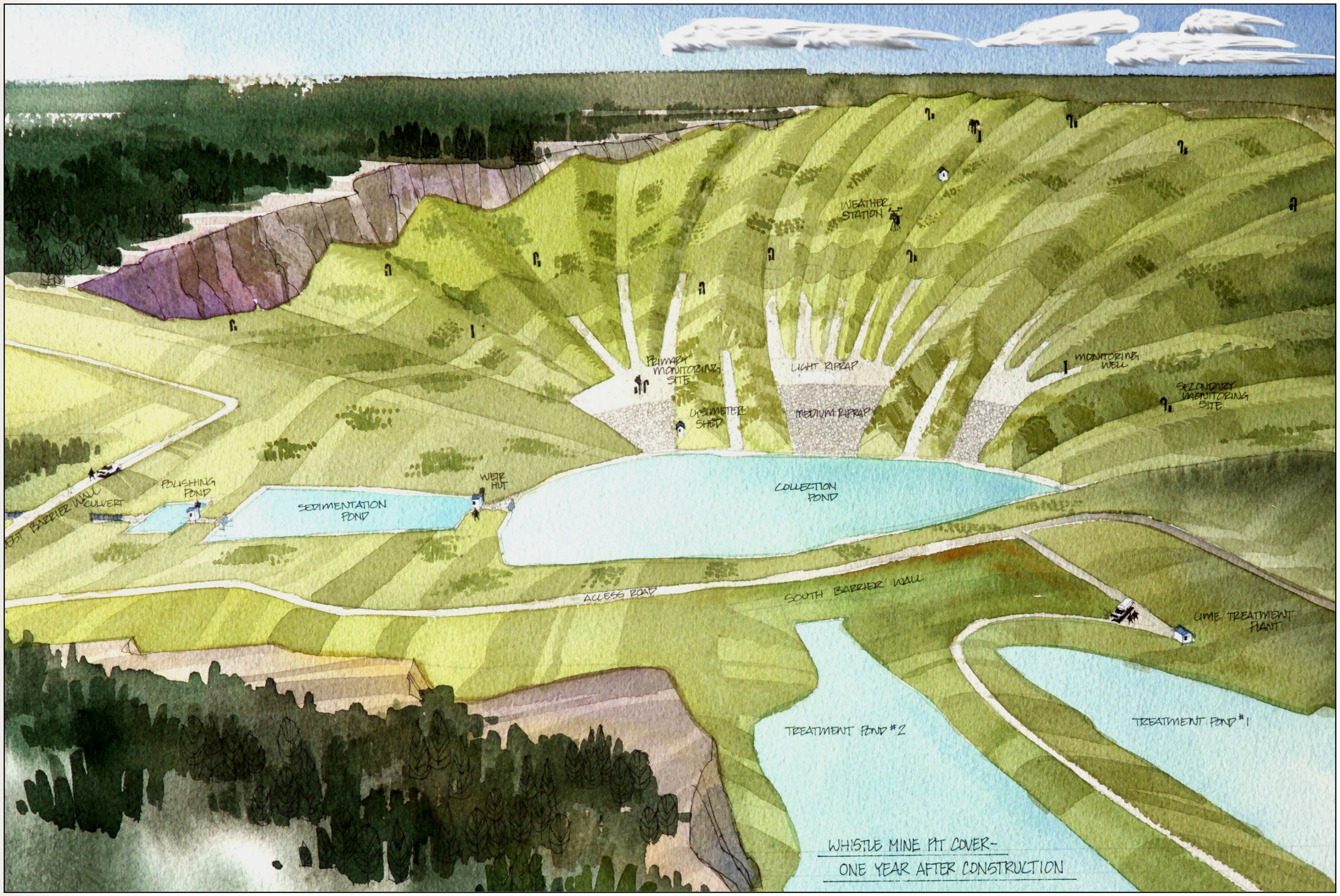




- Lateral berms used to direct runoff to drainage channels

- **100 Years Later…**
  - Significant gully/rill erosion
  - Interrill erosion
  - Design change required

Preferred Final Landform Design



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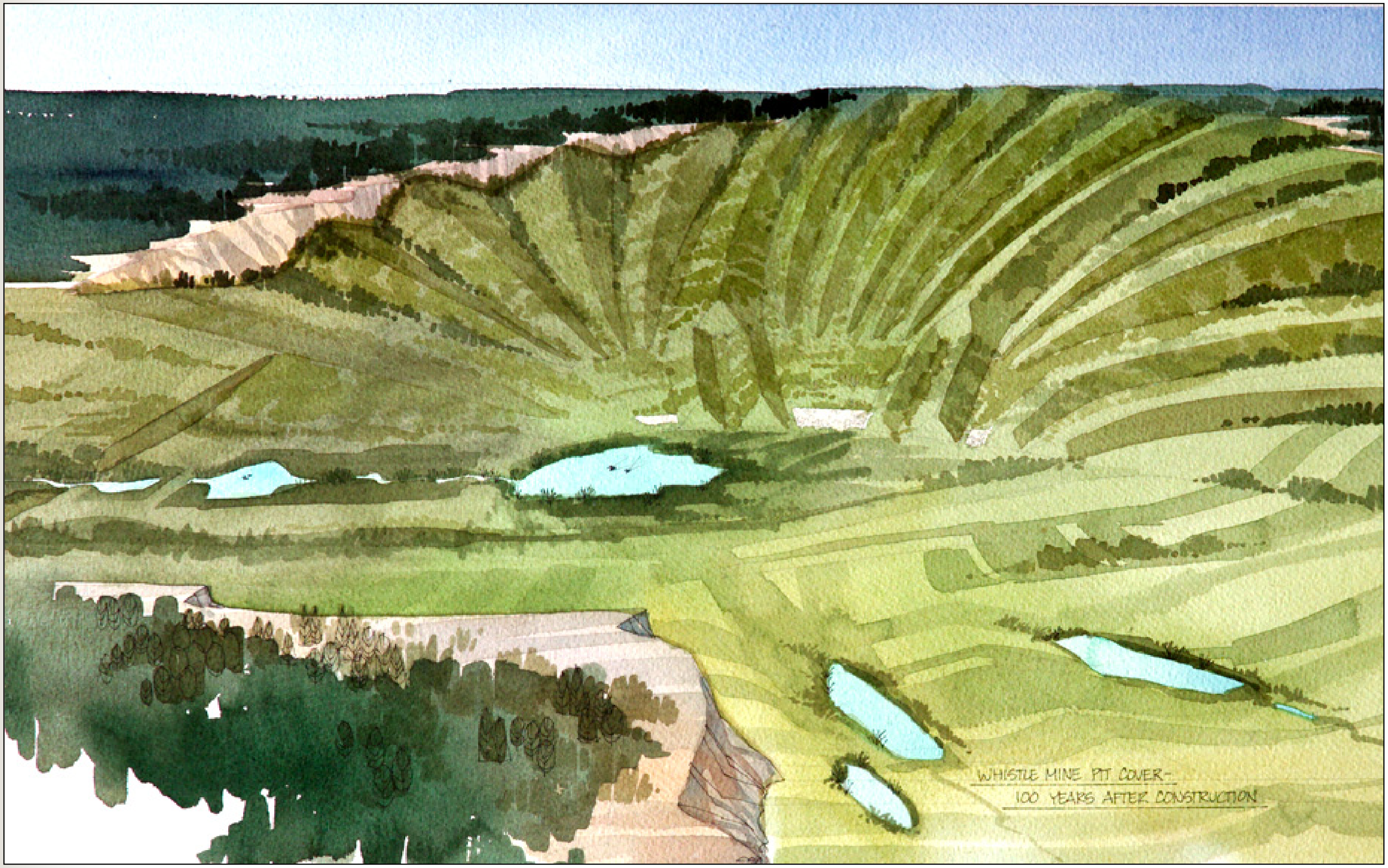
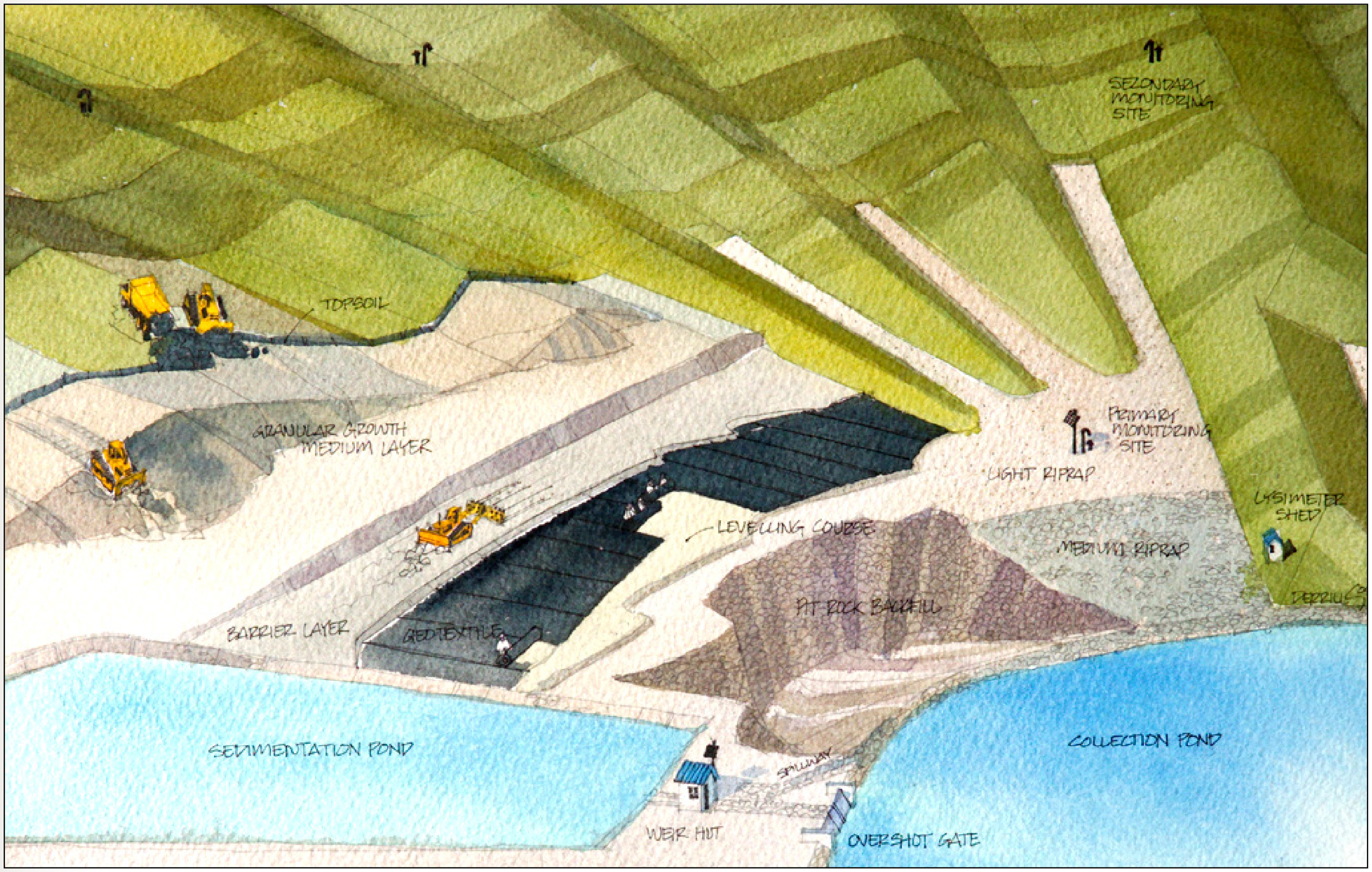
100 Years Later…



Important Construction Details



Cover Performance Monitoring System

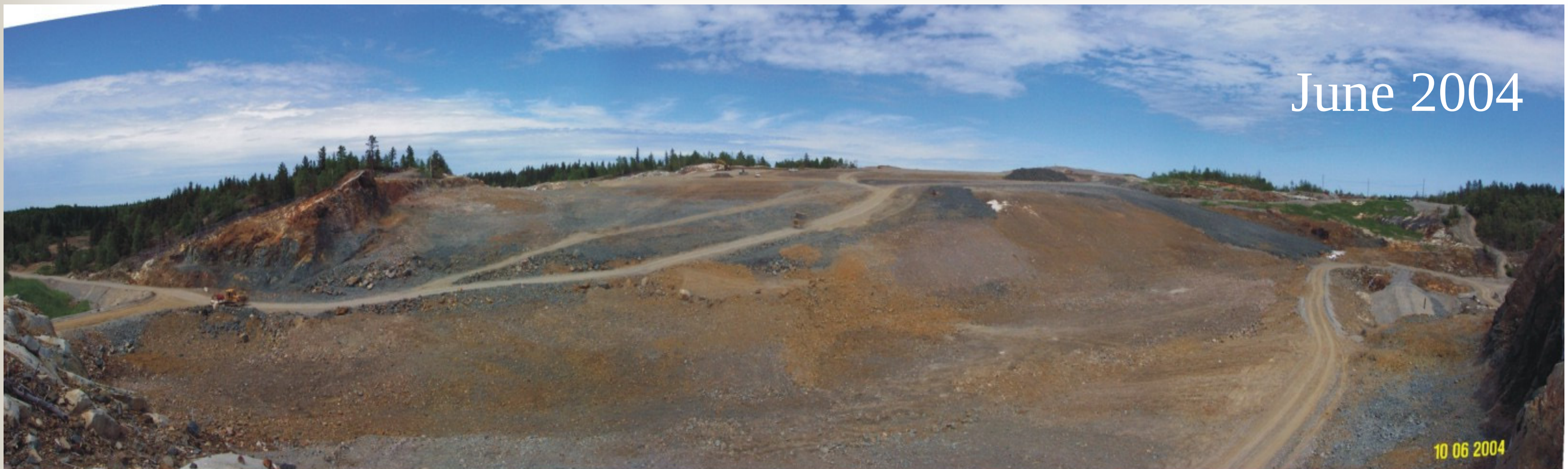
- Primary in situ cover monitoring:
  - Automated
  - Net percolation
  - Suction / water content
  - Temperature
- Secondary in situ cover monitoring (portable moisture probe & O2 / CO2 gas analyzer)
- Groundwater monitoring wells
- Surface runoff (automated weirs)
- Meteorological monitoring

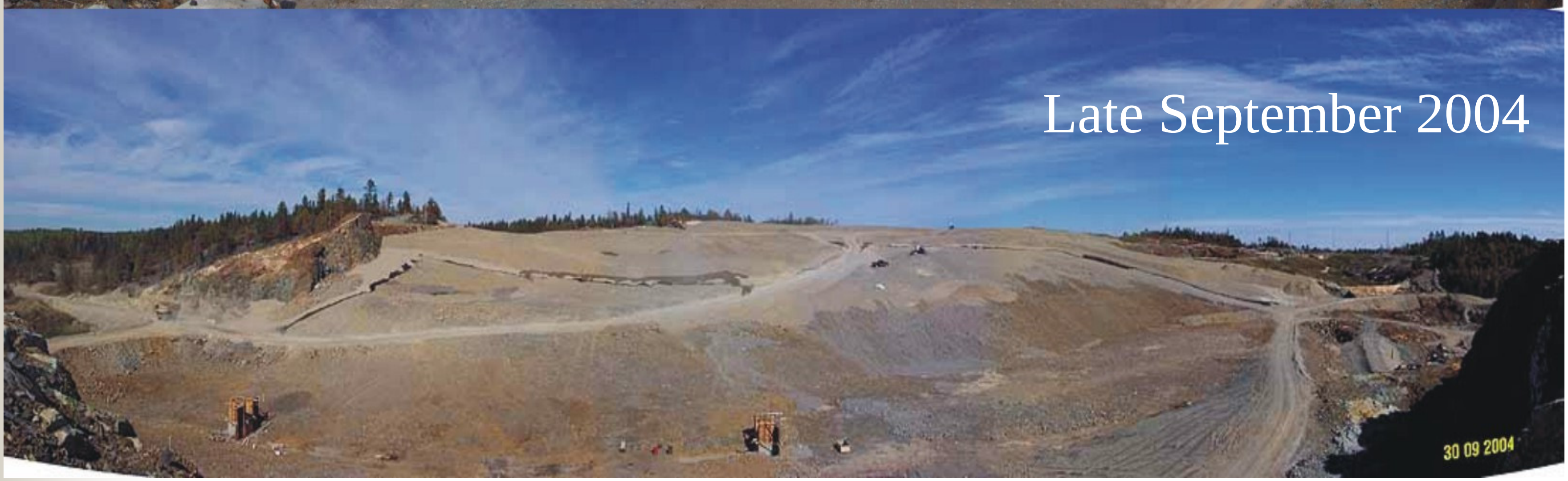
Growth Medium Layer/Revegetation

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


June 2004
10 06 2004


Late September 2004
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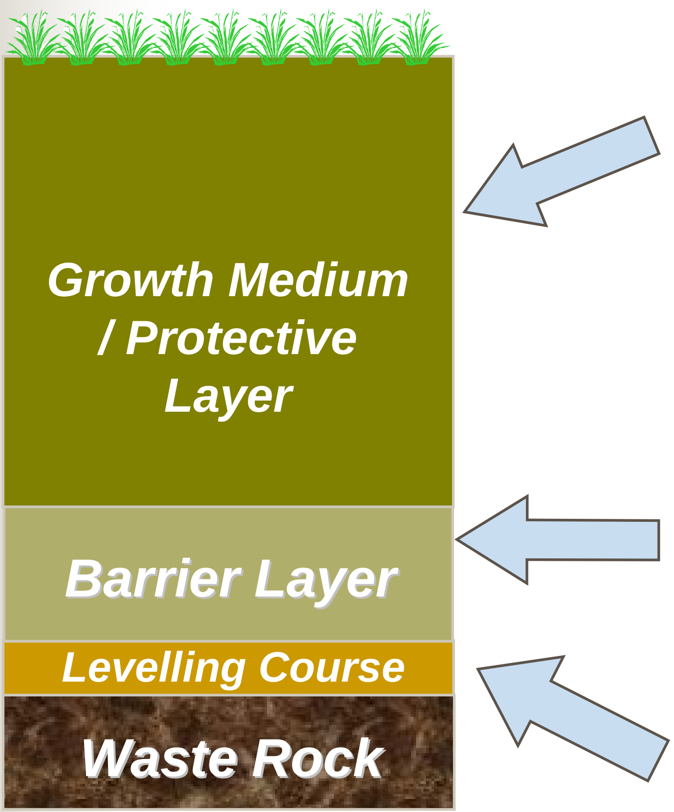
Preferred Pit Cover System Design



- 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_2SO_4/t.

– Average ANC ⇒ 20 kgH_2SO_4/t.

Particle Size - Whistle

Dominance of cobble to boulder sized particles

SENES Model 2003

Summary of Results

- **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 SO_4 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**
  - **O_2/CO_2 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