Advanced Site Characterization of Salt Contaminated Lands

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Tulsa, OK

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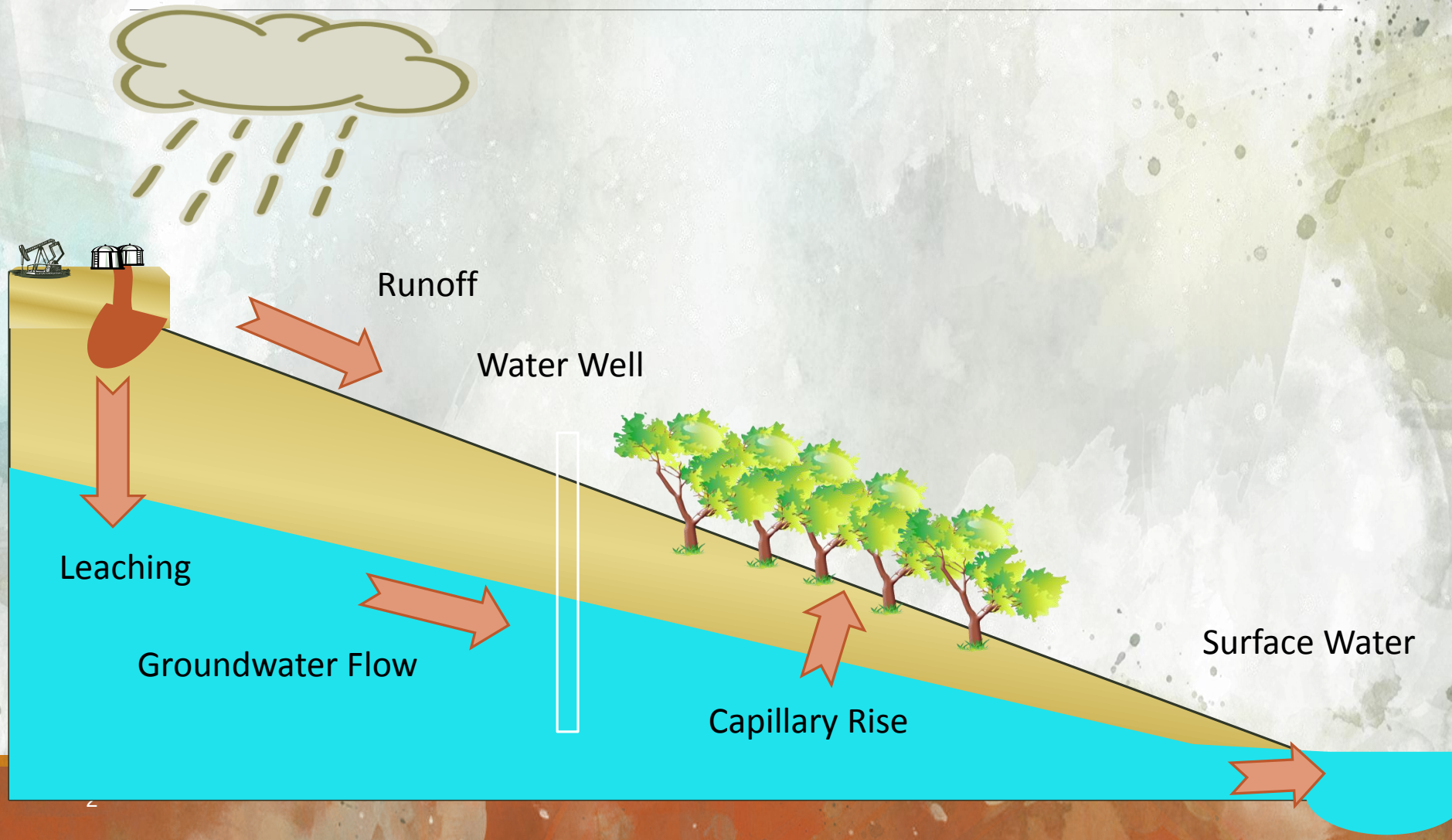
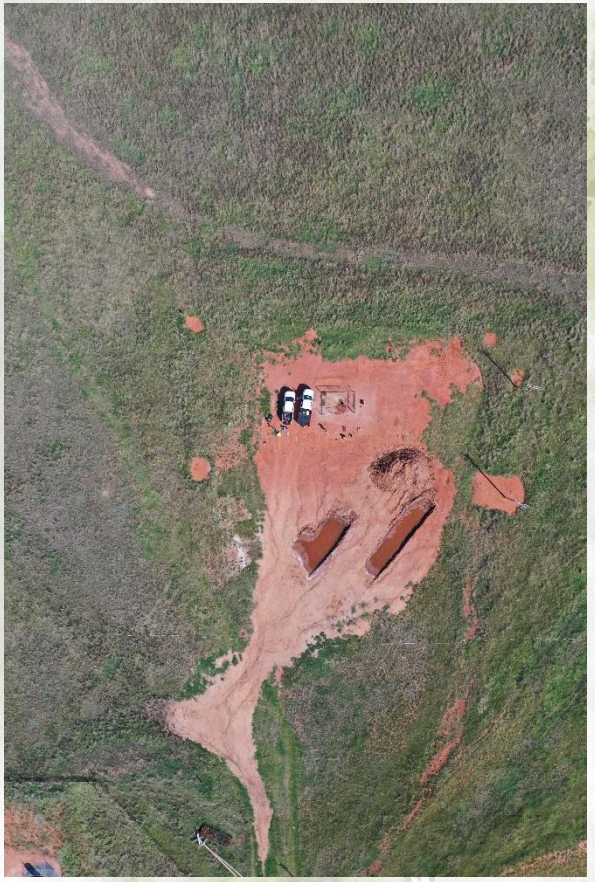
Pathways of Salt Movement



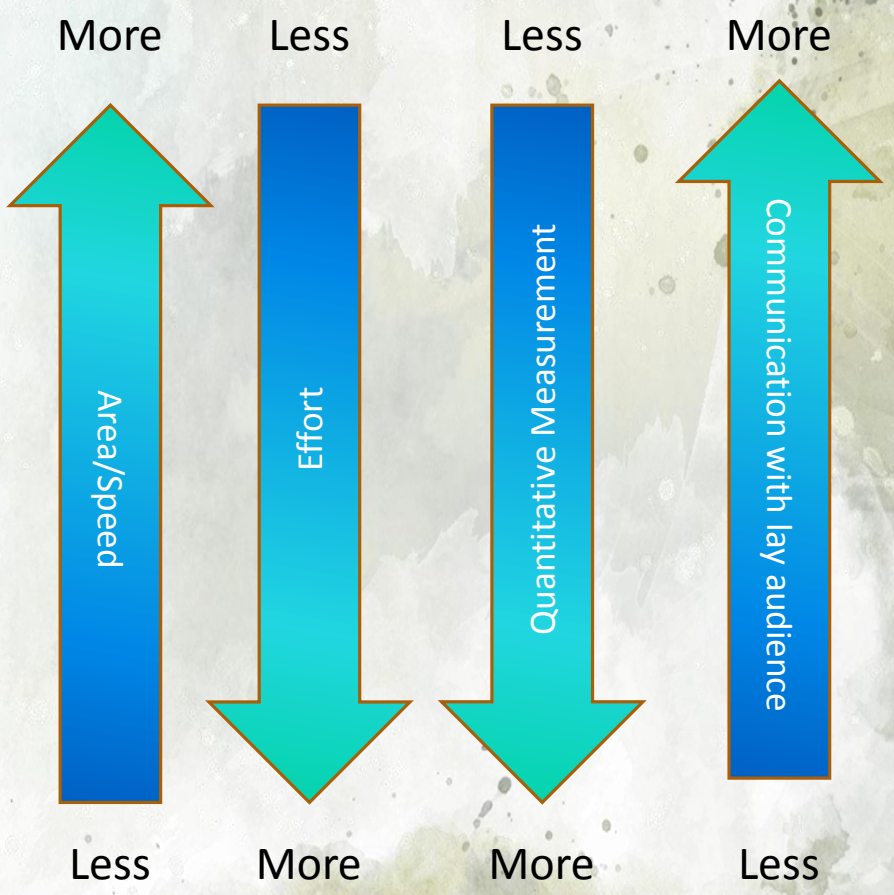
Salt Contamination Assessment

- Injury
  - Extent and Severity of Contamination
  - Potential of Contamination to Spread
- Damages
  - Land Use and Land Capability
  - Receptors
  - Remedial Measures
- Causation
  - Source of salt

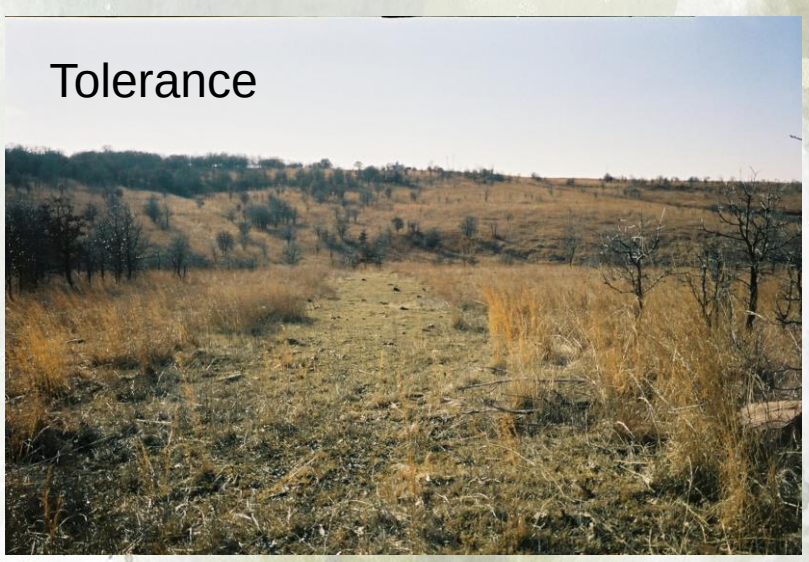


Salt Site Assessment Tools

- Visual Indicators
  - Vegetation Damage
  - Salt Tolerant Vegetation
  - Corrosion
  - Haloclastic Weathering
  - Salt Crusts
  - Erosion
- Geophysical Measurement
  - Electromagnetic Survey
  - Resistivity Survey
- Field Screening Techniques
- Soil Sampling/Lab Analysis



Vegetation



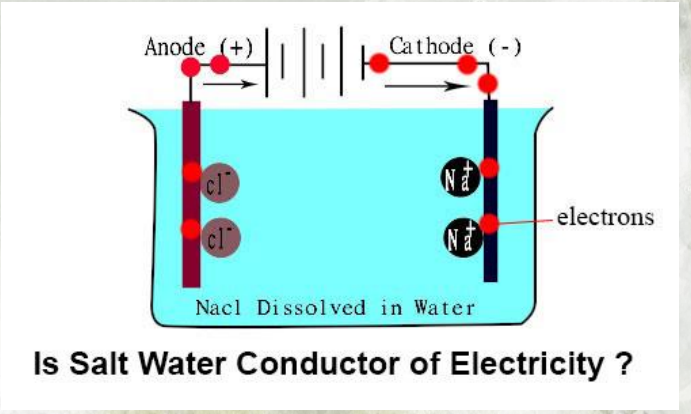
Salt Crusts & Weathering

Erosion and Corrosion

Field Screening / Sampling

Electrical & Electromagnetic Methods

- Used where changes in electrical resistivity define a target
  - Metal detection
  - Metallic ores
  - Saltwater
  - Acid rock drainage
  - Water saturated vs. unsaturated pores
  - Voids (tunnels & karst)



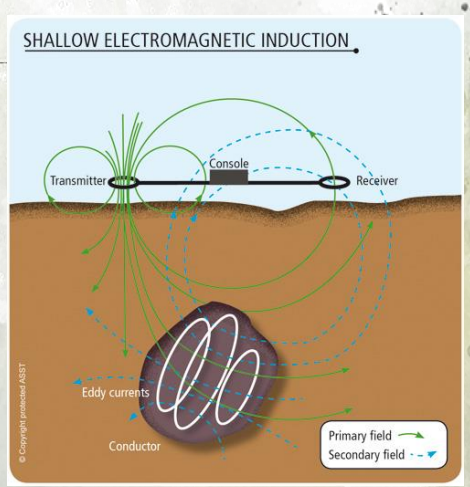
Most frequently used for salt contamination investigations

Spatial Distribution (i.e. mapping)

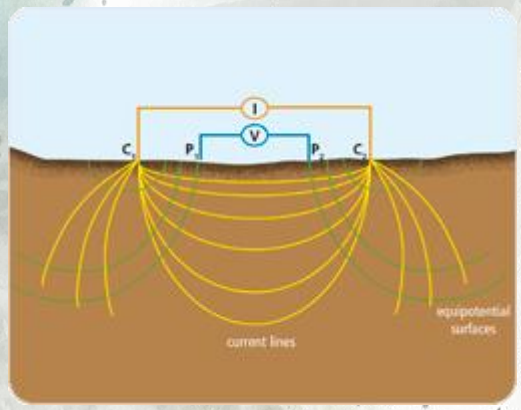
- Frequency Domain Electromagnetic

Depth Distribution

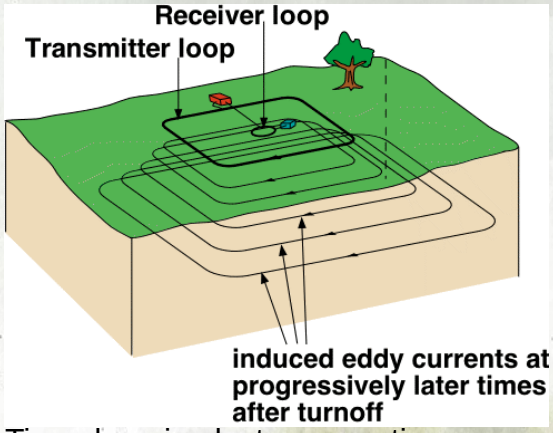
- Resistivity
- Time Domain Electromagnetic



Frequency domain electromagnetic



Resistivity



Time domain electromagnetic

Old methods – new technology

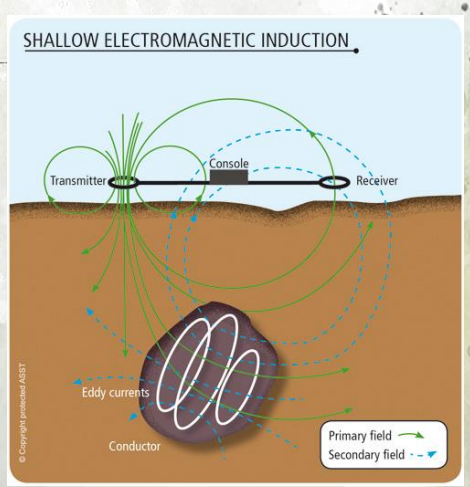
Known and used from early to mid-20th century

Cumbersome until recently:

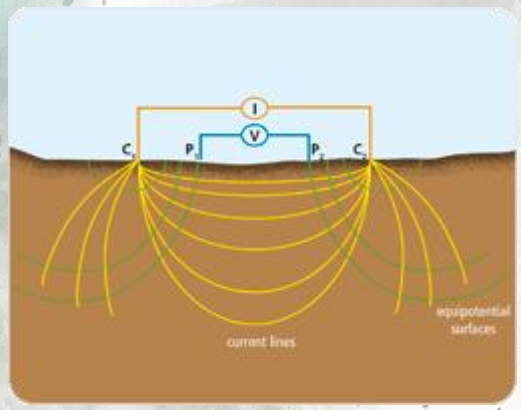
(1) Reliable electronics

(2) Computer controlled data acquisition

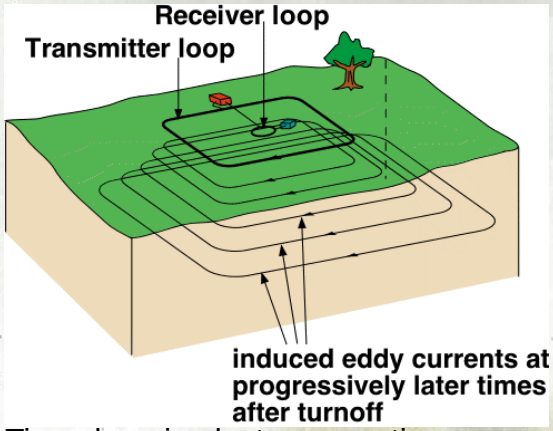
(3) Sub-meter GPS



Frequency domain electromagnetic

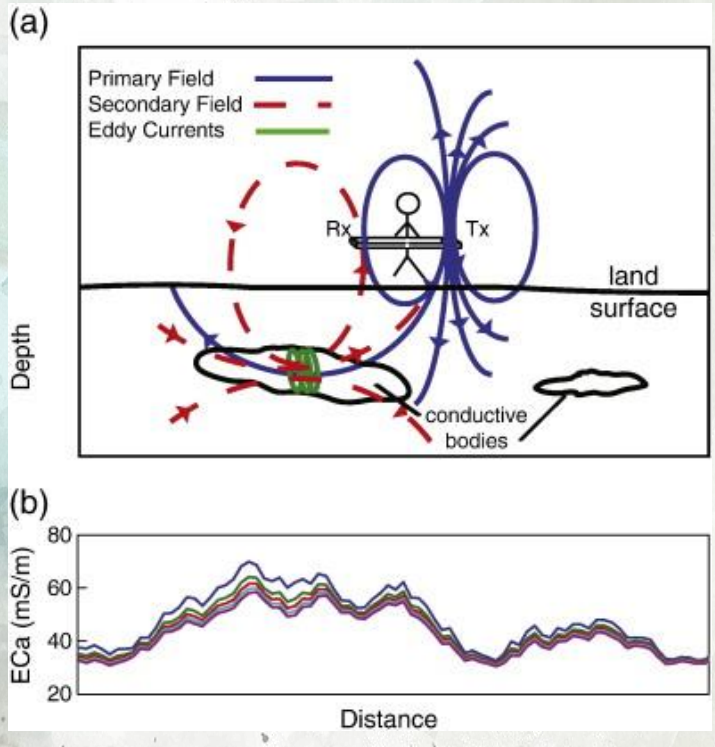


Resistivity



Time domain electromagnetic

Frequency Domain Electromagnetic Survey



- Oscillating EM field penetrates ground
- Eddy currents induced
- Secondary EM field produced by eddy currents
- Instrument measures secondary EM field
- Strength of secondary EM field increases with increasing electrical conductivity of soil/objects

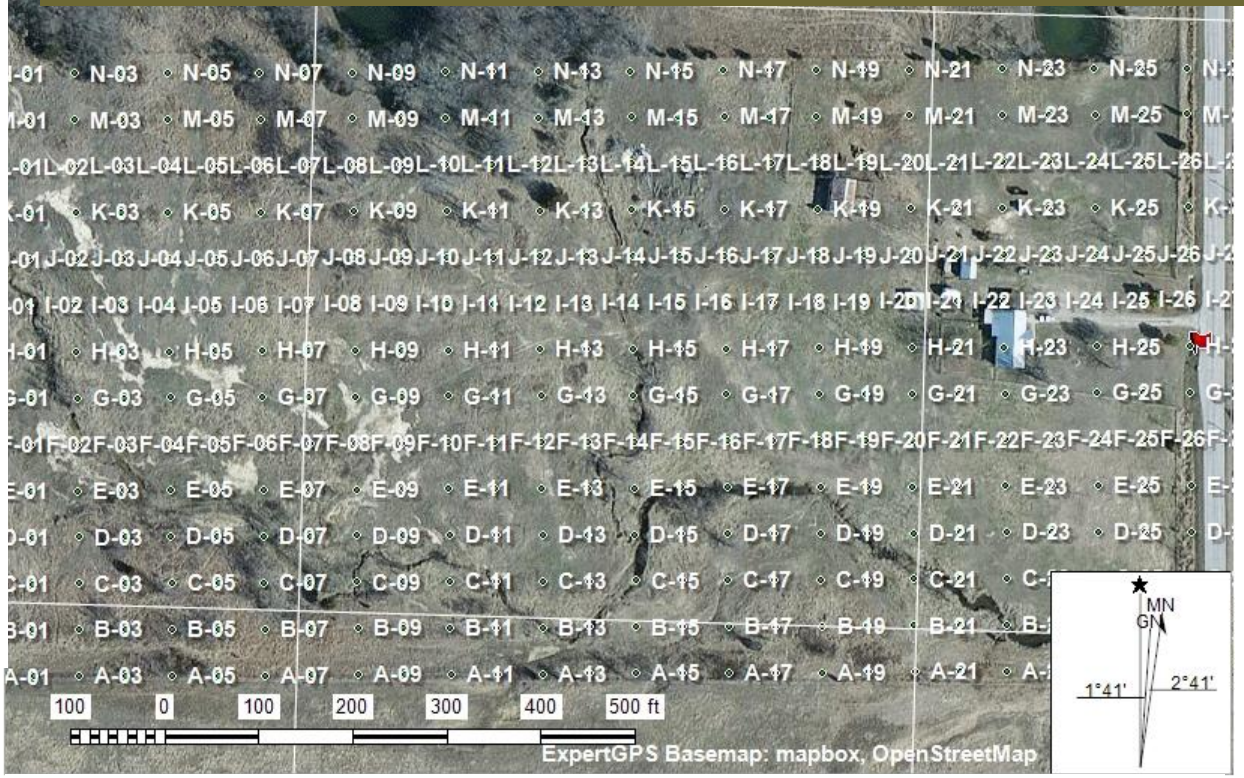
EM-31
3.66-m inter-coil spacing
9.8 kHz operating frequency
12.4 kg instrument weight
8 “C” cells (20 hrs)

Release of Oilfield Brine to Surface Drainage: Creek Co.

Release of Oilfield Brine to Drainage

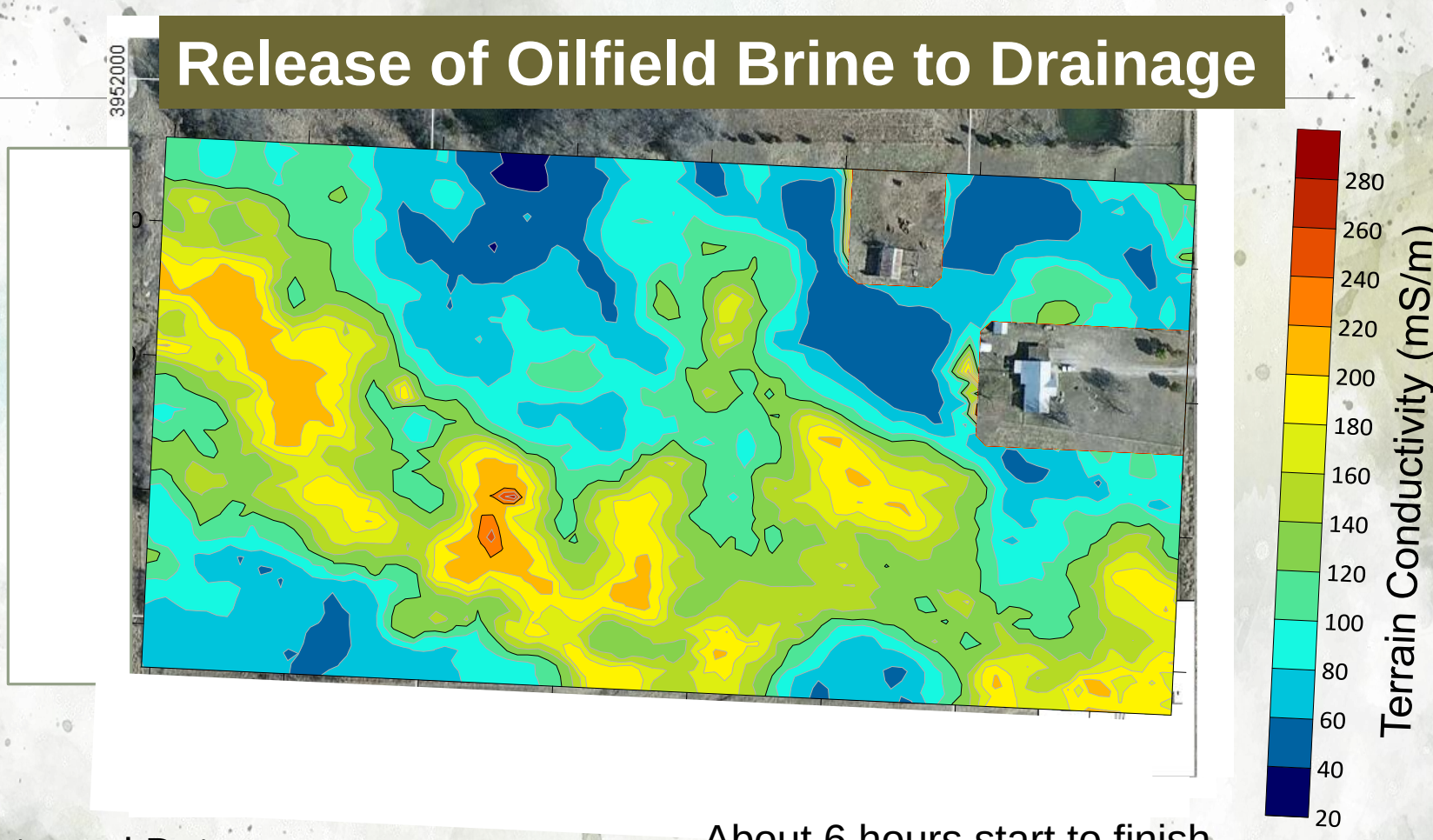
Study Area

Release of Oilfield Brine to Drainage



Navigation Grid

Release of Oilfield Brine to Drainage



Contoured Data

About 6 hours start to finish

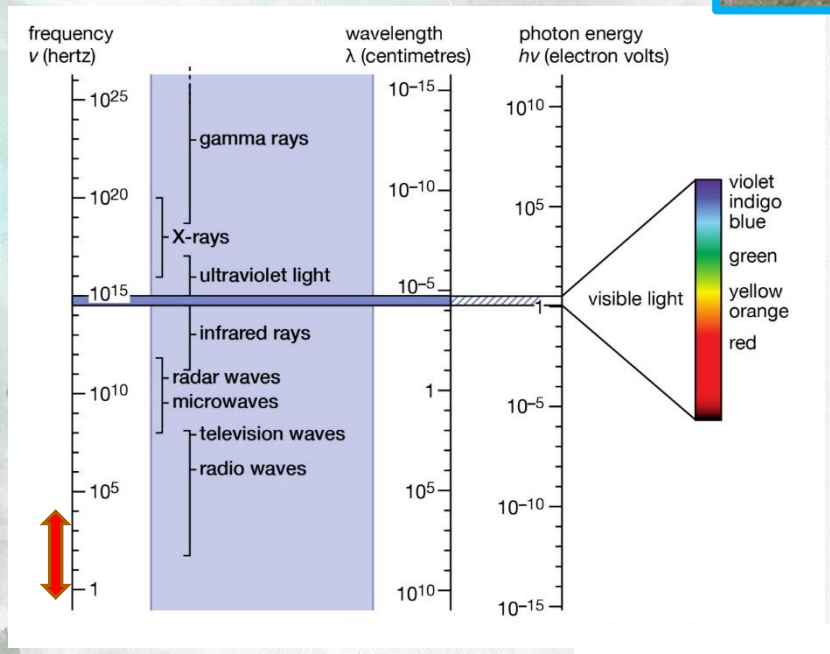
What about depth?

Change frequency and transmitter-receiver spacing

Investigation Depth
is a
Function of Frequency & Transmitter/Receiver Separation

1-m / 0.5-m spacing

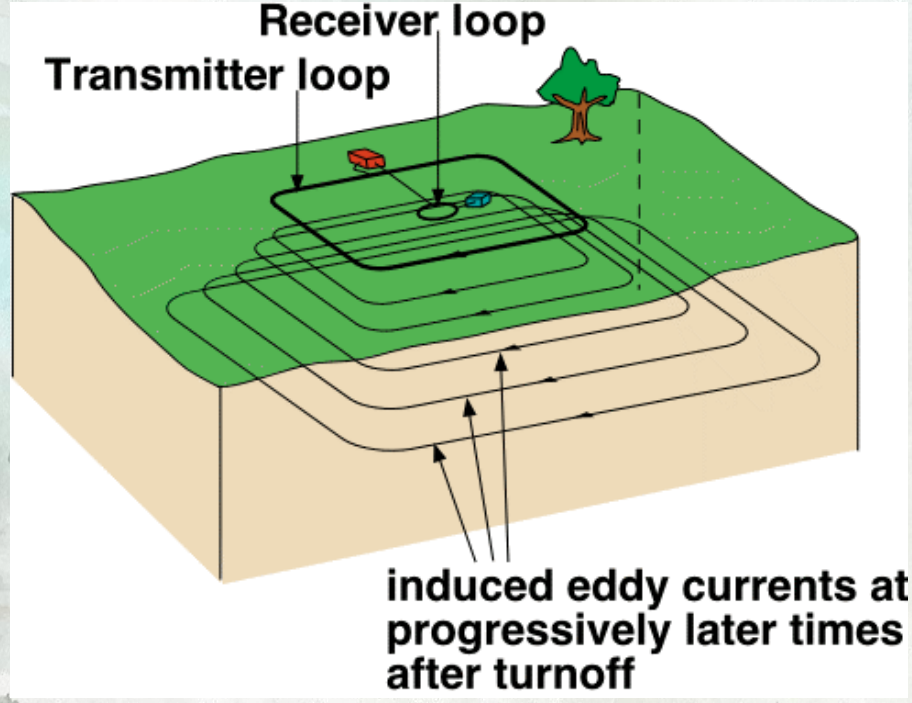
Instrument	Freq. (kHz)	Depth (m)
EM-38	14.5	1.5
EM-31	9.8	5.5
EM-34	6.4	10
EM-34	1.6	20
EM-34	0.4	40

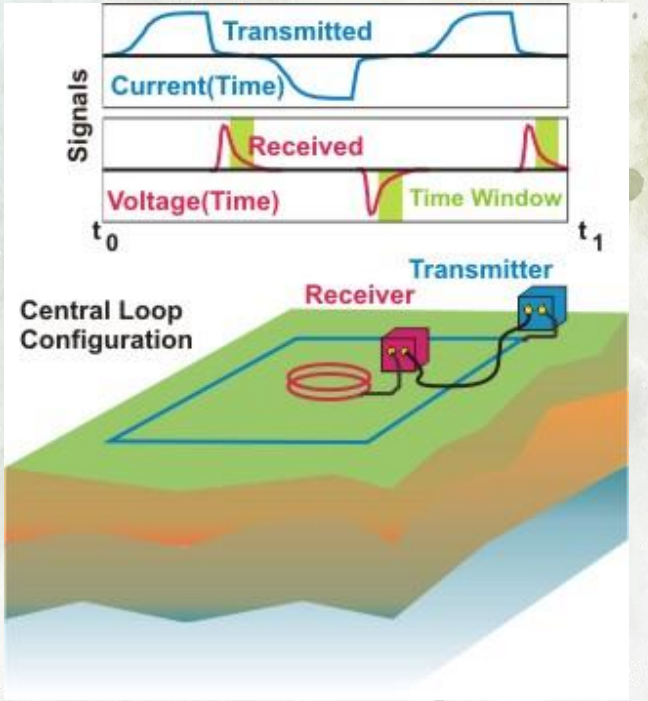


3.66-m spacing

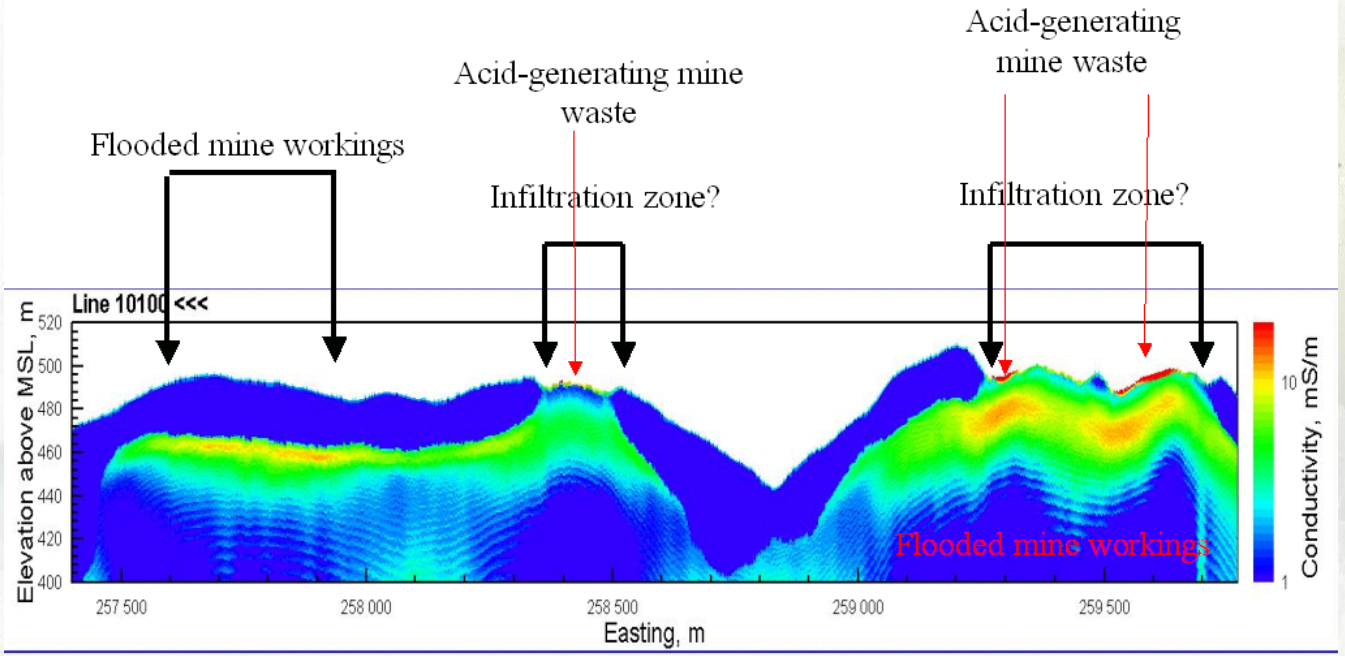
10-, 20-, 40-m spacing

Electromagnetics – Time Domain

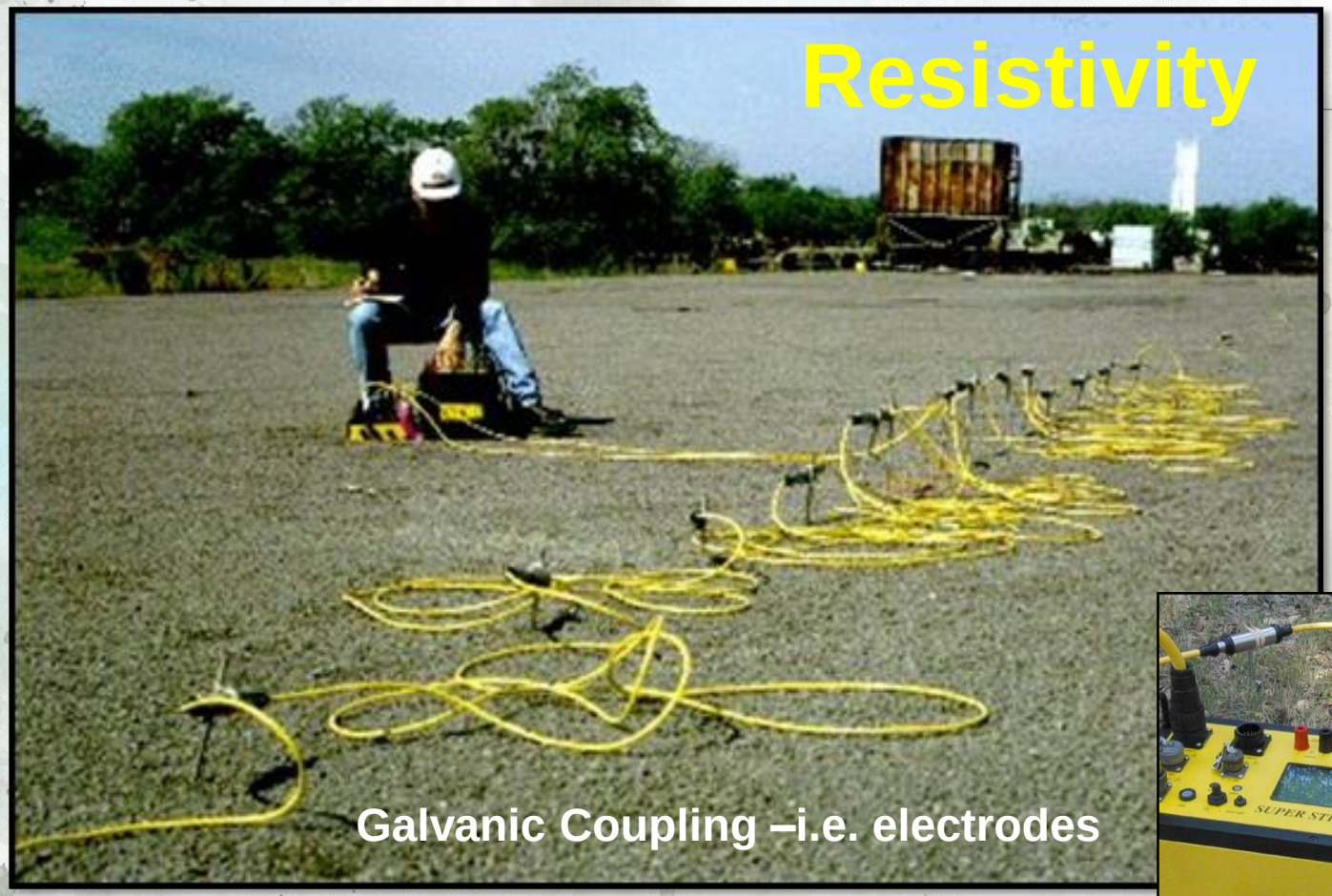




Acid-Generating Mine Waste

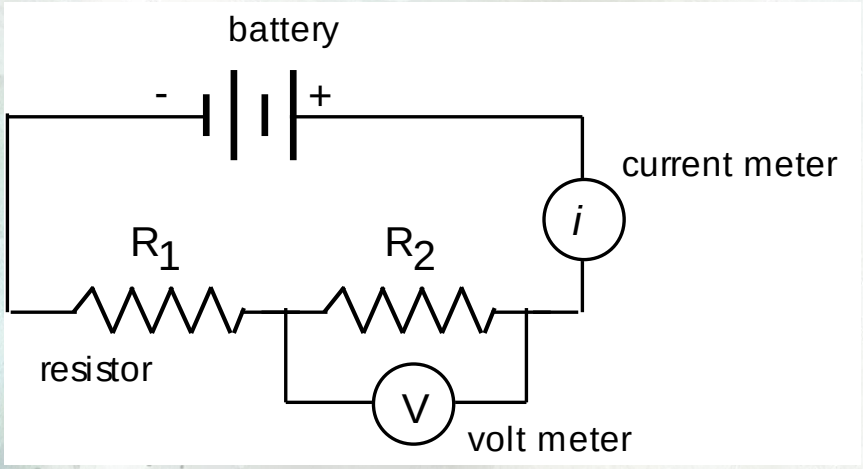


Resistivity



Galvanic Coupling –i.e. electrodes

Some basic electricity for galvanic coupling



Battery - energy supply, pushes electrons around the circuit

Resistor - resists the flow of current

Voltmeter measures the potential difference between two points

Current meter measures the current flow at a point

OHM's LAW

V = I x R (Voltage = Current multiplied by Resistance)

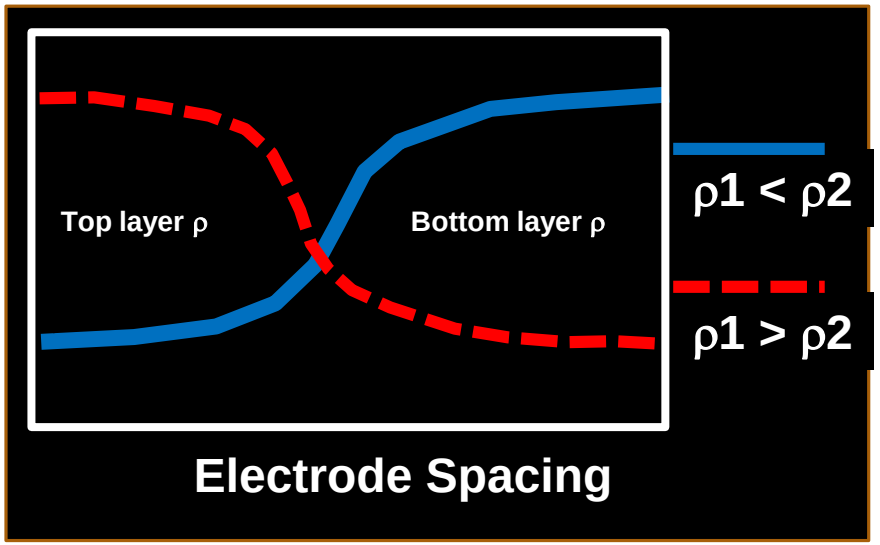
R = V / I (Resistance = Voltage divided by Current)

I = V / R (Current = Voltage Divided by Resistance)

Apparent Resistivity and Electrode Spacing

As electrode spacing increases, we “see” deeper and deeper.

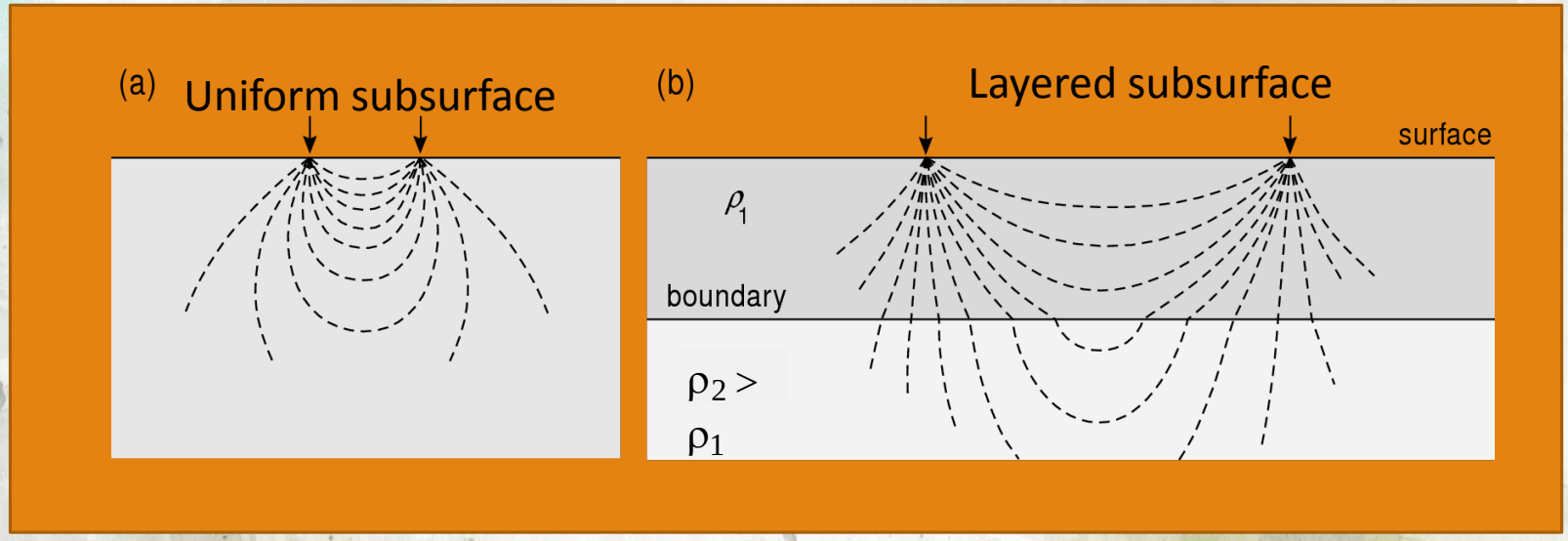
At some point the upper layer will have much less effect than the bottom layer

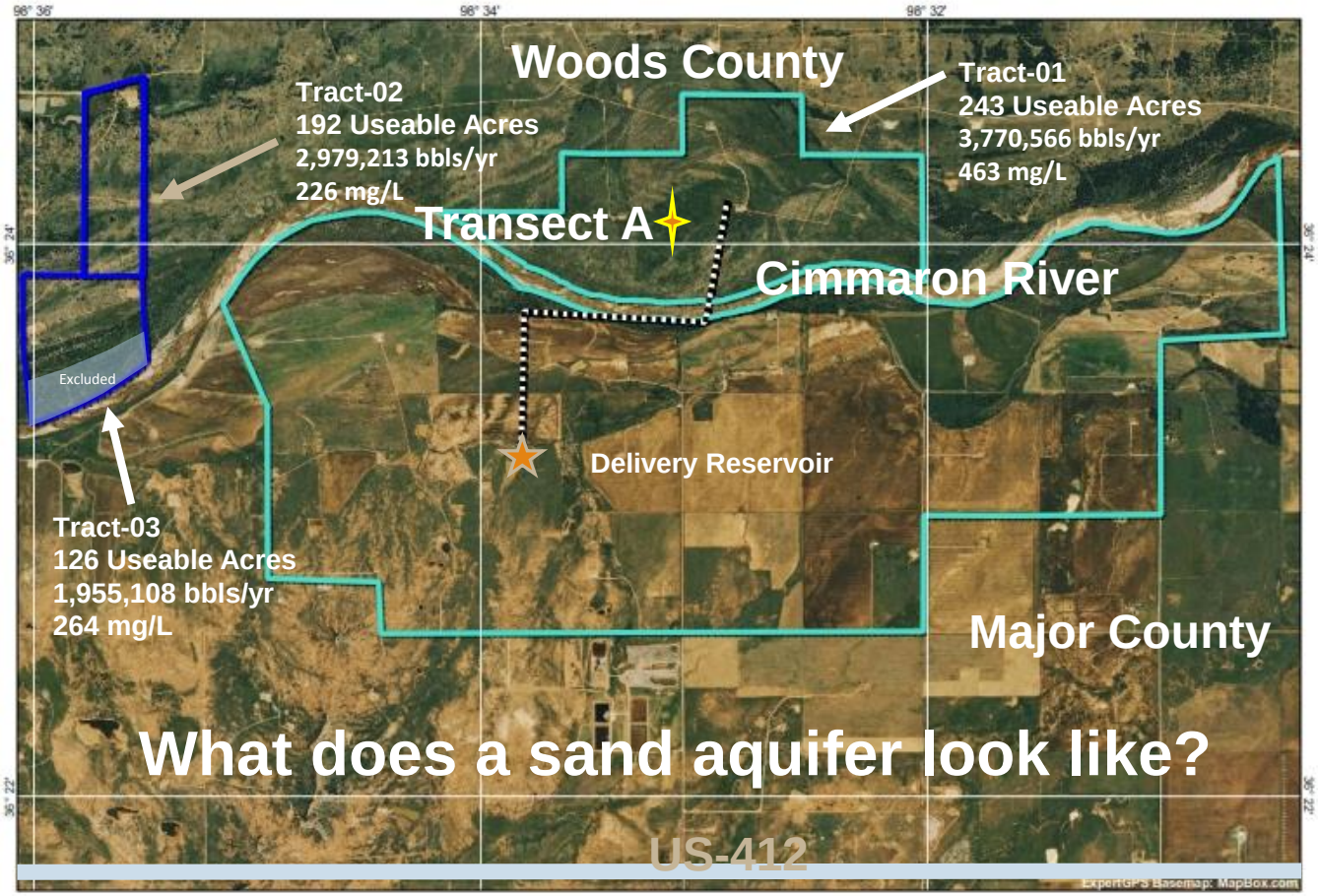


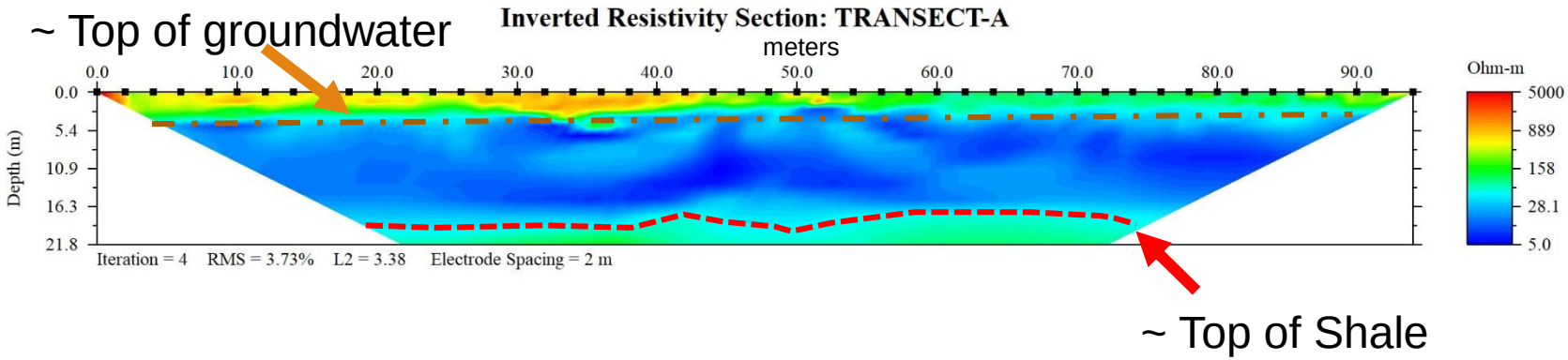
Current refraction

Refraction changes the distribution of current in a layered subsurface

Ratio of V/I changes ∴ can measure change in resistivity with depth

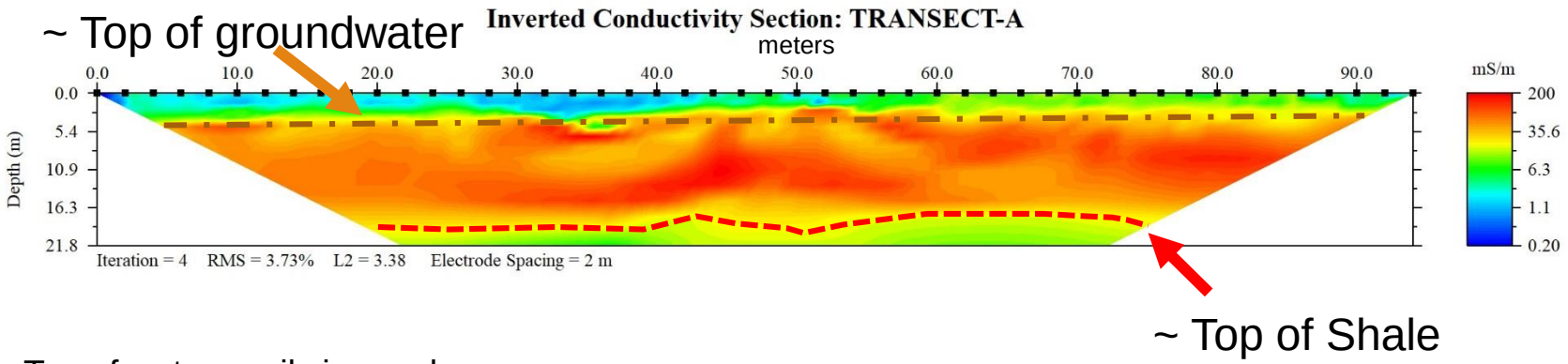



Woods County
Tract-02
192 Useable Acres
2,979,213 bbls/yr
226 mg/L
Tract-01
243 Useable Acres
3,770,566 bbls/yr
463 mg/L
Transect A
Cimmaron River
Excluded
Delivery Reservoir
Tract-03
126 Useable Acres
1,955,108 bbls/yr
264 mg/L
Major County
What does a sand aquifer look like?
US-412
ExpertGPS Basemap: MapBox.com
ExpertGPS
0.25 mi



North

South



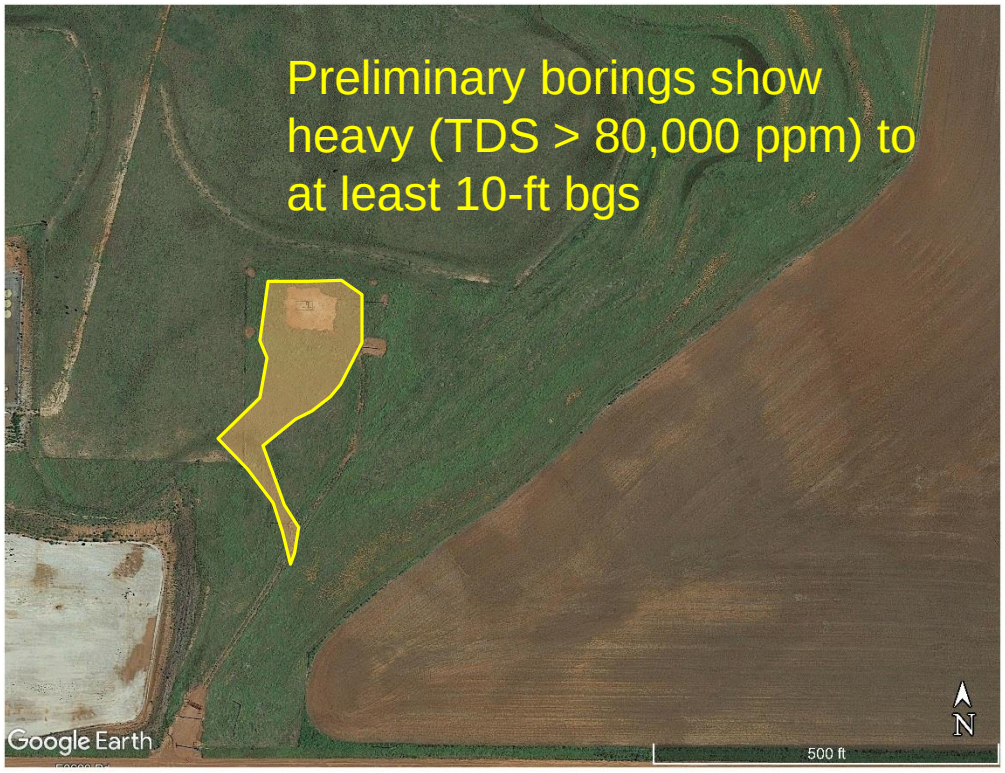
- Top of water easily imaged
- Bedrock topography easily imaged – large resistivity contrast with sandy aquifer

Since water saturation in the aquifer is 100% and salinity is constant, variations in resistivity reflect sedimentary fabric or composition changes

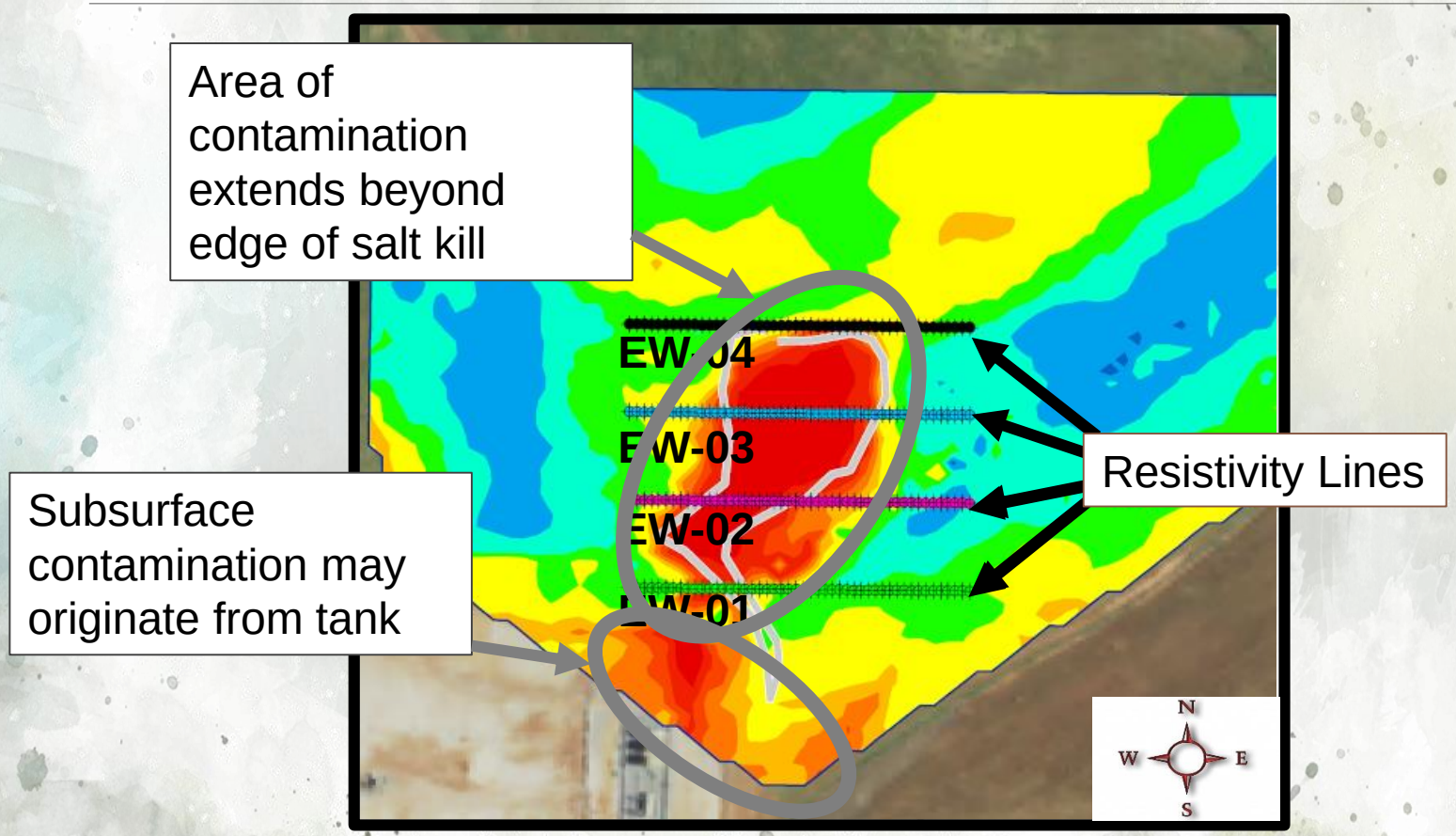
IMMIX, LLC			
Job Code	Rhodes	Survey Date	Apr 19, 2018
Project Site	Woods County, OK	Instrument	SuperSting R8
Approved By		Software	EarthImager 2D
Data File	A1-A3-merged_trial4_Scaled_trial3.stg		

Combining FDEM & Resistivity

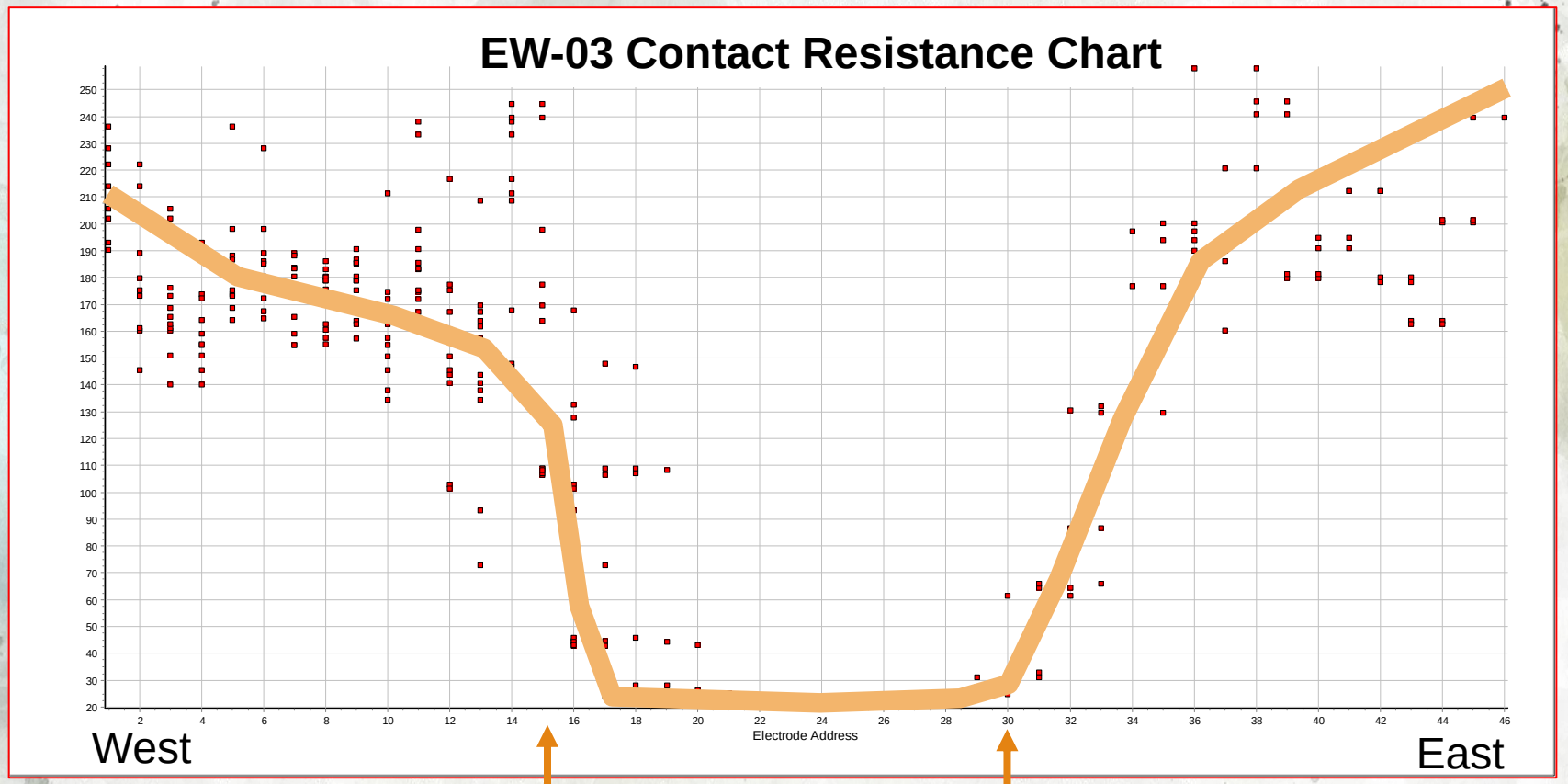
The release: Kingfisher County, OK



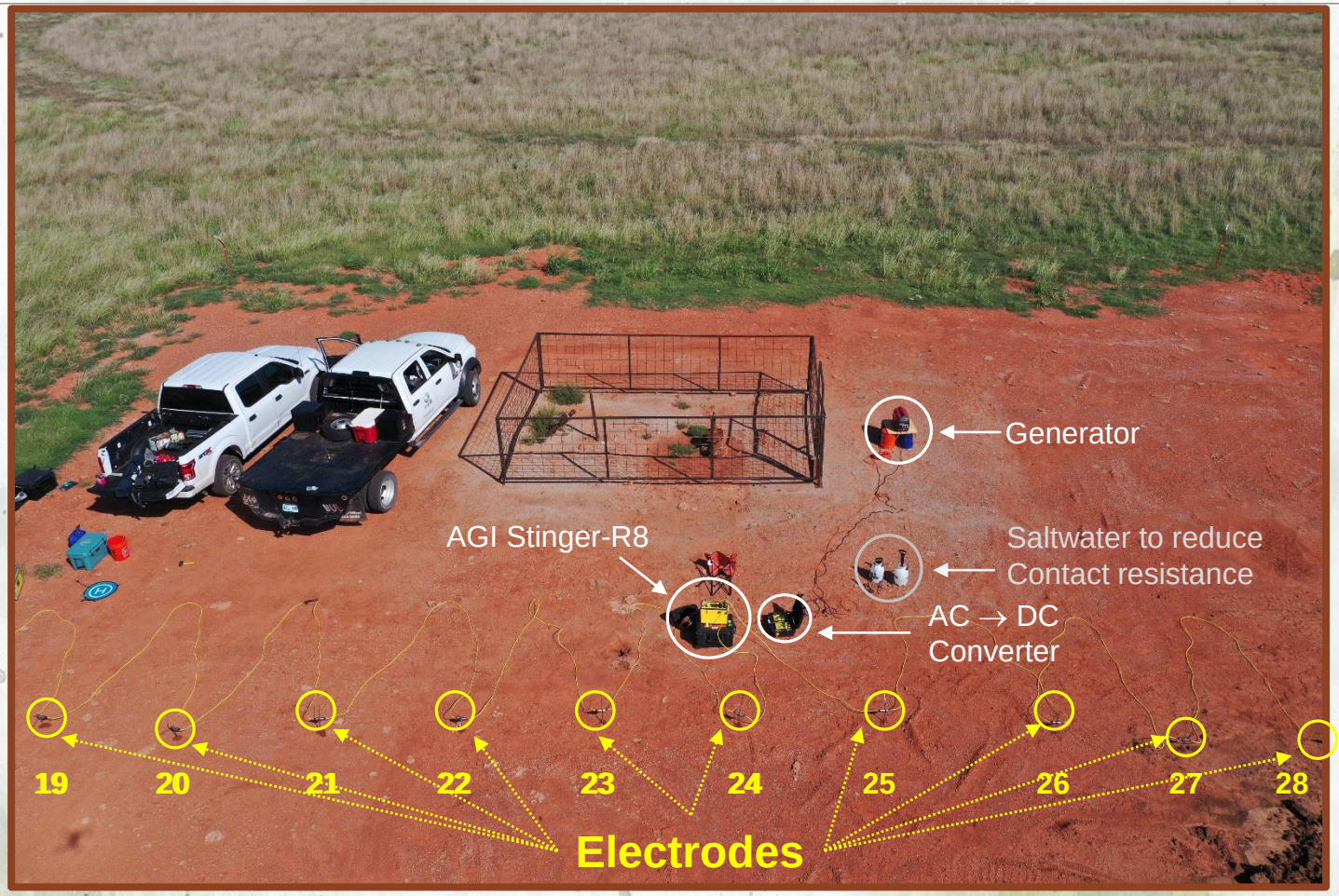
FDEM Survey (Geonics EM-31)



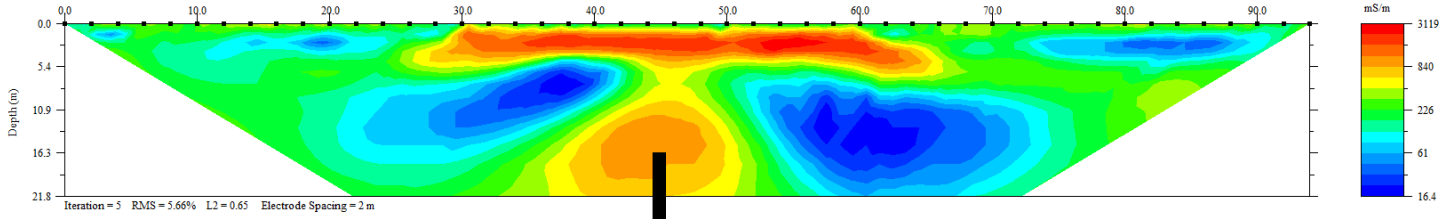

Resistivity Line EW-03
W
S
N
E

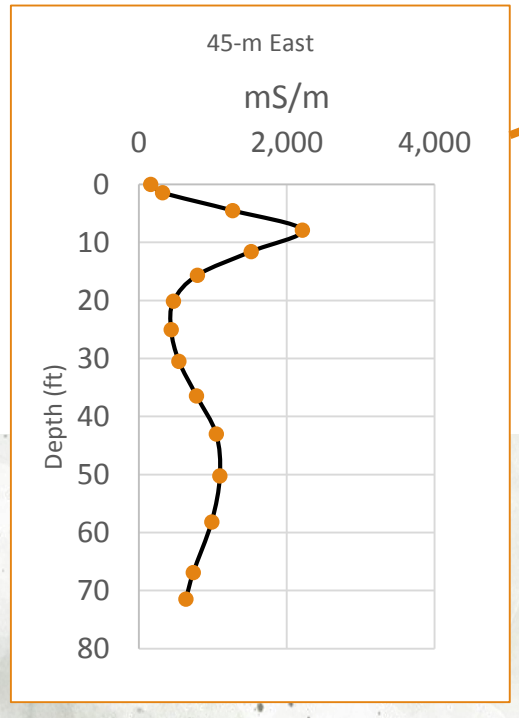

EW-03 Contact Resistance Chart
Electrode Address
West
East
30-meters
60-meters

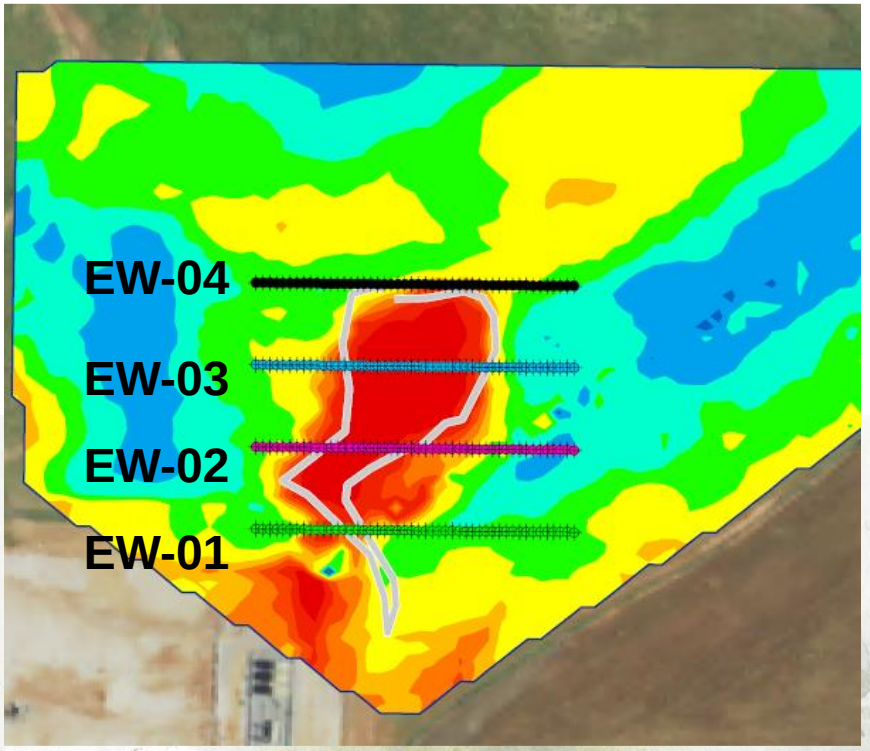
Electrical Resistivity Profile (VES)

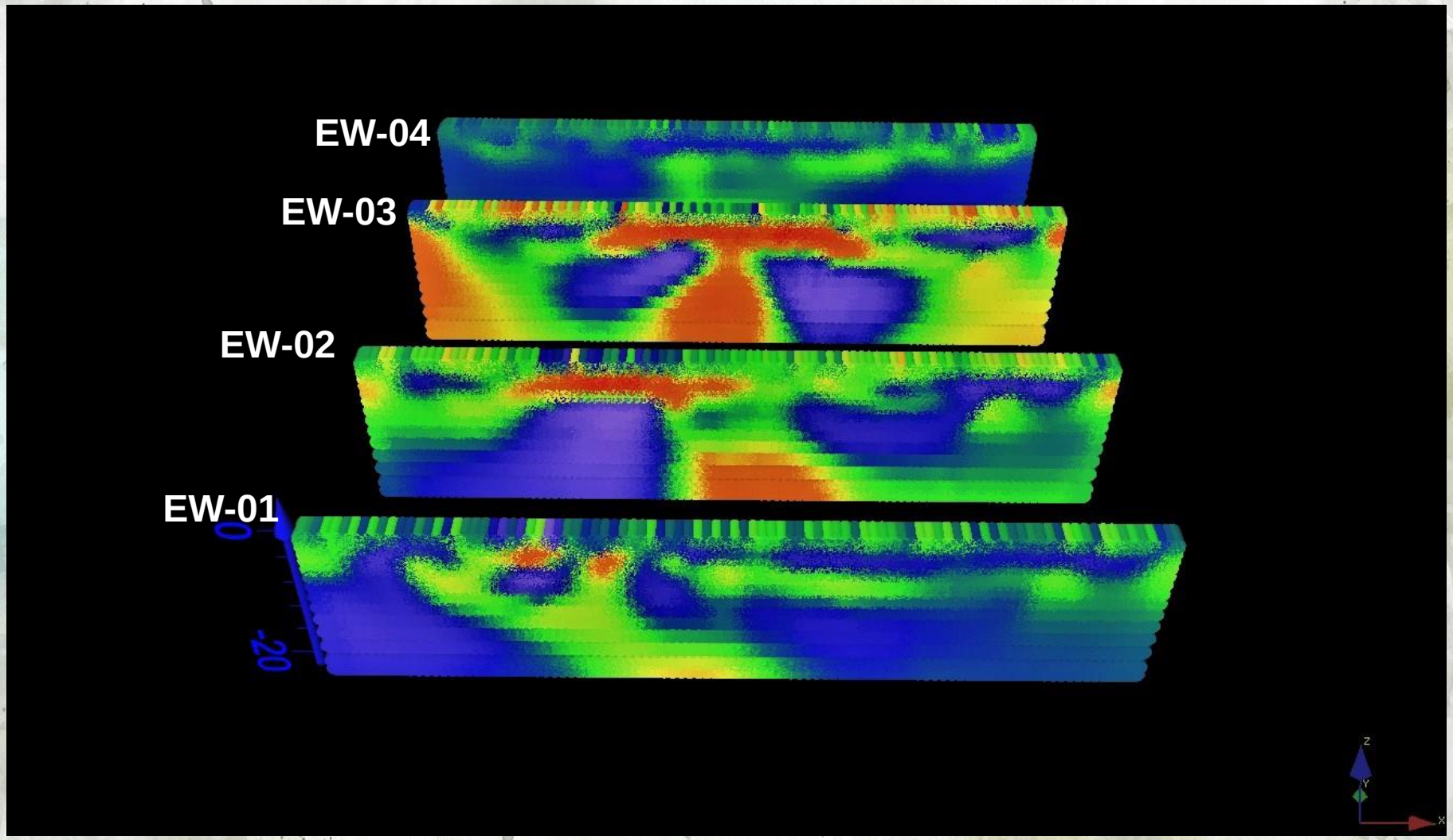


EW-03 Conductivity Section







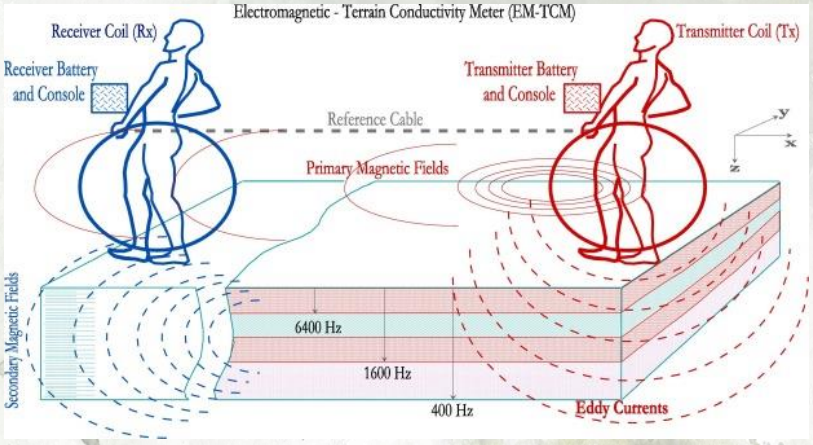

EW-04
EW-03
EW-02
EW-01
0
-20
Z
Y
X

Conclusions

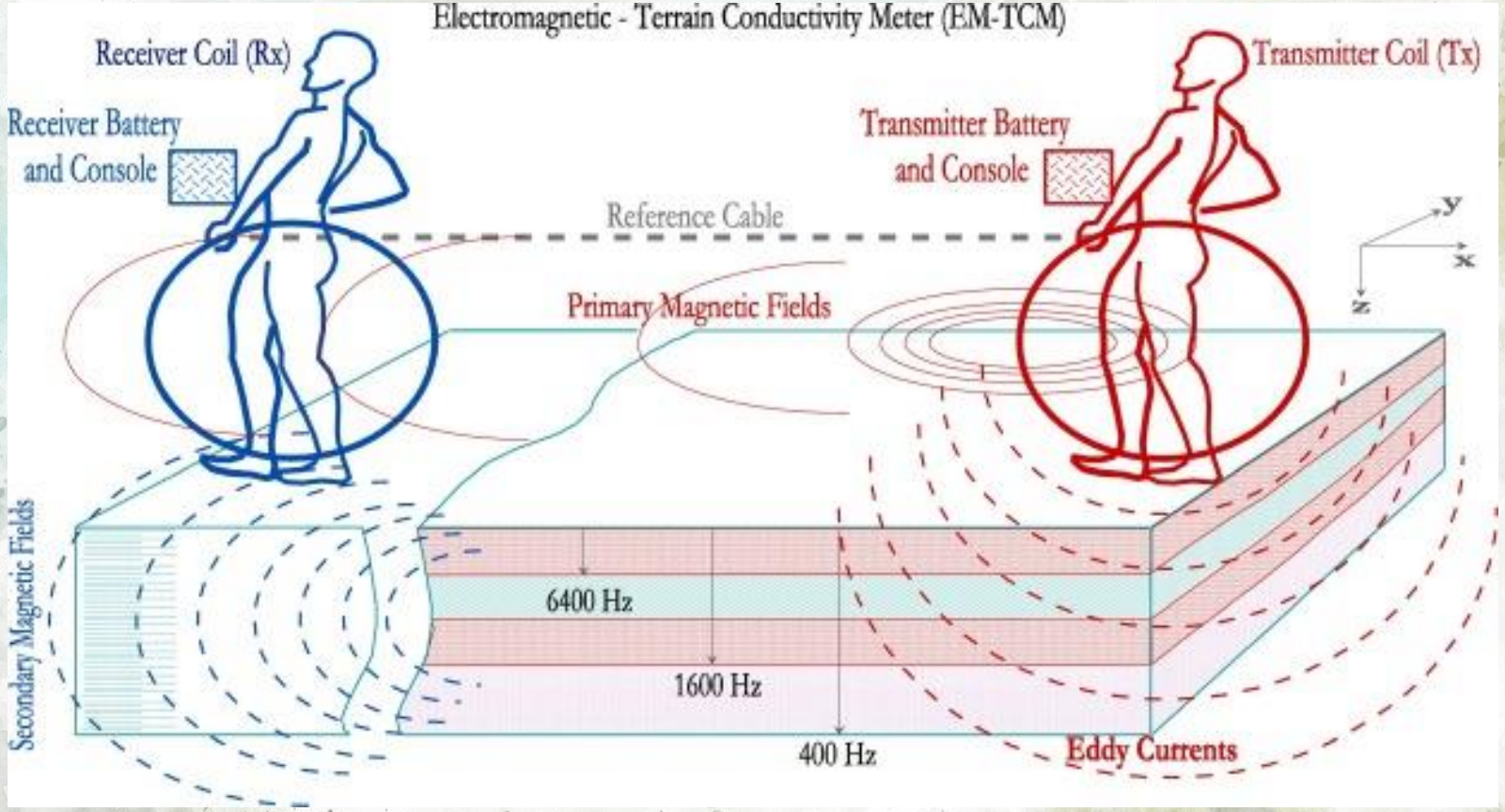
Electrical geophysics rapidly provide lateral and vertical extent of salt contamination in the shallow subsurface

Visual evidence of salt contamination provides a point of beginning for electrical geophysical surveys

Actual soil and/or water samples must still be collected to ground truth geophysical data



QUESTIONS?


Electromagnetic - Terrain Conductivity Meter (EM-TCM)
Receiver Coil (Rx)
Receiver Battery and Console
Transmitter Coil (Tx)
Transmitter Battery and Console
Reference Cable
Primary Magnetic Fields
y
x
z
Secondary Magnetic Fields
6400 Hz
1600 Hz
400 Hz
Eddy Currents