Field Characterization of a Brine Spill Site for Long-Term Reclamation Success

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Case Study – Brine Spill

~1,500 barrels produced fluid

~33 acres

Burke County, ND

Case Study – Brine Spill

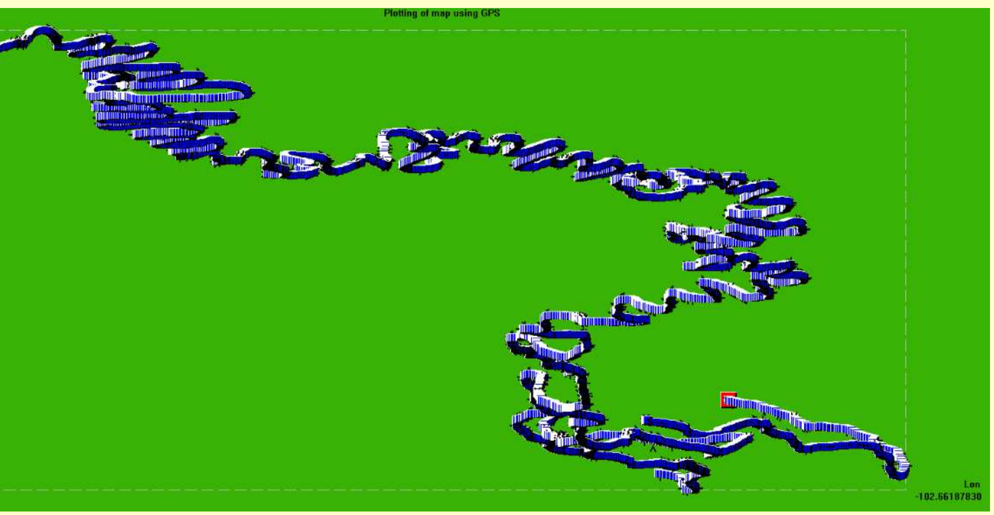
- evation: ~2,300 Ft.
- recipitation: 17” annually
- oils: Loam/Clay Loam
- egetation:
  - Improved pasture
  - Wetlands
- ydrology: Adjacent to etlands and intermittent ream

Mitigation Process

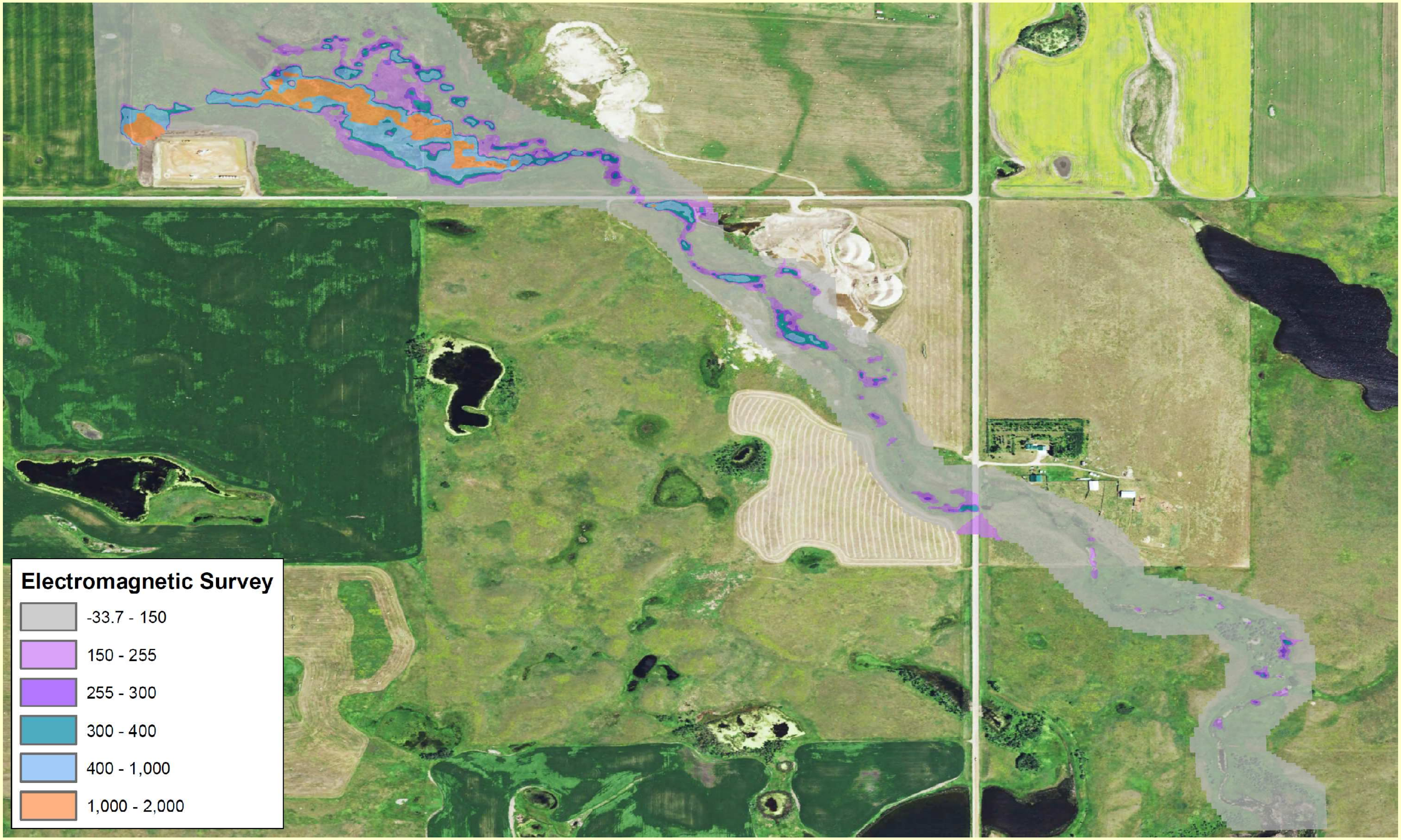
1. Initial Response
2. Electromagnetic Survey
3. Surface and ground water monitoring
4. Soil investigation and assessment
5. Wetland delineation to support potential 404 permitting
6. Design and installation of subsurface tile drainage system
7. In-situ soil mitigation
8. Revegetation of affected areas
9. Vegetation inventory and monitoring of the disturbed area

Field Assessment – Electromagnetic Survey

- EMP-400
- 3000, 9000, & 15000 kHz



Field Assessment – Electromagnetic Survey



Surface & Groundwater Monitoring (TetraTech

Field Measurements

- Electrical Conductivity
- Chloride

Lab Analyses

- pH
- Electrical Conductivity
- Total Dissolved Solids
- Total Suspended Solids
- Total Alkalinity
- Hardness, Ca/Mg

- Sodium Adsorption Ratio
- Anions
  - Alkalinity
  - Br, Cl, S
- Cations
  - Ca, Mg, K, Na

- Total & Dissolved Metals
  - Ar, Ba, B, Cd, Cr, Pb, Hg,
- Organics
  - Benzene
  - Gasoline & Diesel Rang Organics

Surface Water Monitoring – Field + Lab

urface Water - Field	Thresholds		Sample Range	
	NDDoH	Irrigation	Max	Min
ectrical Conductivity (dS/m)	**1.5**	**3.0**	**80.4**	1.1
hloride (mg/L)	**250**	**350**	**12,000**	12.0

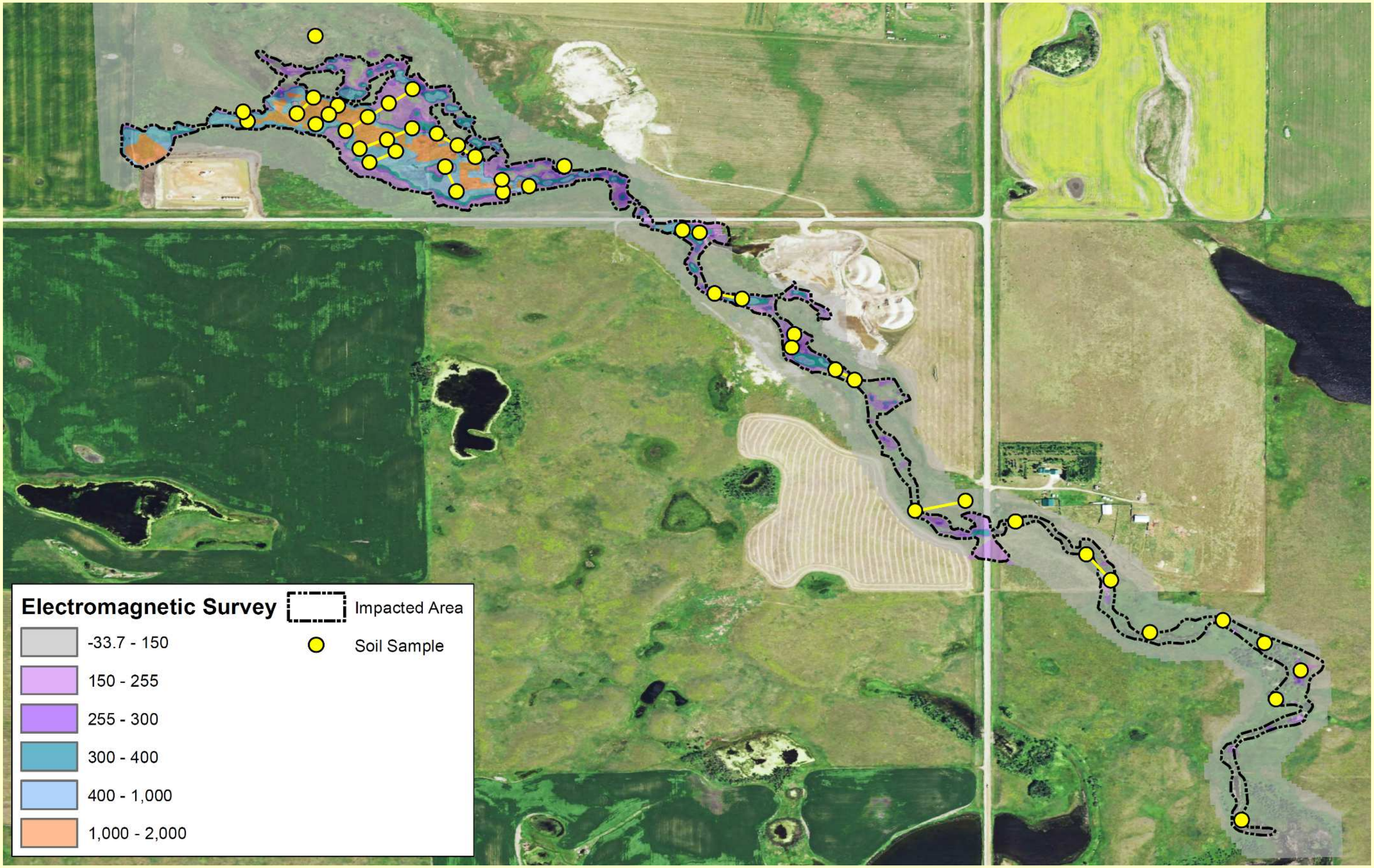
urface Water - Lab	Thresholds		Sample Range	
	NDDoH	Irrigation	Max	Min
ectrical Conductivity (dS/m)	**1.5**	**3.0**	**63.3**	1.4
hloride (mg/L)	**250**	**350**	**33,900**	11.4

Groundwater Monitoring – Field + Lab

	Thresholds		Sample Range	
roundwater –Field	**NDDoH**	**Drinking Water**	**Max**	**Min**
ectrical Conductivity (dS/m)	**1.5**		**47.7**	0.75
hloride (mg/L)		**250**	**12,668**	4.0

	Thresholds		Sample Range	
roundwater – Lab	**NDDoH**	**Drinking Water**	**Max**	**Min**
ectrical Conductivity (dS/m)	**1.5**		**44.6**	0.74
hloride (mg/L)		**250**	**15,200**	2.43

Field Assessment – Soil Sampling



Soil Investigation & Assessment – Sampling

- xcavated soil pit or hand auger
- mpled in 1-ft
- crements to 4-ft
- eld descriptions
- eld chemistry
  - 1:5 dilute water extract
  - EC
  - Chloride

Soil Investigation & Assessment – Analysis

- pH
- Electrical Conductivity
- Organic Matter
- Carbonate ($CaCO_3$)
- Calcium
- Magnesium
- Sodium
- Sodium Adsorption Ratio (SAR)
- Cation Exchange Capacity (CEC)
- Chloride
- Texture (% S, Si, C)
- Coarse Fragments
- Total Metals
  - Ba, Cd, Cr, Pb, Se, Ag, Hg
- Benzene
- Gasoline & Diesel Range Organics

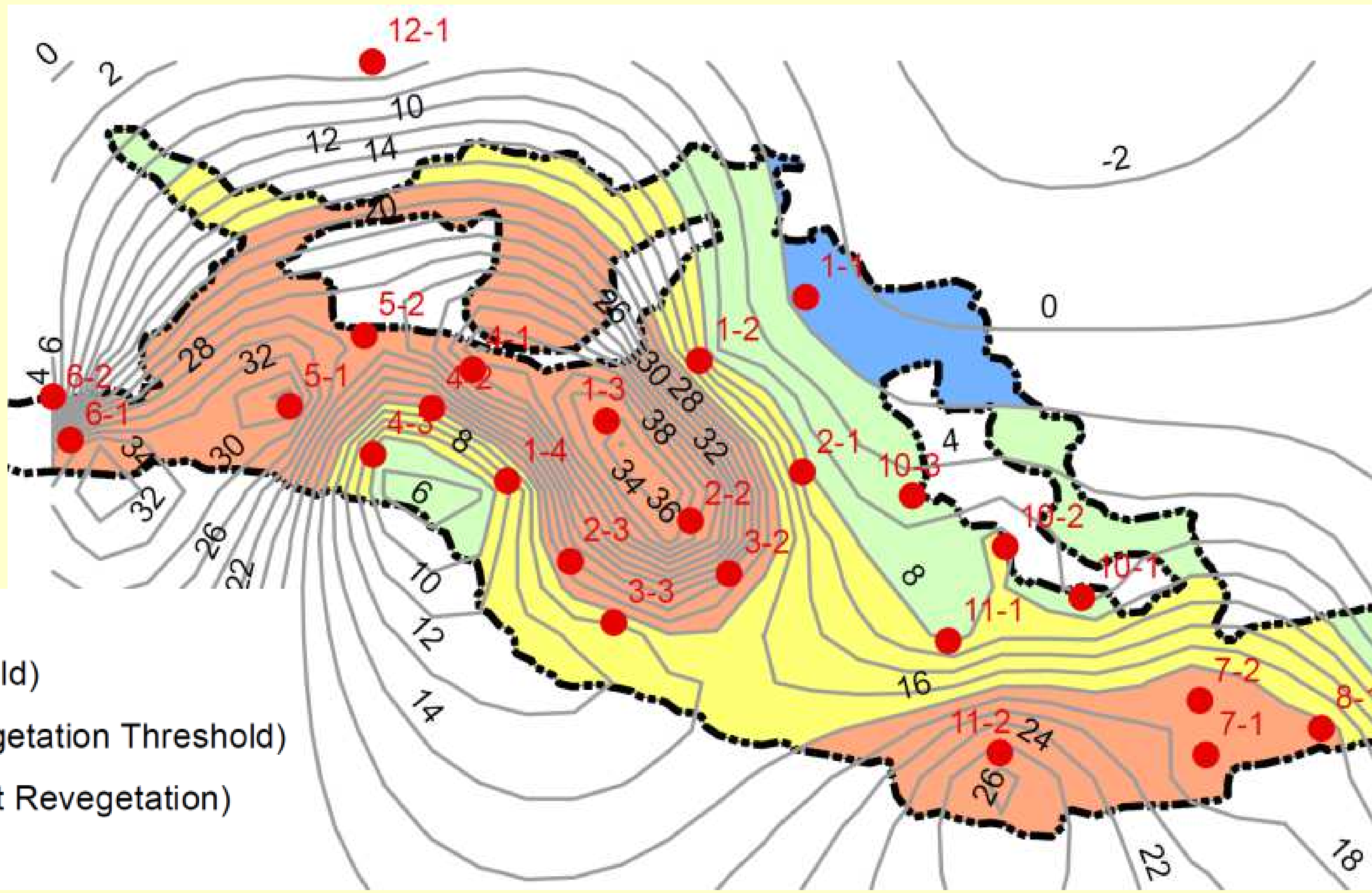
Soil Investigation & Assessment – Field Results

onstituent	Thresholds		Sample Range	
	NDDoH	Reclamation	Max	Min
ectrical Conductivity (dS/m)	**2**	**12**	**190.1**	0.87
hloride (mg/kg)	**250**	**250**	**40,370**	1.8

Soil Investigation & Assessment – Lab Results

onstituent	Thresholds		Sample Range	
	NDDoH	Reclamation	Max	Min
H		8.5	8.2	5.9
ectrical Conductivity (dS/m)	**2**	**12**	**73.2**	0.61
odium Adsorption Ratio	**12**	**12**	**139**	0.79
nloride (mg/kg)	**250**	**250**	**114,000**	25
asoline Range Organics (mg/kg)	100		20	nd
iesel Range Organics (mg/kg)	100		nd	nd

Soil Investigation & Assessment – Results



cal Conductivity

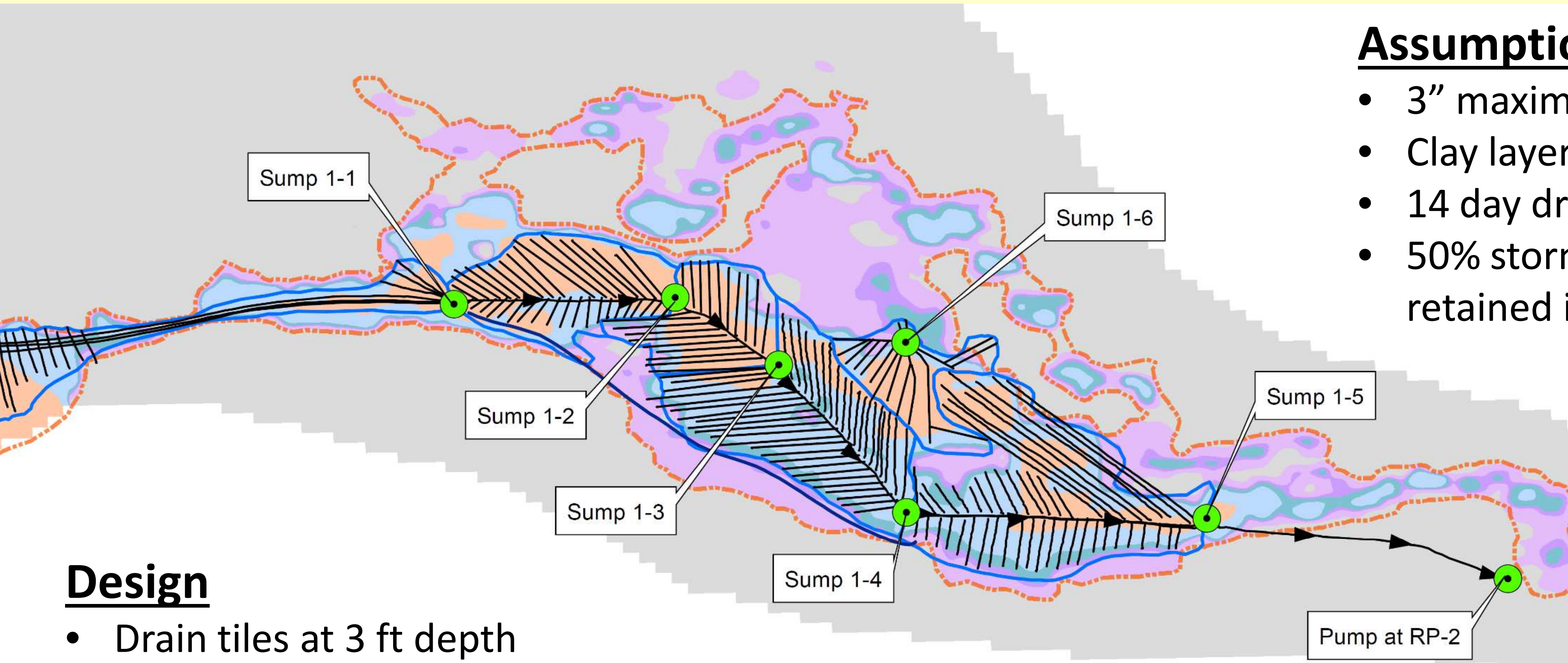
<2 dS/m (NDDoH Threshold)

2-8 dS/m (Standard Revegetation Threshold)

8-16 dS/m (Saline Tolerant Revegetation)

>16 dS/m

n-Situ Mitigation – Tile Drain System



Assumptions

- 3” maximum rain
- Clay layer at ~3 ft
- 14 day dry time
- 50% storm volum retained in soil

Design

- Drain tiles at 3 ft depth
- Laterals on 15-ft centers
- 3” slug of water during dry months
- 14 day dry time

n-Situ Mitigation – Soil Amendments

il Amendments

alcium Nitrate

- 1 bbl LCA-II™ / 25 bblwater
- 24” depth

ypsum

- 400 mesh particle
- 5 – 70 ton/acre

vegetation

roadcast seed

- 100 PLS/SqFt
- Native upland & wetland graminoids

mproving the Process

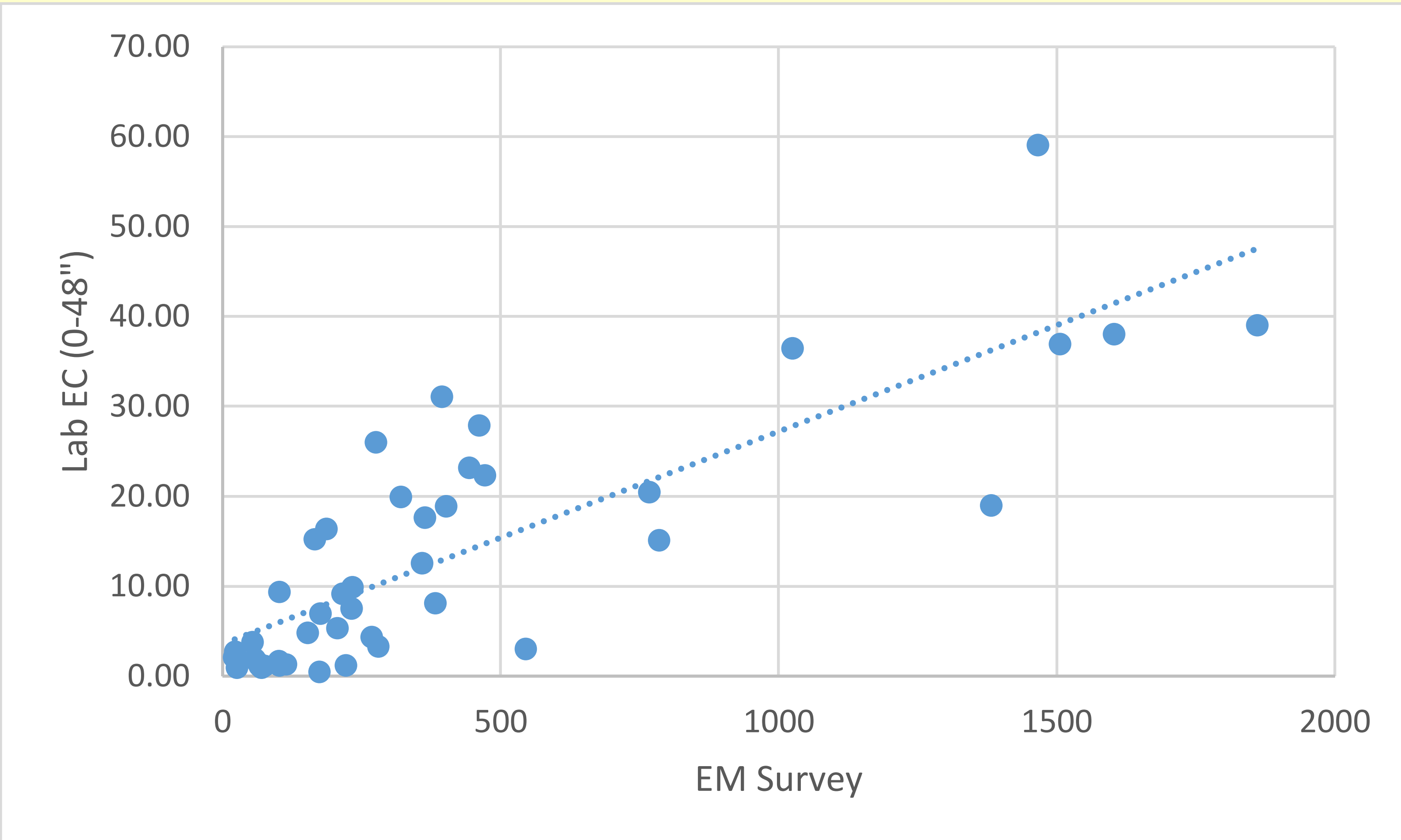
Learning from the data

- Saving time and money
- Improving results

Questions asked:

1. How well does EM survey fit the soil lab data?
2. Can EM survey and/or field soil data be used to improve reclamation designs?
3. Could field water data be used to reduce the number of samples sent to the lab?

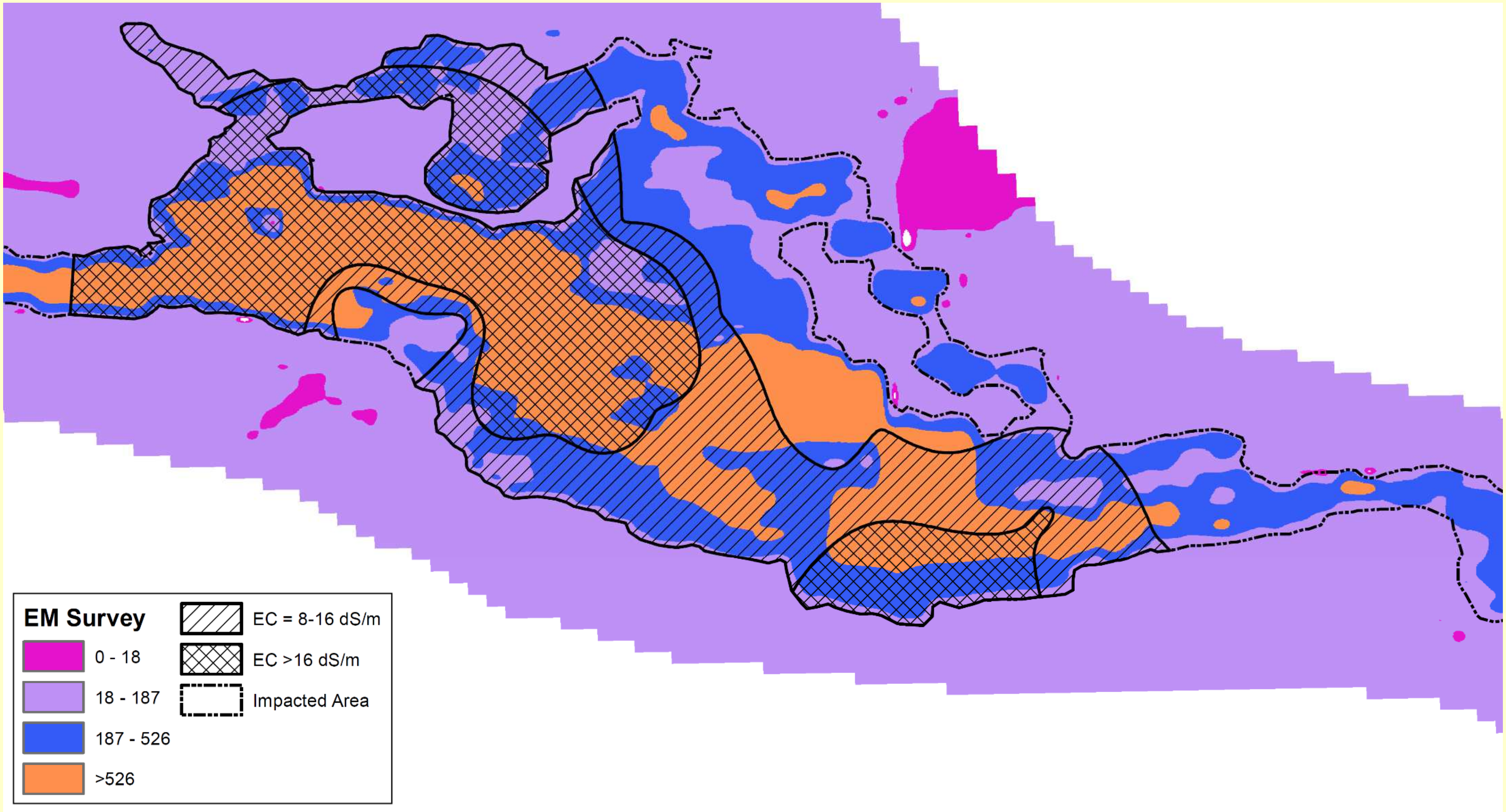
EM Survey vs. Soil Lab Data?



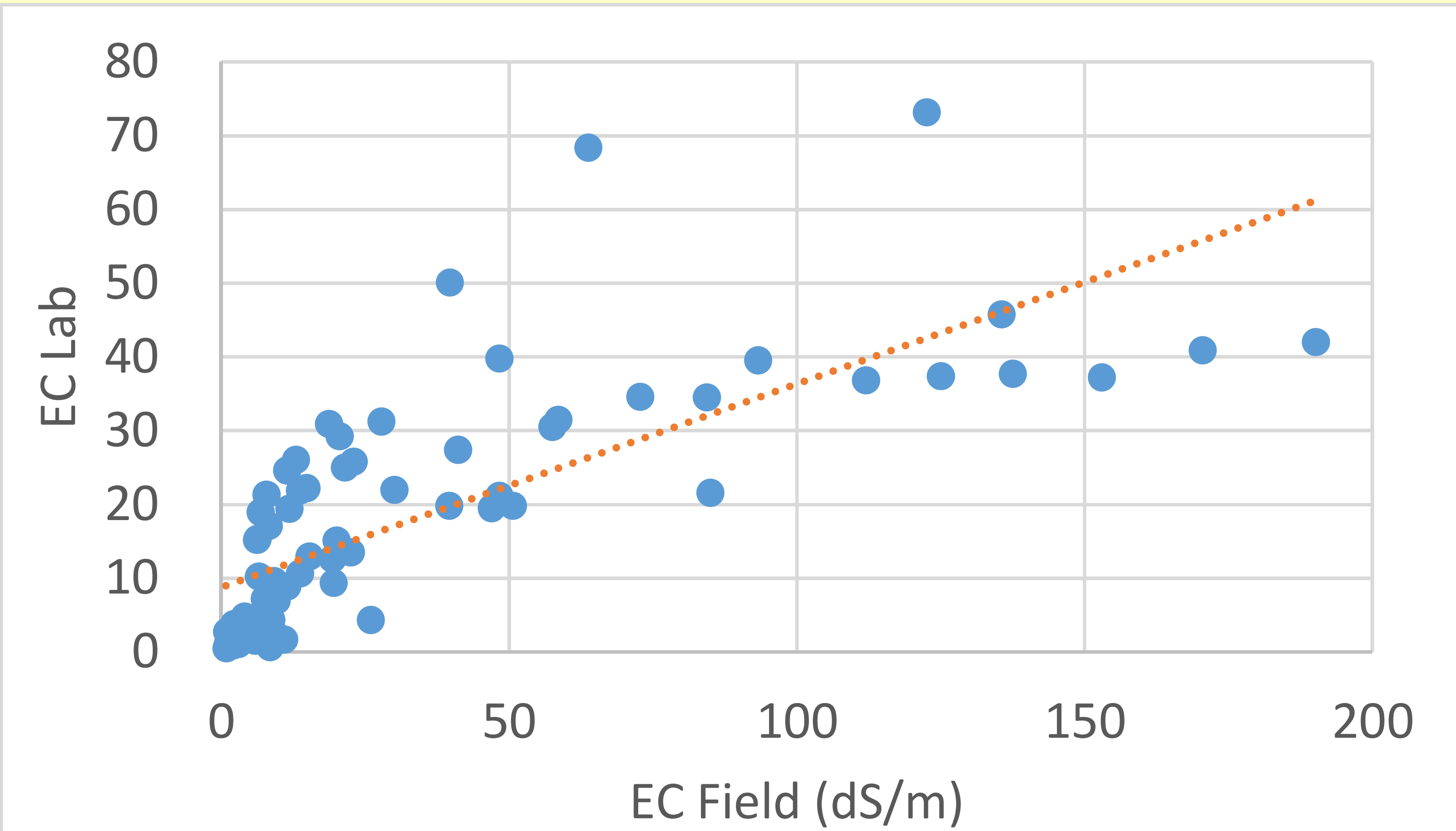
$R^2 = 0.66$

y = 0.0236x + 3.5

EM Survey vs. Soil Lab Data?

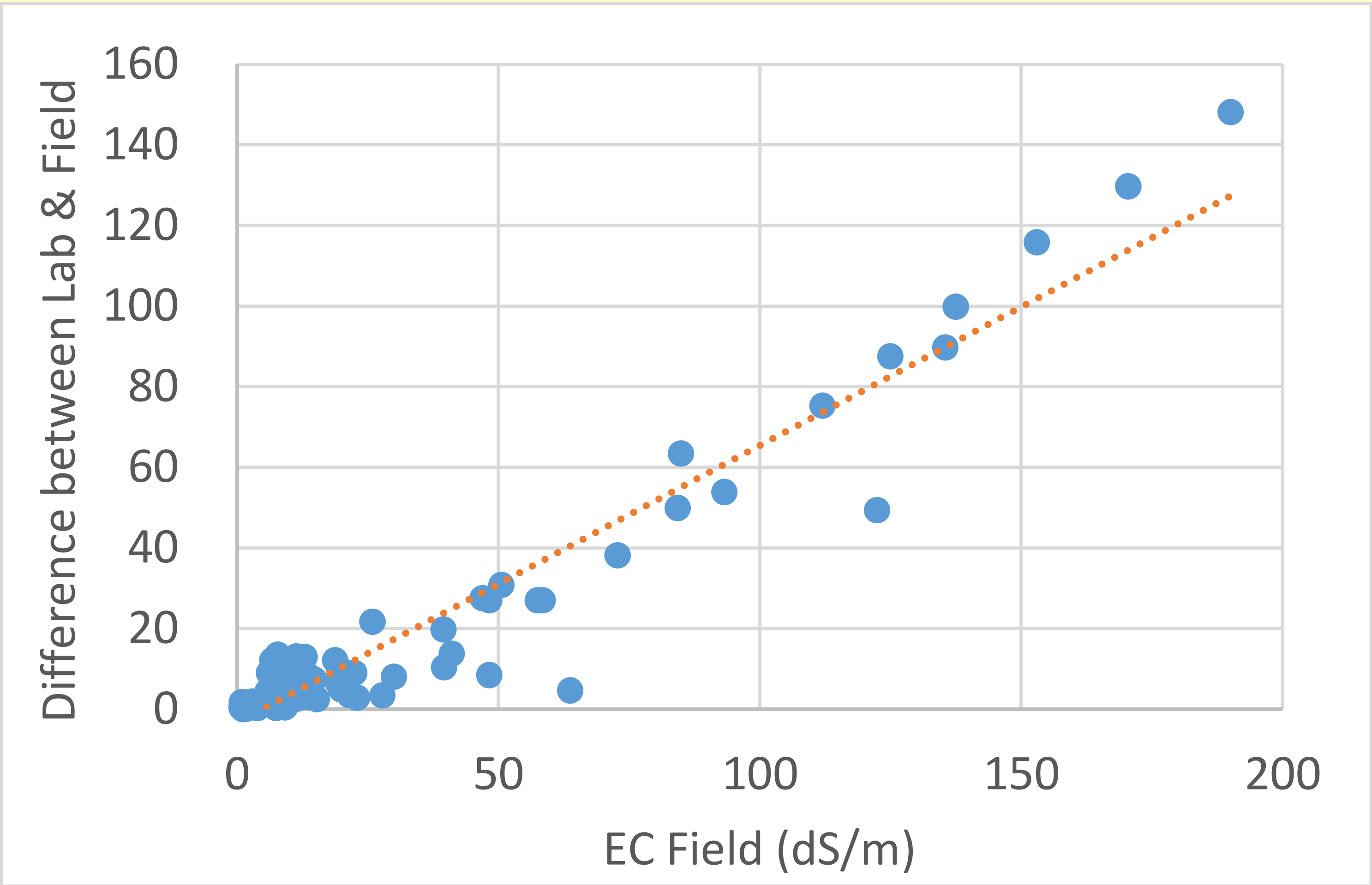


Field Data vs. Lab Data - Soil?



$R^2 = 0.5$

Field Data vs. Lab Data - Soil?



$R^2 = 0.9$

eld Data vs. Lab Data – Differences in Soil EC?

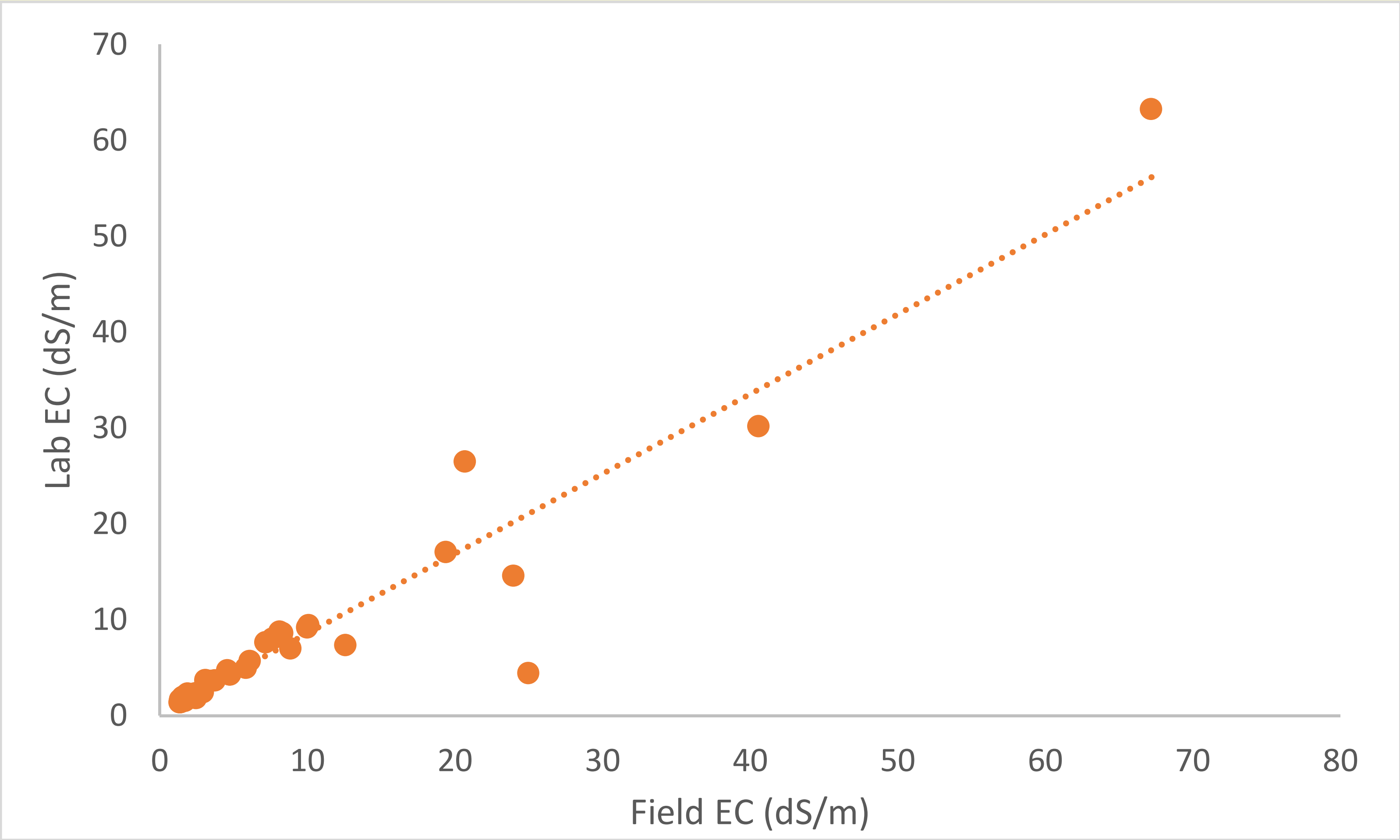
Dilution
- Field EC – 1:5 water:soil mixture
- Laboratory EC – Saturated Paste Extract from oven dried soil

Other Soil Characteristics
- Moisture, texture, clay content, and chloride

Instrument Calibration

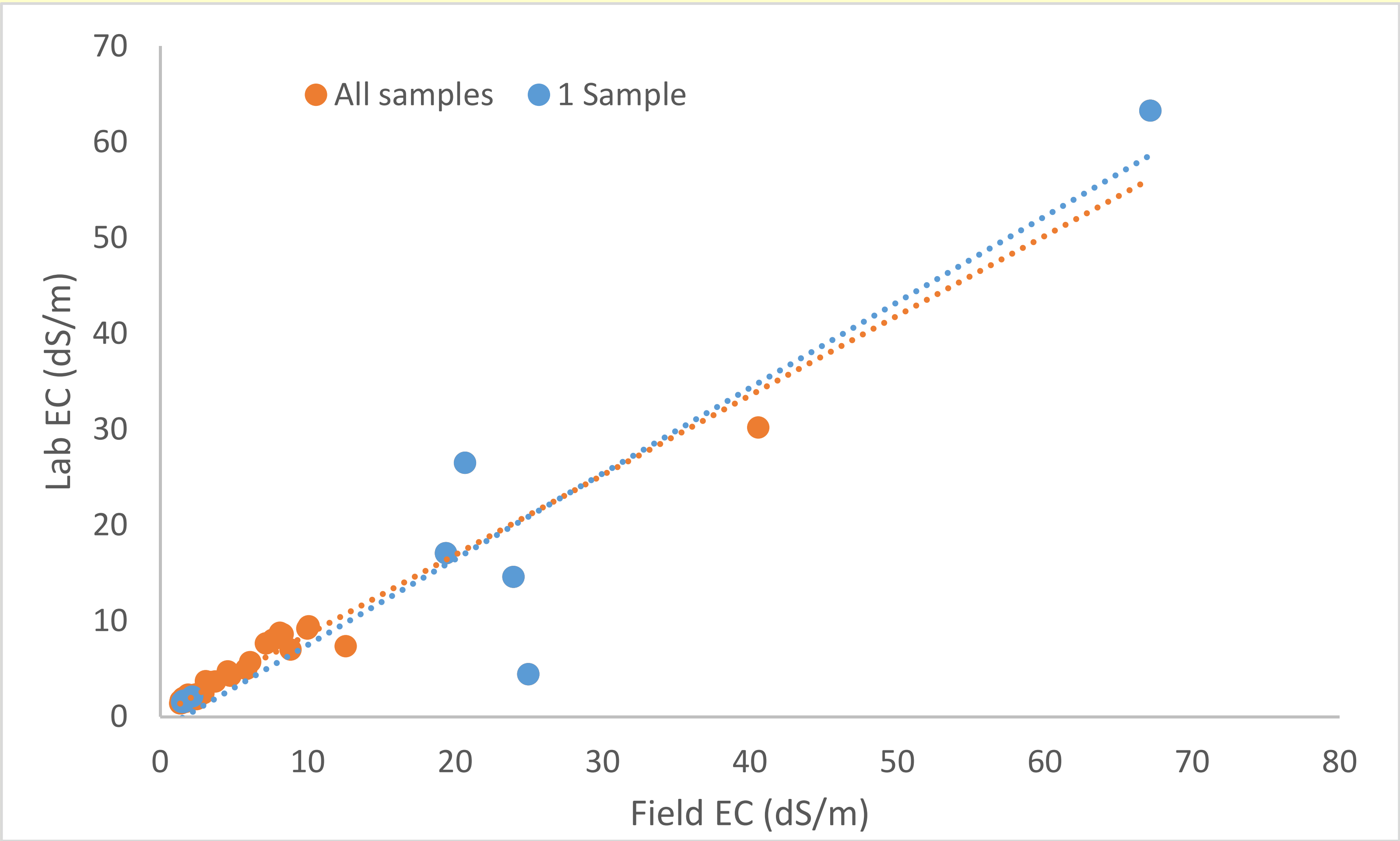
Use a regression analysis to determine a correction factor based on your data or use literature
- Oklahoma State University (2005) – 1.85 correction factor
- USDA (1954) – 3.0 correction factor

Field Data vs. Lab Data – Surface Water?



$R^2 = 0.9$

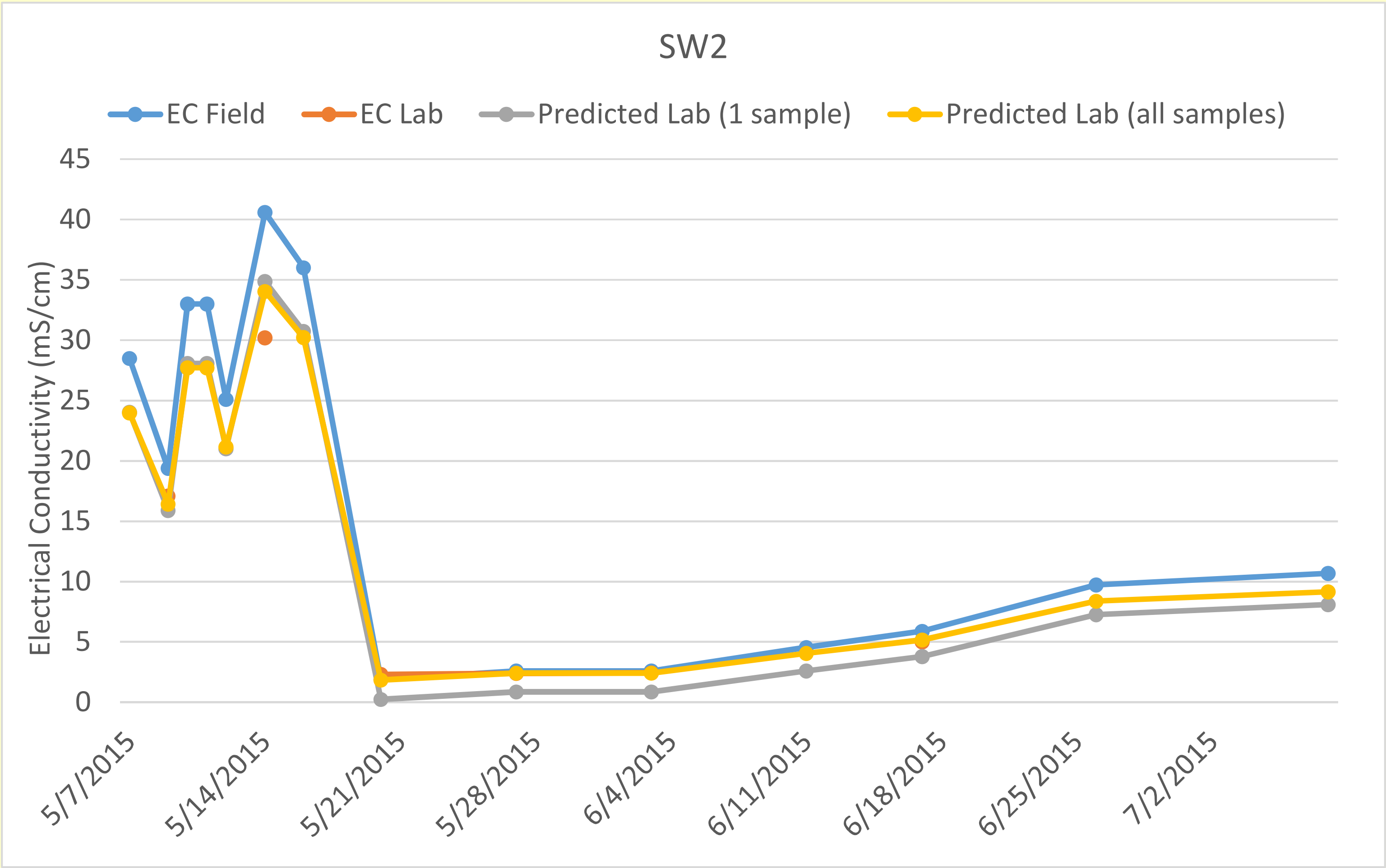
Field Data vs. Lab Data – Surface Water?



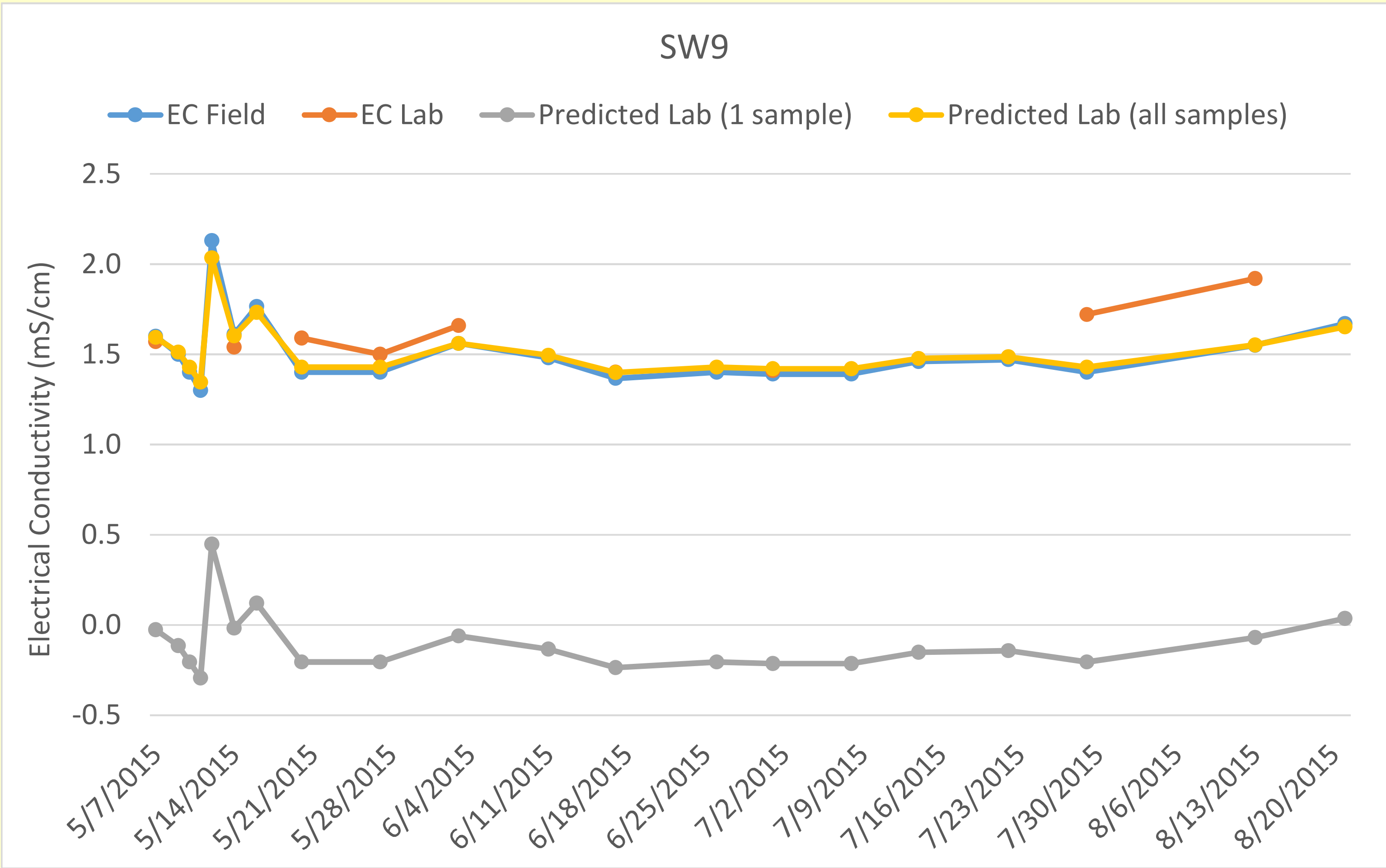
$R^2 = 0.9$

$R^2 = 0.8$

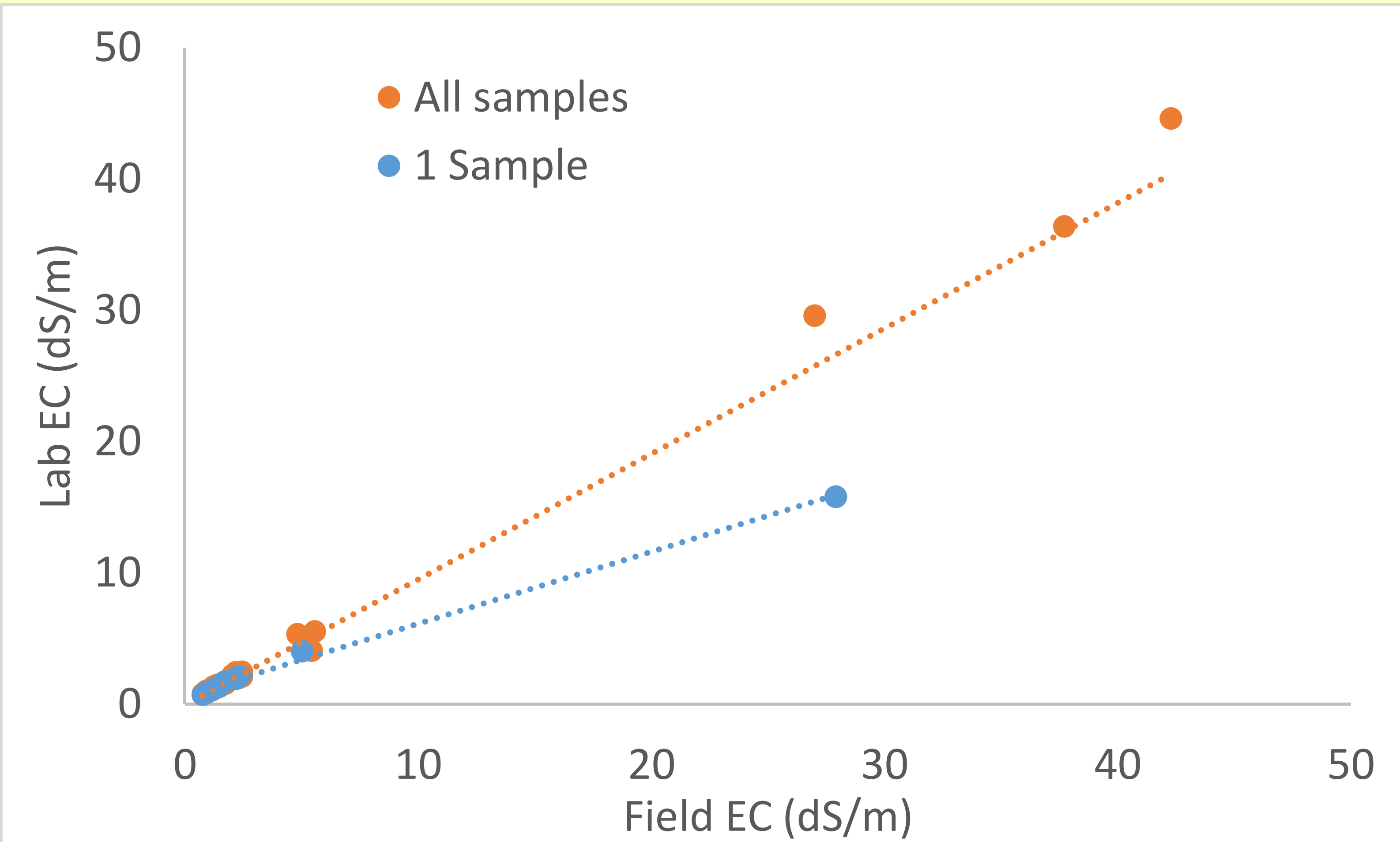
Field Data vs. Lab Data – Surface Water?



Field Data vs. Lab Data – Surface Water?



Field Data vs. Lab Data – Groundwater?



$R^2 = 0.9$

$R^2 = 0.9$

Field Data vs. Lab Data – Summary

atistical Analysis	Electrical Conductivity *(dS/m)* Soil	Surface Water	Ground Water	Chloride *(mg/kg or mg/L)* Soil	Surface Water	Groun Water
eld Mean	32.57	1.9	1.458	5095	897.1	12
ab Mean	17.74	1.4	0.962	12625	1572.7	42.54
ample Size (N)	77	65	41	71	52	27
earson Correlation R-Value	0.752	0.953	0.979	0.93	0.963	0.984
egression R2 Value	0.566	0.909	0.959	0.862	0.928	0.968

Lessons Learned for Future Efforts

EM survey data can reduce quantity of soil samples

Regression models developed using EM survey data and field soil data have the potential to improve reclamation designs

Regression models developed with water field data can reduce quantity of lab samples for both surface and ground water

All of these methods used in concert can reduce lab costs and improve mitigation and reclamation designs

Thank You!

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Environmental & Natural Resource Services