Bio-mediated Soil Improvement Field Study for Erosion Control and Site Restoration

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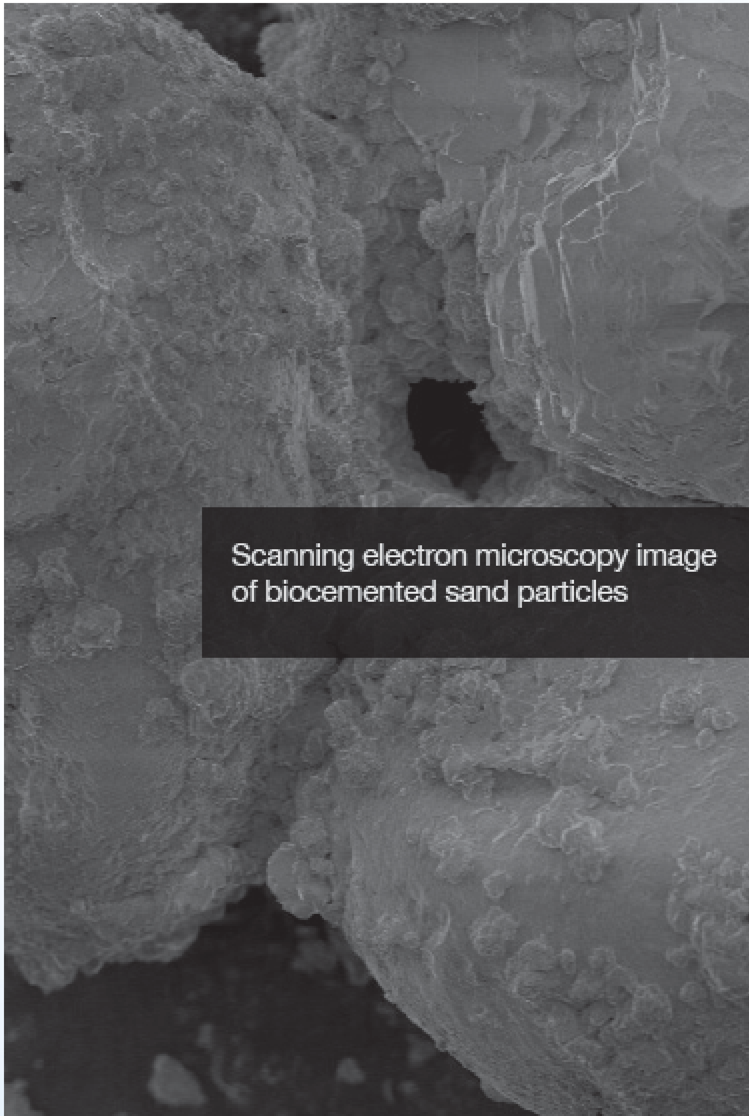
Outline

- What is Microbial Induced Calcite Precipitation (MICP)?
- Project Team
- Field Study Overview
- Results



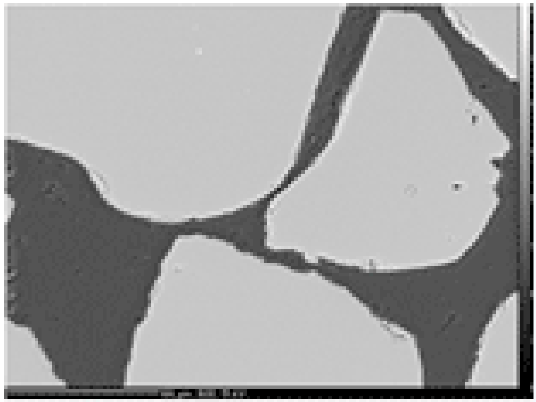
Microbial Induced Calcite Precipitation

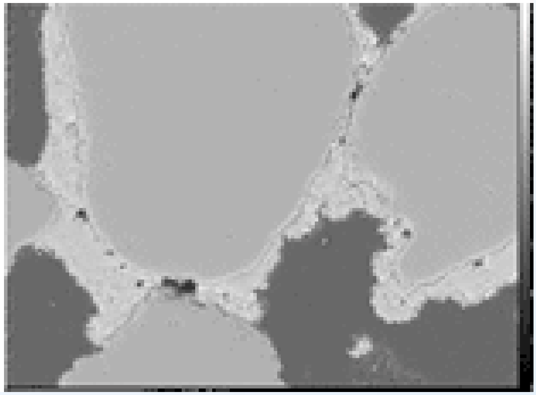
Motivation

- Multi-billion dollar ground improvement industry
- Possible applications include strength & stiffness increase, liquefaction control, permeability reduction, erosion control, dust suppression, . . .

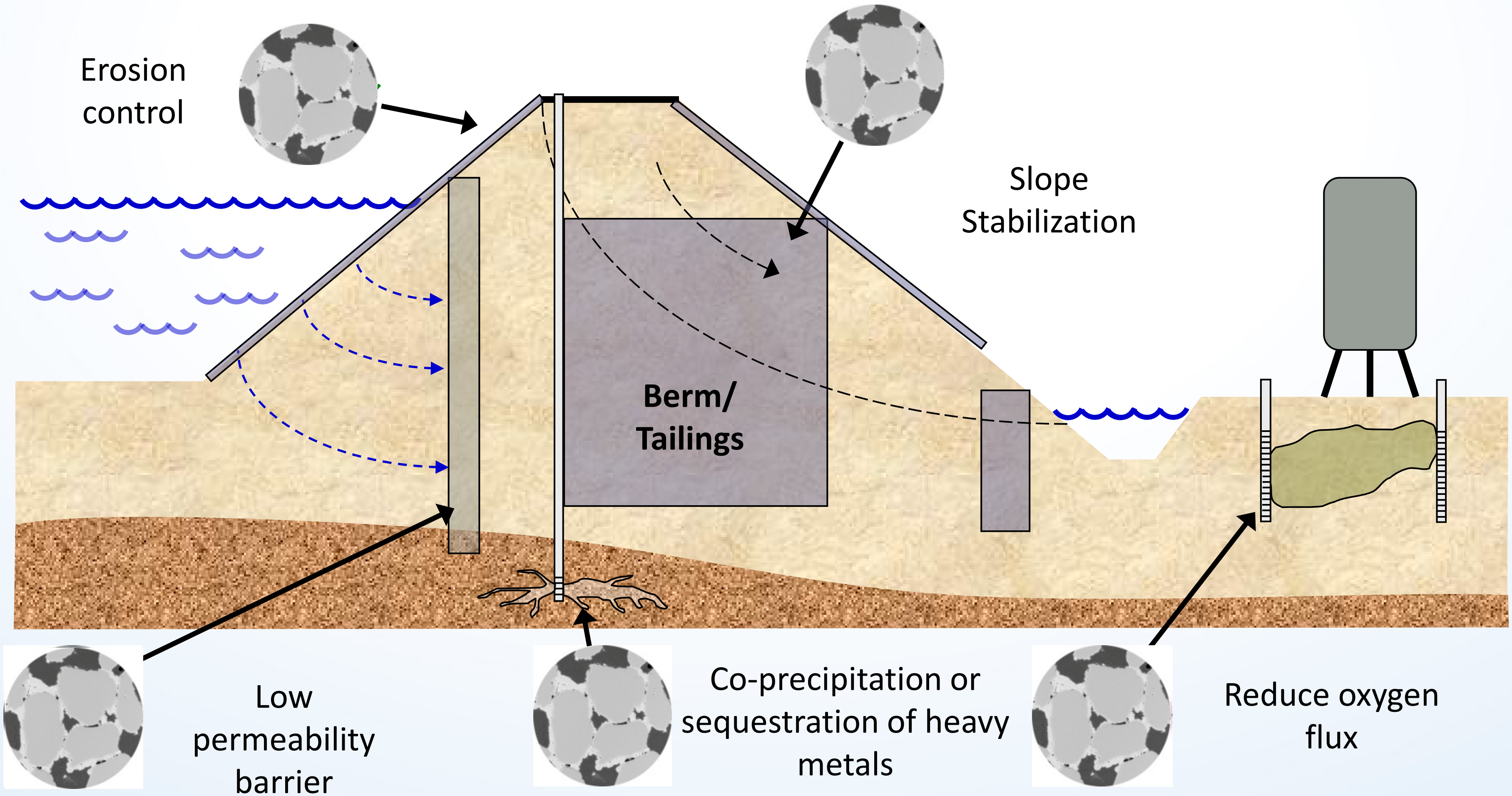
Technology

- Bacteria consume urea (nutrient) and produce ammonia and carbon (carbonate and bicarbonate) as by-products
- pH goes up and calcite (calcium carbonate) precipitates on sand grains
- Precipitation on grains results in
  - "Binding" of grain to grain contacts → stiffness & strength increase
  - Increased solid mass → reduction in pore size and permeability
- For above to happen, may need to add bacteria, urea, and calcium if not already present in groundwater





MICP Soil Improvement For Mining



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Project Team

University of California Davis

- Jason DeJong – Geotechnical Professor / Principal Investigator
- Mike Gomez – Geotechnical Doctoral Student / Field Implementation & Data Processing

Geosyntec - Oakland

- Brian Martinez – Technology Expert / Field Trial Design & Implementation
- Chris Hunt – Geotechnical Engineer / Applications Focus

Geosyntec – Guelph and Waterloo

- Dave Major – Project Director / Microbiologist
- Len deVlaming – Project Manager / Application System Design

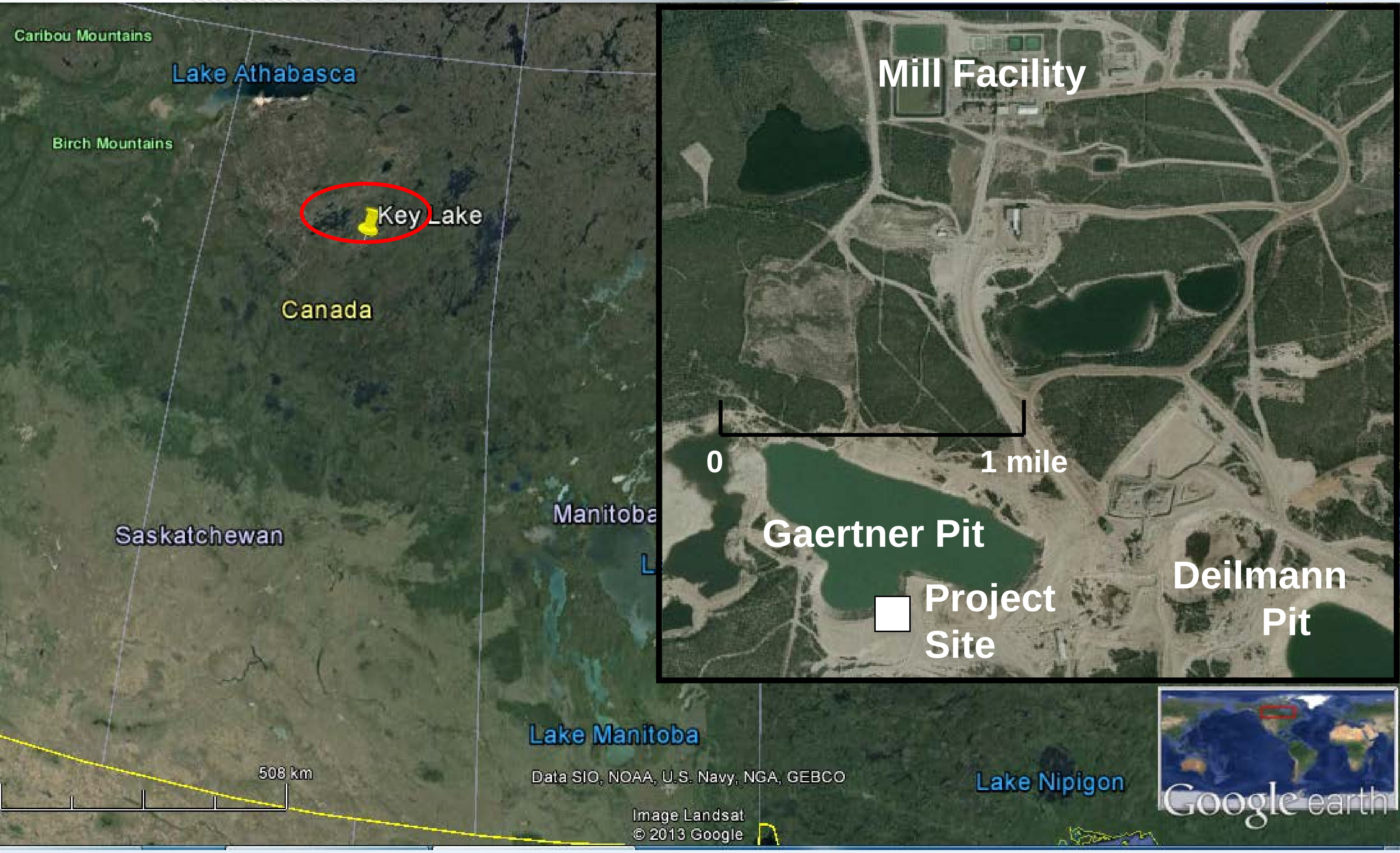
SIREM (a Geosyntec Company)

- Sandra Dworatzek – Bacterial culture production

Cameco Corporation

- Dana Fenske – Geo-Environmental Engineer / Client Lead

Cameco Key Lake Facility Location



Project Motivation

- Loose, poorly graded sands eroded by wind, rainfall, and snowmelt
- Stabilization needed for erosion control to promote long term closure and revegetation, reduce water use for dust control, and maintain site roads and slopes

Test Plot Setup

Test Plots

MIXING TOTES
WATER TANKS
PLOT 1
NO TREATMENT
PLOT 2
HIGH TREATMENT
PLOT 3
MEDIUM TREATMENT
PLOT 4
LOW TREATMENT
HEEL PLOT
LEFTOVERS
FROM 2, 3, 4

Ingredients

Urea

Calcium Chloride

Bacterial Solution

Nutrient Broth

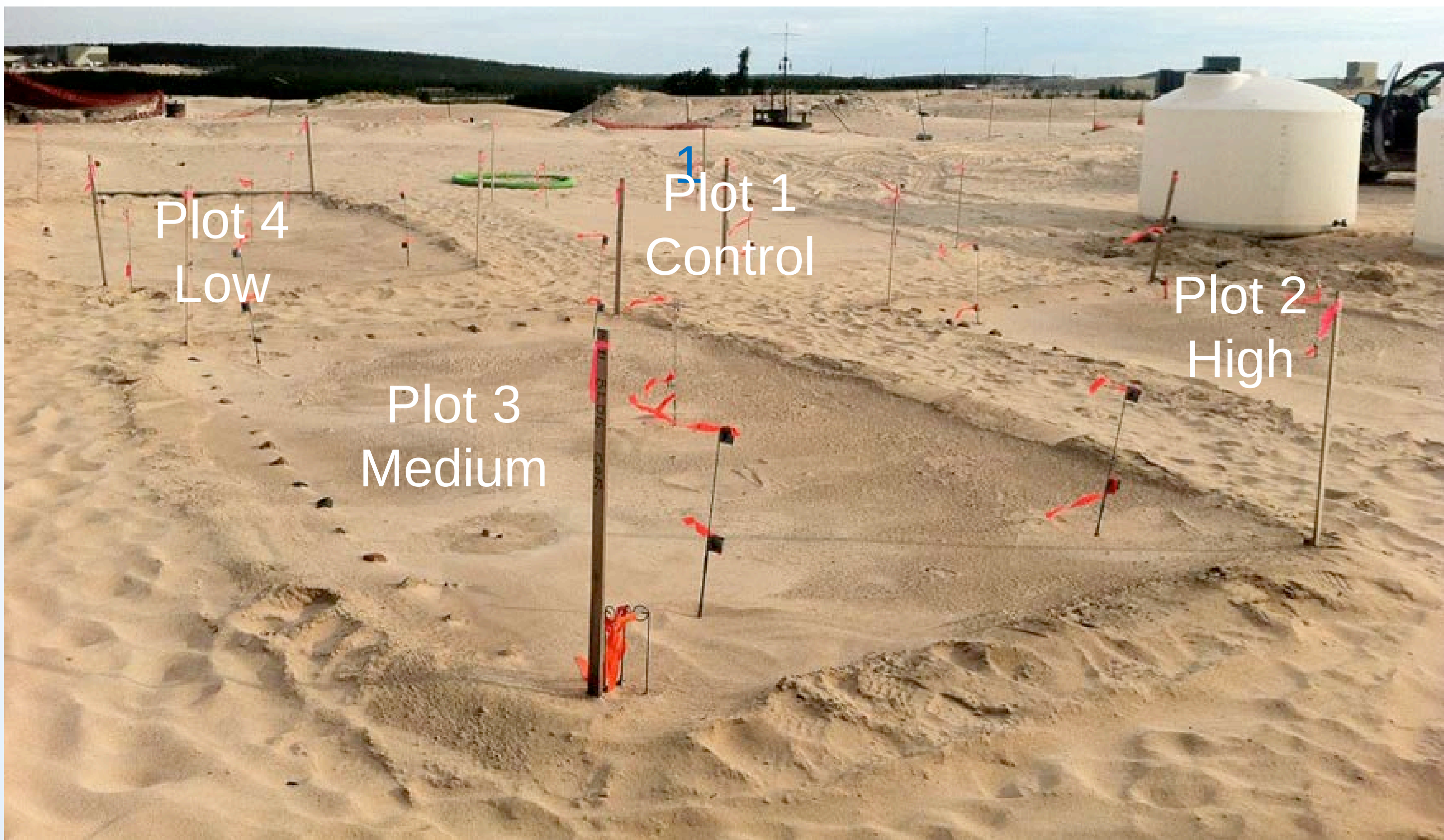
Treatment Approach

Treatment Cycle

- Five 4-day cycles, 20 days total
- Day 1 = Bacterial amendment with nutrients
- Days 2, 3 and 4 = Nutrient amendment only

Variables

- Plot 1 = Water only
- Plots 2, 3 and 4 = Varying nutrient (urea + calcium chloride) quantities



First Evidence of Crust Development

Water Jetting

Plot 1 - Untreated

Plot 4 - Light Treatment

Hard Crust Development

Heel Plot Excavation

Dried Sample from Heel Plot

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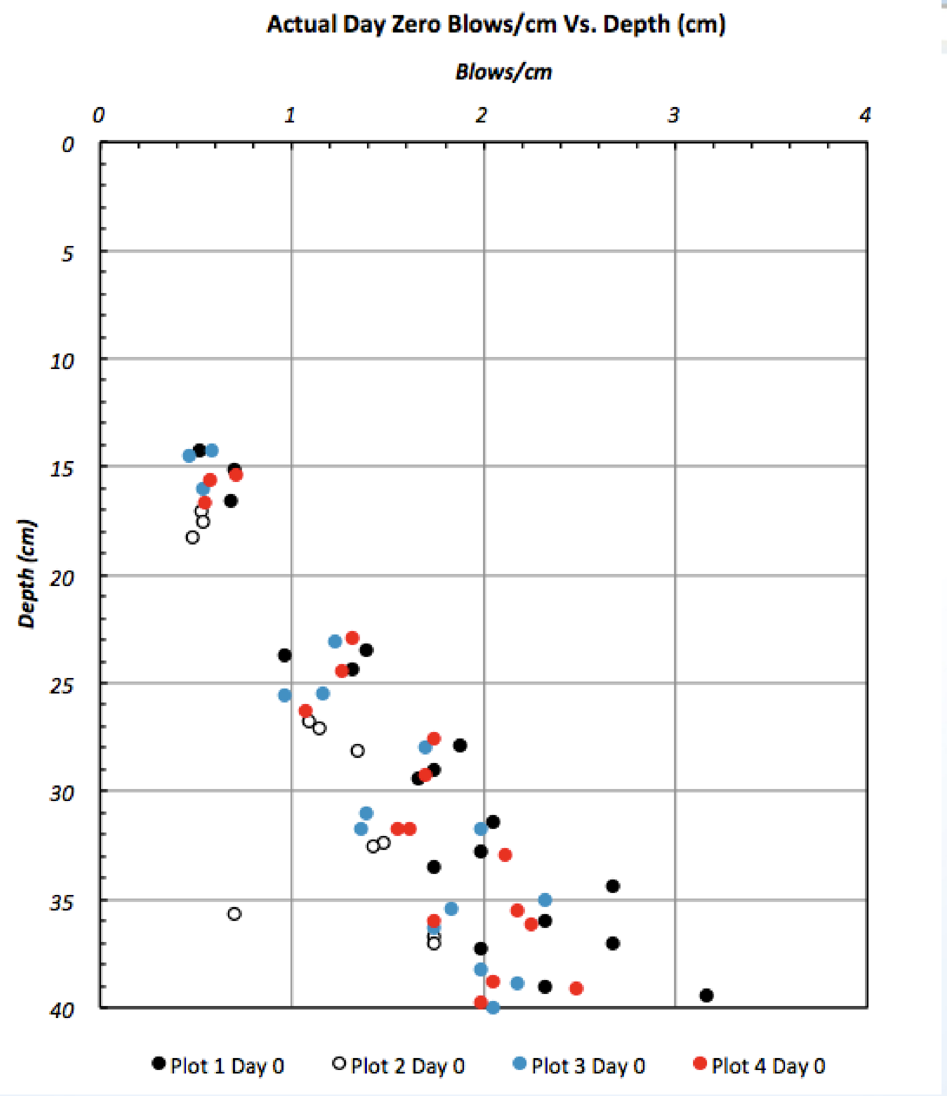
Measurements

Dynamic Cone Penetrometer (DCP)

Sample Collection

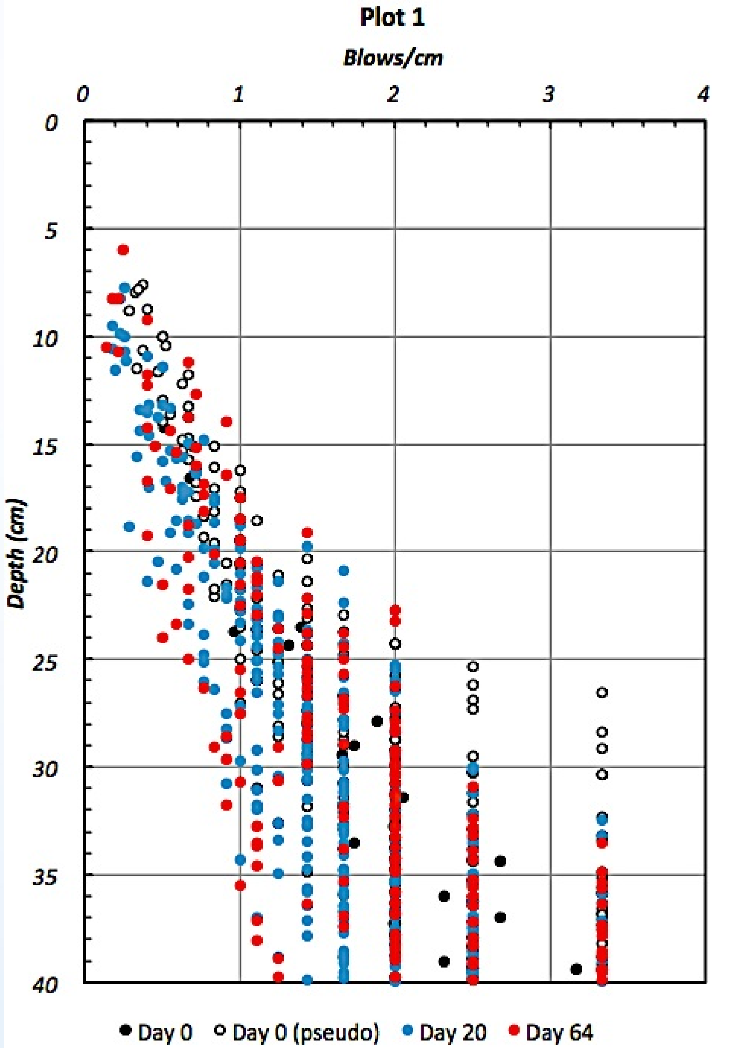
Calcite Measurement

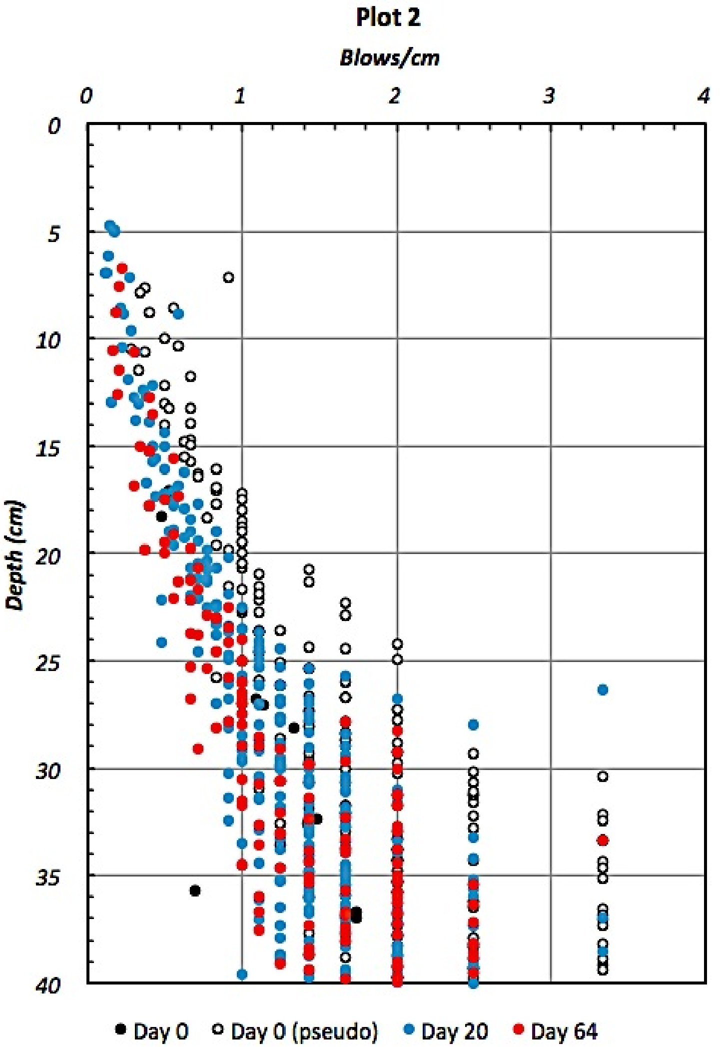
Day Zero DCP Blows/cm



Plot 1 = Control; Plot 2 = Heavy Treatment; Plot 3 = Medium Treatment; Plot 4 = Light Treatment

Plot 1 & 2 DCP Results – Raw Data





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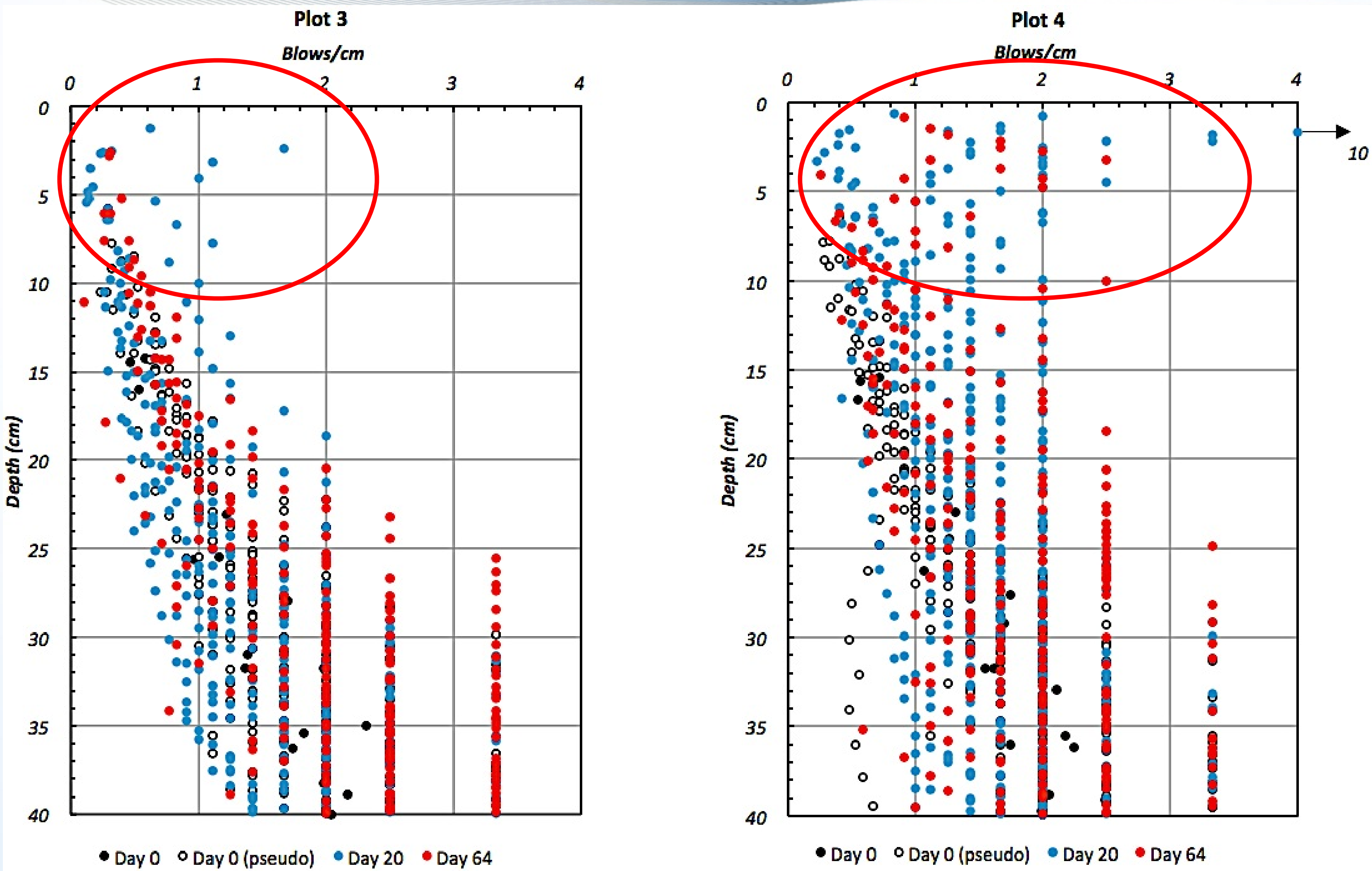
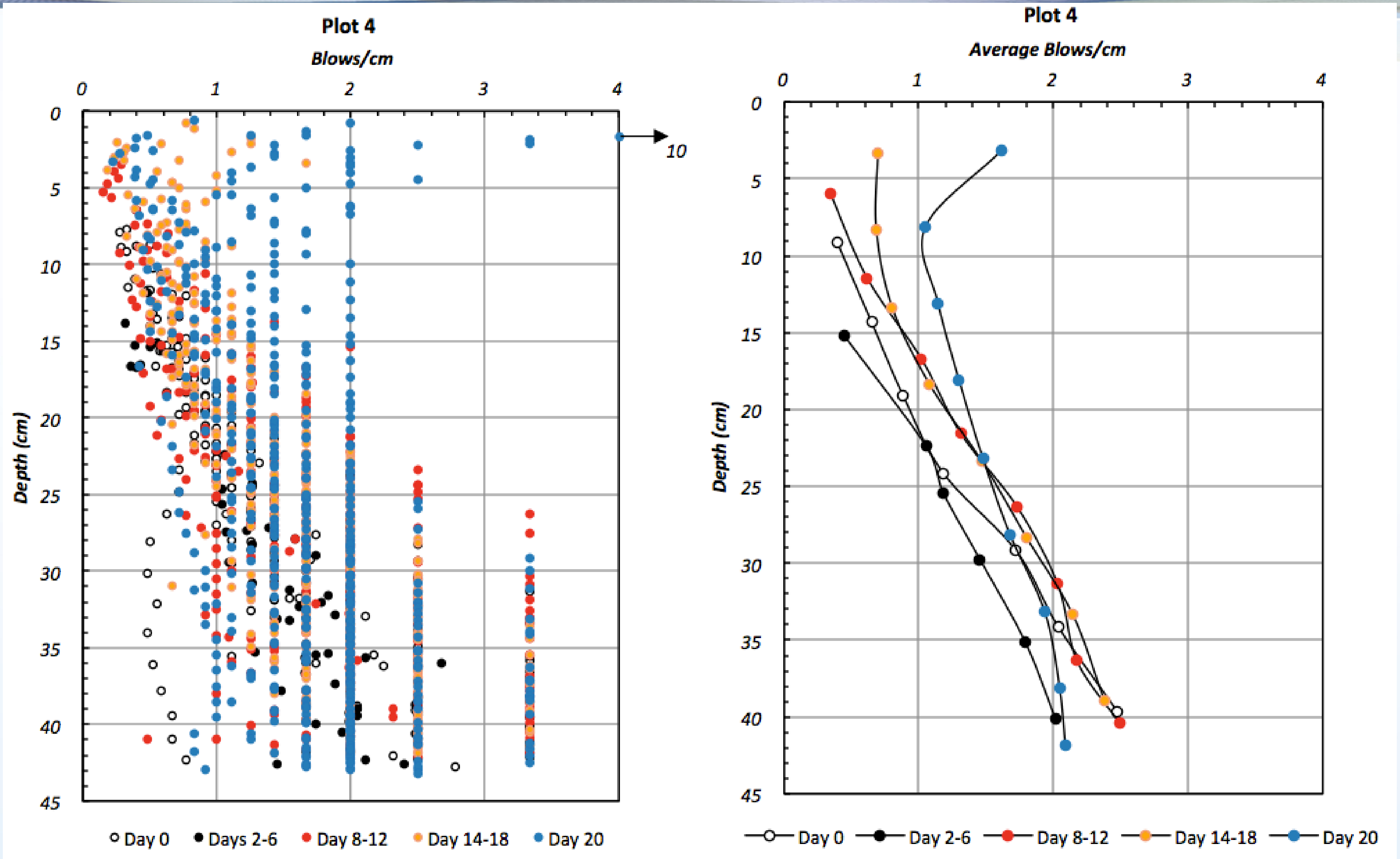
Plot 3 & 4 DCP Results – Raw Data



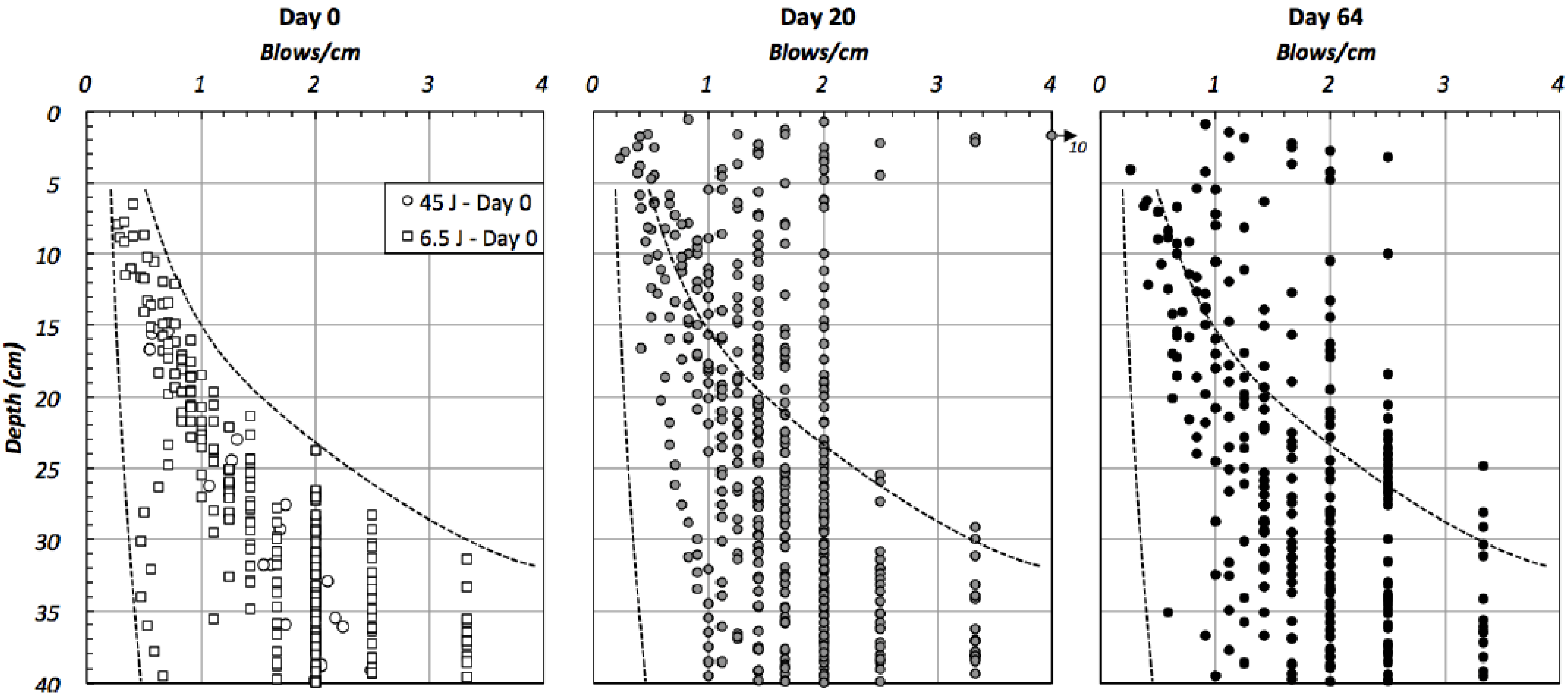
Plot 1 = Control; Plot 2 = Heavy Treatment; Plot 3 = Medium Treatment; Plot 4 = Light Treatment

Plot 4 DCP Results – Average Blows/cm

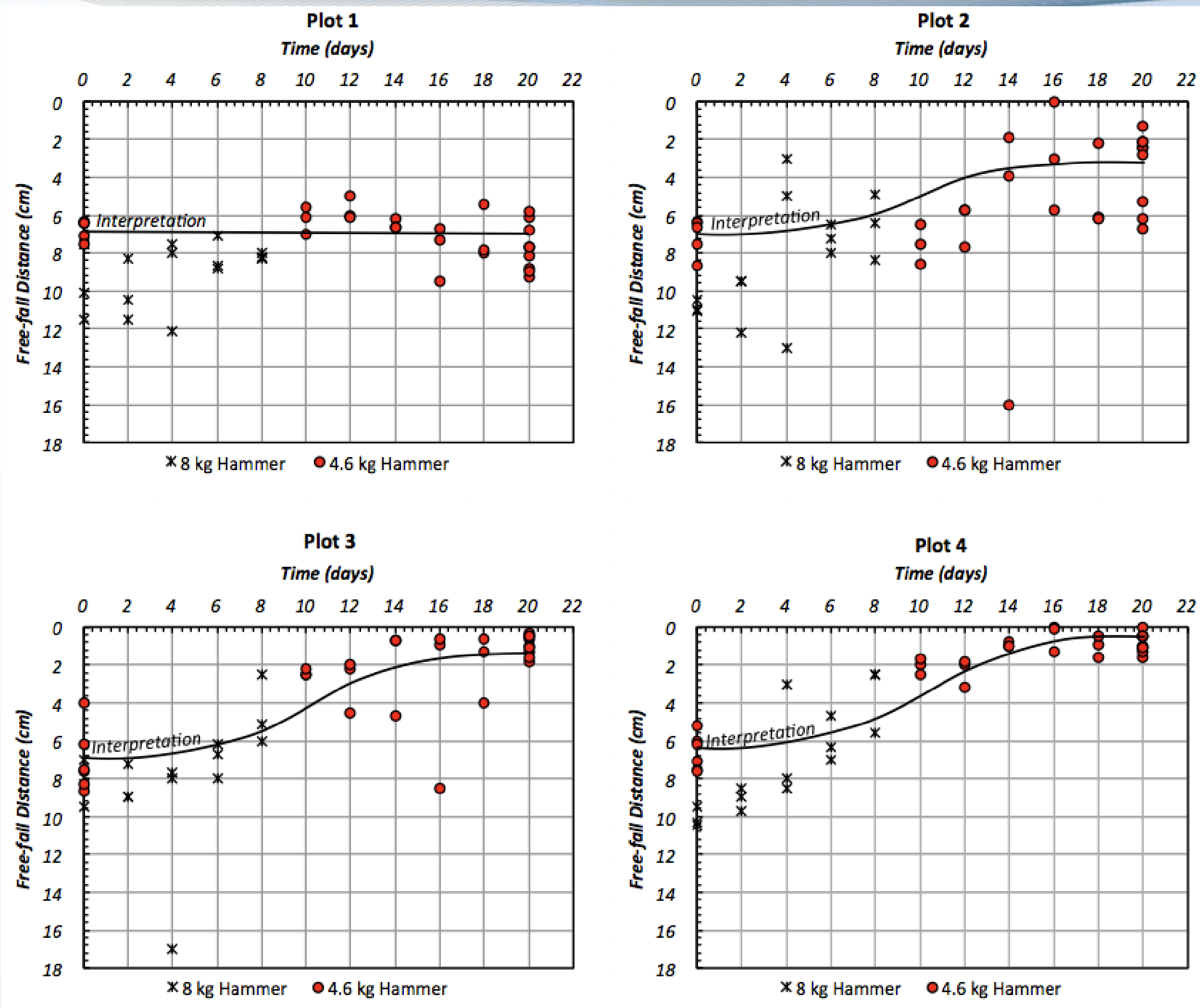


Plot 1 = Control; Plot 2 = Heavy Treatment; Plot 3 = Medium Treatment; Plot 4 = Light Treatment

Plot 4 DCP Results after 44 Days



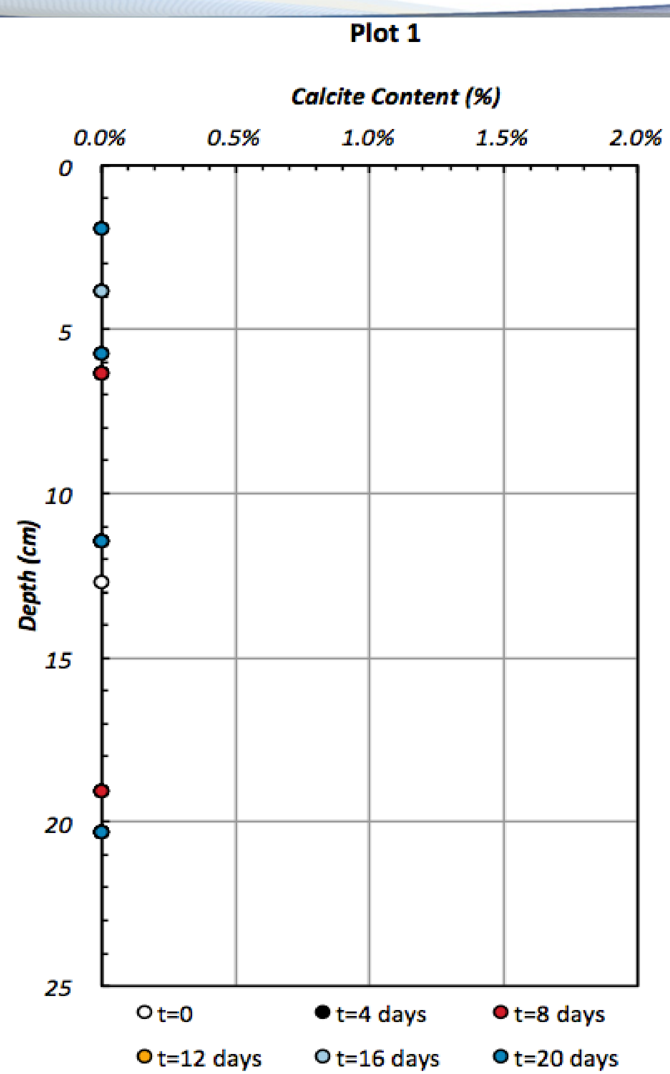
Plot 1 to 4 DCP Results – Crust Formation

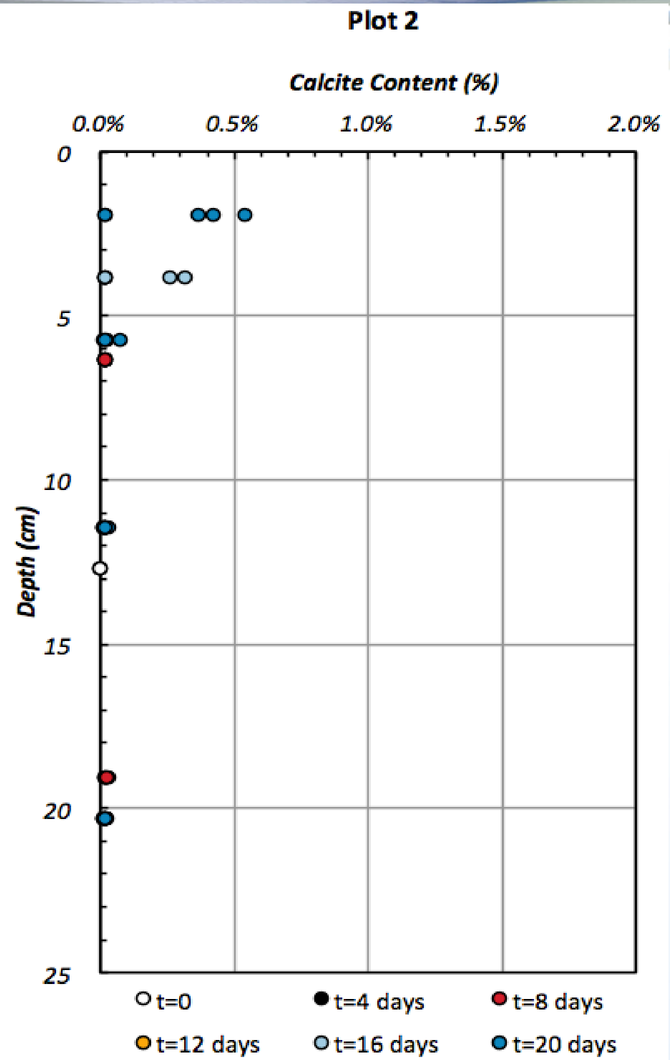


- Free-Fall Distance is the distance the DCP cone tip sank under self-weight.
- Smaller distance means more resistance = crust.

Plot 1 = Control; Plot 2 = Heavy Treatment; Plot 3 = Medium Treatment; Plot 4 = Light Treatment

Plot 1 & 2 Calcite Content – Raw Data





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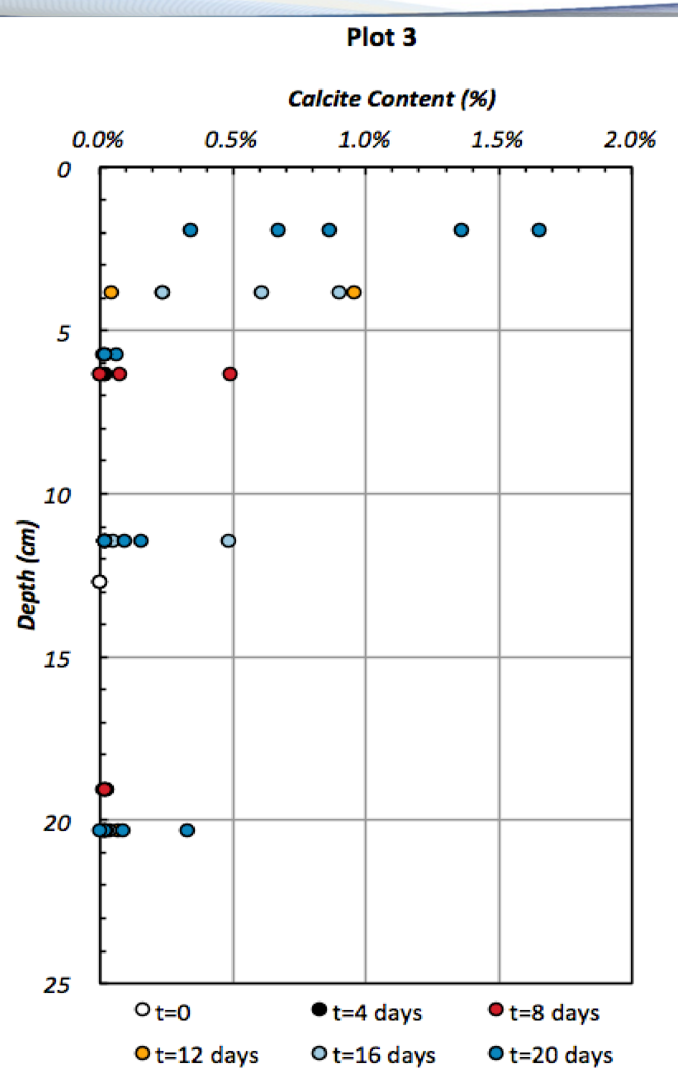
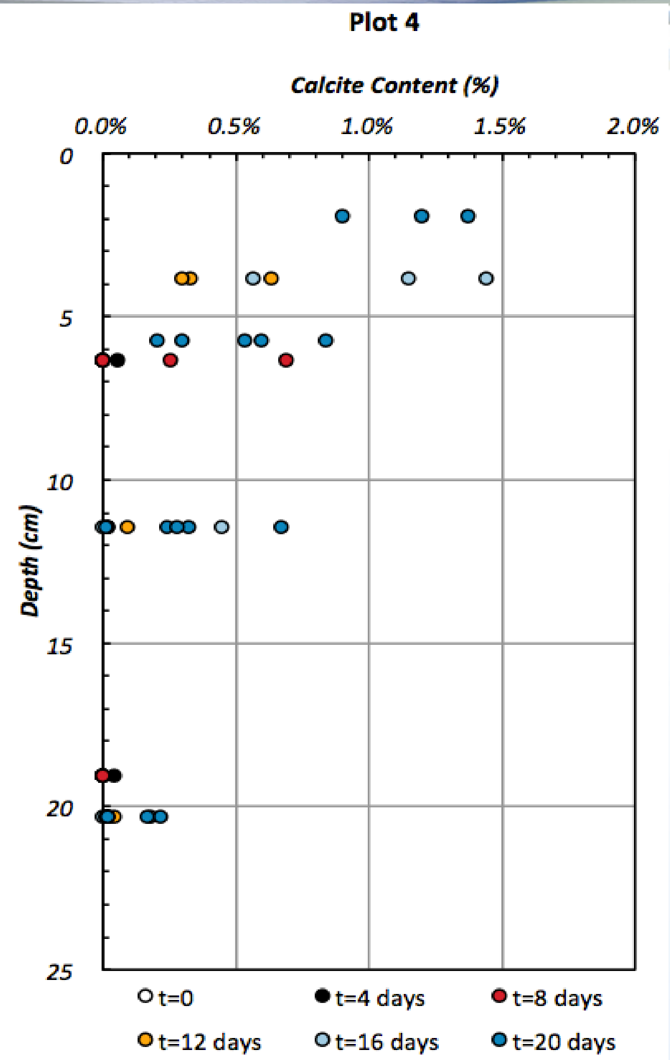
Plot 3 & 4 Calcite Content – Raw Data





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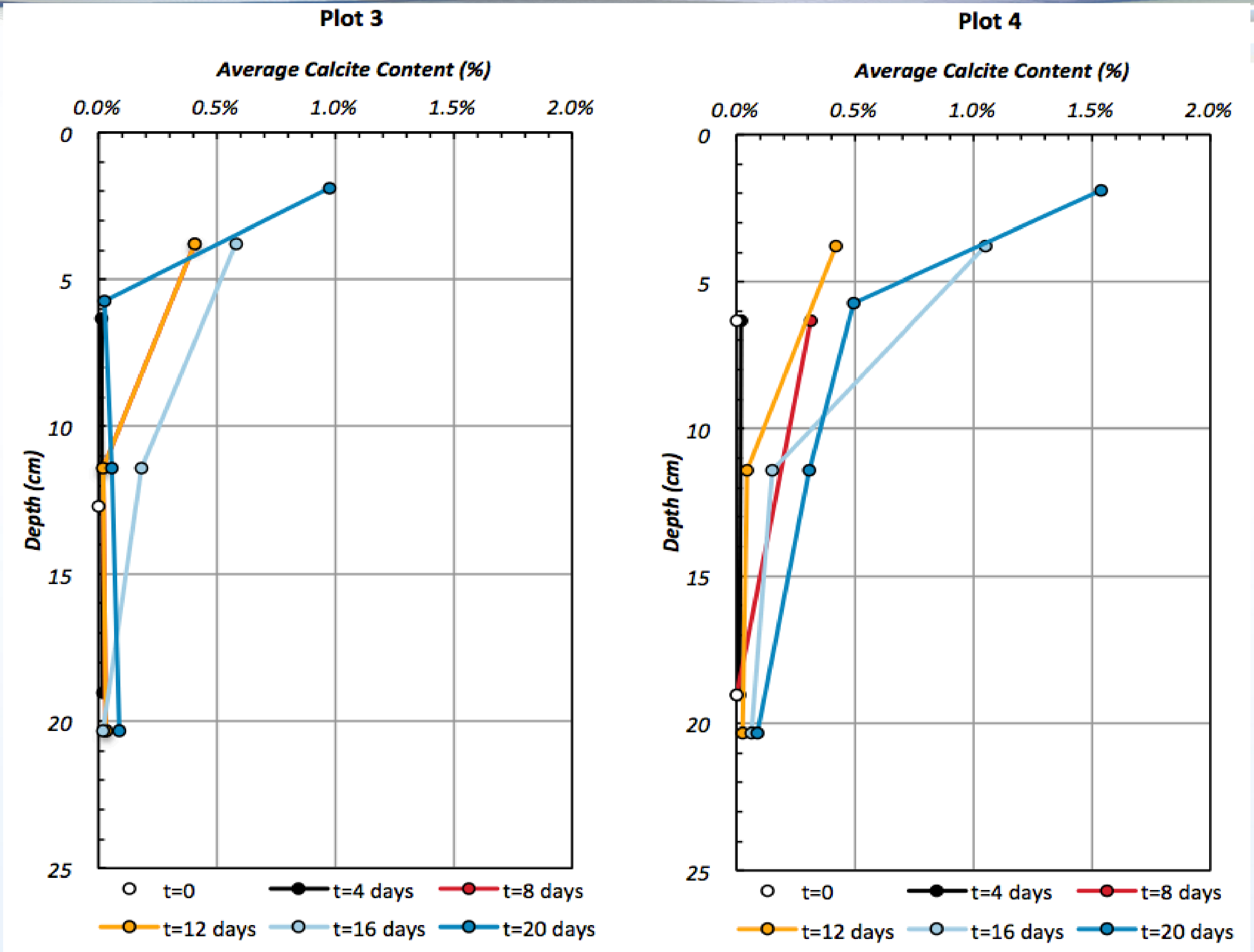
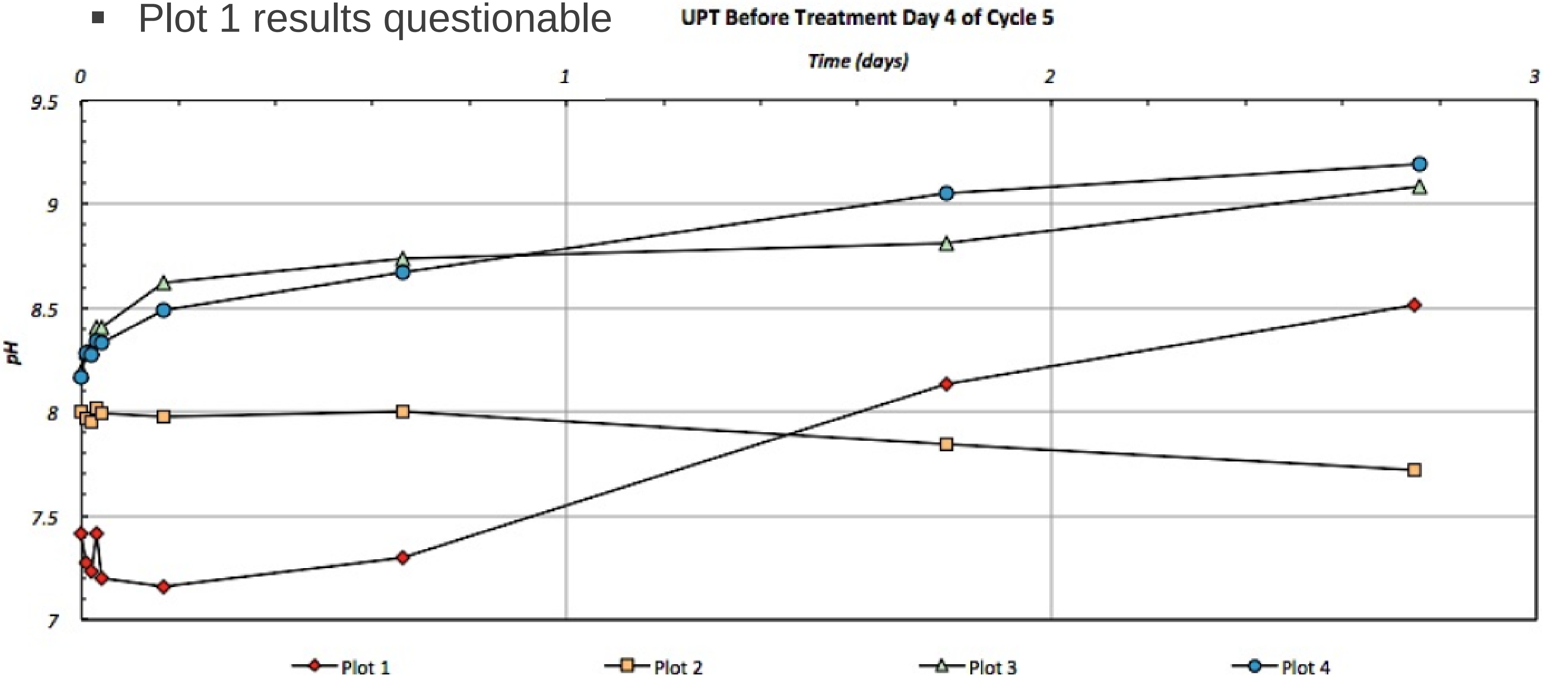
Plot 3 & 4 Calcite Content – Average



Plot 1 = Control; Plot 2 = Heavy Treatment; Plot 3 = Medium Treatment; Plot 4 = Light Treatment

Ureolytical Potential Test

- Plots 3 and 4: Strong ureolytic potential (significant bacterial activity)
- Plot 2 shows low ureolytic potential
- Plot 1 results questionable



Plot 1 = Control; Plot 2 = Heavy Treatment; Plot 3 = Medium Treatment; Plot 4 = Light Treatment

Results

- MICP improved erosion resistance and suppressed dust from mine site soils
  - Up to 28 cm in observed improvement
  - Up to 4 cm of sandstone-like crust
  - Load bearing under human and animal weight
  - Resistant to erosion under water jetting
- Monitoring captured spatial and temporal improvement
  - DCP free fall and blow count measurements
  - Calcite measurements
- Biological activity was confirmed
  - Ureolytic Potential Tests

Video
Water Jetting

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Video Scrape Test

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Questions? Thoughts? Ideas?

A few things we know

- Treatment was not optimized – the lightest treatment worked best
- Results will depend on site materials and depth of treatment required
- As a short term erosion control solution, may not be cost competitive yet
- As a long term ground modification approach, it can be very cost competitive
- Evaluation is needed on fate of ammonia byproduct