Remediation of Brine Spills- What Goes Wrong

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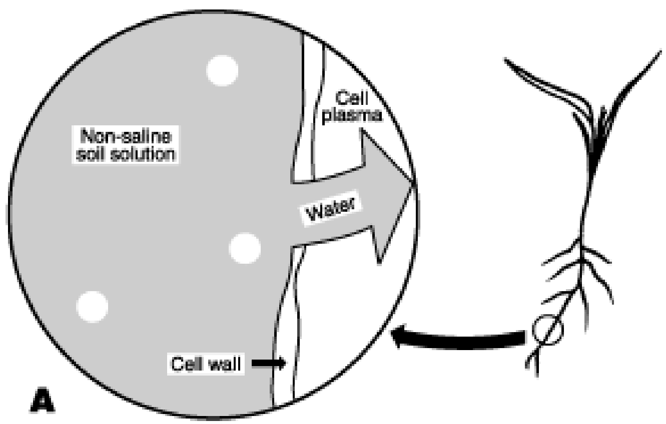
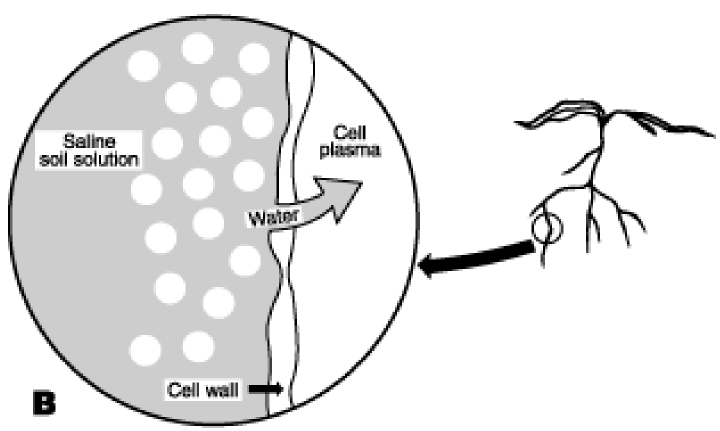
University of Tulsa

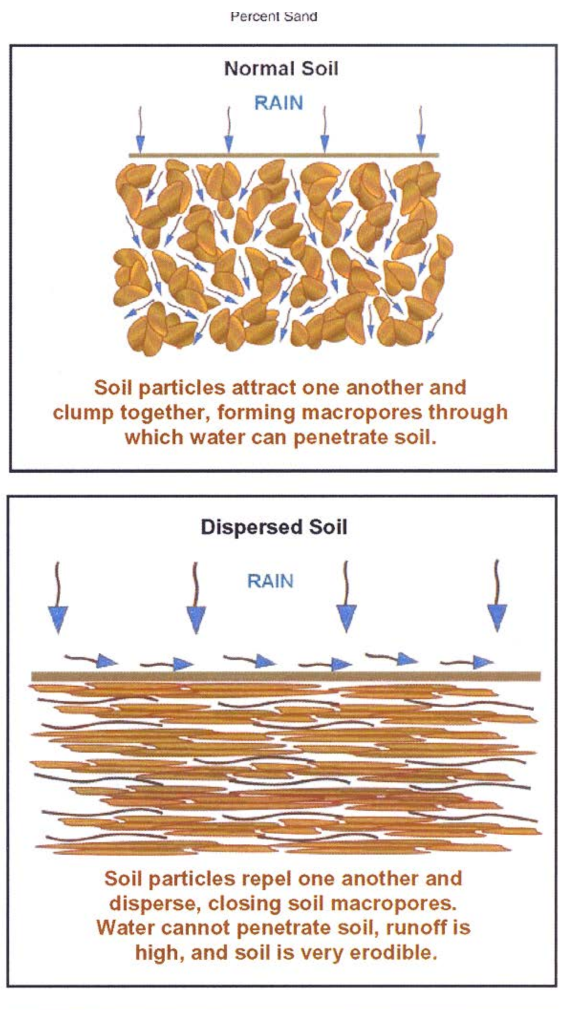
Spills of produced water or brine on soil result in two types of damage:





- Excess salinity
  - Creates an osmotic imbalance that reduces water uptake by plant roots. Plants can go into drought stress even though there is plenty of water in the soil.

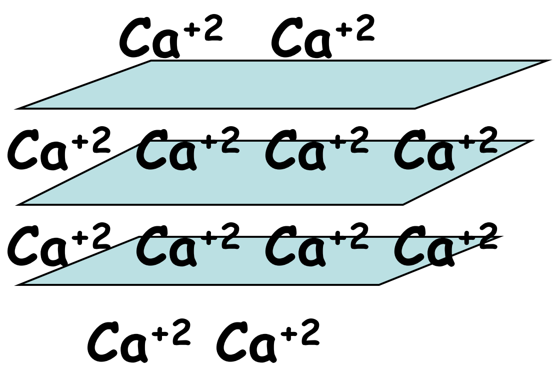
Spills of produced water or brine on soil result in two types of damage:



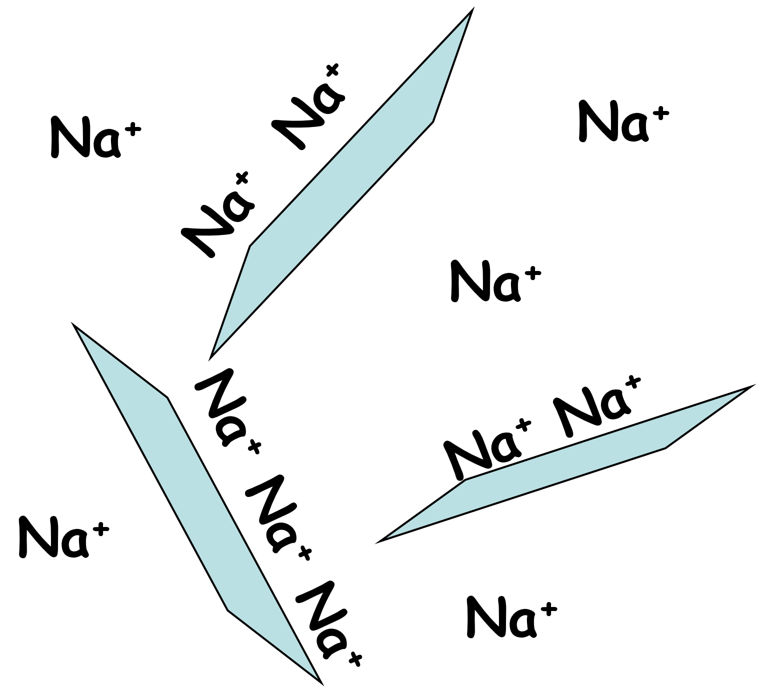
- Excess sodicity (an excess of sodium)
  - Destroys soil structure by dispersing clays
  - Produces a hardpan that will not transmit water
  - Erosion

Both salinity and sodicity must be addressed in any successful remediation of a brine impacted site

Sodicity and soil structure

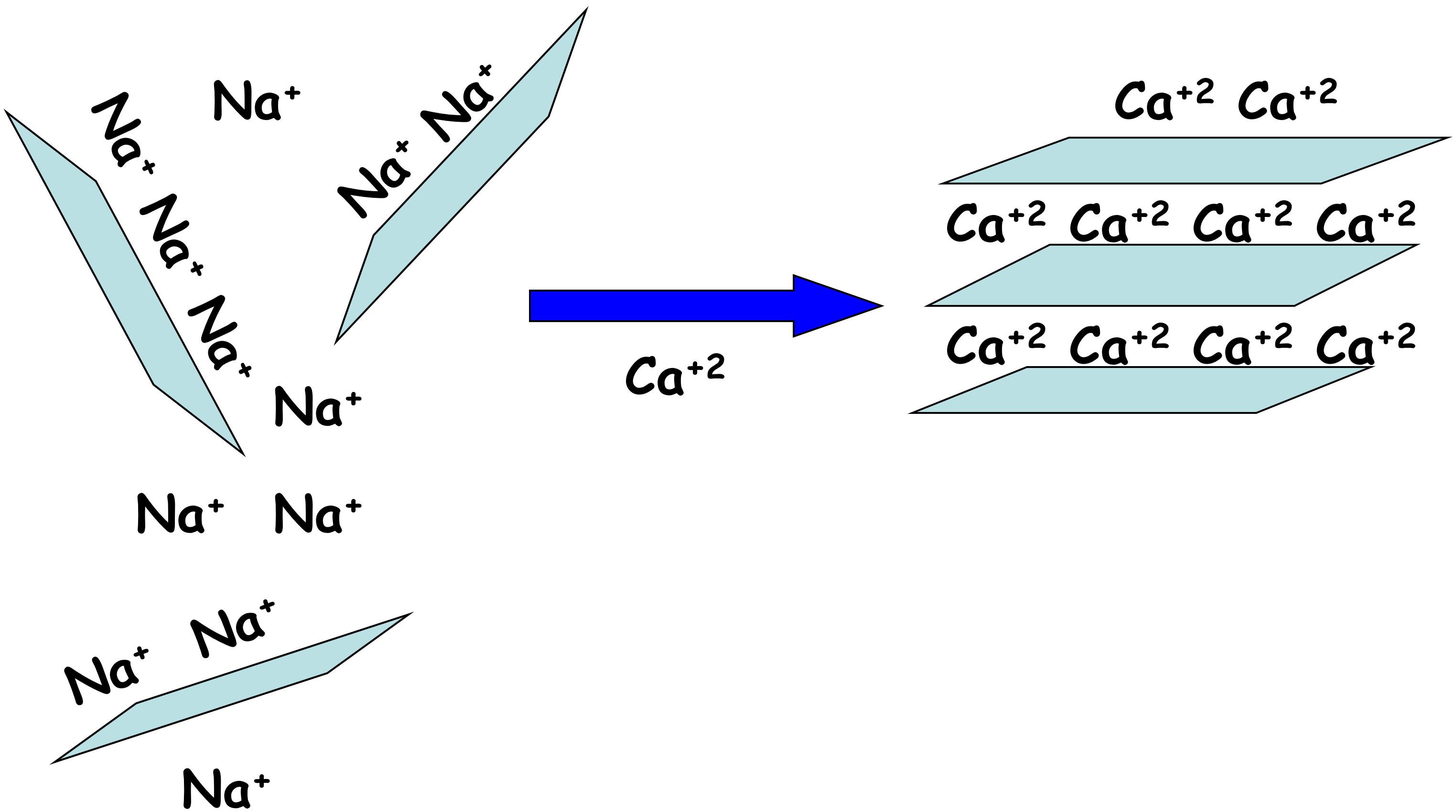


Clay particles or platelets in soil are held together by Ca^{+2} ions



High concentrations of Na^{+} ions can displace the Ca^{+2} and cause the clay particles to disperse

Calcium is required to fight sodicity



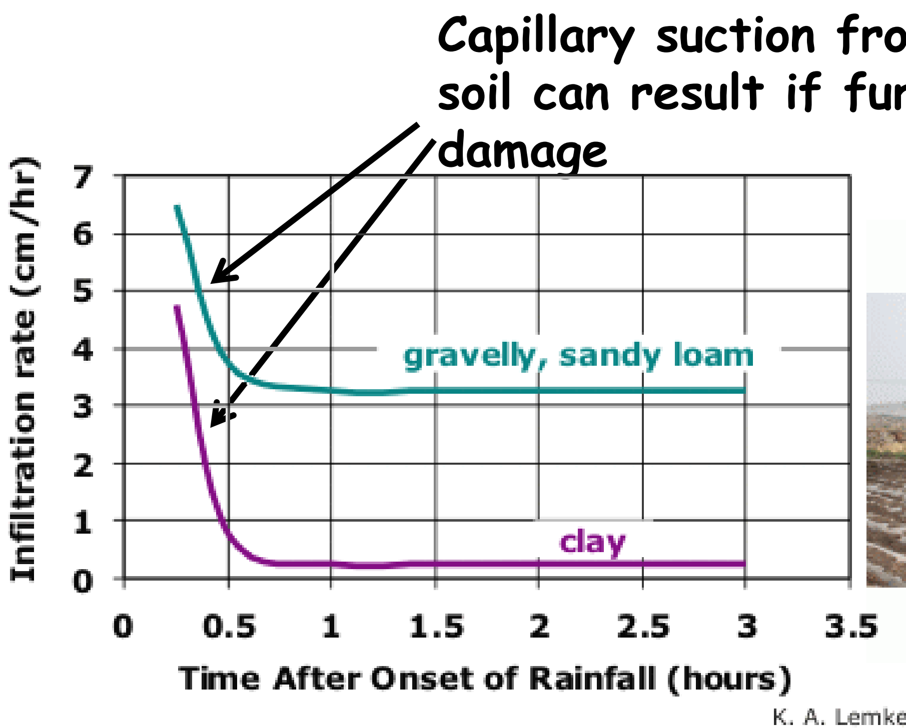
Remediation of a Brine Spill In Brief

- First response
  - Flushing and containment
- Reducing salinity
  - Breaking open the soil
  - Bulking agents
  - Fresh water
  - Drainage
- Reducing sodicity
  - Soluble calcium ion to reverse sodic reaction with clays
- Revegetation
  - Taking advantage of plant root systems

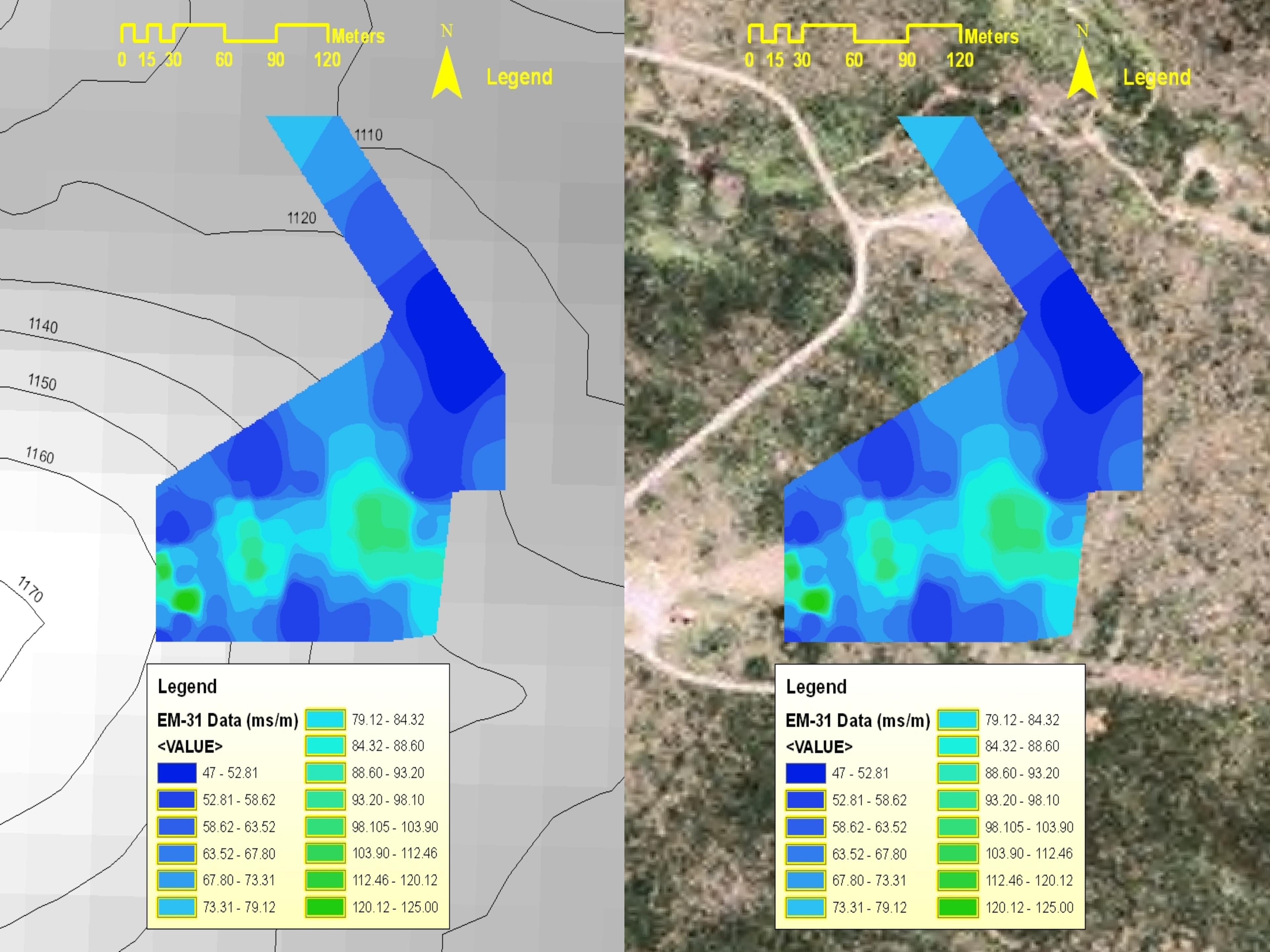
There are many ways for this process to go wrong

First response to a brine spill

- Flushing with fresh water into a receiving body followed by disposal of salty water
  - Soak the area between the spill and the receiving body with fresh water **before** flushing



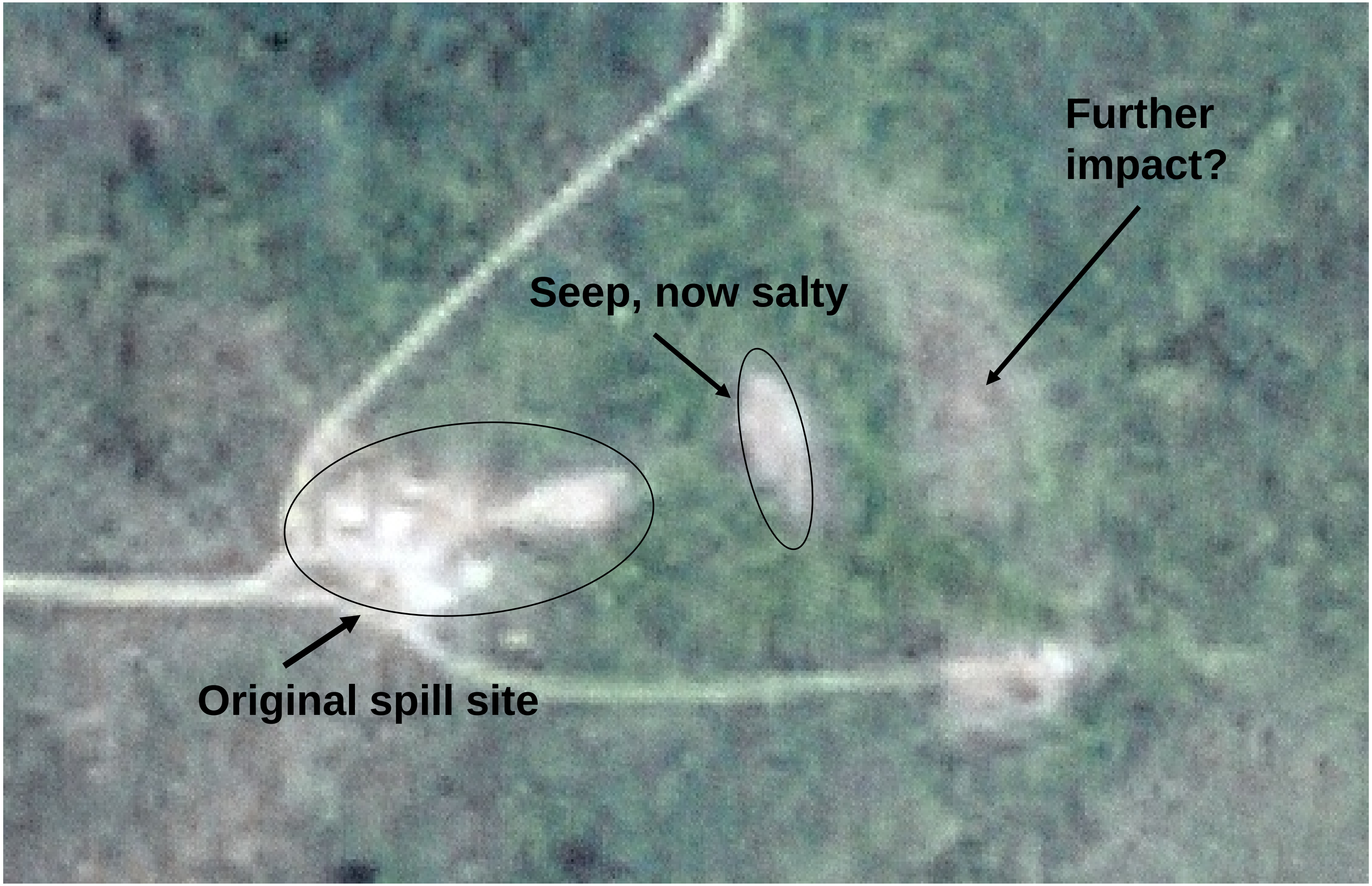
- EM Geophysical surveys detect salt from 1 to 3 meters deep.
- Krig EM Data
- Develop Soil Sampling Plan



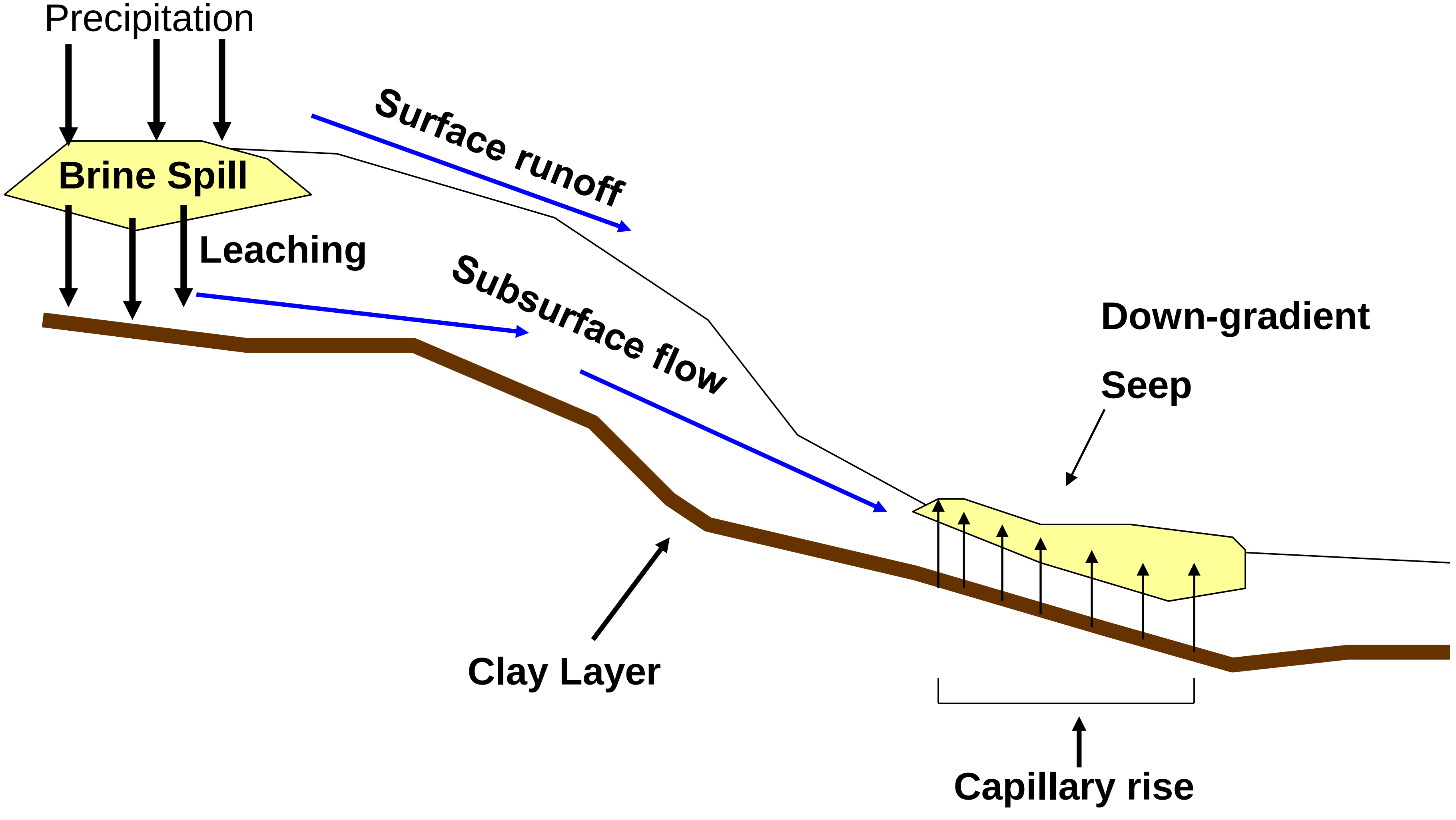
Meters
0 15 30 60 90 120
N
Legend
1110
1120
1140
1150
1160
1170
Legend
EM-31 Data (ms/m)
<VALUE>
47 - 52.81
52.81 - 58.62
58.62 - 63.52
63.52 - 67.80
67.80 - 73.31
73.31 - 79.12
79.12 - 84.32
84.32 - 88.60
88.60 - 93.20
93.20 - 98.10
98.105 - 103.90
103.90 - 112.46
112.46 - 120.12
120.12 - 125.00

Expect things to go from bad to worst if you don't do anything or don't do enough

Google Earth 2004



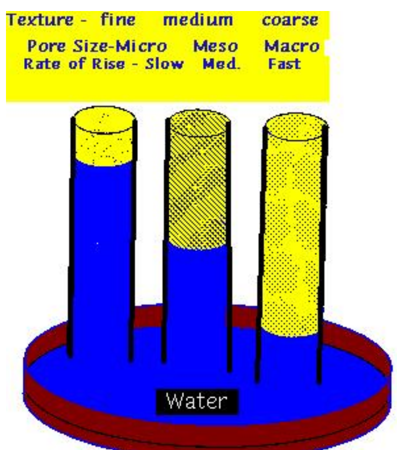
Site topography is an issue

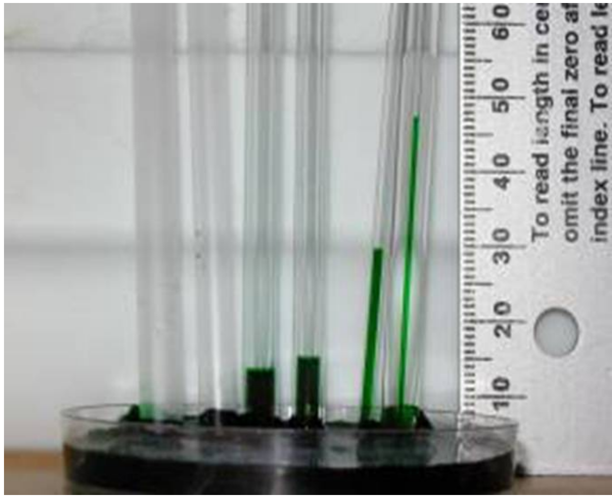



Site 5
N
0 145 290 580 870 1,160
Meters
Legend

Capillary Migration?

- Capillarity can be described as the migration of soil moisture against the forces of gravity
  - Occurs in unsaturated soil environments
- Three contributing factors of capillary action
  - Pore size in the soil matrix
  - Surface tension of soil water
  - Wettability of soil mineral particles





Capillary Migration

- Capillary action causes the unexpected migration of brine within the soil
  - Has proven to negate remediation efforts
  - The same forces causing the vertical migration of brine also cause the LATERAL migration of brine
- Helps explain the persistence and growth of brine scars
- Brine components must be driven well beyond the plant root zone in the long term to allow revegetation

Guidance on estimated capillary rise

Handbook of Drainage Principles (OMAF, Pub. 73)

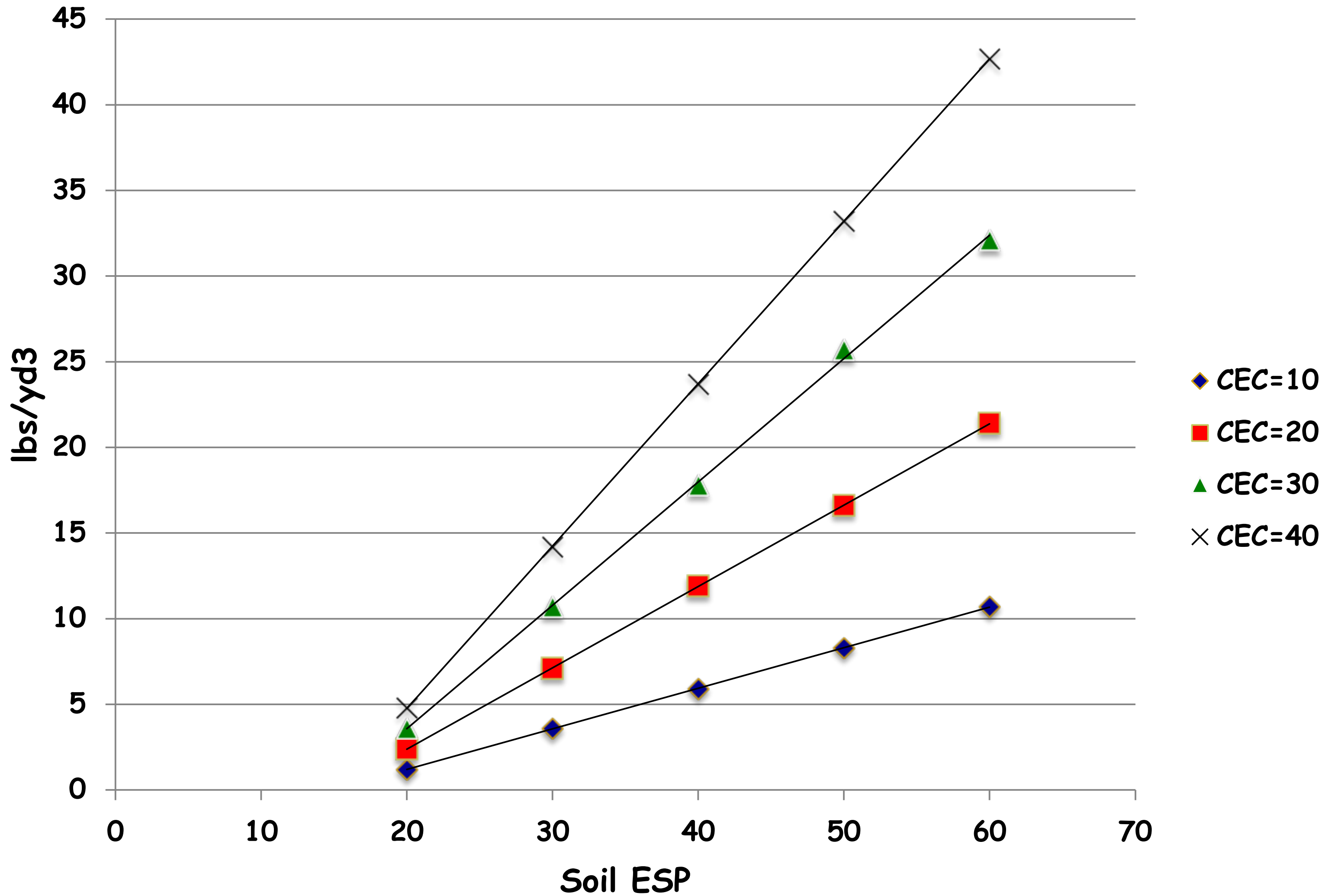
Soil type	Capillary rise (inches)
Very coarse sand	0.8
Coarse sand	1.6
Medium sand	3.2
Fine sand	6.8
Very fine sand	16.0
Silt	40.0
Clay	> 40.0

Depending on soil texture salt must be moved at least this far out of the root zone of desired vegetation

Recommended remediation methods

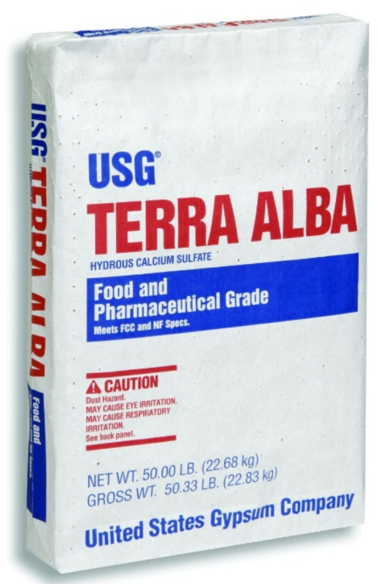
- Ripping and deep tilling with hay, recalcitrant OM, fertilizer application, fine calcium source
- Irrigation
- Subsurface drain at the bottom of the spill
  - Predicted that the salt was going to continue down slope and pool
- Hay and fertilizer application with deep tilling was done (once); calcium source (fine gypsum), artificial drainage used

Gypsum application rates



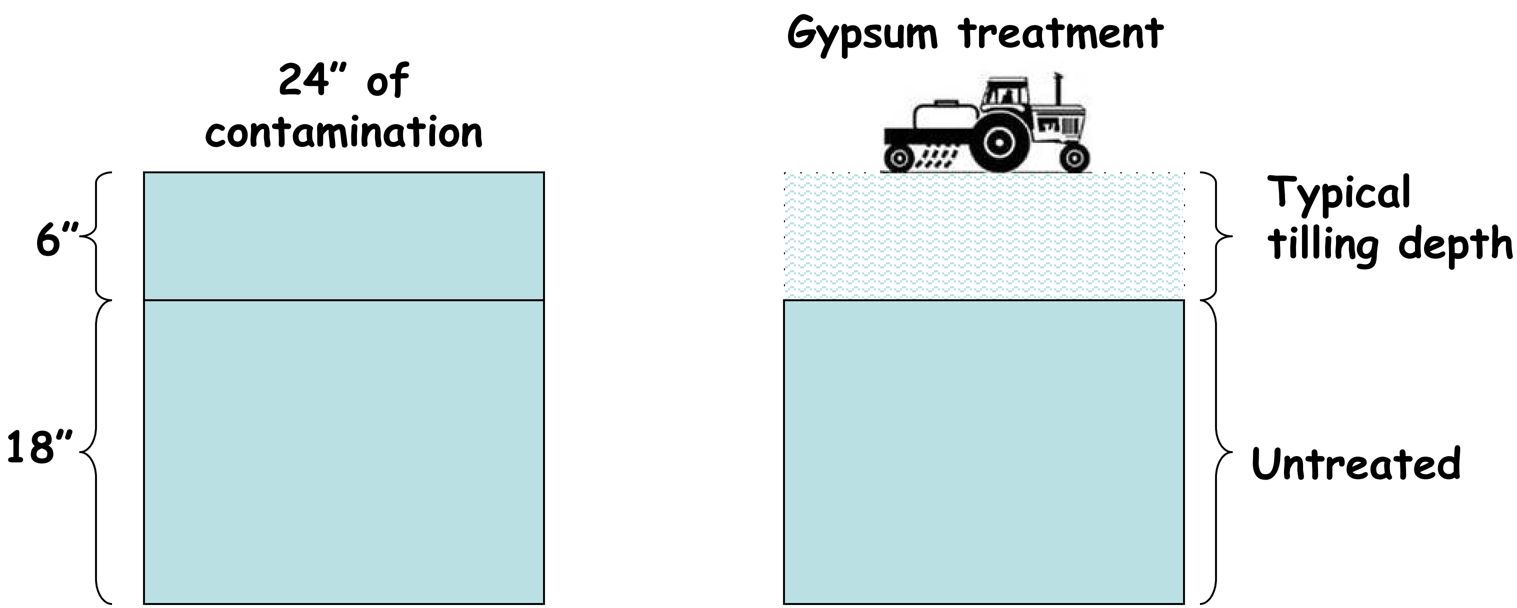
If you use gypsum remember that particle size is important

Use 400 mesh solution grade gypsum



Due to the low solubility of gypsum, gypsum is typically effective only within the depth to which it is incorporated into soil

- Need to Deep Rip to 24"+




DEERE

Metrics

- Salinity
  - Soil salinity is measured as a **saturated paste** EC
  - $EC_{sat\ paste} \approx 3 \times EC_{1:1}$
    - Assumes good contact and dry soils
- Sodicity
  - Sodium adsorption ratio (SAR)

$$SAR = \frac{[Na^+]}{\left[\frac{[Ca^{+2}] + [Mg^{+2}]}{2}\right]^{1/2}}$$

All units meq/L

Before:

Soil, Water & Forage Analytical Laboratory

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

SOIL SALINITY REPORT

SUBLETTE CONSULTING, INC
8802 E. 98TH ST

TULSA, OK 74133

Name :

Location :

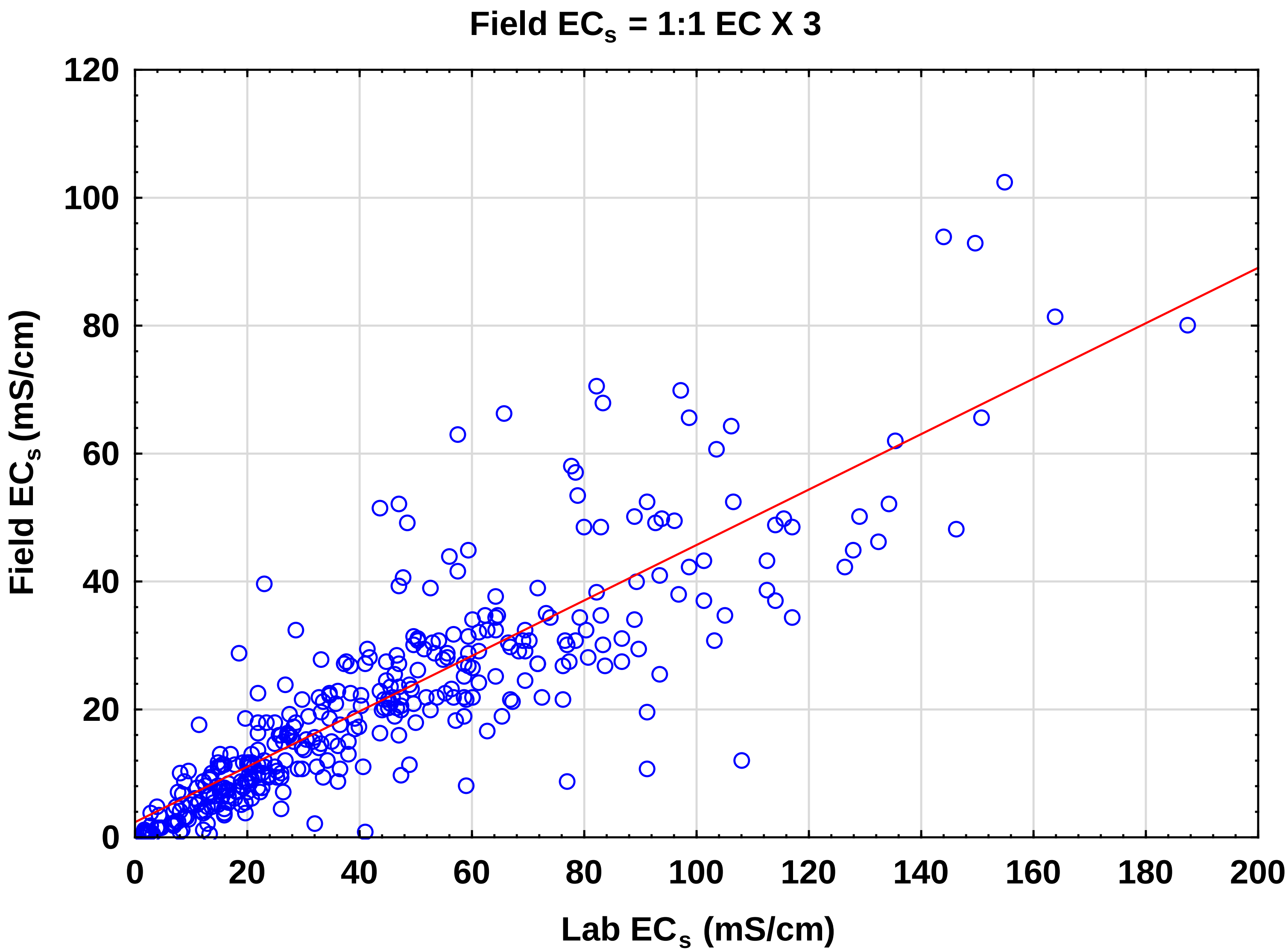
Lab ID No.: 663008
Customer Code : 1392
Sample No. : 805
Received : 9/19/2012
Report Date : 9/25/2012

Test Results for Comprehensive Salinity(Saturated paste extraction)

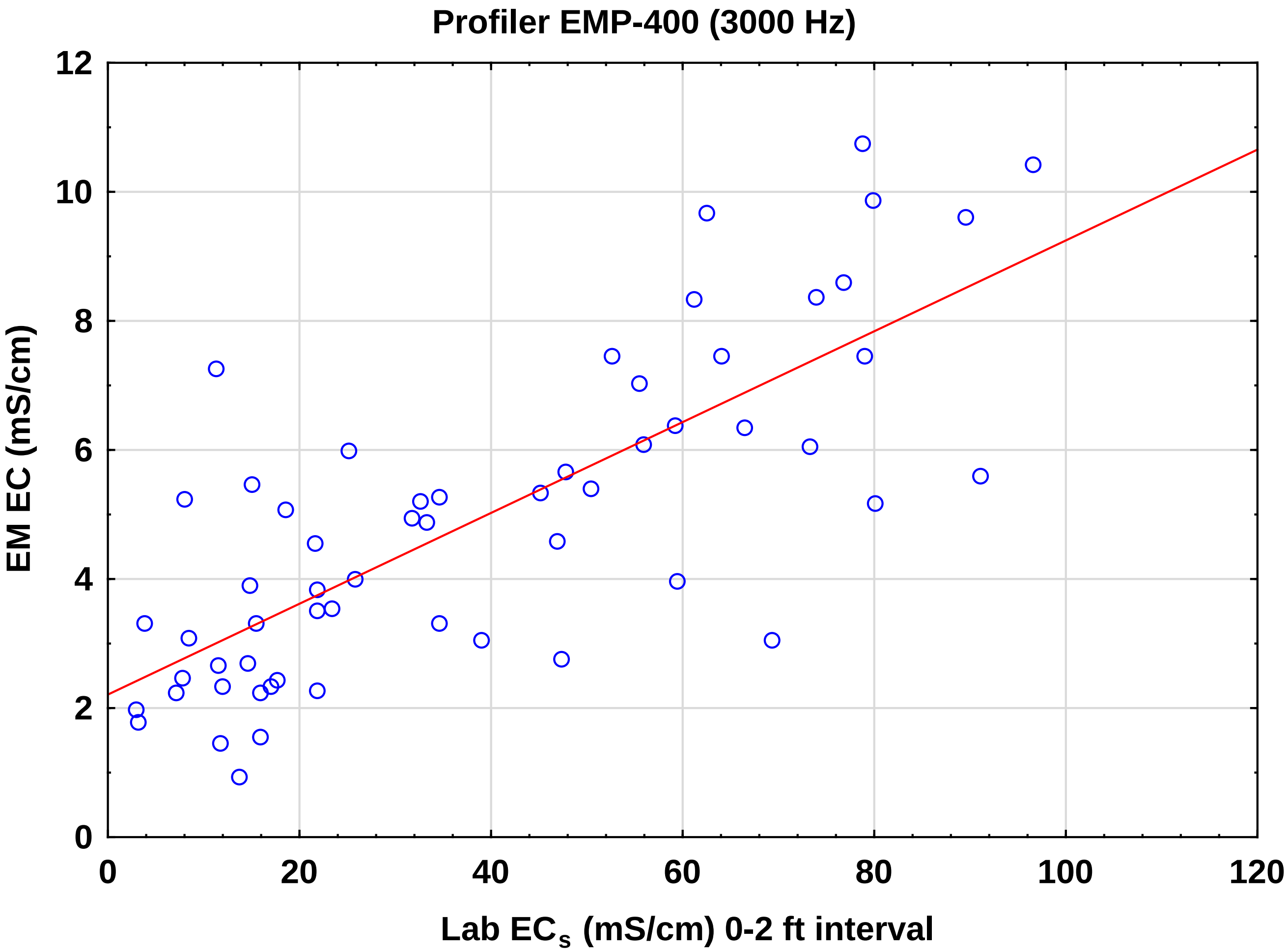
Cations		Anions		Other	
Sodium (ppm)	4922.1	Nitrate-N (ppm)	<1	pH	7.4
Calcium (ppm)	2914.9	Chloride (ppm)	13646.7	EC (μmhos/cm)	34900
Magnesium (ppm)	570.5	Sulfate (ppm)	622.4	Texture	Coarse
Potassium (ppm)	105	Boron (ppm)	0.3		
		Bicarbonate (ppm)	309.7		

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		

Example of correlation between field and lab EC: heavy clay, high moisture content



EMP EC correlates with lab EC_s but greatly underestimates actual soil EC_s



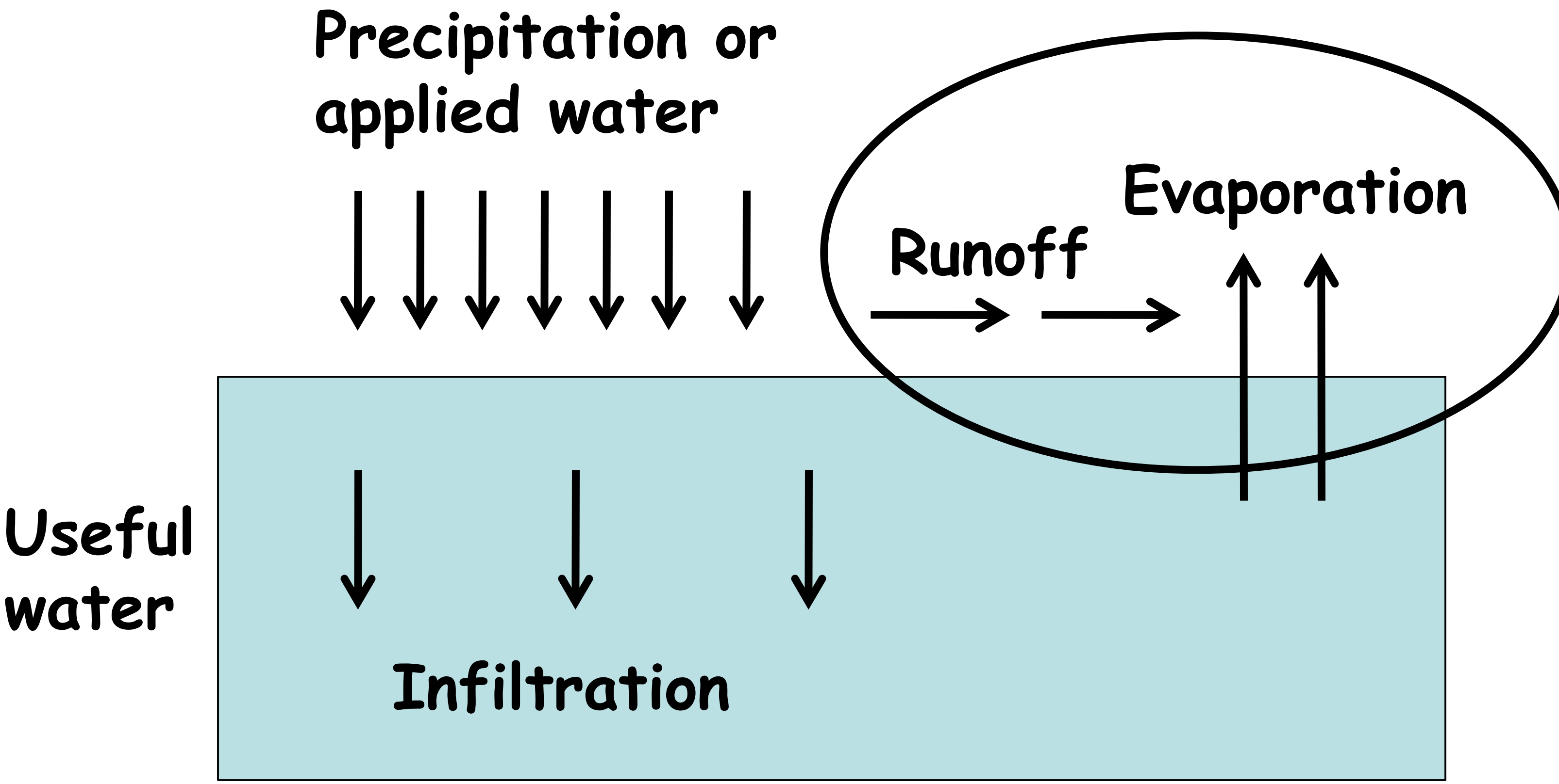
Water

- Soluble salts are transported by water – **No water no movement**
- How much water? A unit depth of water will remove about 80% of the salts from the same depth of contaminated soil.

Example: 12 in interval of contamination with an EC of 28 mS/cm

Leaching water (in)	% of salts leached	Approximate EC (mS/cm) after leaching
6	50	14
12	80	5.6
24	90	2.8

Remediation of brine spills will require <u>more</u> than the calculated amount of water to be applied because of runoff and evaporation.



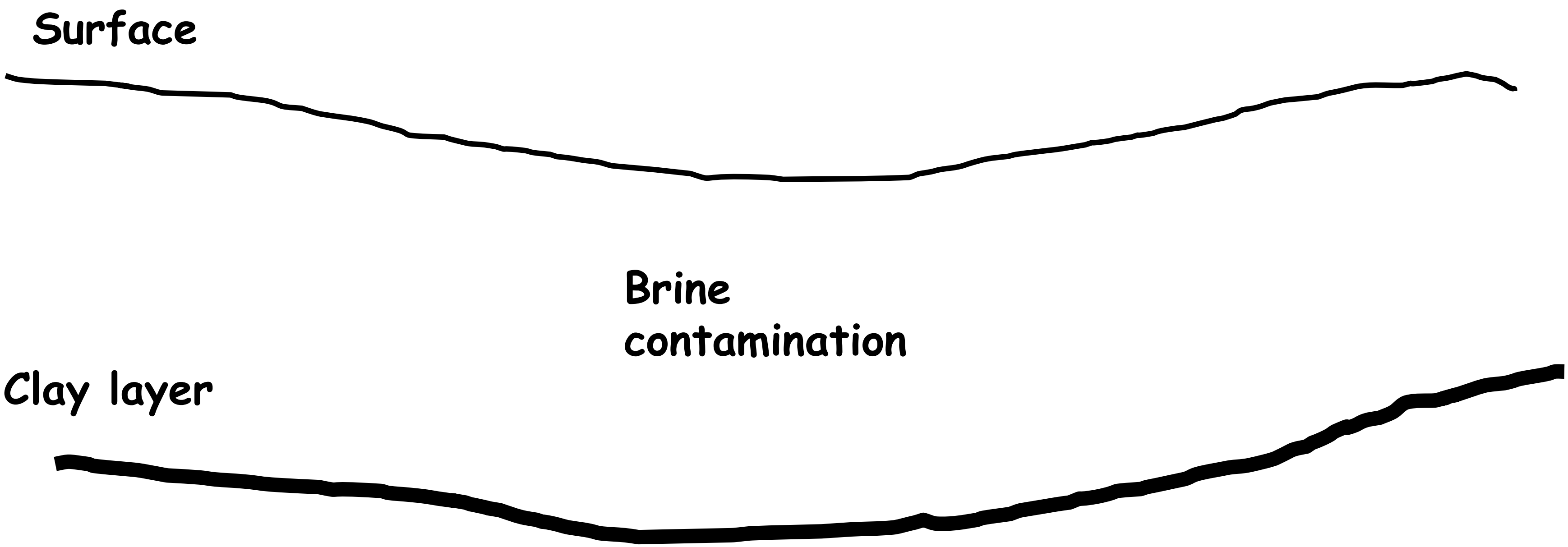
Water Drives the Chemical Reactions

- Lots of water is required which means lots of time if you don't irrigate. Where does it all go?
- Lots of organic matter in the soil improves permeability to water. Also, a thick layer of surface mulch retains moisture and reduces evaporation.

Drainage: the salt has to have somewhere to go

- What are the options?
  - Natural Vertical drainage
    - Will it go deep enough?
    - Will it impact groundwater?
  - Natural Lateral drainage
    - Will it cause additional damage?
    - Can I protect environmental receptors?
  - Drain tile and Sumps
    - Pump and dispose removed brine

Where will the salt go?



After:

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

WATER QUALITY REPORT

SUBLETTE CONSULTING, INC
8802 E. 98TH ST

TULSA, OK 74133

Name :

Location :

Lab ID No.: : 668766
Customer Code : 1392
Sample No. : 1
Received : 11/16/2012
Report Date : 11/21/2012

Test Results for Irrigation Water

---------- Cations ---------------		----------- Anions -------------		------------- Other --------------	
Sodium (ppm)	14	Nitrate-N (ppm)	10.6	pH	7.7
Calcium (ppm)	78	Chloride (ppm)	87	EC (µmhos/cm)	589
Magnesium (ppm)	12	Sulfate (ppm)	10		
Potassium (ppm)	3	Boron (ppm)	0.03		
		Bicarbonate (ppm)	115		

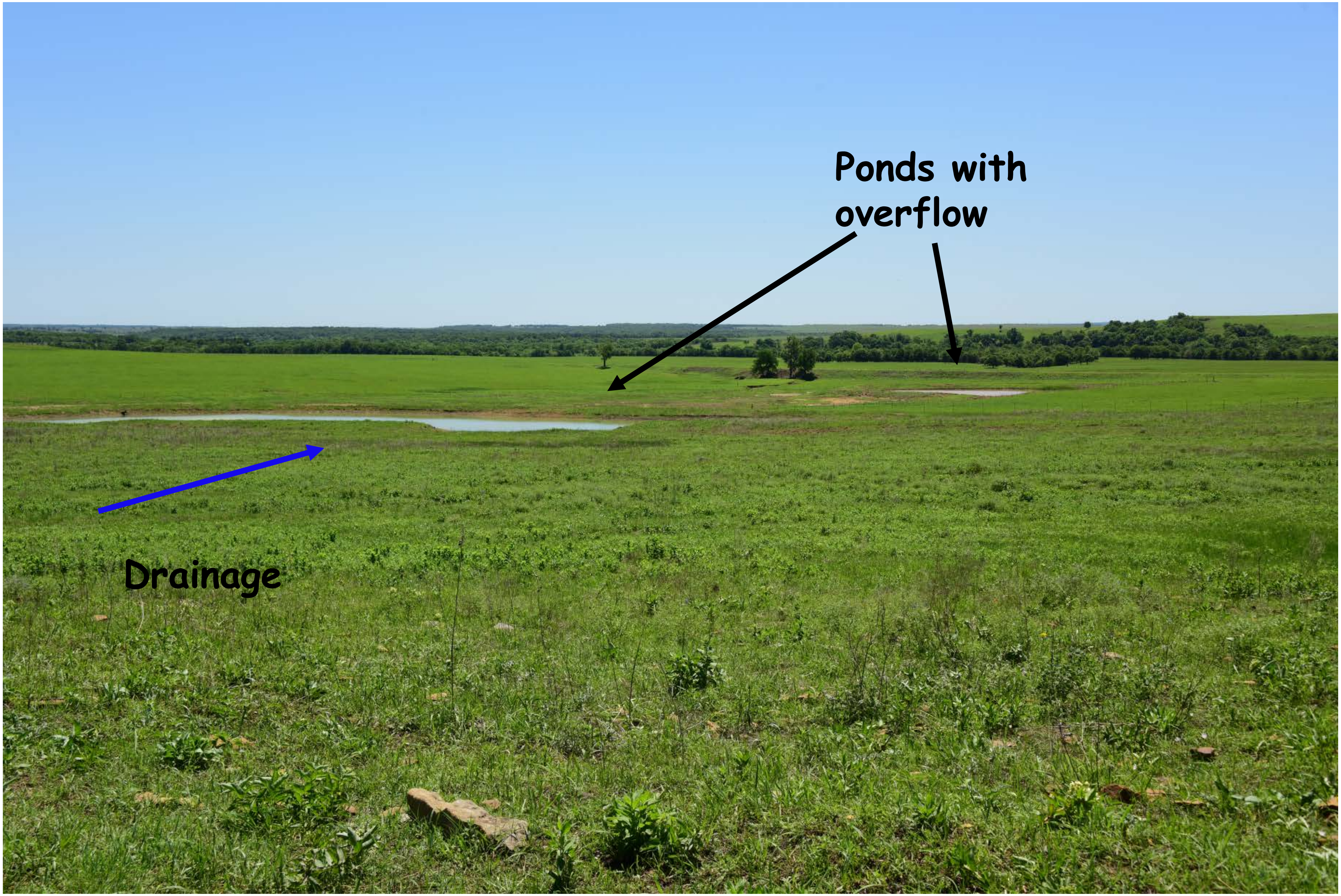
------------ Derived Values -----------------		-------- Derived Values(cont'd) --------------	
Total Soluble Salts (TSS in ppm)	388.7	Sodium Percentage	10.9 %
Sodium Adsorption Ratio (SAR)	0.4	Hardness (ppm)	243.9
Potassium Adsorption Ratio (PAR)	0.0	Hardness Class	Very Hard
		Alkalinity (ppm as CaCO3)	94.4

INTERPRETATION AND REQUIREMENTS FOR *Irrigation Water*

Water of this quality is suitable for use on most crops under most conditions. A problem may eventually arise with continued use of this water on very heavy soils where essentially no leaching occurs. If rainfall is sufficient, it will dilute the salts and reduce the hazard. If sodium is the main problem, gypsum can be used to help remedy the problem.

Signature

The salt has to have somewhere to go



Remediation using lateral drainage

Underlying clay
at about 3-4 ft

After 7 months of treatment

7 months of treatment

20 months of treatment (June)

Factors affecting risk to groundwater from surface brine release

- Chloride mass moves fast
- Aquifer thickness
- Depth to groundwater
- Effective width of surface impact
- Annual precipitation
- Pan evaporation index
- Surface soil type top 3 ft
- Slope
- Vadose zone material (from 3 ft to aquifer)
- Hydraulic conductivity of aquifer

Groundwater Protection

- Site characteristics might argue for vertical migration of salts below the root zone for successful revegetation
  - Clay lens below root zone are protective of groundwater
  - Sandy soil minimizes potential for capillary suction
  - Low recharge rate minimizes movement of salt in the subsurface under natural rainfall conditions
  - Deep groundwater results in spreading and therefore dilution of any salt that gets to the aquifer
  - High hydraulic conductivity results in rapid dilution of any salt reaching the aquifer
- Irrigation required to drive salts below the root zone
- Removal of salty water with drainage and sumps to minimize GW impacts


Any Questions?
SCENIC
TURNOUT
AHEAD