

So Where is that Treatment Sludge Going in the Waste Rock?

M. Coleman¹, K. E. Butler², E. Mott²,
T. Al³ and K. Phinney⁴


¹ NB Power

²University of New Brunswick, Dept. of Earth Sciences

³University of Ottawa, Dept. of Earth Sciences

⁴Consulting Chemist/ Chemical Engineer



Mine Location



Background

- Mined 1982-1985;
 - ◆ 250 acre site (100 ha).
- AMD since mid-80's.
- Hydrated lime treatment
 - ◆ 4 acre sludge ponds/yr
- Long term solution-sludge disposal into waste rock
- Mining company ceased to exist in 2009
- Parent company- when will the liabilities end?



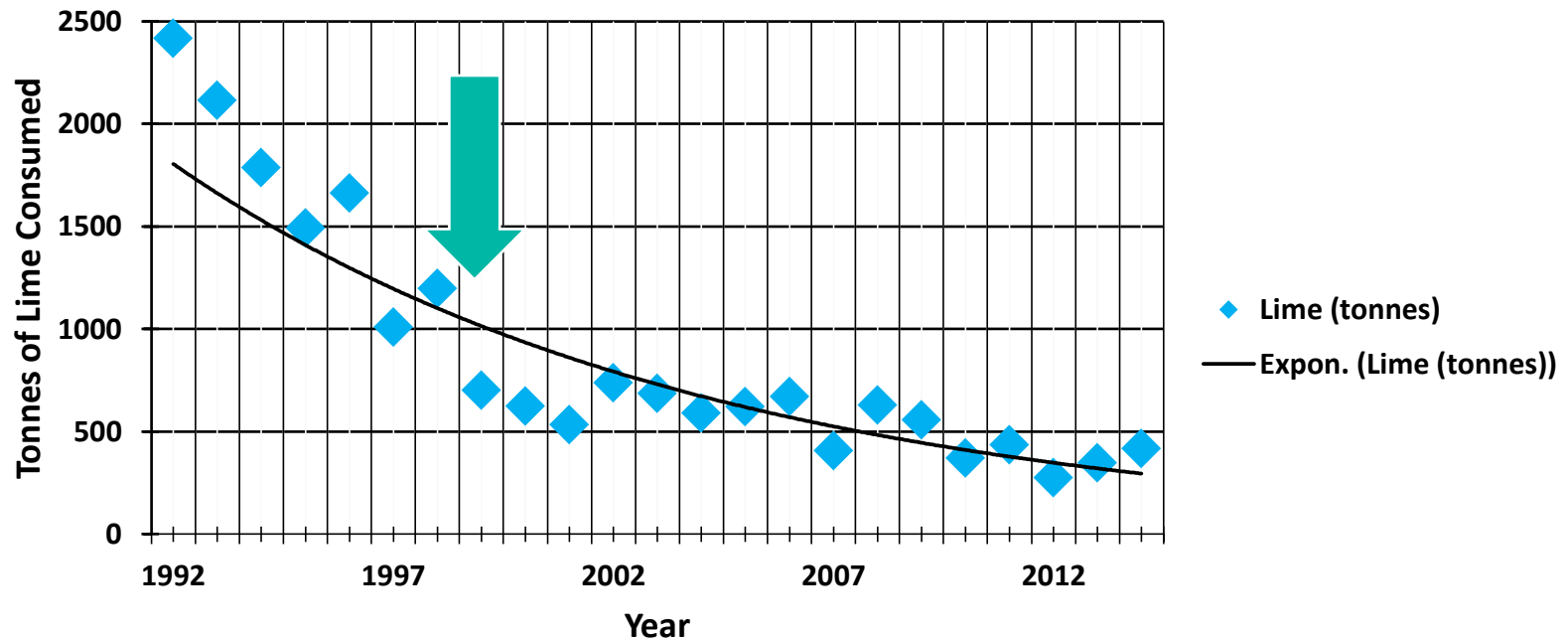
Initial Dredging Rationale

- Disposing of lime neutralization sludge into acid generating rock could provide several benefits including:
 - ◆ utilization of the excess alkalinity
 - ◆ final disposal area for sludge, still dredge cost
 - ◆ reduce diffusion of oxygen into the waste rock
 - ◆ decrease personal liability
 - ◆ minimize land disturbance.



Decreasing Lime Demand in Mine Water Chemistry

Trend in Lime Demand (tonnes)



Geophysical Investigations

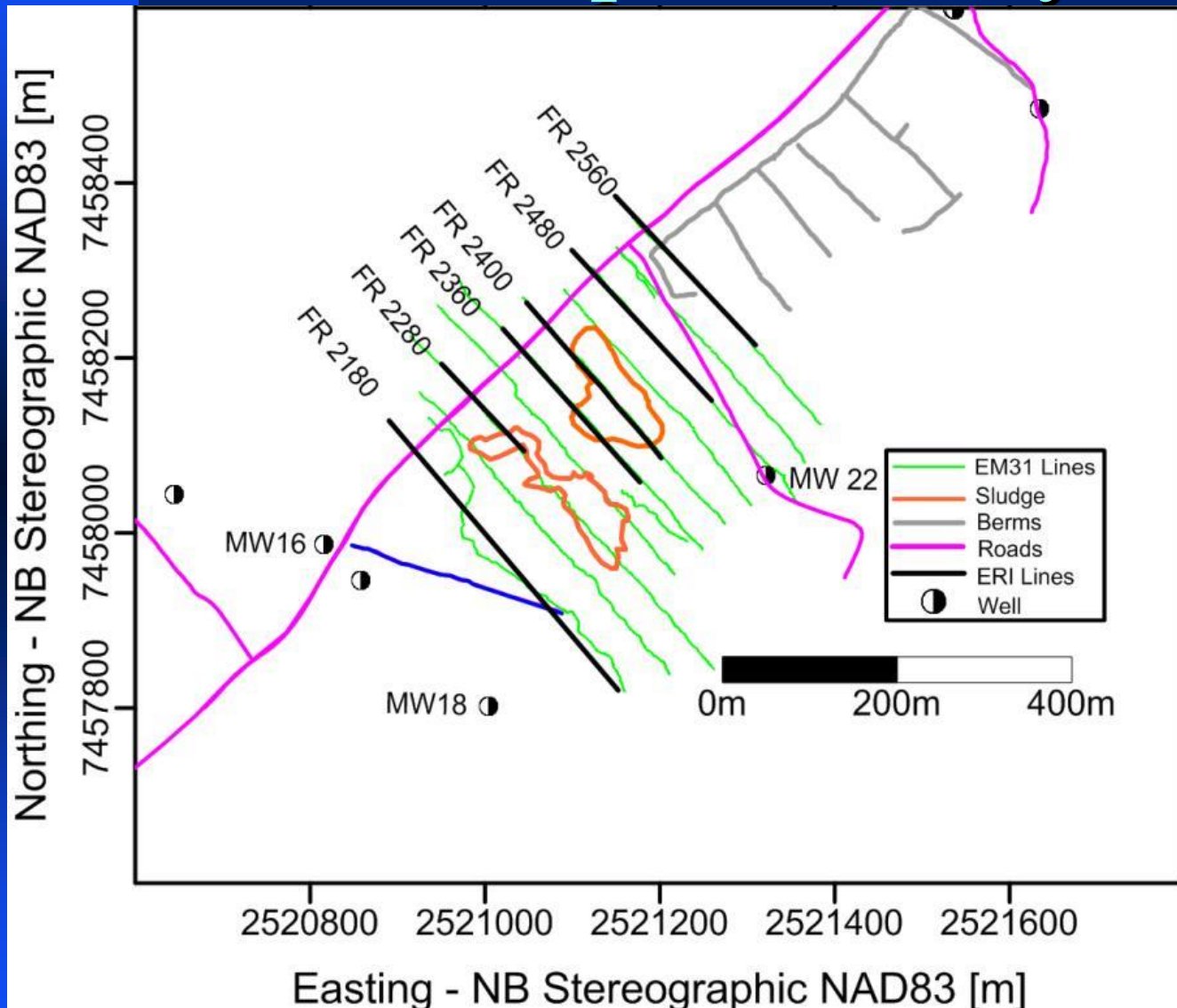
- University of New Brunswick Earth Sciences Department Field Camps, senior projects, graduate students research at the site since 2000
- Electrical resistivity imaging (ERI) and electromagnetic apparent conductivity (EM):
 - ◆ map lateral and vertical variations in AMD and sludge concentration within the mine site
 - ◆ Conductivity is proportional to ion concentration, ion valence, and ion mobility.
 - ◆ AMD, sludge and clays have high electrical conductivity compared to natural ground waters

Objectives

- Are there seasonal variations to the conductivity?
 - ◆ We see the decreases over long periods of time (years) but
 - ◆ Investigations usually conducted in early May, during or shortly after Spring freshet
- Can the shorter term impact of sludge distribution be profiled?
 - ◆ Are we plugging up the voids where acid generation is /was occurring?
 - ◆ Can we monitor the flushing of in-situ AMD waters?

Longer term goal-Target deposition to spot treatment of higher acid generating areas.

Seasonal Impact Survey Transects



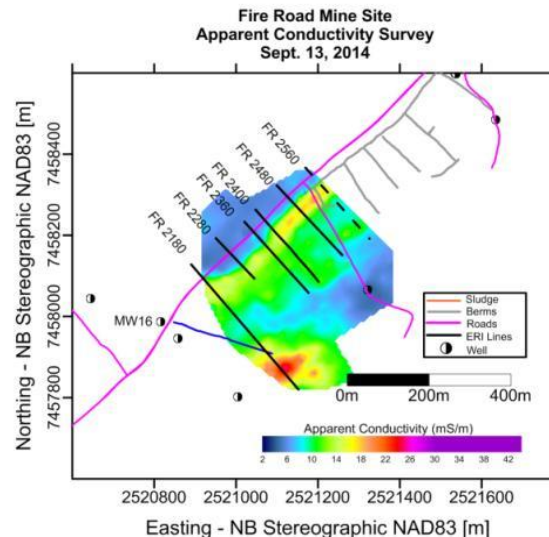
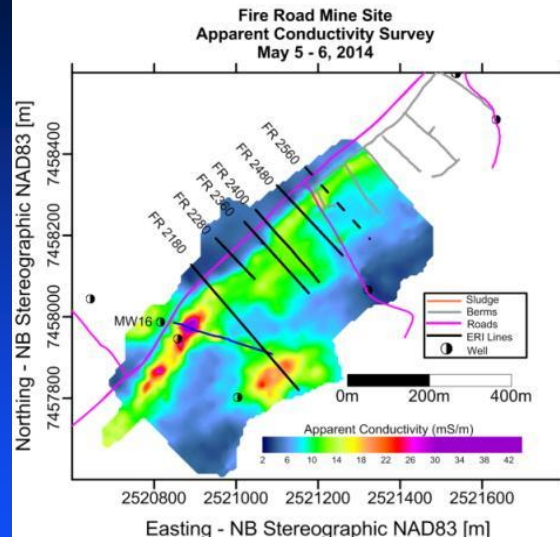
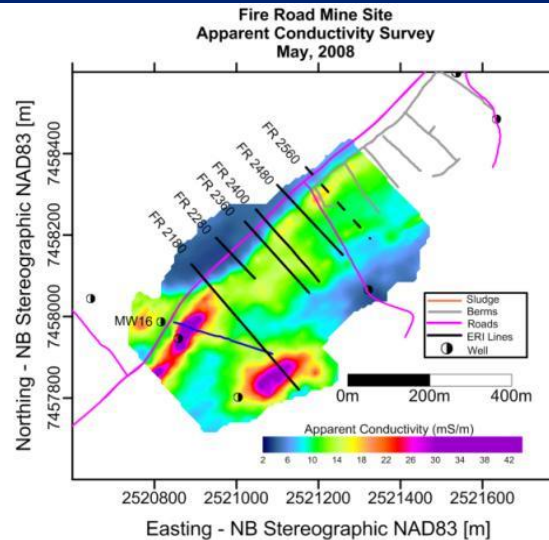
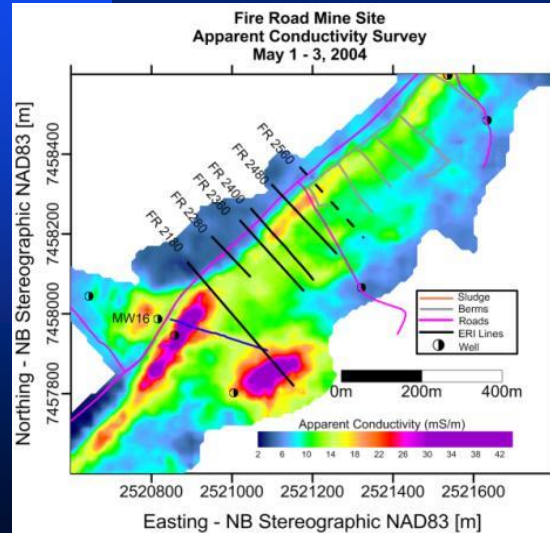
- Location map showing ERI and EM31 lines completed fall 2014 winter 2015 and again spring 2015.

Time Lapse and Seasonal Variations EM31 Apparent Conductivity

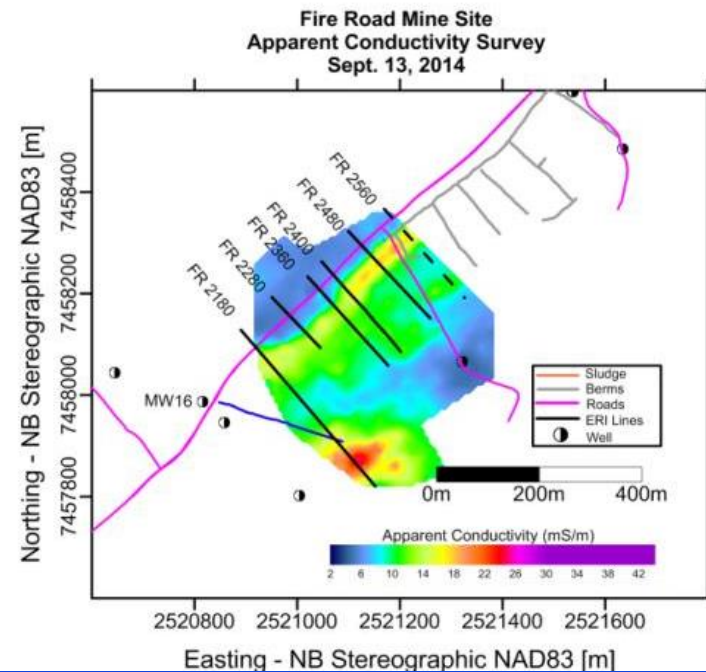
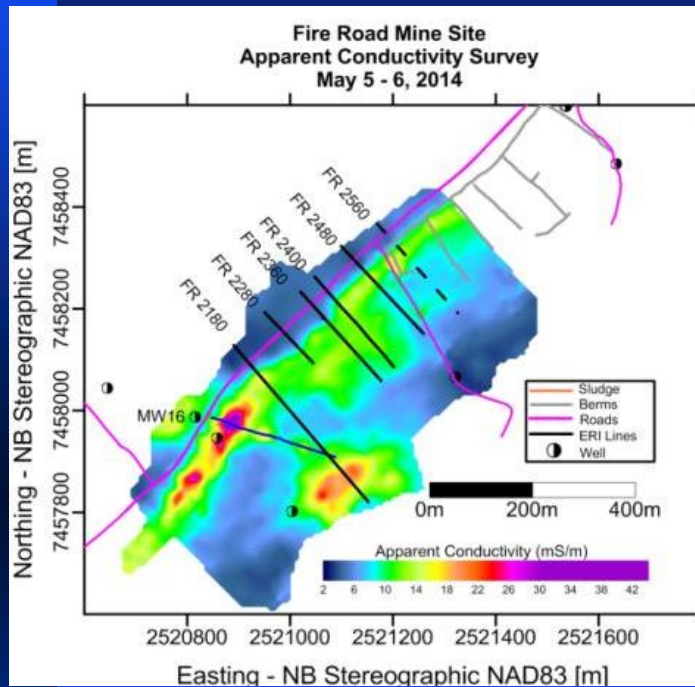
Long term survey results-

Electrical conductivity decreasing over time.

Possible effects of annual variability including heavy snow and late snow melt in 2014.



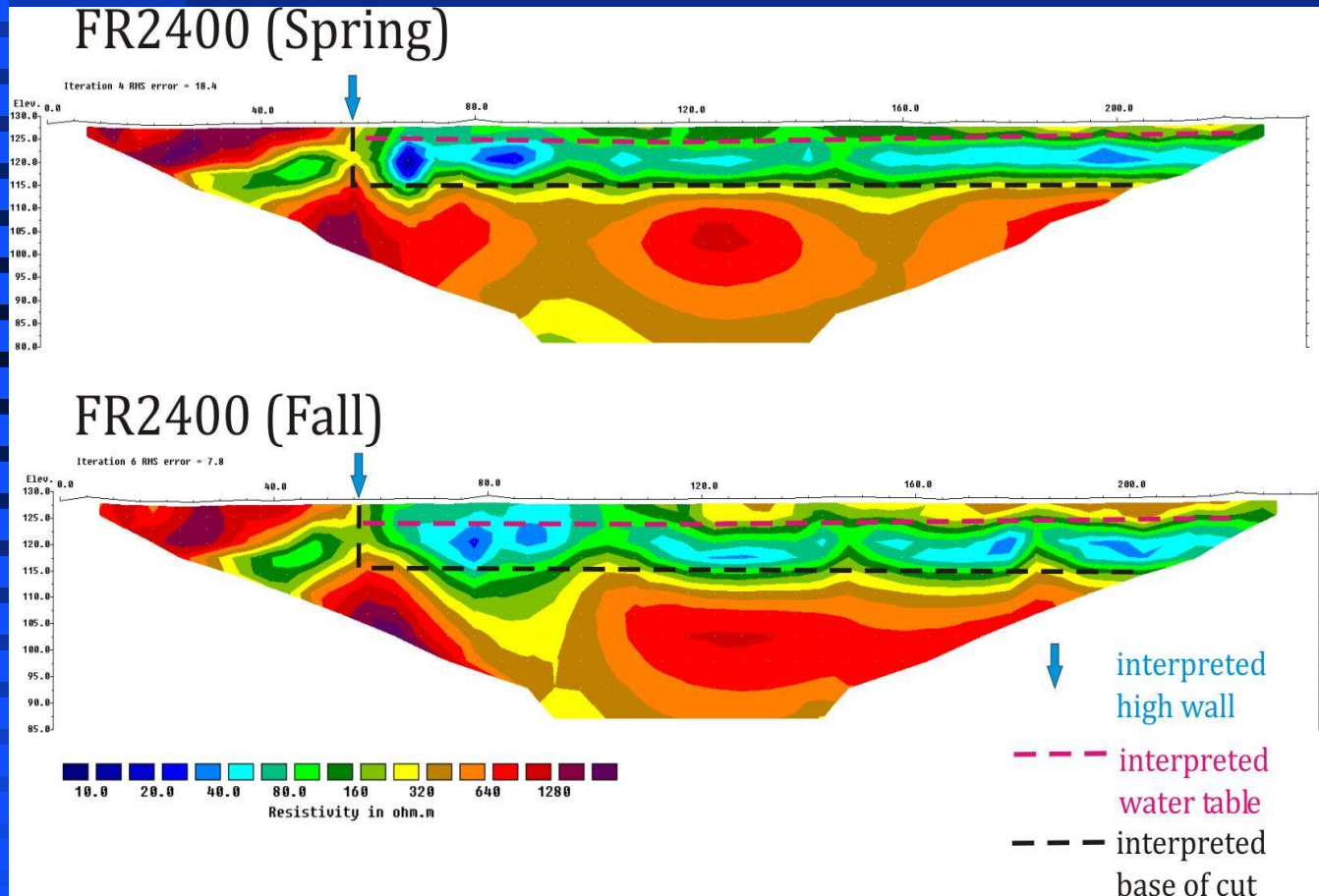
Time Lapse and Seasonal Variations EM31 Apparent Conductivity



- Spring to Fall Comparison – no obvious seasonal effect
- Seasonal higher conductivity band along high wall in fall due to more concentrated acidic mine water (less dilution)?
- Fluctuations with depth not defined, but instead averaged so two different layers may not be differentiated (+/- 6m)

Seasonal Variations

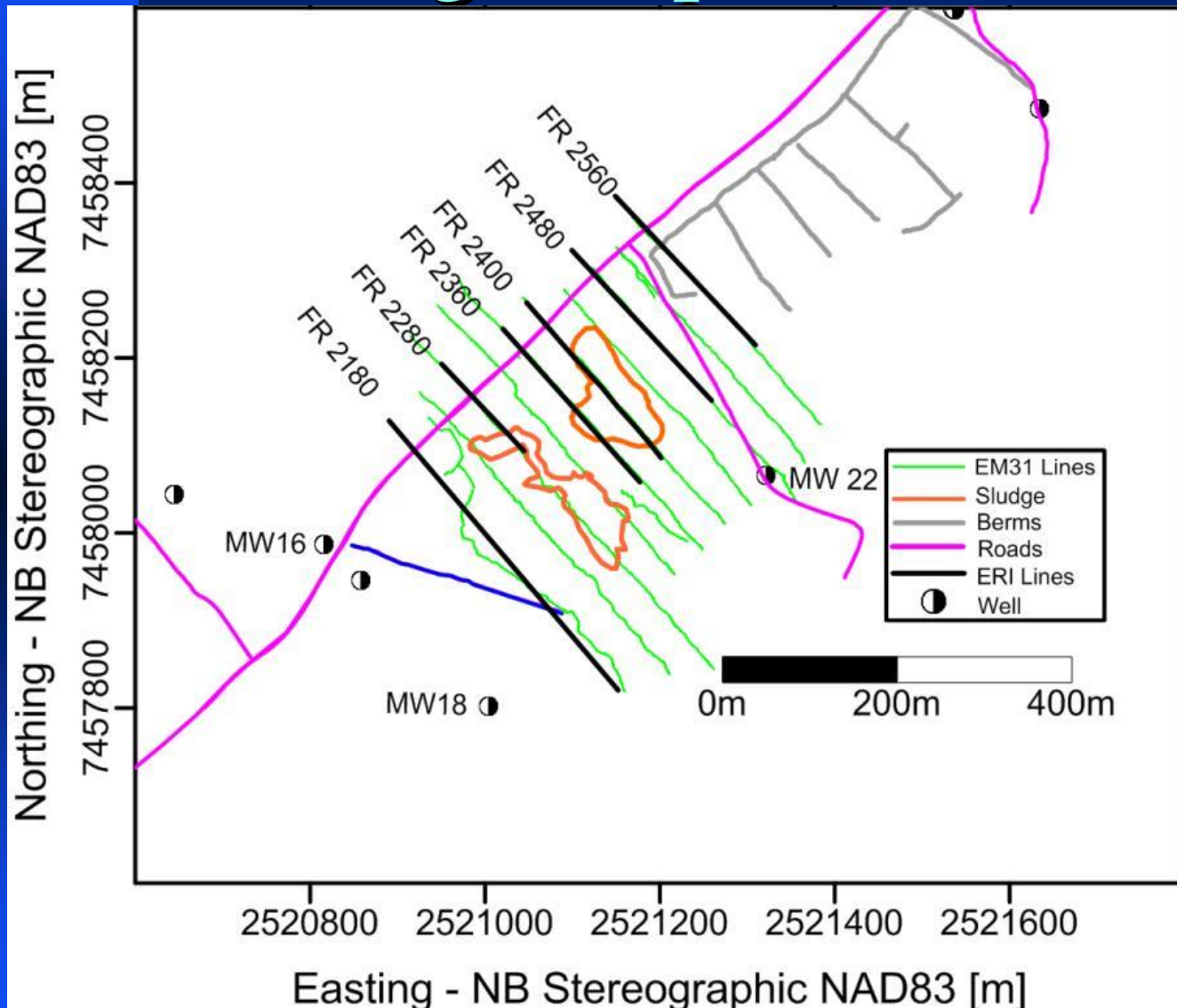
Electrical Resistivity Imaging :Spring, Fall 2014



- Vadose zone less conductive, except for area around 20m in from high wall (Remnant surface amendments?).
- Area below water table lower conductivity but change is subtle; spring flushing only minor impact.

Note: High conductivities (low resistivities) are deep blue in the ERI sections (i.e. opposite to the apparent conductivity map color scheme)

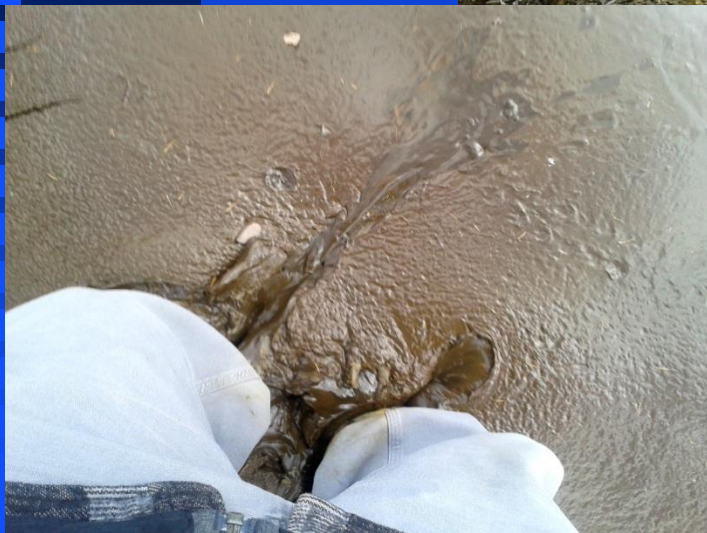
Sludge Depositional Areas



- Location map showing ERI and EM31 lines completed fall 2014 winter 2015 and again spring 2015.

Sludge Deposition

- 26,000 m³ sludge, late fall 2014
- Original plan was to resurvey directly after dredging



Original Plan for Surveying Sludge Deposition Impact

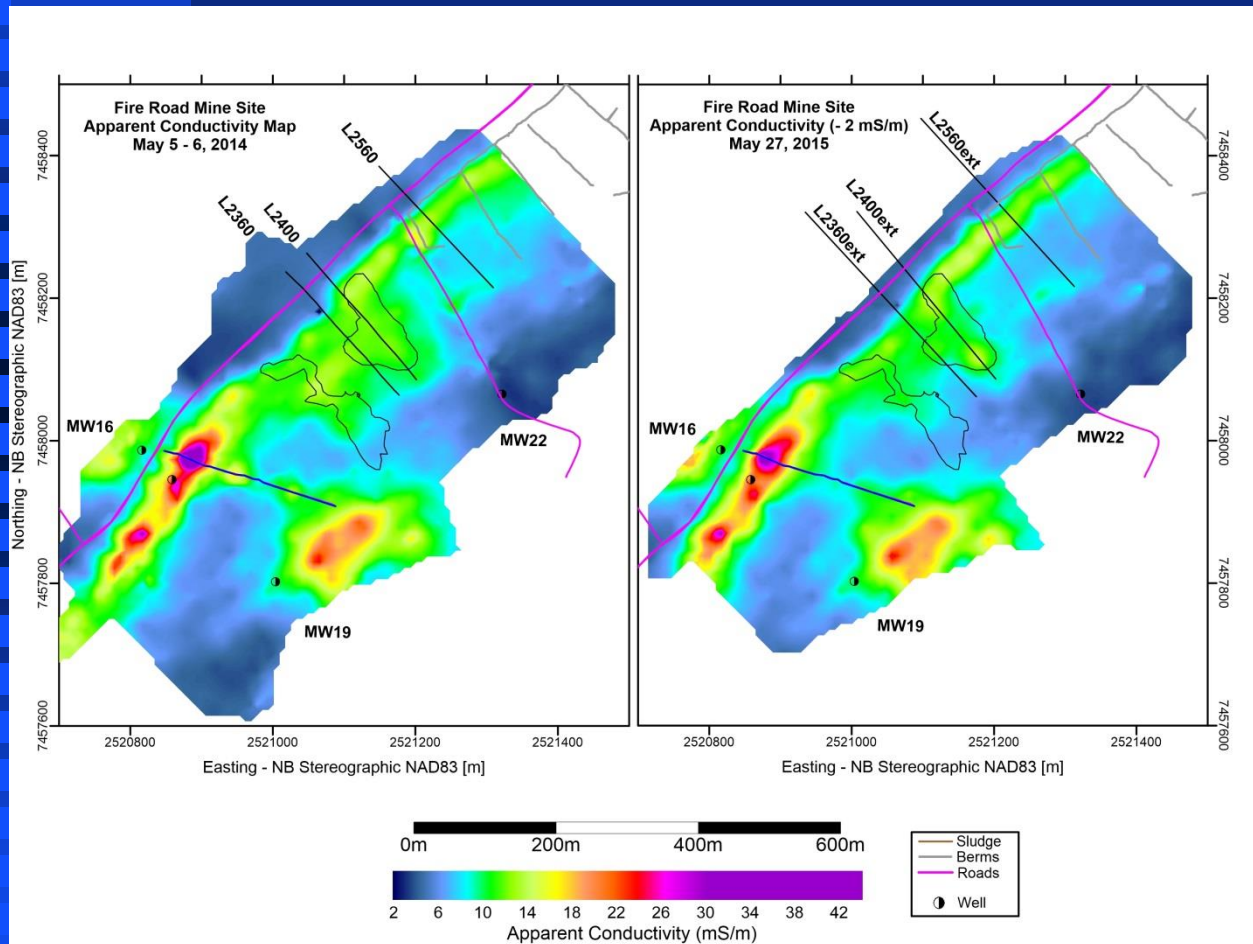
- The impact of sludge application on the EM31 apparent conductivity mapping survey was difficult to assess
 - ◆ very strong seasonal effects observed in the January survey, associated with cooling and freezing of the near-surface layer.
 - ◆ In Canada, January is not a great time for field work
- New Plan-Repeating EM31 and ERI surveys in summer (2015)
 - ◆ This work was completed in May 2015

ERI electrode connected to the cable which is elevated from the deposited sludge



Sludge Impact

EM31 Apparent Conductivity after Fall 2014 Dredging

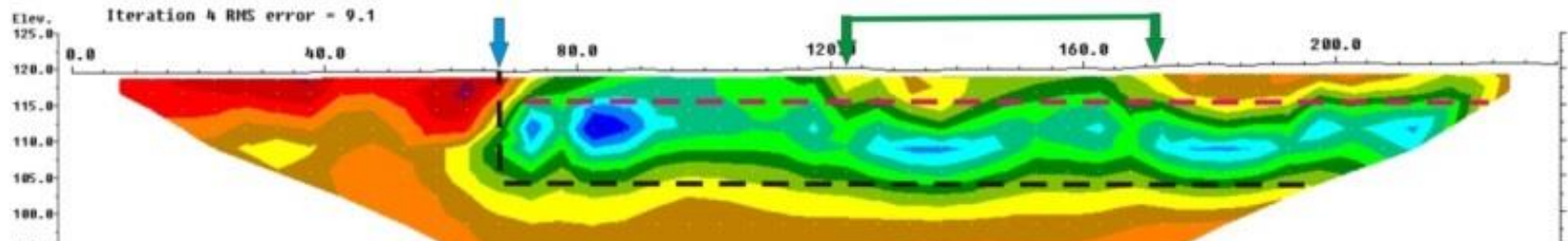


Electrical conductivity of the sludge in the waste rock backfill not as evident as expected.

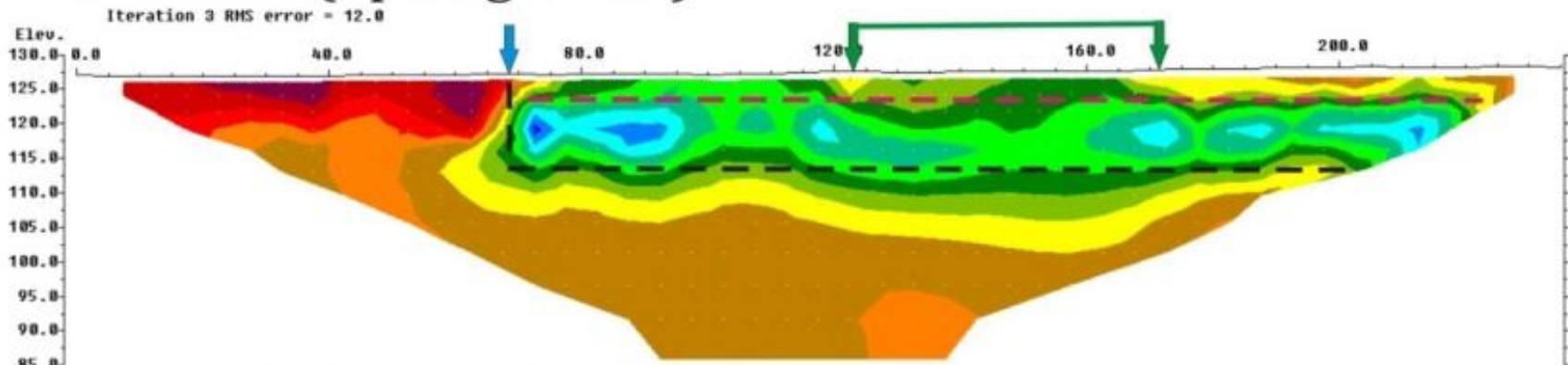
- Possible effects of timing (2 weeks later), much drier Spring.
- Dewatered sludge much less conductive?
- Did the sludge deposition back up ground water flow?
- Is the averaging of the conductivities over 6 m depth masking the impact?

ERI Variation Due to Sludge Addition

FR 2360 (Fall 2014)



FR 2360 (Spring 2015)



Sludge
deposition

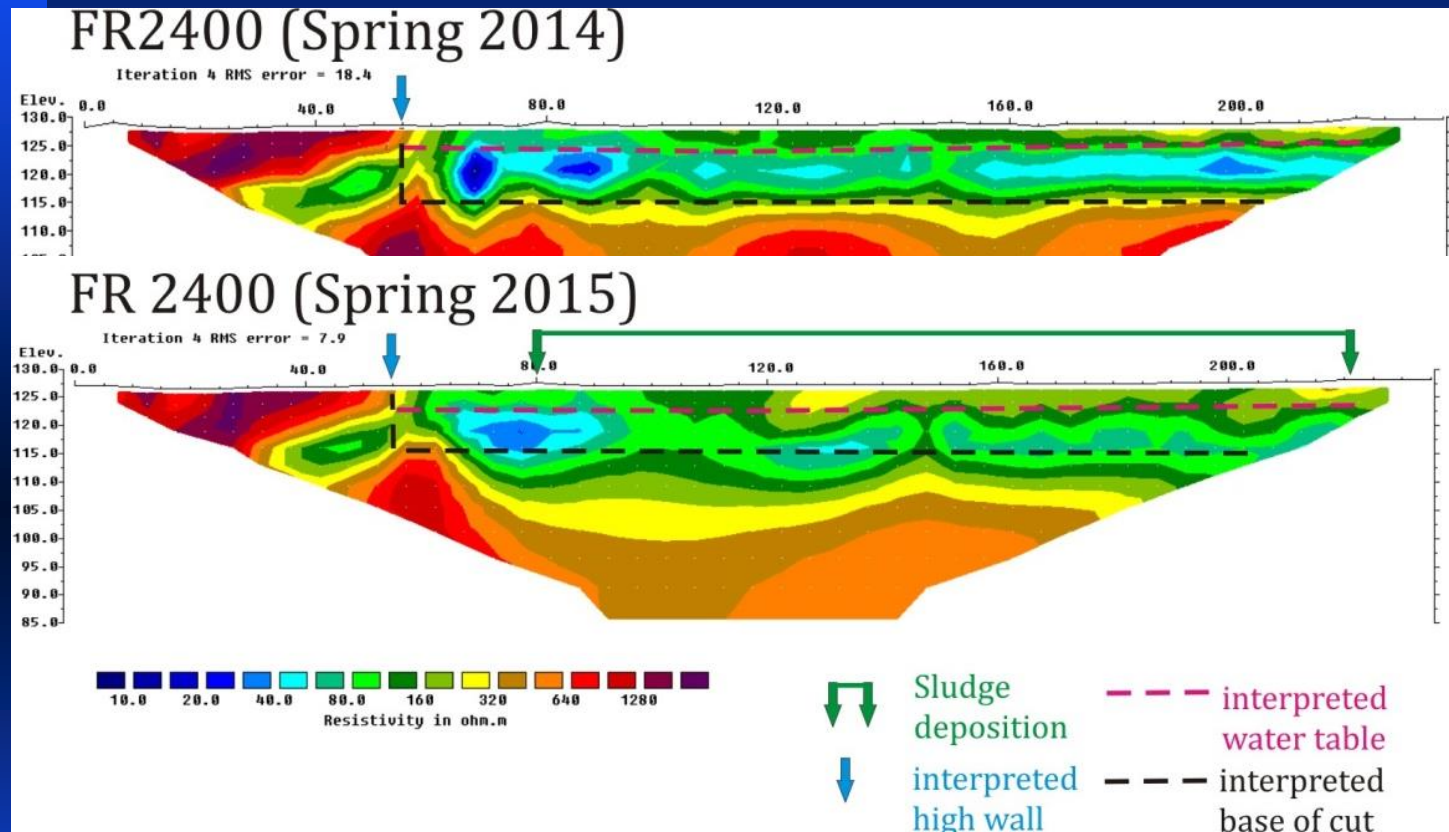
interpreted
high wall

--- interpreted
water table

--- interpreted
base of cut

- Expect: more conductive in vadose zone, less conductive below water table
- Seasonal effect?

ERI Variation Due to Sludge Addition



- Expect: more conductive in vadose zone, less conductive below water table, as in previous line
- Line 2400- less conductive in vadose zone and below water table
- So is sludge less conductive than acid mine water and wet spring overburden in vadose zone?
- Note higher conductivity area at “200” also picked up in ER survey.

Conclusions

■ 1. Seasonal versus long term impacts

May, Sept. 2014, Jan. 2015, May 2015

◆ Apparent conductivity mapping

- ☞ Little impact on seasonal compared to obvious reduction on long term.
- ☞ January is not a good time for field work in Canada

◆ Electrical Resistivity

- ☞ Lower conductivity in vadose zone in the fall (drier).
- ☞ Slightly higher conductivity in water saturated zone (warmer temp. and reduced freshwater infiltration)

Conclusions

- 2. Effects of depositing sludge into the waste rock
 - ◆ EM Apparent conductivity impact not as evident as anticipated
 - ◆ Was “averaging” of conductivities to ± 6 m depth masking the effect?

Conclusions

- 2. Effects of depositing sludge into the waste rock
 - ◆ ERI survey results anticipated more conductivity in vadose zone, less conductive below water table
 - ◆ vadose zone underlying the deposition area was more conductive but not in all surveys
 - ☞ suggests sludge was indeed at least partially filling the void space in the vadose zone (and thereby acting to limit oxygen diffusion).
 - ☞ But as the sludge dewateres, there is evidence that the conductivity decreases.
 - ◆ Conductivity of waste rock below the water table reduced
 - ☞ as expected if infiltrating sludge was less conductive than AMD and has partially flushed AMD from the region.

Further Research on the Impact of Sludge Deposition

- Did not get a good handle on tracking the sludge distribution
- Test pitting in mine to determine
 - Behaviour of sludge at depth (moisture content)
 - extent of sludge filling in void space in the vadose zone
- Would be interesting to see the behaviour of the sludge below the water table but not sure we can dig that deep.

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