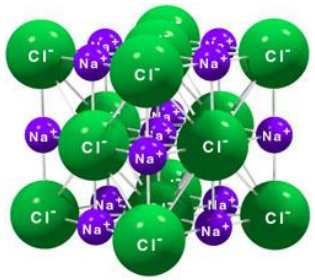

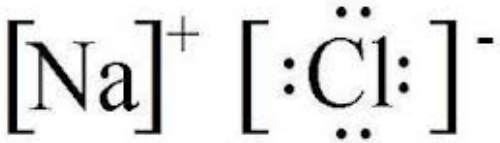

Effective Saltwater Remediation

Dustin Anderson
Chris Athmer
Brad Stevens

Under Advisement of the NDPC Brine Task Force

May 24, 2016

EERC
Energy & Environmental Research Center®

School of Natural Resource Sciences
Soil Science
Natural Resources Management
Range Science
Entomology
North Dakota State University

VERTEX

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Introduction

- Brine Task Force
- How Brine Impacts Soil
- Remediation Options
  - Electrokinetic Treatment
  - Crystallization Inhibitor - Ferric Hexacyanoferrate /Prussian blue)
- Successful Reclamations in North Dakota

DMR, DoH, ND Agriculture, EERC and Industry Joint Task Force

Overall Goal: We recognize the value of topsoil as a non-renewable resource. We intend to provide effective remediation alternatives that promote the conservation of this resource.

Objective: Provide industry with information and tools to make informed decisions regarding remediation options.

Action Items:

- Develop an industry checklist for immediate spill response. **This action item has been accomplished.**
- Provide comments to the Department of Health's *Guidelines for the Assessment and Cleanup of Saltwater Releases* Document. **This action item has been accomplished.**
- Work with the Energy and Environmental Research Center (EERC) and NDSU to develop and disseminate the *Spills Cleanup Primer* and author the *North Dakota Remediation Resource Manual* – **Out for final review.**
- Conduct stakeholder meetings and explain alternative approaches **– In development.**
- Seek legislative funding for a demonstration project. **This action item has been accomplished (HB 1358).**

Spills Cleanup Primer

Description of spills and spill cleanup

- Understanding spills
- How spills are regulated
- How infrastructure is built
- The remediation process
- Reclamation – the final step
- Projects done right

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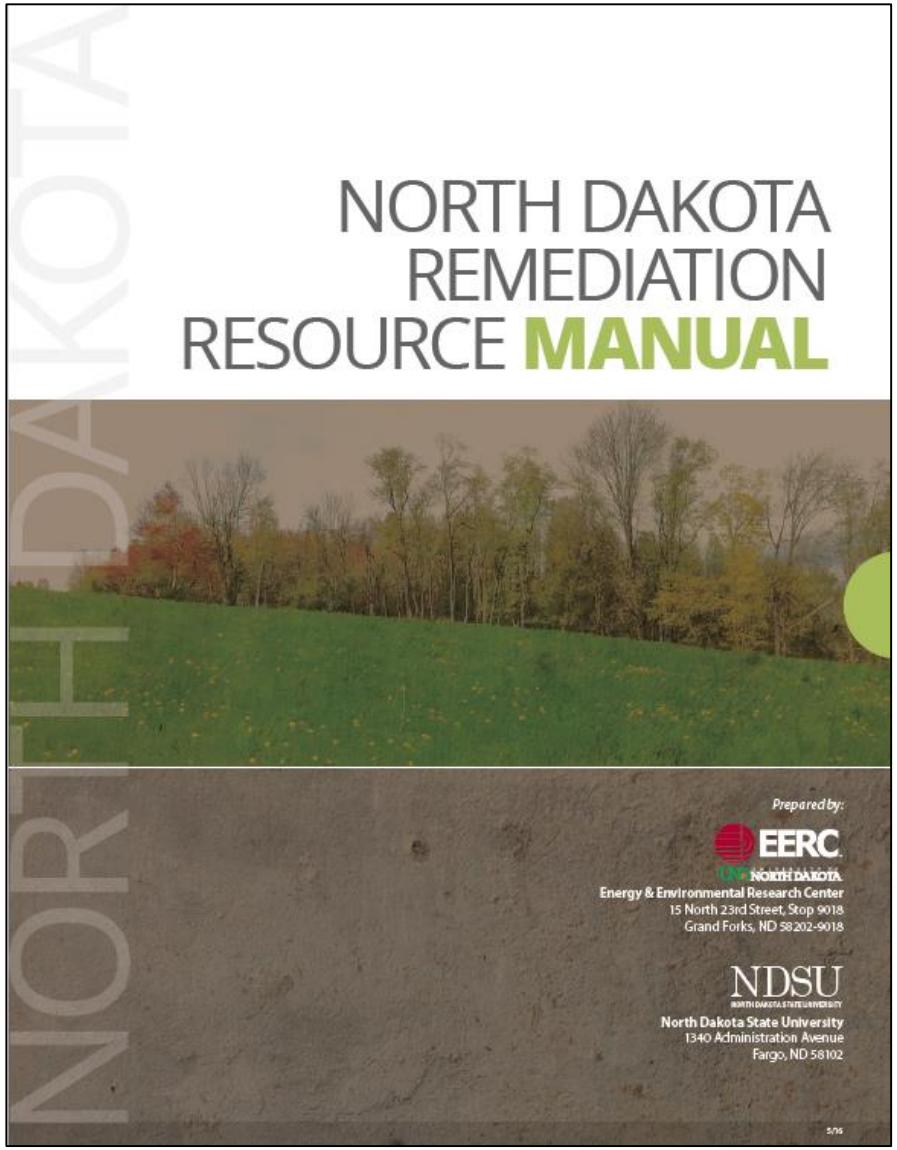
North Dakota Remediation Resource Manual

Conceptualized as a detailed description of the remediation and reclamation process

- North Dakota regulation
- Site and spill evaluation
- Hydrocarbon spill remediation
- Brine spill remediation
- Reclamation

Authored by the EERC, North Dakota State University (NDSU), and Industry Stakeholders

Currently in draft form



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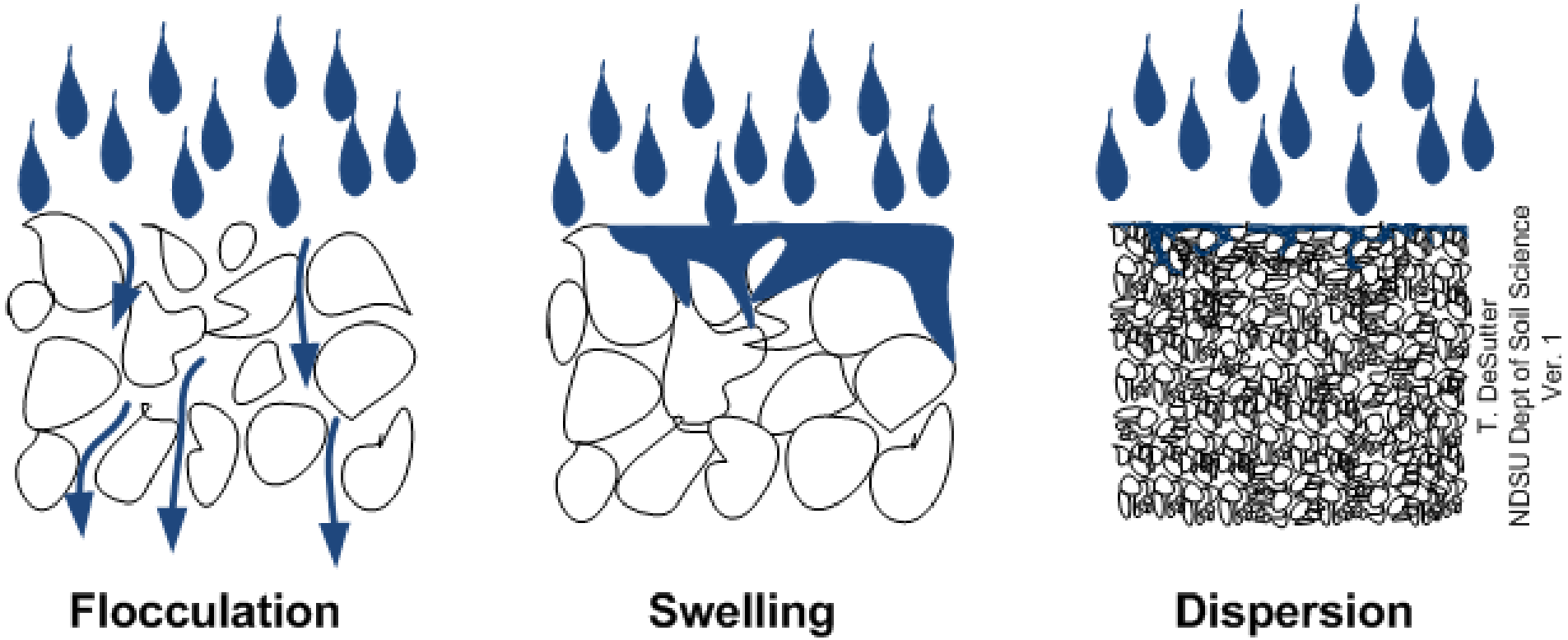
How Brine Impacts Soil

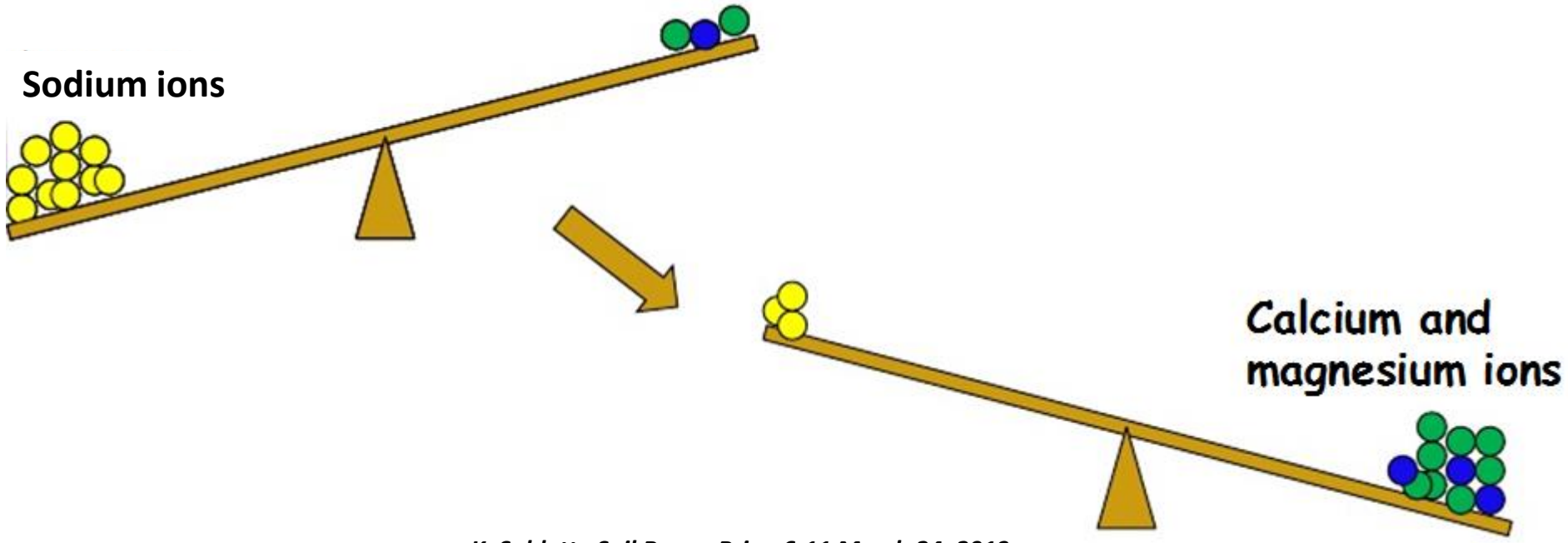
Swelling clay reduce water infiltration and percolation
this results in the inability of the soil to sustain vegetation



Remediation of Brine Impacted Soil

Brine impacted soil

Non-impacted Soil

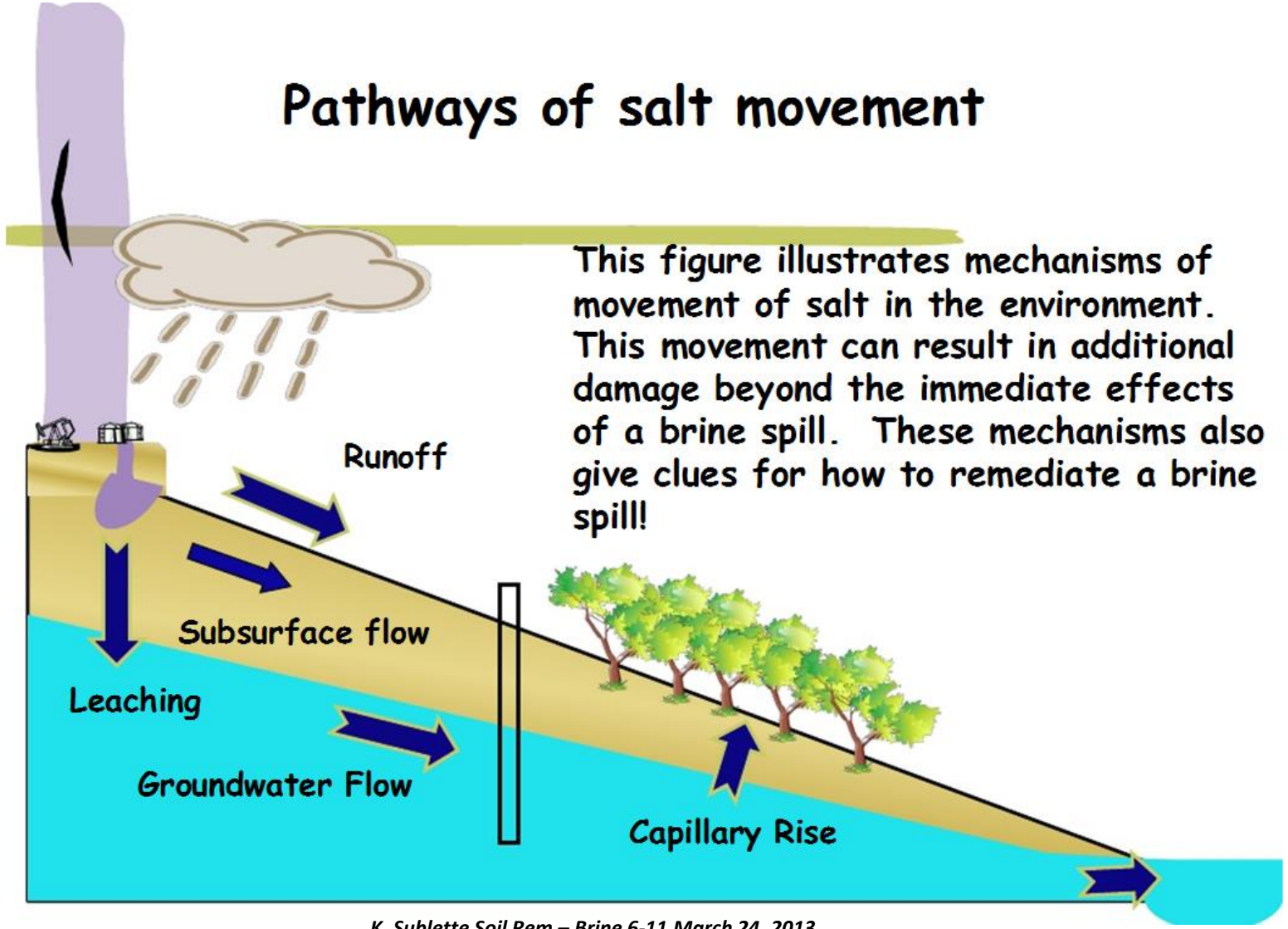


Landscape Position

Risk Assessment

- What is the landscape position?
- What is/are the soil texture(s)?
- What is the depth of useable water and sensitive receptors?
- What is the land use (range or cropland)?

Now that you understand the **Risk** you can better choose your treatment.

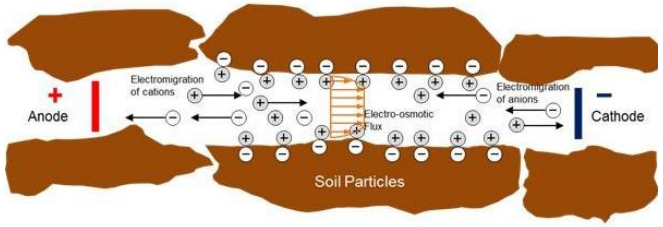


K. Sublette Soil Rem – Brine 6-11 March 24, 2013

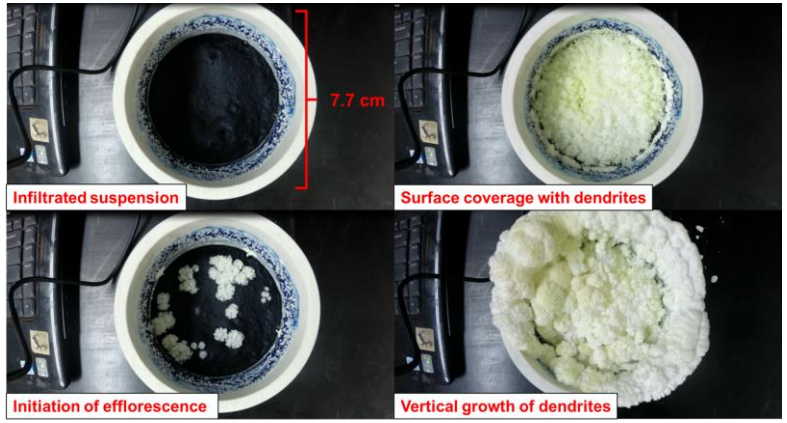
Brine Remediation Options

- Scoop and haul

- Amend soil with calcium
- Electrokinetic



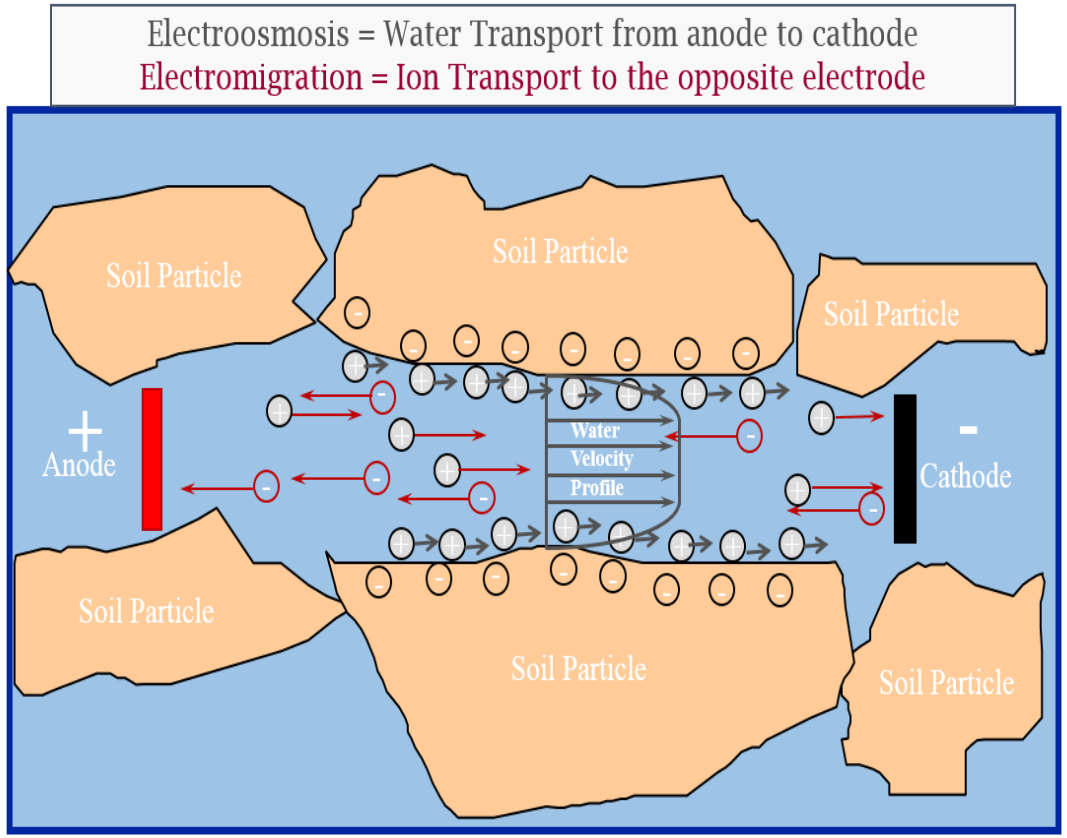
- Additional technologies
  - Crystallization inhibitors



Daigh and Klaustermeier. 2016. Agricultural and Environmental Letters 1:150013 (Open Access)

Electrokinetic Remediation

- Application of direct current (DC) electricity to the soil
- Polarized electrodes invoke movement of pore water and ions contained in the pore water, even in low permeability soils
- **Electroosmosis** – Movement of pore water and contaminants toward the cathode
- **Electromigration –** Migration of ionic species toward respective electrodes (anions toward anode, cations toward cathode) by electrical attraction



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Electrokinetic Applications

- Environmental Remediation
  - Heavy Metals (lead, chrome)
  - Organic Solvents (with in-situ ZVI)
  - Others (arsenic, nitrate, ISCO, bio-amendments)
- Dewatering/Stabilization
- Desalinization
- EK works in saturated & unsaturated zones

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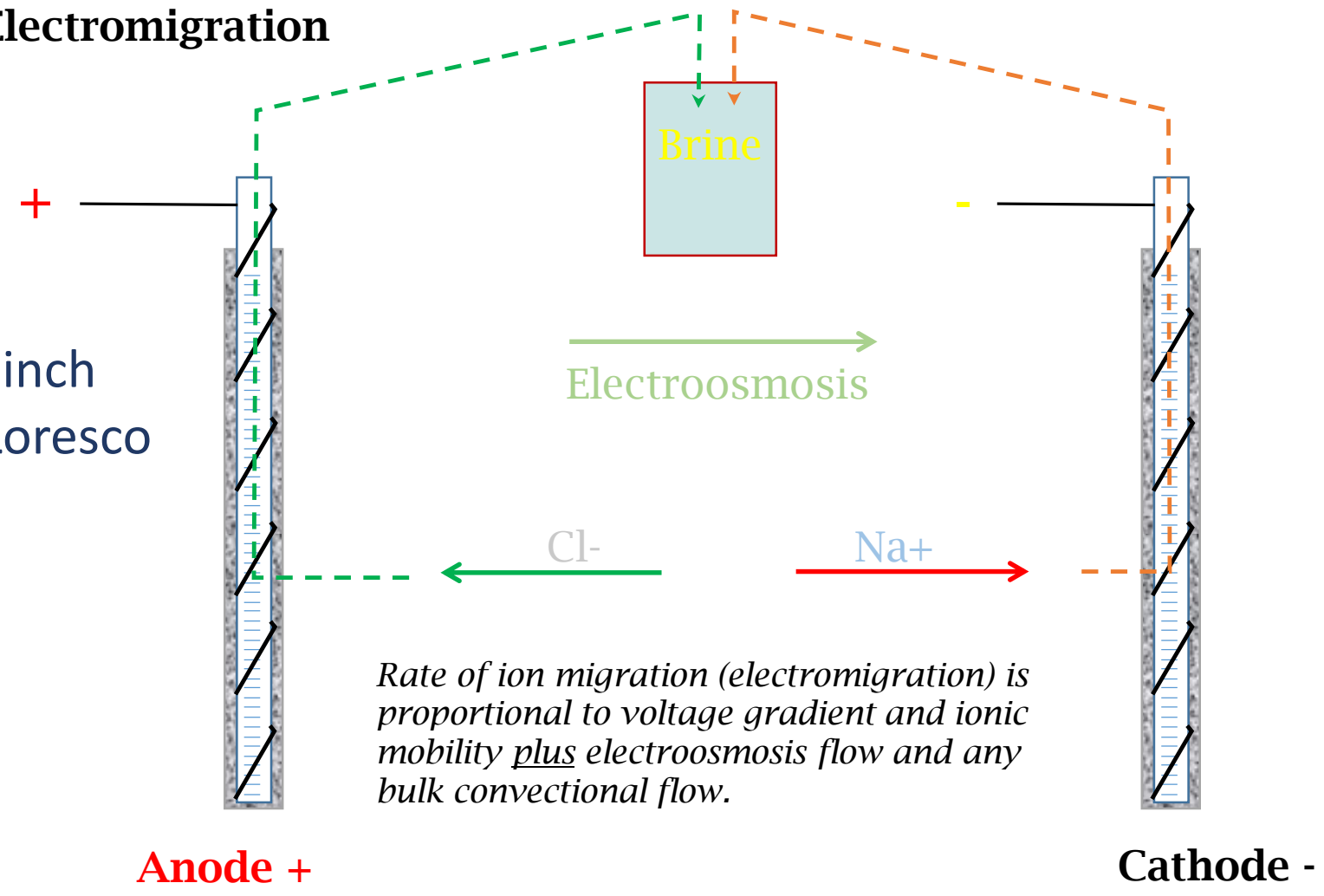
EK Desalinization Application

Wells = 3 inch bore hole with a 1.5 inch screened PVC well surrounded by Loresco coke.



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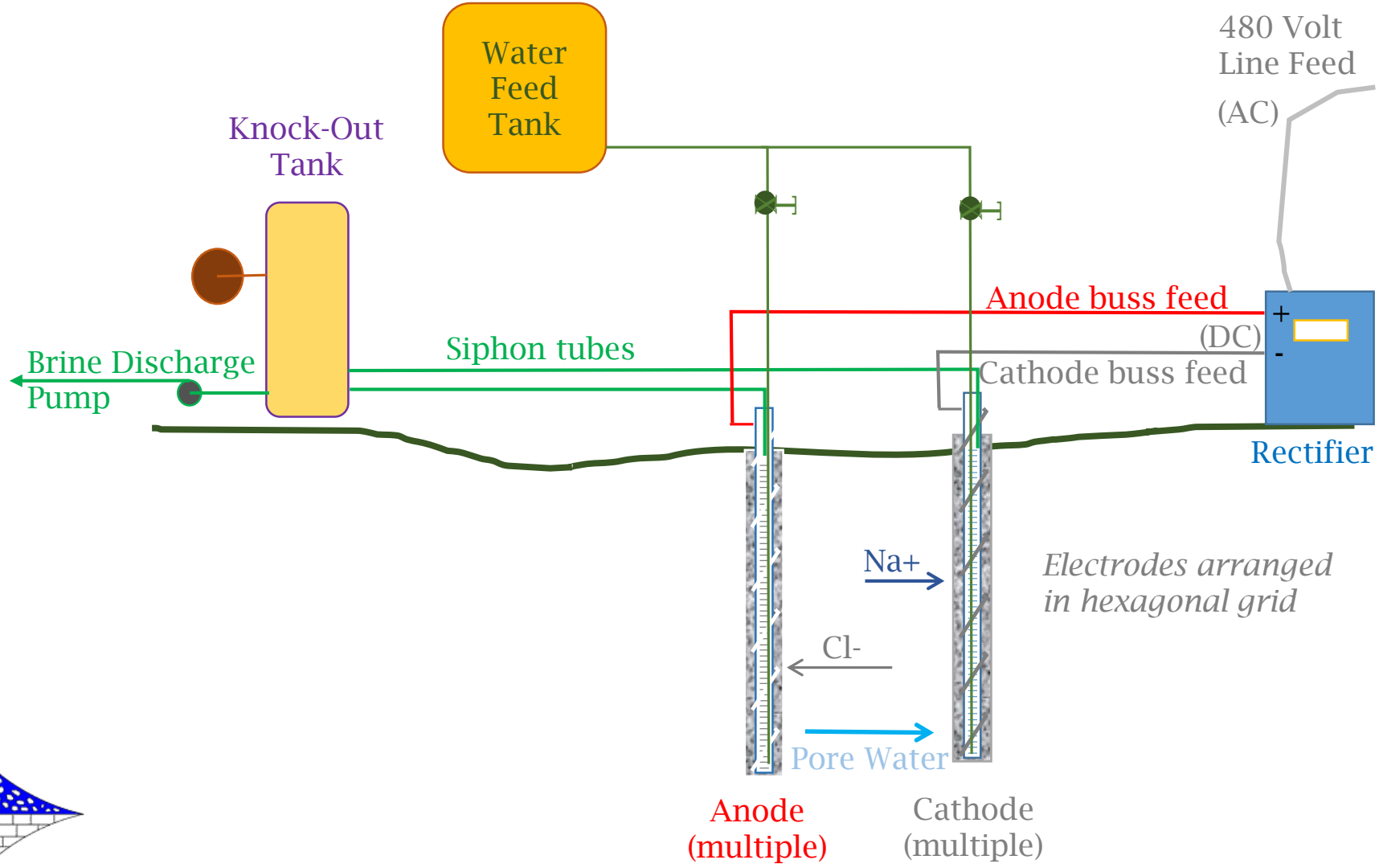
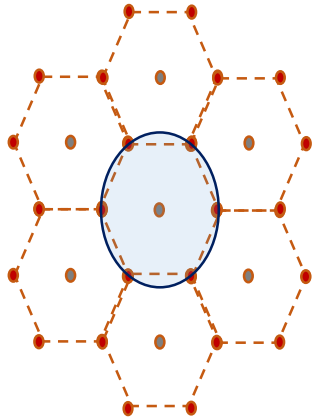
EK Desalinization Process



Electrodes arranged in hexagonal grid



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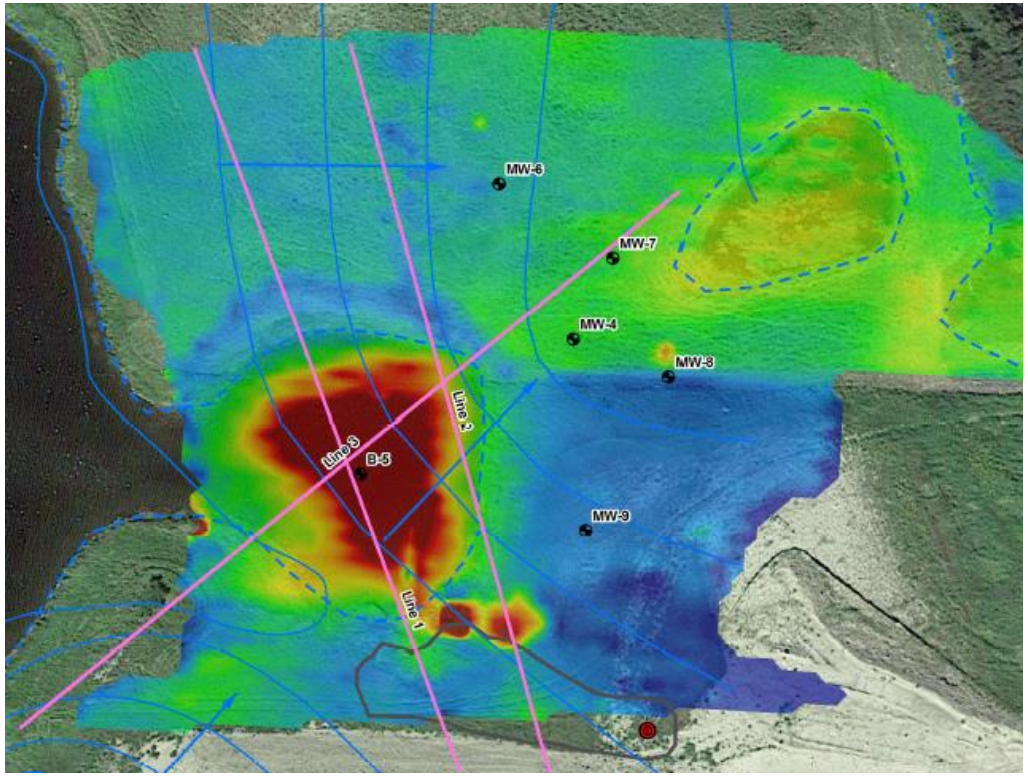
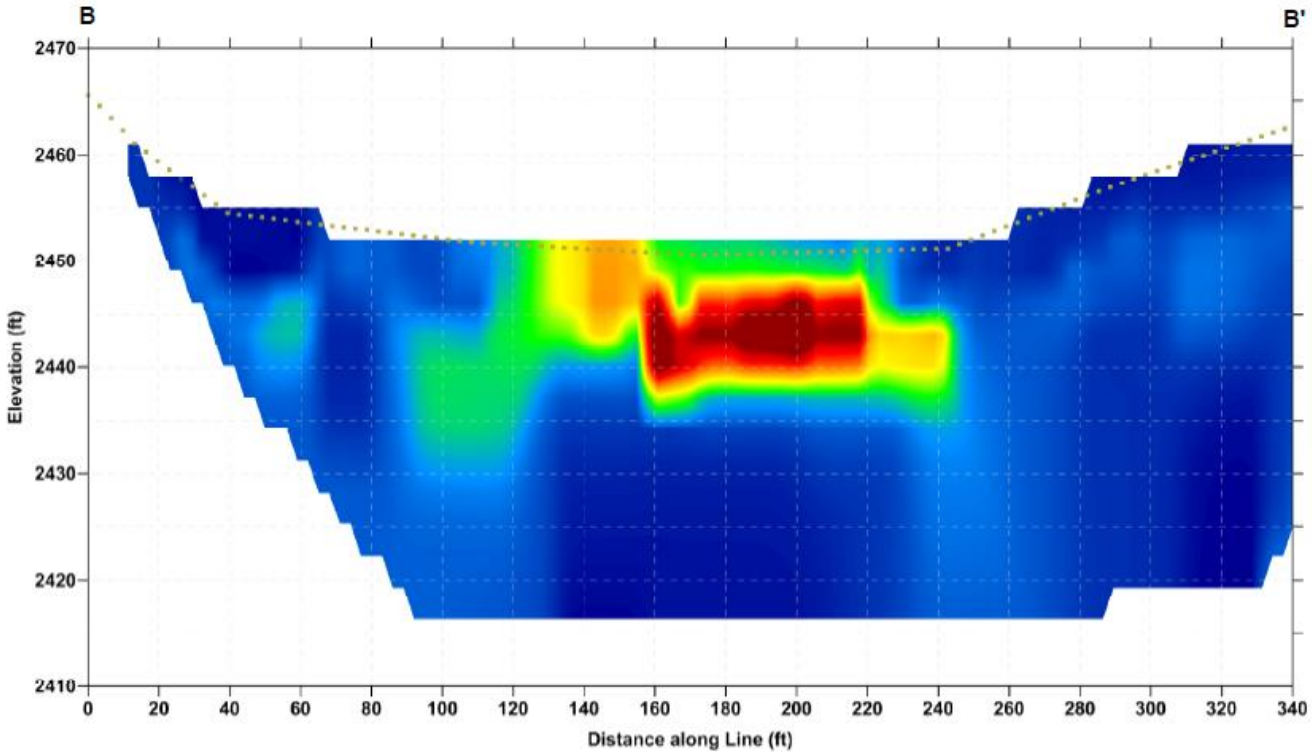
Case Study – Geophysical Characterization



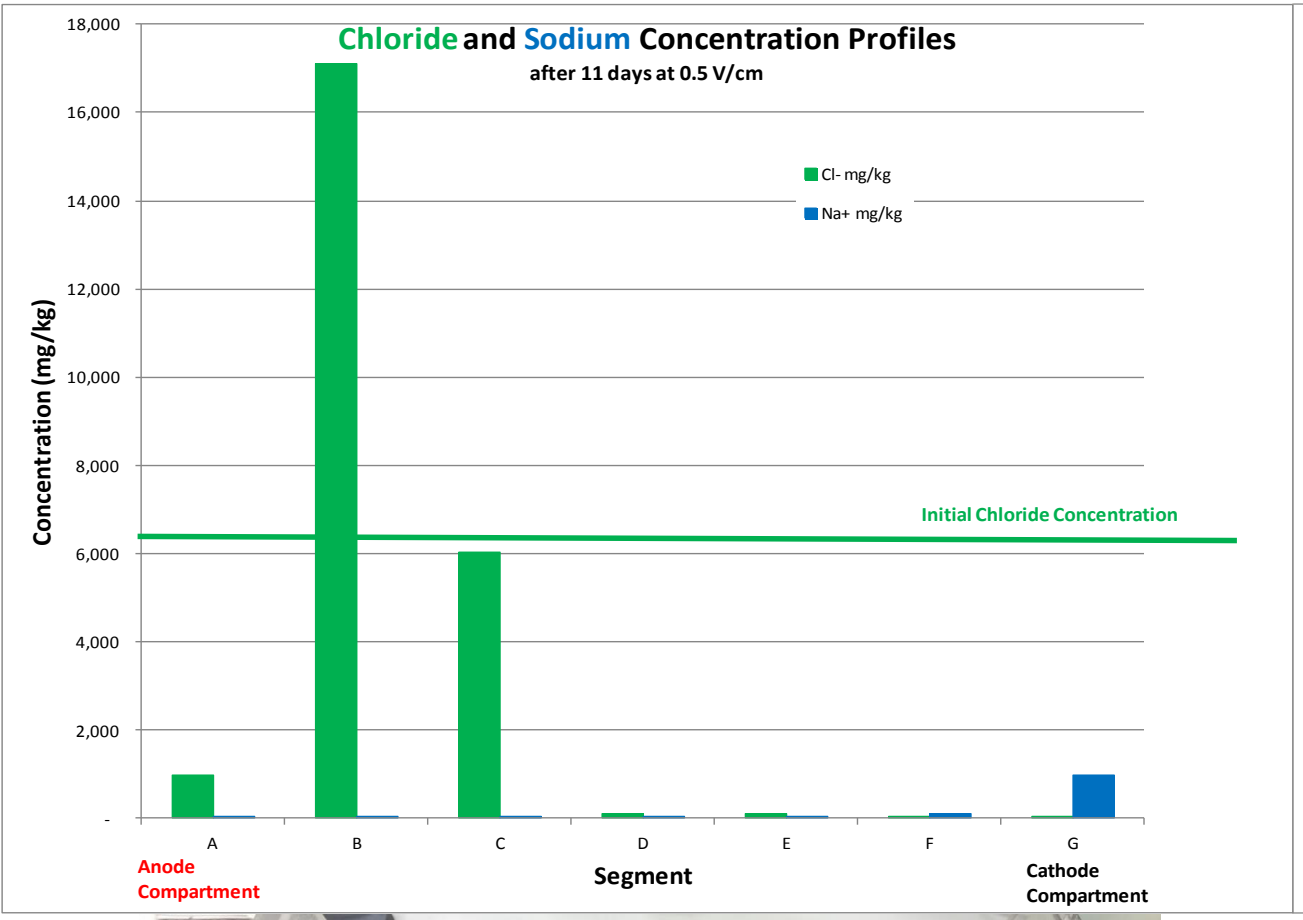
Electromagnetic Induction Survey - measure subsurface electrical conductivity.
- Use to direct bore placement

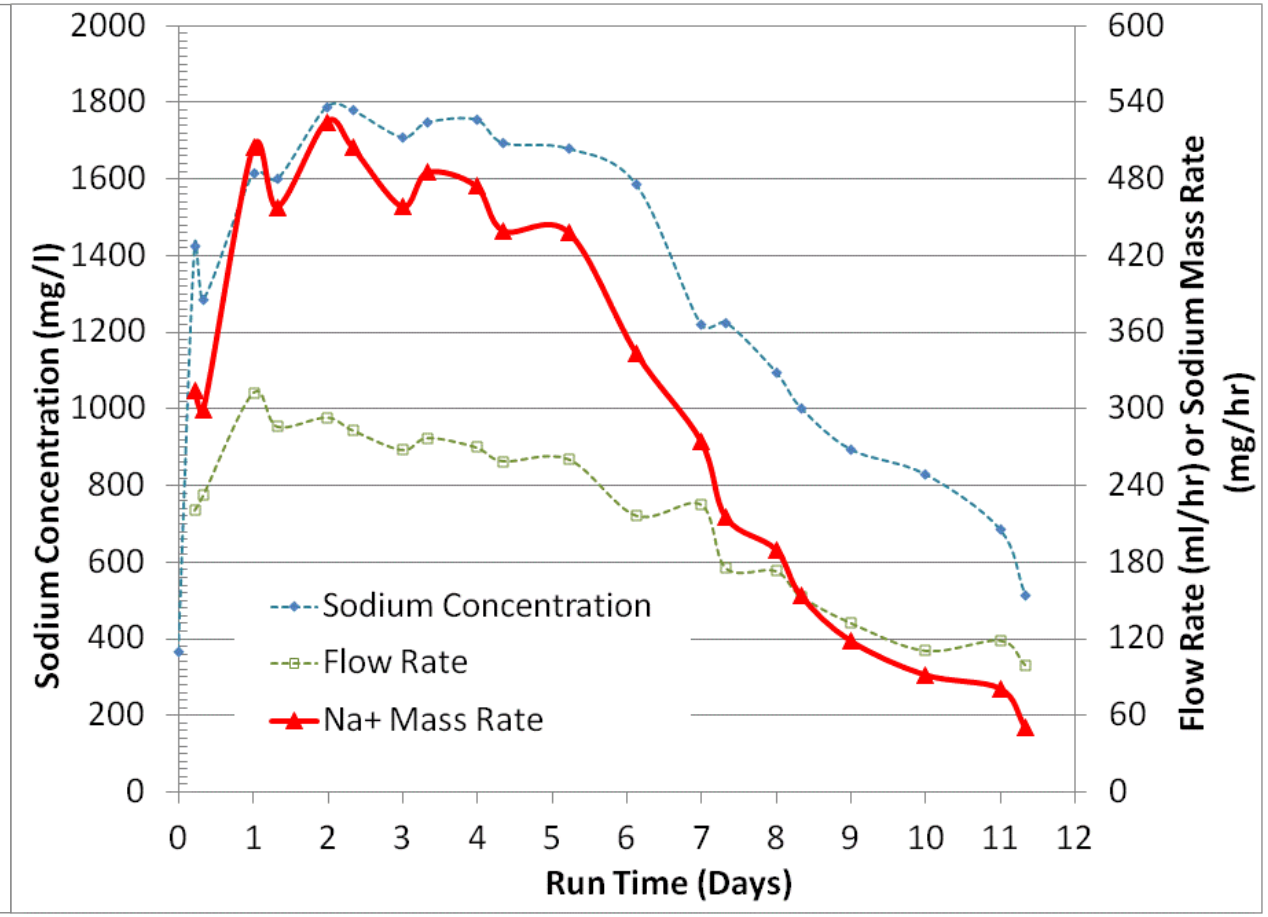
Electrical Resistivity Tomography – measures subsurface resistivity



VERTEX

Case Study - Electrokinetics Bench Testing Results





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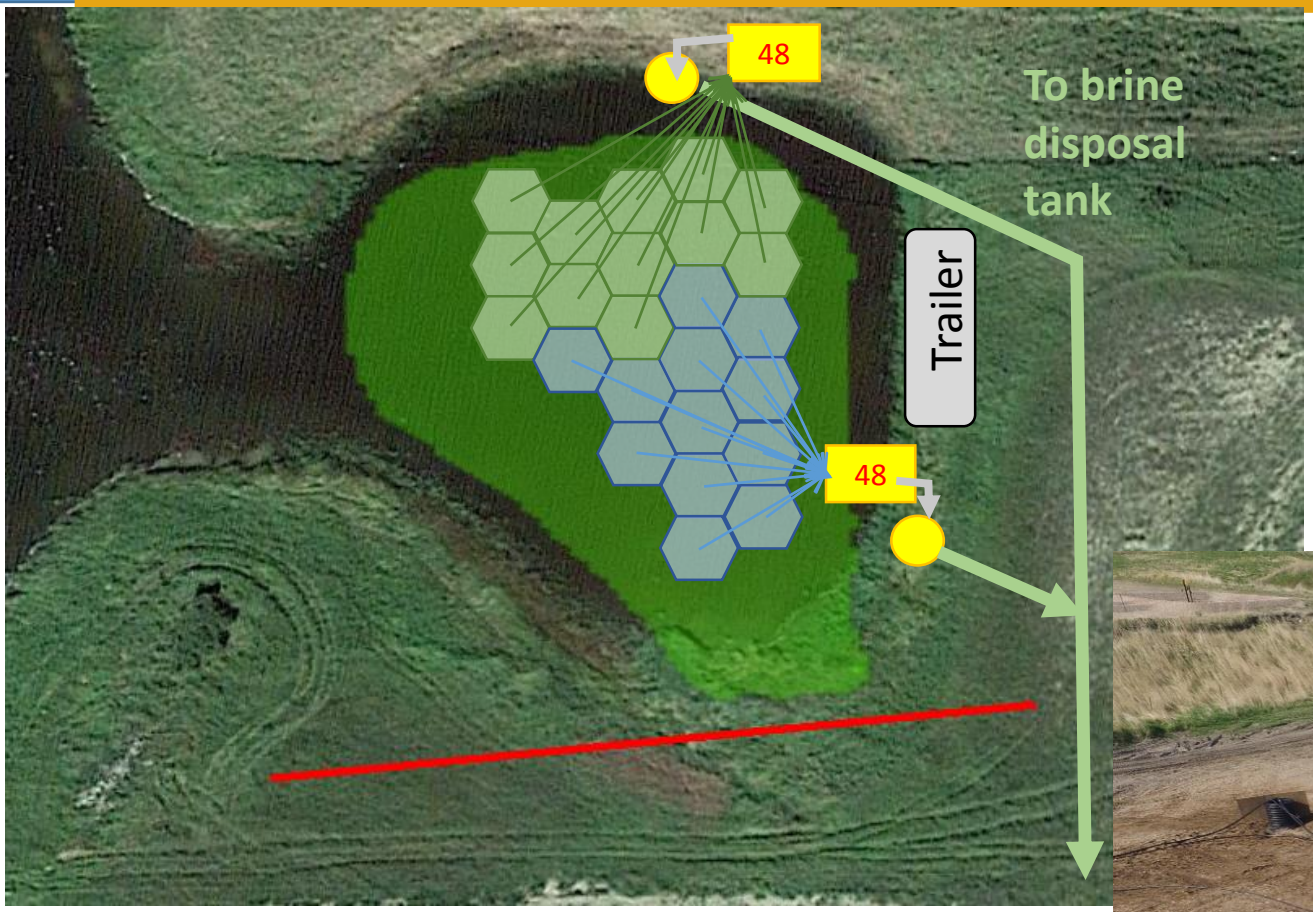
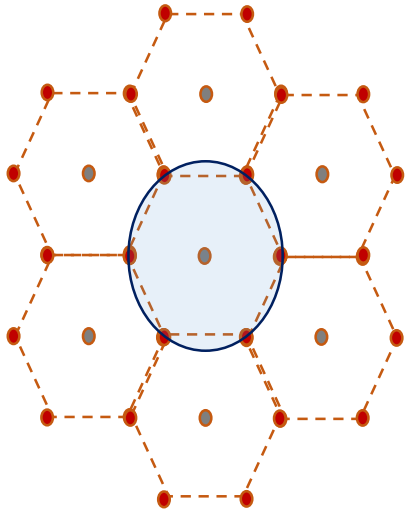
Case Study - Treatment - Electrokinetics





Hexagon of anodes surrounding a cathode

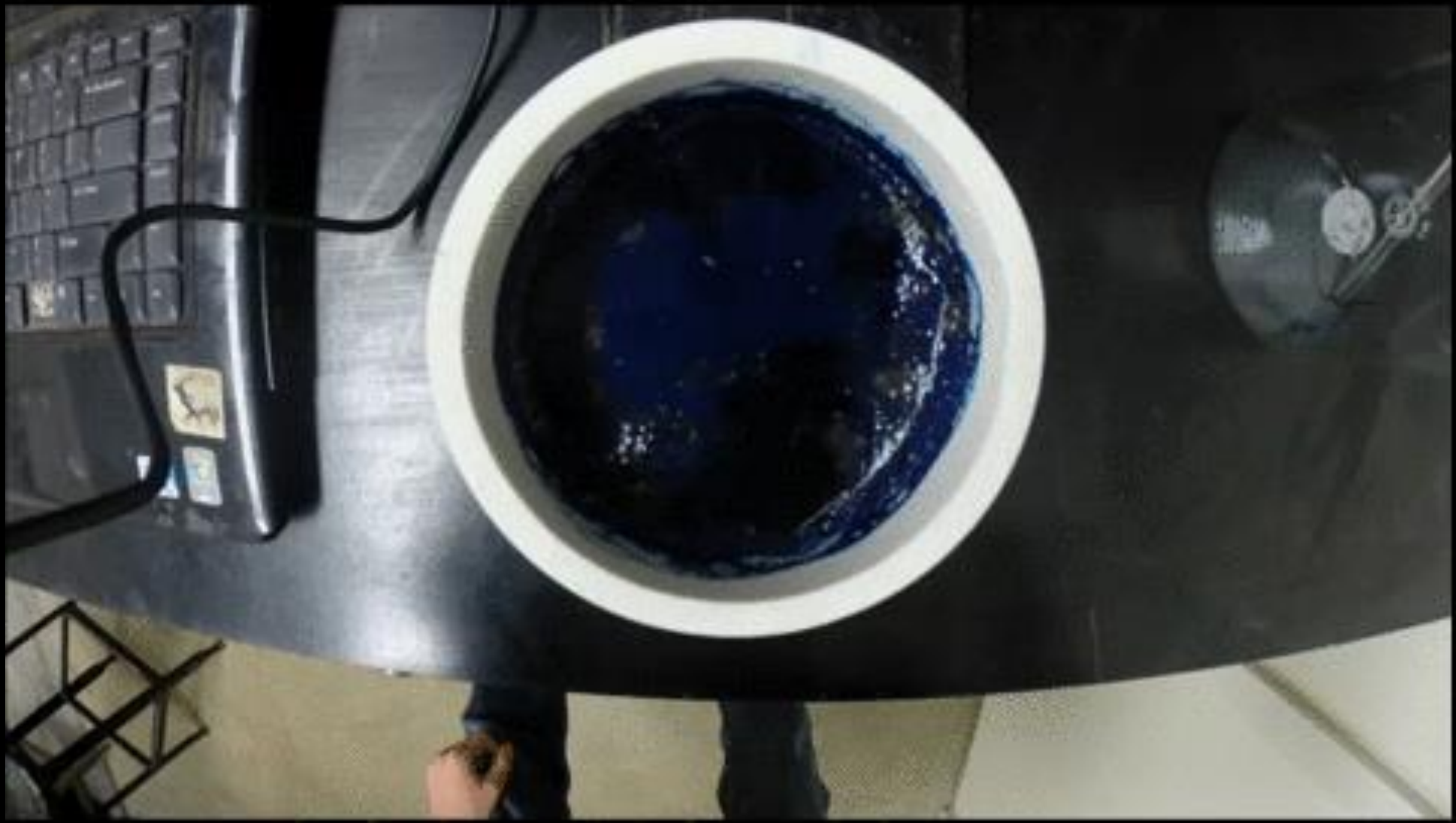
TERRAN

Can salts be recovered from the surface?

- **Employing crystallization Inhibitors (Ferric Hexacyanoferrate and ammonia) in brine remediation to harvest salts from the soil surface.**

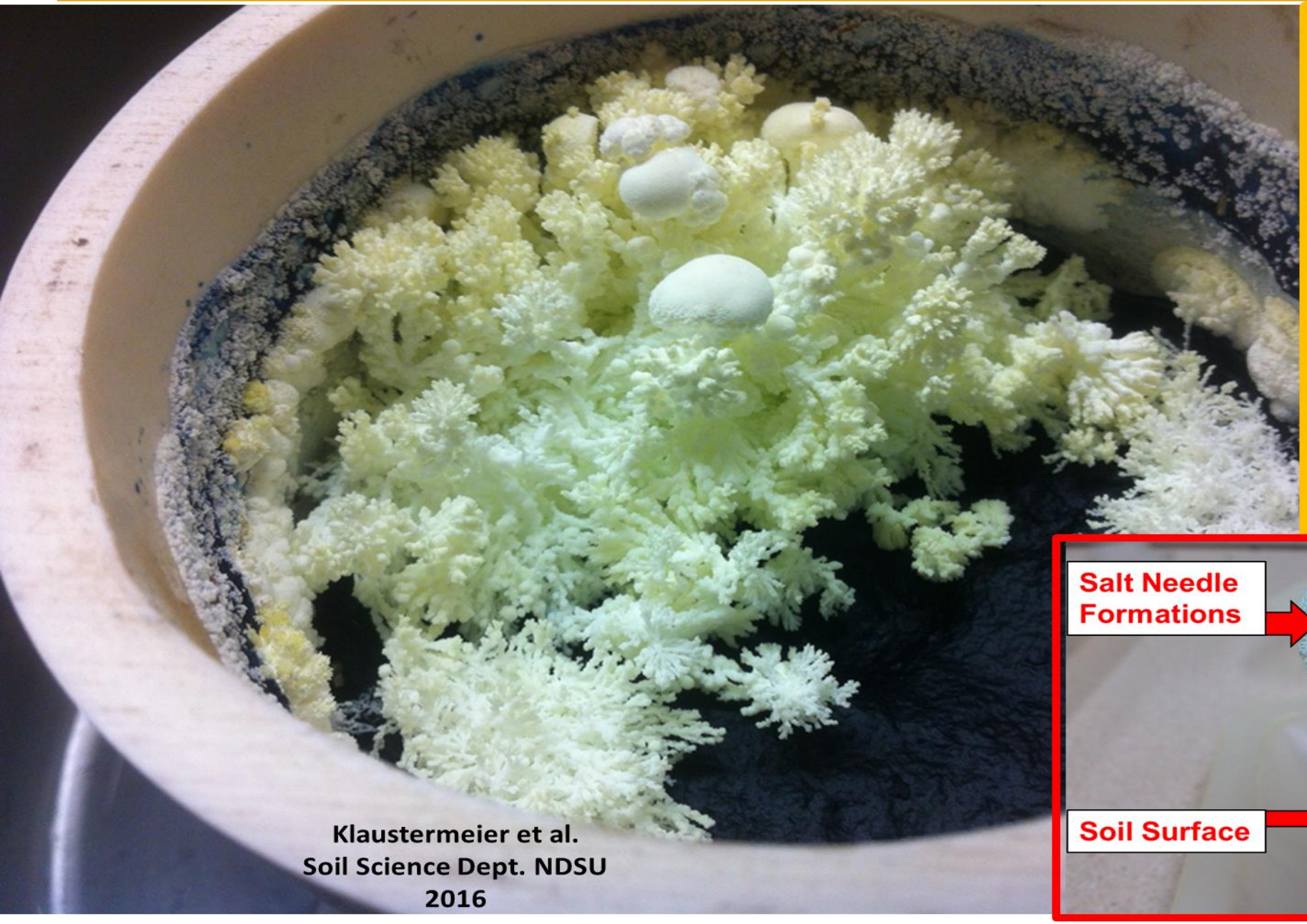
Reference - *Approaching Brine Spill Remediation from the Surface: A New In Situ Method*

Aaron L. M. Daigh* and Aaron W. Klaustermeier

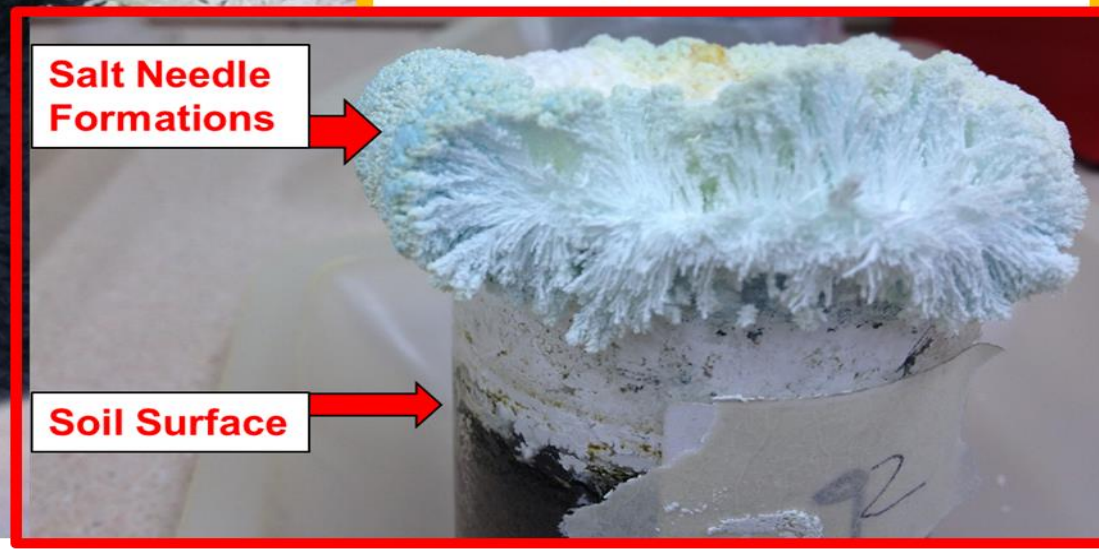


Klaustermeier and Daigh
Soil Science Dept. NDSU
2016

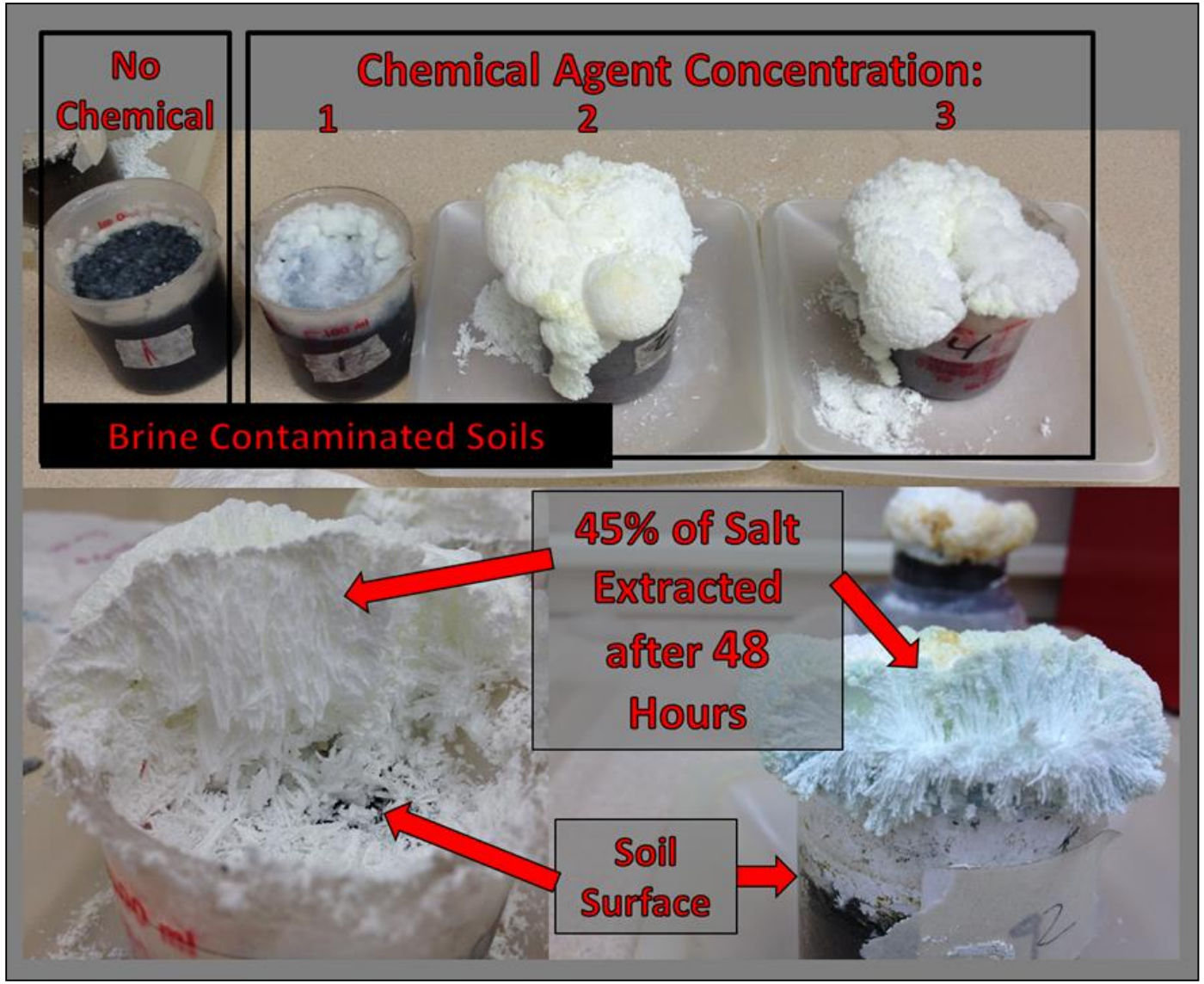
NDSU Technology



Cemented Salt Crust
without crystallization inhibitor



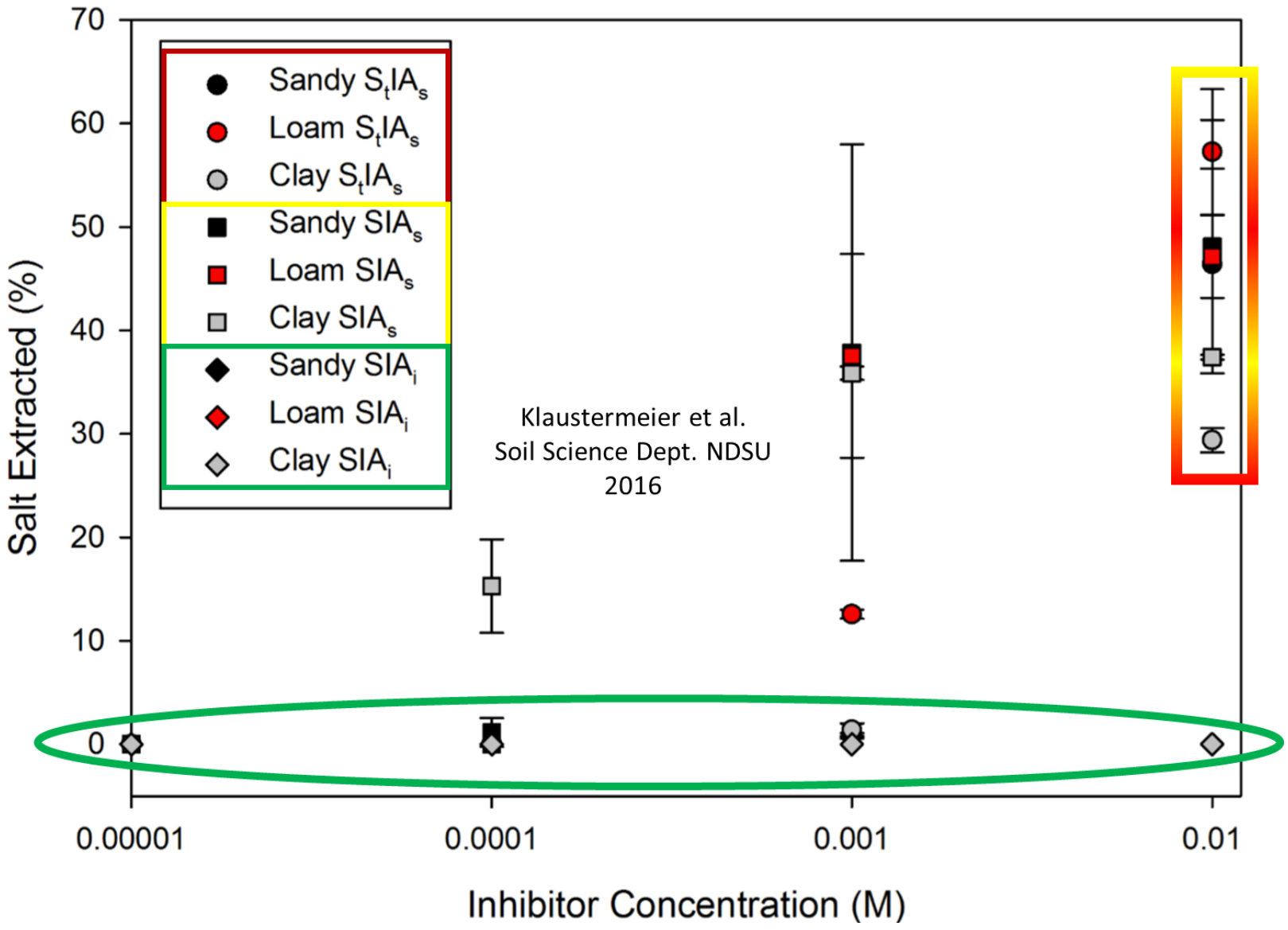
NDSU Technology



NDSU Study - Aaron Daigh 8-23-2015

NDSU Technology

- Test ran for 7 days
- 29 to 57% percent of salts recovered
- Soils with more sand had highest salt recovery



Summary

- The NDPC Brine Task force is developing sustainable remediation processes in North Dakota.
- Industry is employing proven science and the latest technologies in the remediation process of spills.
- Despite these efforts there is still room for improvement.

1997 Pipeline Release

Initial Soil Analysis EC 27.0 mS/cm
Native Soil Analysis EC 0.8 mS/cm

Final 2001

Soil Analysis EC 1.0 mS/cm

2000 Pipeline Release

Final 2007

Initial Soil Analysis EC 17.9 mS/cm
Native Soil Analysis EC 0.5 mS/cm

Soil Analysis 1.5 mS/cm

2015 Illegal Disposal of Brine

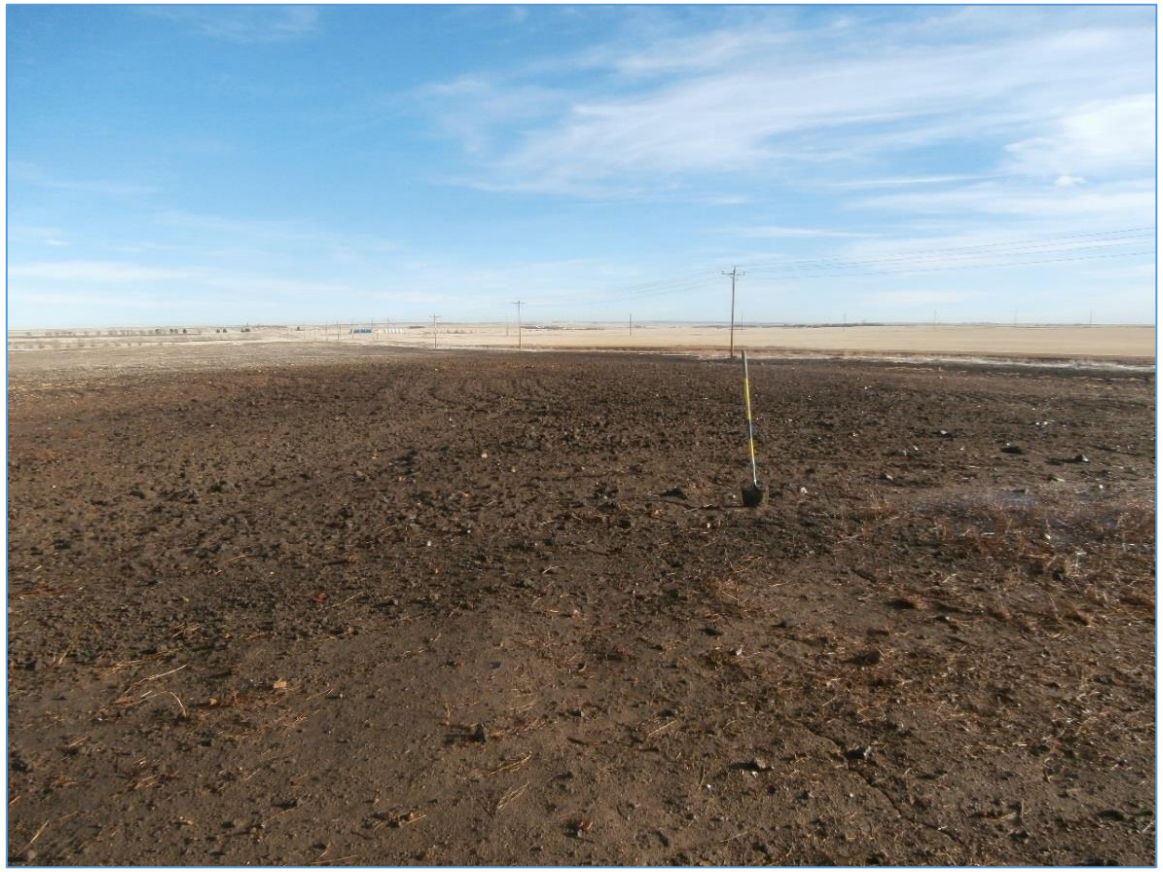
Final 2015

Initial Soil Analysis EC 16.1 mS/cm
Native Soil Analysis EC 1.1 mS/cm

Final Soil Analysis EC 2.7 mS/cm

Lightning Strike of a SW Disposal in 2014

2014



2015

Brine Remediation References:

- Strategies for Addressing Salt Impact of Produced Water Releases to Plants, Soil, and Groundwater. API, September 2006 Publication 4758. www.api.org/produced_water.
- Remediation of Salt-Affected Soils at Oil and Gas Production Facilities. Health and Environmental Science Department. October 1997. API Publication 4663
- A Guide for Remediation of Salt/Hydrocarbon Impacted Soil. North Dakota Industrial Commission. Department of Mineral Resources. Bismarck, ND. NDIC website.
- Salt Contamination Assessment and Remediation Guidelines. Environmental Sciences Division Environmental Service. May 2001. http://environment.gov.ab.ca/info/library/6144.pdf
- Soil Remediation for the Petroleum Extraction Industry. 1998. Lloyd E. Deuel.
- Daigh. Aaron L.M. and A.W Klaustermeier. Approaching Brine Spill Remediation from the Surface: A New In Situ Method. Agricultural & Environmental Letters. February 9, 2016.