Remediation of Orphan Well Sites: Success is in the Science

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Santa Fe, New Mexico
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The need to plug abandoned and orphan wells

- Prevent emissions of greenhouse gases (methane, CO_2), and VOCs
- Prevent surface discharges of brine and hydrocarbons
- Prevent groundwater contamination

Restoring the site

- Remove and dispose of surface equipment
  - Tanks, piping, separators
    - Complicated by NORM
  - Concrete pads
    - Bury?

Restoring the site

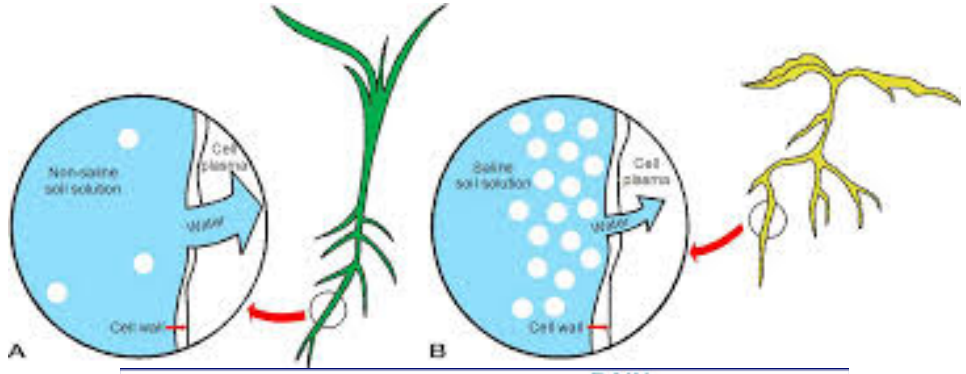
- Remediate damage to the land
  - Hydrocarbons
    - Highly weathered material excavated for disposal
    - Liquids
      - Surface: bioremediation
        - Help out Mother Nature with aeration, water, and nutrients
      - Deeper: ISCO
        - Caution: Use Ca-based oxidant

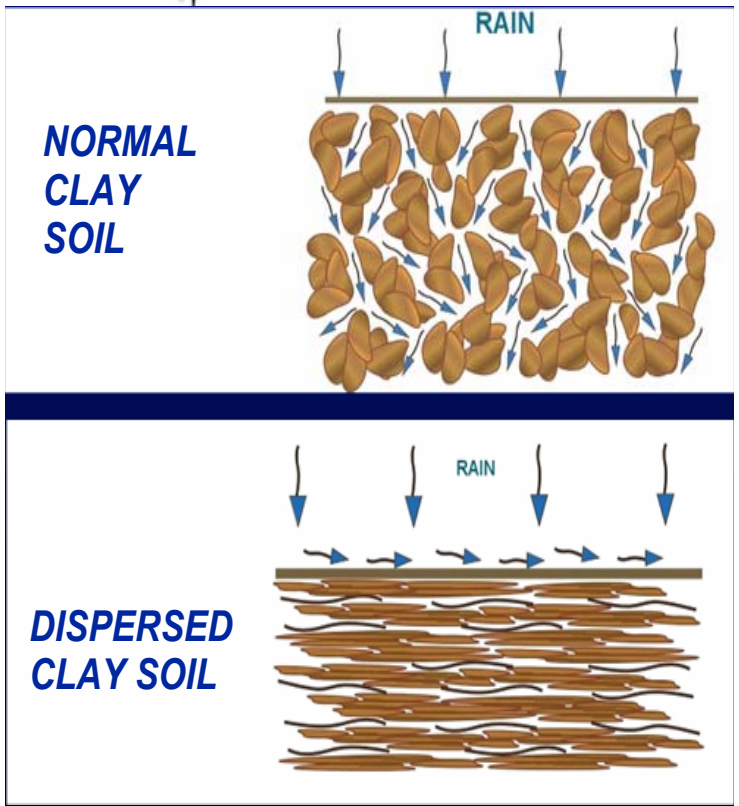
Restoring the site

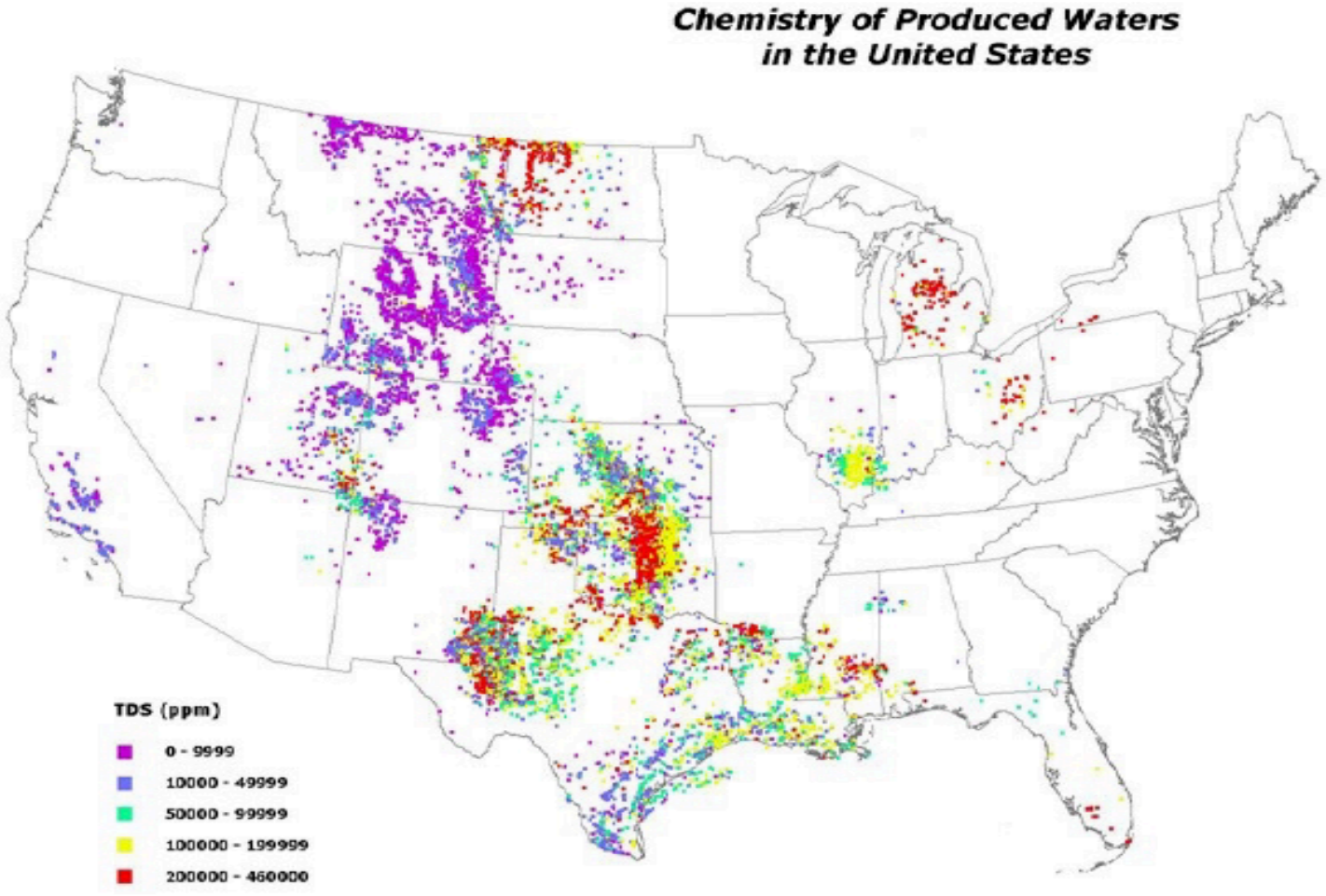
- Remediate damage to the land
  - Brine
    - In latter stages of production the well was producing many times more produced water than oil
    - Historical releases of brine typically the #1 obstacle to restoring some productive value to the land after plugging and removal of surface equipment
    - Brine is highly mobile in the environment and has likely moved beyond the sites of original releases, horizontally and vertically

Restoring the site: Brine

- The impact of brine contamination
  - Salinity
    - Inhibition of plant growth
    - Inhibition of soil biota
  - Sodicity
    - Destruction of soil structure
    - Clay dispersal
      - Exchange of Na^{+} for Ca^{+2} on clays lattice
    - Hardpan formation
    - Severe inhibition of water infiltration
    - Erosion





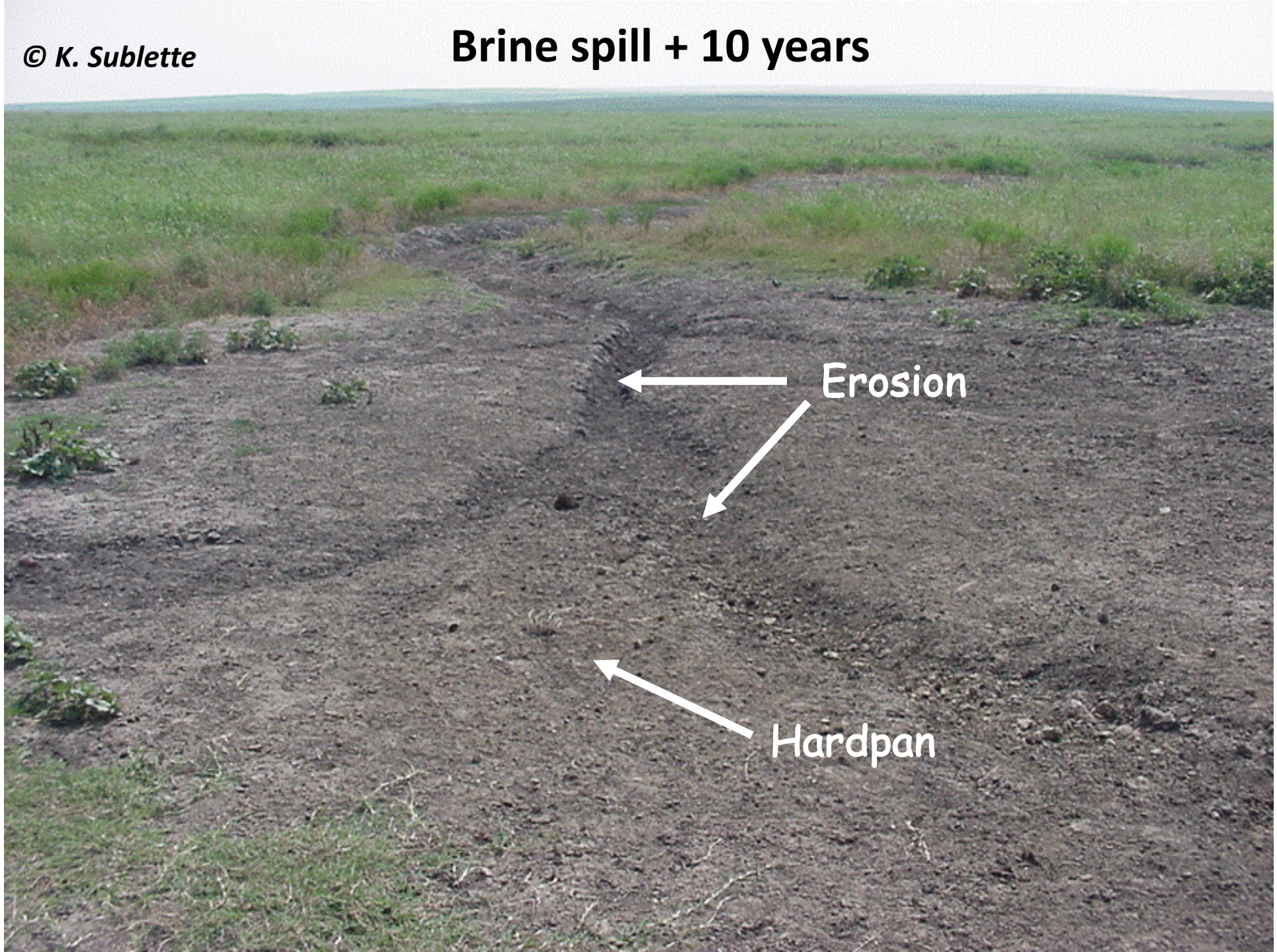


water.usgs.gov/orh/nrwww/Otten.pdf

Salinity and sodicity effects are dependent on mass of salt introduced to soil

Mass of salt = TDS X Volume

Brine spill + 10 years




© K. Sublette
Brine spill 60+ years

Restoring the site: Brine remediation

- Addressing misconceptions
  - You cannot destroy or degrade salt (you can only move it for collection or dispersal)
    - There are no microorganisms that will “eat” salt
  - There are no amendments that will permanently bind salt
  - There is no remediation of brine spills without water except for dig and haul
  - There are no magic potions for fast results
  - Scratching the ground, spreading gypsum and walking away is a recipe for failure
  - Short term revegetation is not success, long-term beneficial revegetation is the measure of success

Restoring the site: Brine remediation
Success is in the science

- Site characterization
  - If you don’t take the time to understand the distribution of salt onsite and offsite you are just guessing; what you don’t know will come back to bite you
  - Best course of action for historic sites:
    - Non-invasive geophysical survey of subsurface conductivity
      - Electromagnetic induction profiling (EM)
        - Choice of instrument determines depth of investigation
        - Provides cumulative measure of conductivity in 2D with limited information about depth of contamination
      - Resistivity survey
        - Gives conductivity vs. depth information
    - Soil coring and analysis for ground-truthing of geophysical data, salinity and sodicity

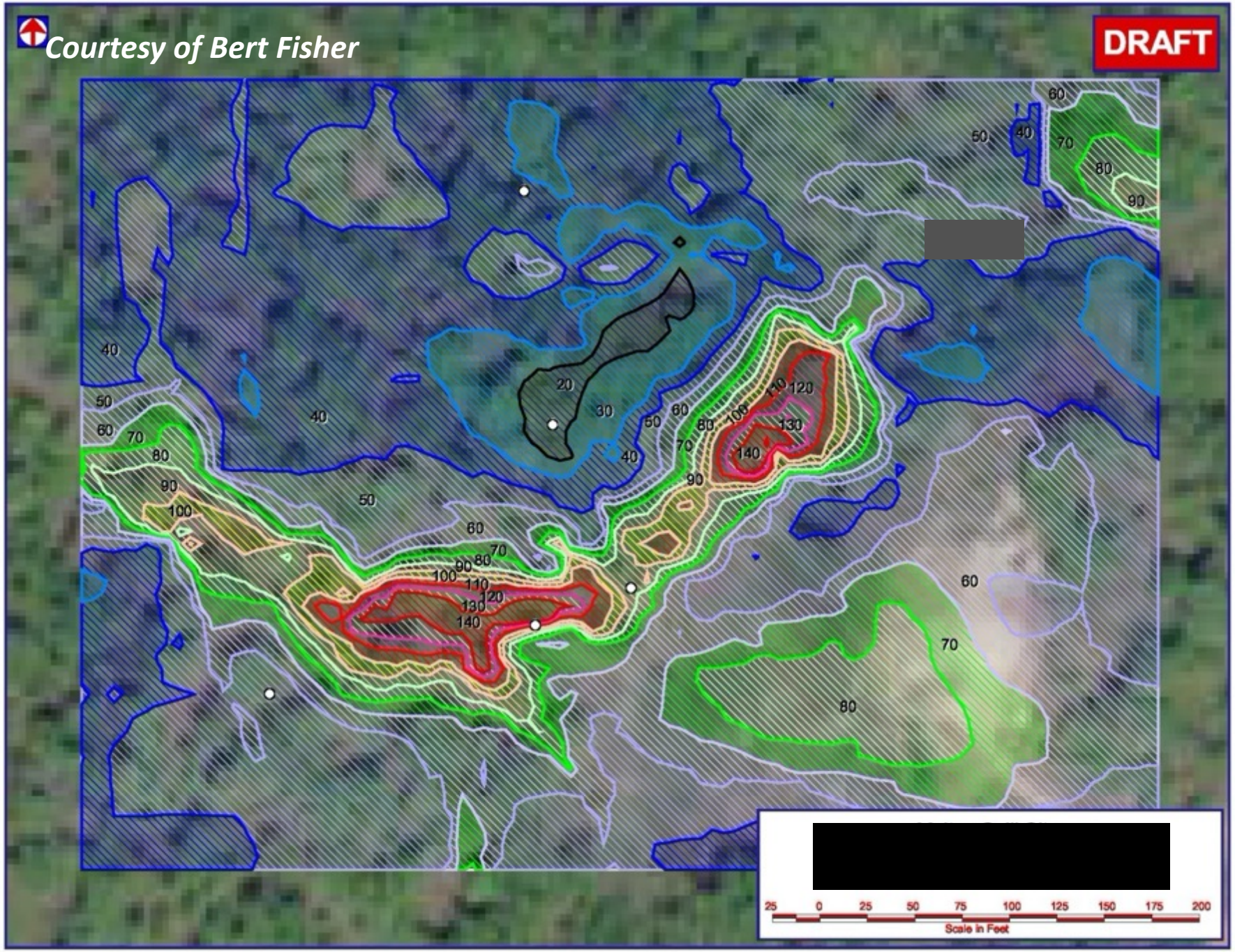
Geophysical methods
Electromagnetic induction profiling (EM)

Depth interval (ft)	H Response (%)	V Response (%)
0-3	38	11
3-6	20	18
6-9	12	15
9-12	5	12
12-15	5	4
15-18	4	6

Geonics Tech Note TN-6 (1980)

EM-31

magara.ca/services/em31-surveys/


Courtesy of Bert Fisher
DRAFT
[redacted]
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25 0 25 50 75 100 125 150 175 200
Scale in Feet

Ground truthing establishes vertical distribution of salt contamination

An ag gives more information for less money

Soil, Water & Forage Analytical Laboratory

Oklahoma State University Division of Agricultural Sciences and Natural Resources
045 Agricultural Hall
Stillwater, OK 74078
E-mail: soiltesting@okstate.edu
Website: www.soiltesting.okstate.edu

SOIL SALINITY REPORT

SUBLETTE CONSULTING, INC
8802 E. 98TH ST

TULSA, OK 74133

Name :

Location :

Lab ID No.: : 663008
Customer Code : [illegible]2
Sample No. : 805
Received : 9/19/2012
Report Date : 9/25/2012

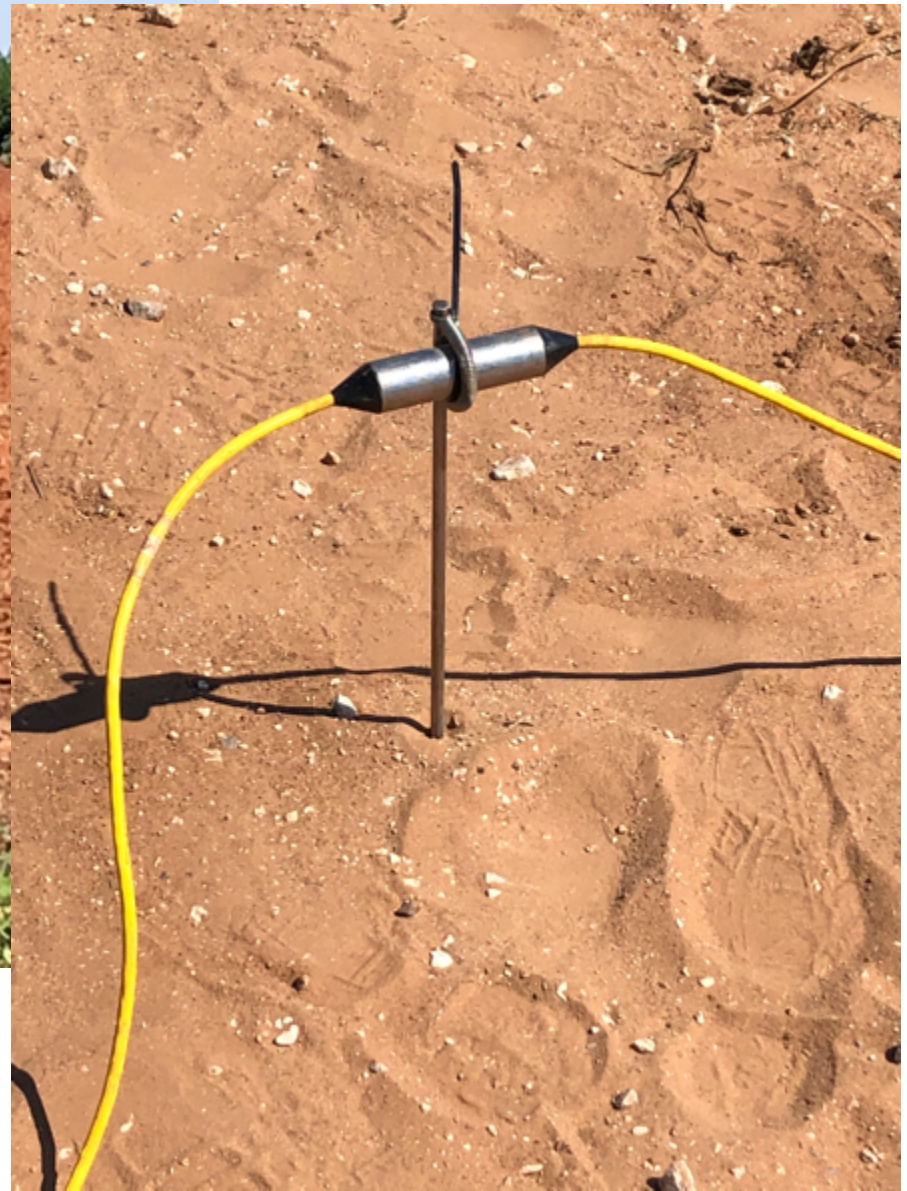
Test Results for Comprehensive Salinity(Saturated paste extraction)

Cations		Anions		Other	
Sodium (ppm)	4922.1	Nitrate-N (ppm)	<1	pH	7.4
Calcium (ppm)	2914.9	Chloride (ppm)	13646.7	EC (µmhos/cm)	34900
Magnesium (ppm)	570.5	Sulfate (ppm)	622.4	Texture	Coarse
Potassium (ppm)	105	Boron (ppm)	0.3		
		Bicarbonate (ppm)	309.7		

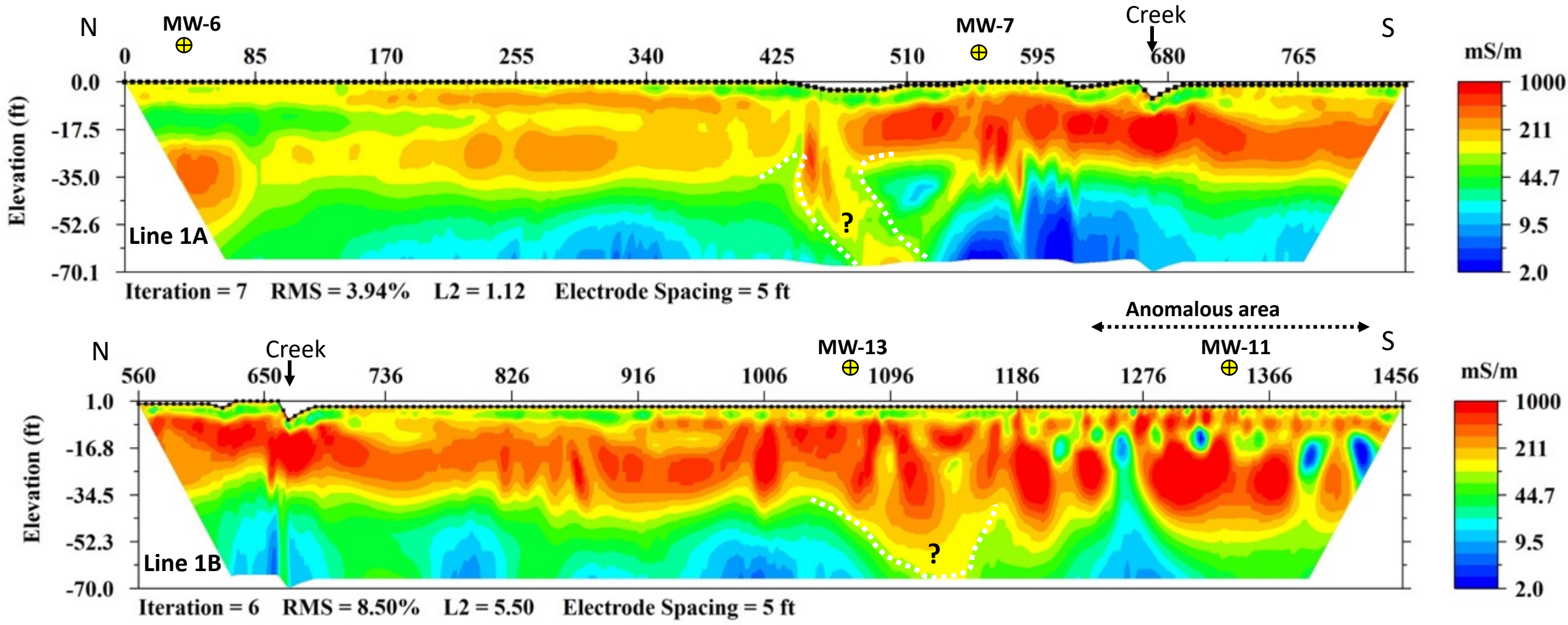
Derived Values		Derived Values (cont'd)	
Total Soluble Salts (TSS in ppm)	23091.4	Exchangeable Sodium Percentage (ESP)	23.5
Sodium Adsorption Ratio (SAR)	21.8	Exchangeable Potassium Percentage (EPP)	6.1
Potassium Adsorption Ratio (PAR)	0.3		

$55

Distance between electrodes determines depth of resistivity measurements.



Resistivity = (1/EC)

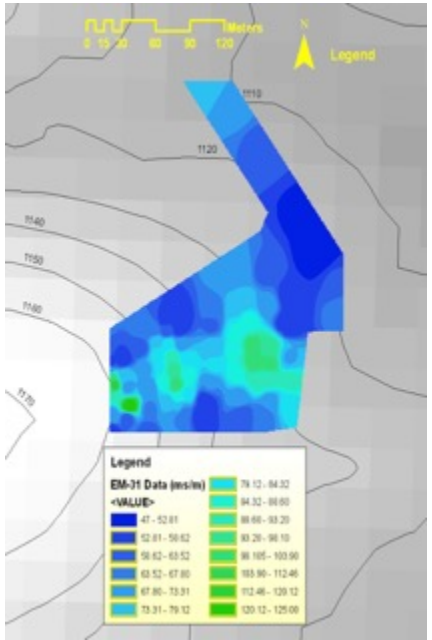

N
MW-6
MW-7
Creek
S
0
85
170
255
340
425
510
595
680
765
mS/m
1000
211
44.7
9.5
2.0
Elevation (ft)
0.0
-17.5
-35.0
-52.6
-70.1
Line 1A
?
Iteration = 7 RMS = 3.94% L2 = 1.12 Electrode Spacing = 5 ft
Anomalous area
N
Creek
MW-13
MW-11
S
560
650
736
826
916
1006
1096
1186
1276
1366
1456
mS/m
1000
211
44.7
9.5
2.0
Elevation (ft)
1.0
-16.8
-34.5
-52.3
-70.0
Line 1B
?
Iteration = 6 RMS = 8.50% L2 = 5.50 Electrode Spacing = 5 ft

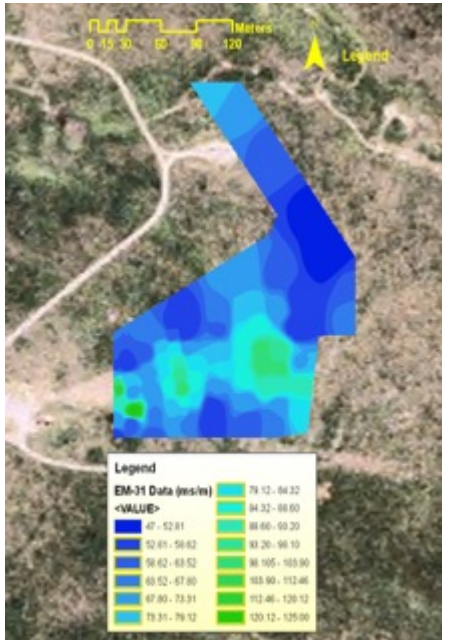
Restoring the site: Brine remediation
Ex situ vs. in situ

- Typically, two types of brine-impacted areas at historic sites
  - Pads and tank batteries
    - Original soil profile missing
    - *Ex situ* or dig-and-haul may be only option
    - Quality of replacement soil is very important to successful restoration of these areas
      - Without attention to chemical, physical and biological properties of replacement soil you can create an ecological island

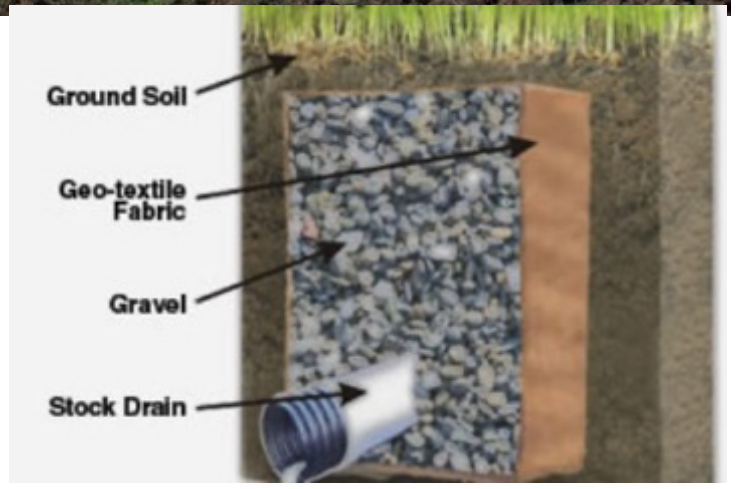
Restoring the site: Brine remediation
Ex situ vs. in situ

- Typically two types of brine-impacted areas in historic site, cont.
  - Originally productive soil brine release or runoff from a primary brine spill
    - *In situ* remediation preferred
    - Minimally disrupts soil integrity, generally results in more productive plant communities comparable to pre-spill conditions





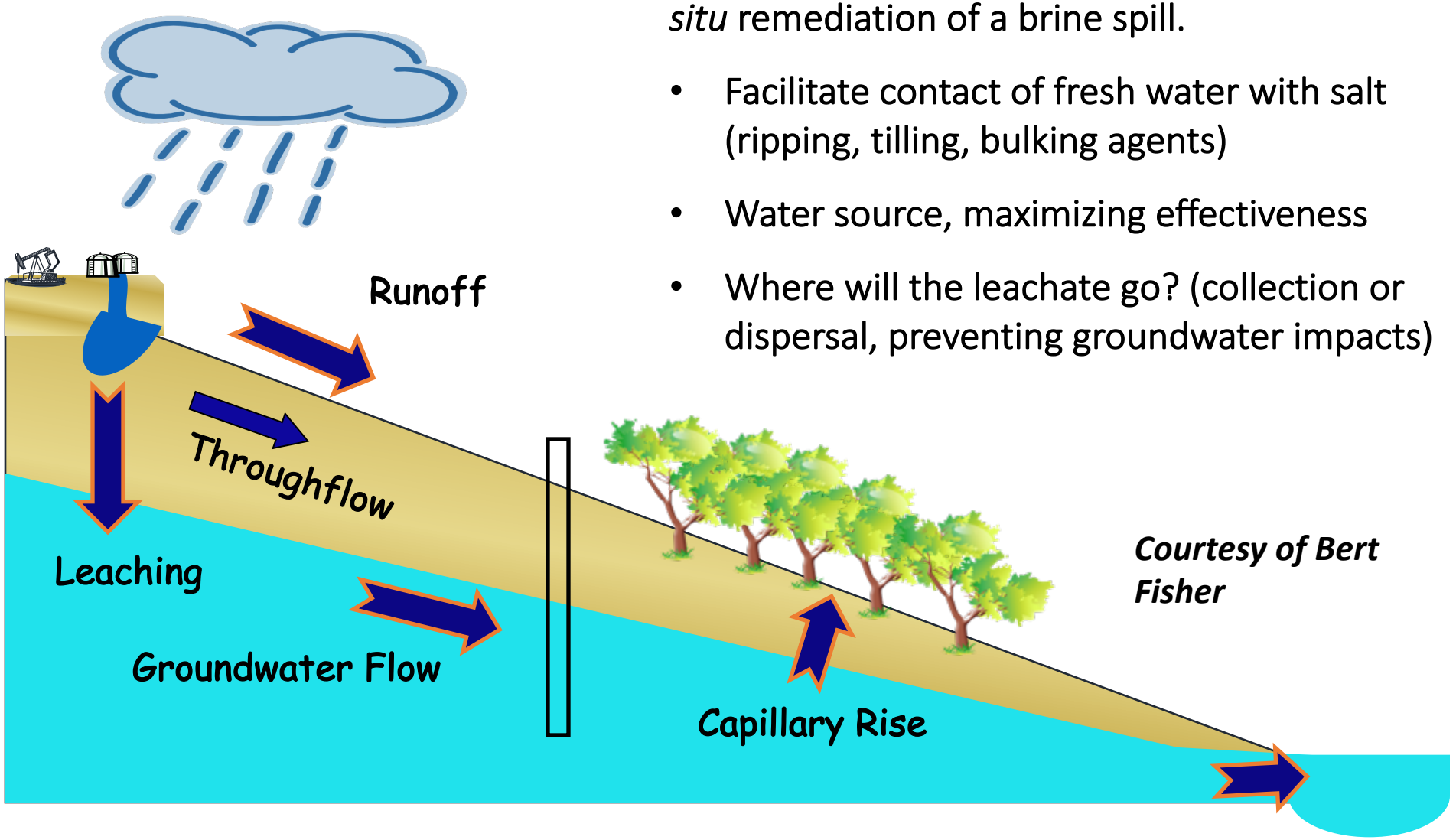
In situ remediation of a brine spill is all about water, calcium, and drainage



archiexpo.com/prod/rain-bird/product-92056-1980311.html

wemakedirtlookgood.com/2014/09/how-to-install-a-french-drain/

Pathways of salt movement in the environment: salt moves with water

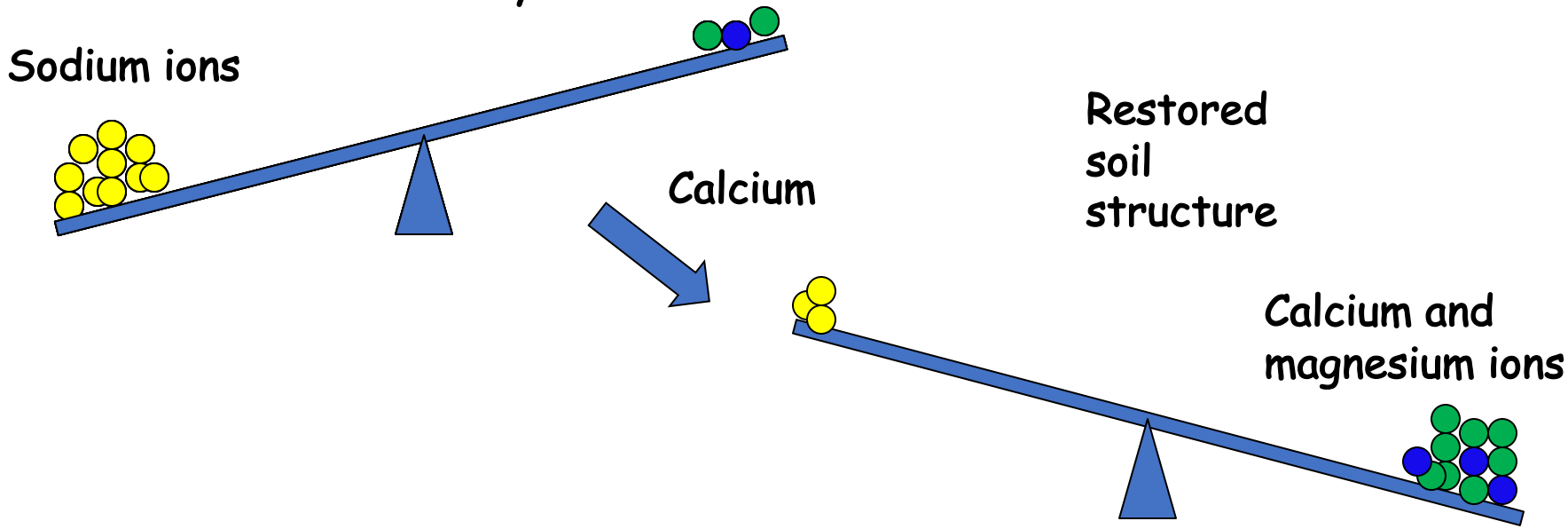


These mechanisms instruct us in how to do *in situ* remediation of a brine spill.

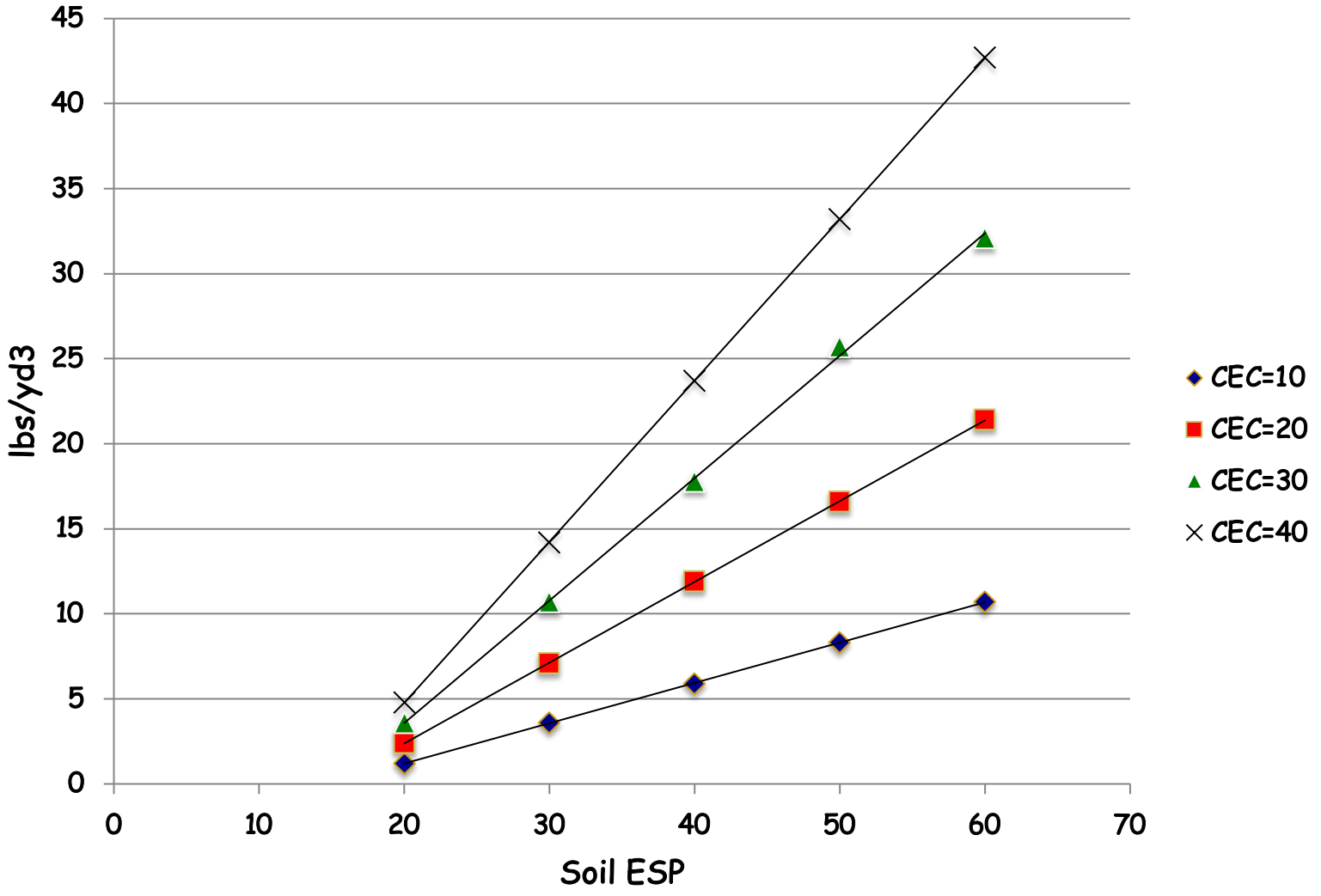
- Facilitate contact of fresh water with salt (ripping, tilling, bulking agents)
- Water source, maximizing effectiveness
- Where will the leachate go? (collection or dispersal, preventing groundwater impacts)

The role of calcium

Sodic soil
- Dispersed clays
- Minimal hydraulic conductivity

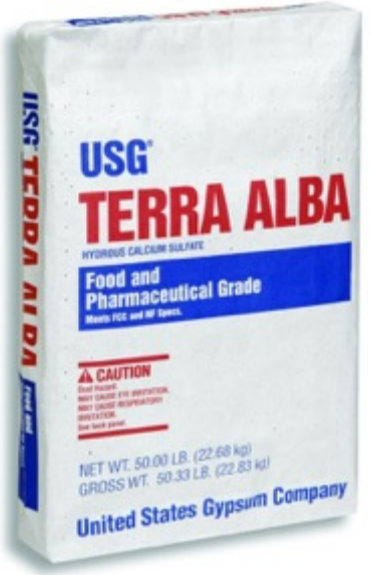


Gypsum application rates



If you use gypsum remember that particle size is important

Use 400 mesh solution grade gypsum



Get the calcium to where it is needed

Restoration of orphan well sites

- Remediation of brine-impacted soil will be a major component of restoration of most orphan well sites
  - Where the original soil profile is undisturbed *in situ* treatment conserves a valuable resource, topsoil, and has the greatest probability of restoring productivity
  - *In situ* treatment typically takes 2-3 years when properly managed but gives a superior result to dig-and-haul at a much lower cost and environmental impact
  - There is no one-size-fits-all formula but *in situ* treatment is not rocket science, it's just agronomy (no offense meant to agronomists)
  - No magic potions! Fine-particle gypsum is 6.5 cents/lb

DAKOTA

WEDNESDAY, OCTOBER 27, 2021 | bismarcktribune.com | SECTION B

Well plugging criticized

ND landowners' report evaluates oil field program

AMY R. SISK
Bismarck Tribune

A landowners group says cleanup of some abandoned oil wells the state sought to plug using federal coronavirus relief money is incomplete, and costs at times far exceeded what's considered typical.

The Northwest Landowners Association released a report on the abandoned well plugging program Tuesday after sifting through numerous publicly available documents and other records obtained from the state.

"While well-intentioned, this program mostly leaves the landowner and North Dakota taxpayers holding the bag," Chairman Troy Coons said.

The North Dakota Oil and Gas Division set out last year to plug hundreds of abandoned wells and reclaim the sites, aiming to put them back into agricultural use and employ hundreds, if not thousands, of oil workers. Numerous workers in the oil patch lost jobs last year or had their hours cut after the coronavirus pandemic hit and sent oil prices plummeting.

State leaders designated $66 million in federal CARES Act funding for plugging abandoned wells, $16 million of which appeared unlikely to be spent by the deadline so was ultimately redirected to reimburse companies for the cost of acquiring water used in the fracking process. Officials authorized another $6 million to finish cleanup work this year. Those efforts are ongoing.

The program has paid for the plugging of 339 wells in 2020 and 2021, Oil and Gas Division spokeswoman Katie Haarsager said. She added that the money kept 3,305 workers employed.

The goal "was to keep our service companies employed," especially after other federal aid for businesses ran out, she said in a statement. State leaders also sought to protect North Dakota from future liabilities surrounding abandoned wells, she said.

The state says the wells included in the program were uneconomic. Many had sat idle for years.

The landowners association says the program revealed shortcomings in how the state handles abandoned wells.

Landowners have told the group that cleanup was at times incomplete. A contractor might remove a gravel well pad, for example, but not address contamination apparent within the surrounding land.

Some of those landowners were told "we're not dealing with all the problems here, we're just getting the surface off," Coons said.

Please see LANDOWNERS, Page B2

Landowners have told the group that cleanup was at times incomplete. A contractor might remove a gravel well pad, for example, but not address contamination apparent within the surrounding land.

Landowners for years have complained about salt contamination in the state's oil fields. Saltwater, a byproduct of oil production, sometimes spills and renders land infertile. Decades ago, it was dumped into open pits to evaporate. Barren patches are common in parts of the state affected by saltwater, especially in the older oil fields of north-central North Dakota.


Any Questions?
SCENIC
TURNOUT
AHEAD