Four Methods for Evaluating Soil Electrical Conductivity of Brine-Impacted Soils

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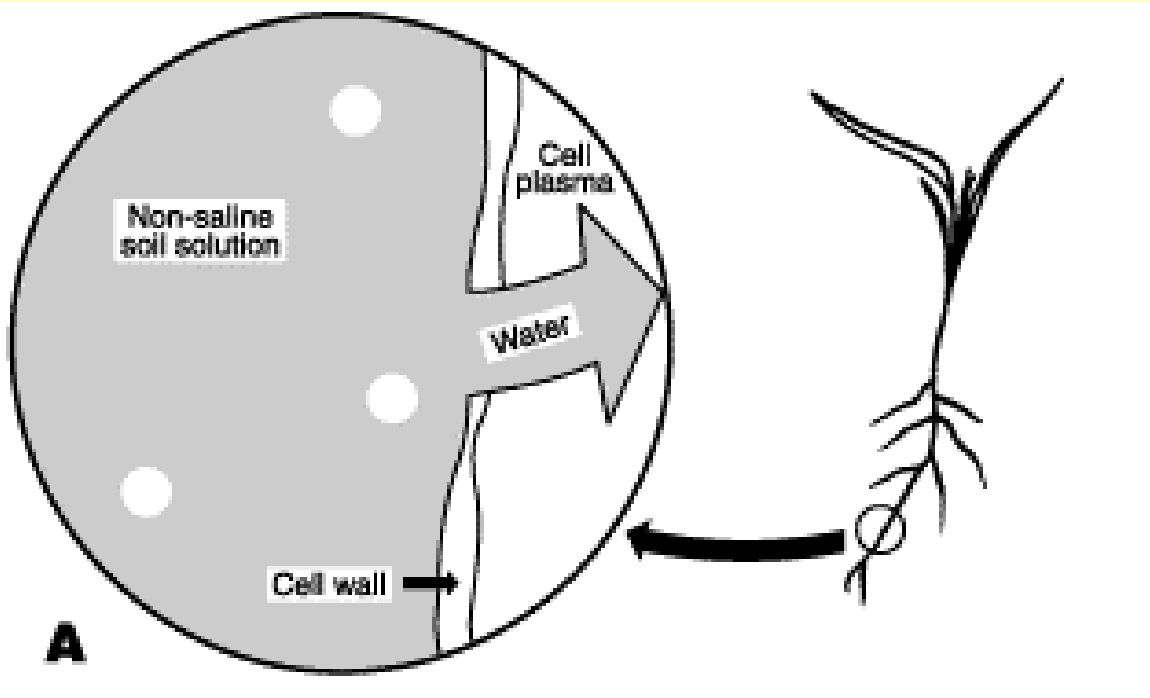
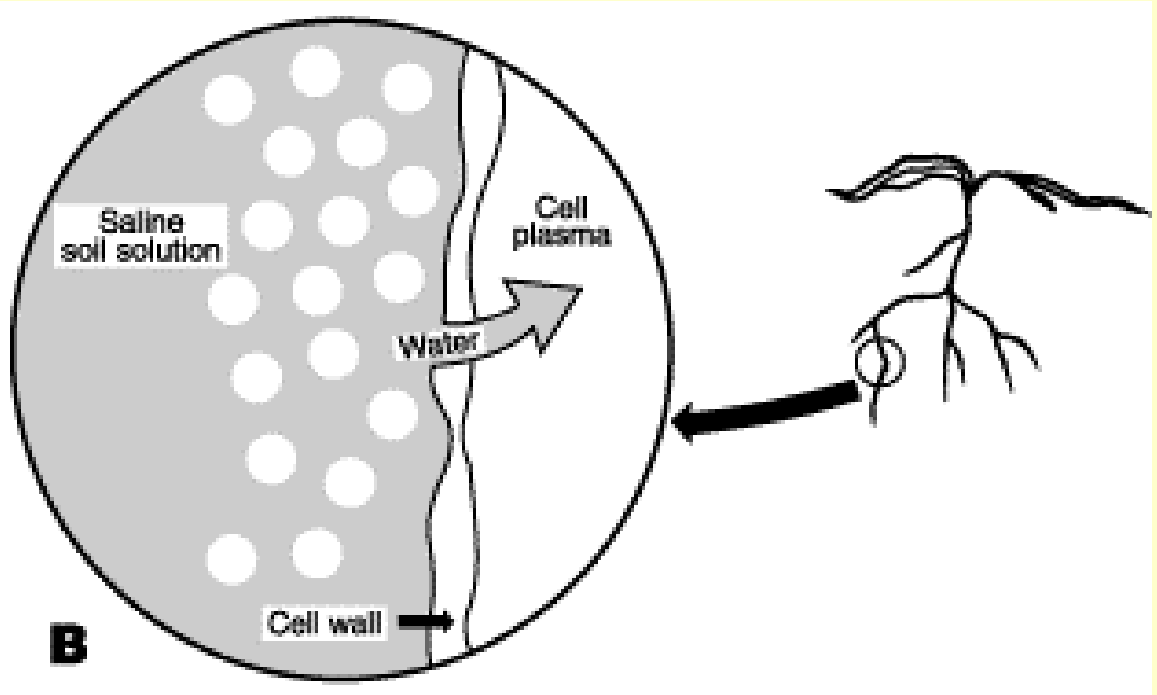
Brine Soil Impacts

- Increases in
  - Salinity
  - SAR
  - Chloride
- Erosion
- Lack of Vegetation

Brine Soil Impacts – Salinity



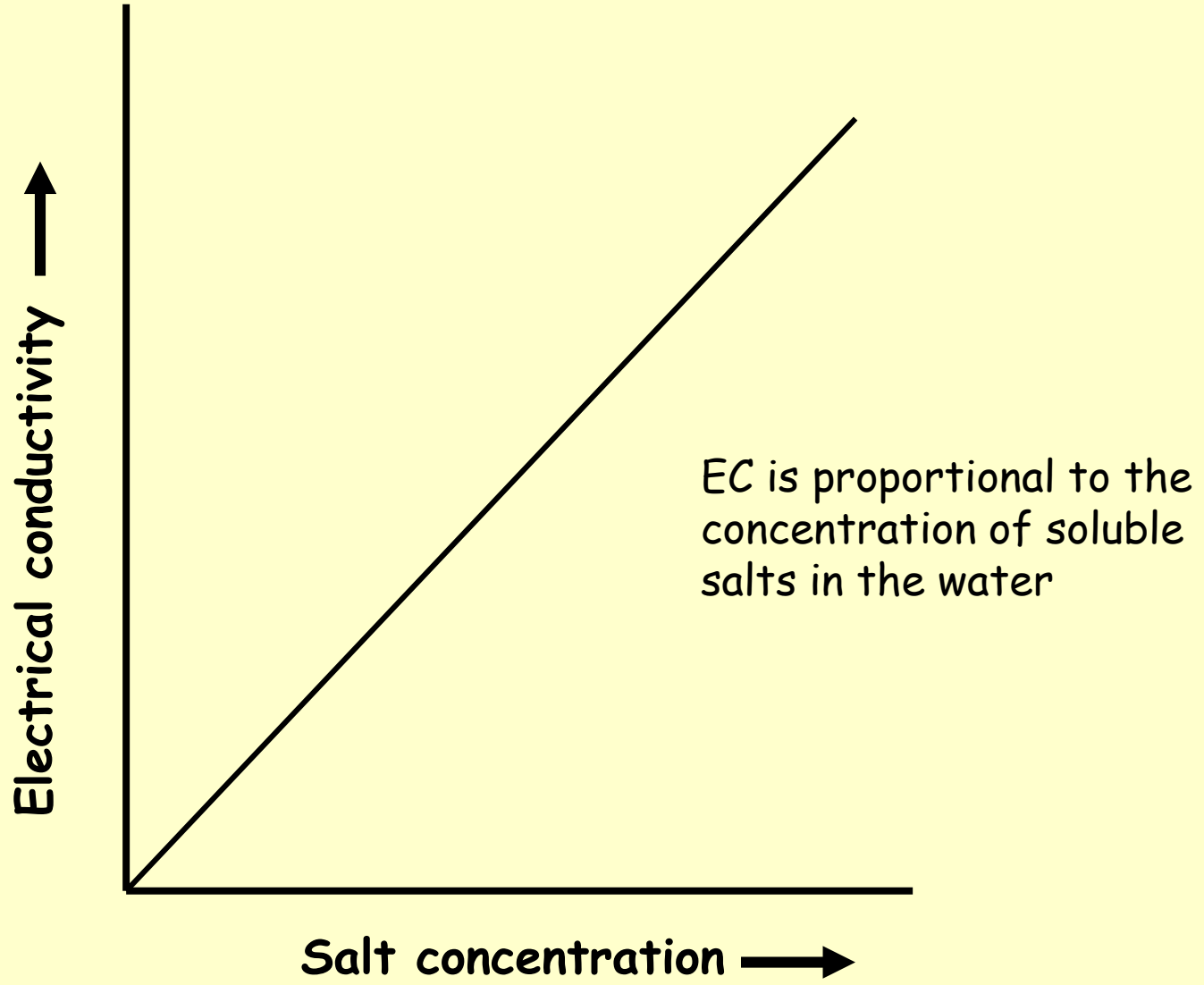


Non-Saline Soil Solution

Saline Soil Solution

Brine Soil Impacts – Salinity

- Electrical Conductivity (EC)
  - 1 mmhos/cm =
  - 1 mS/cm =
  - 1 dS/m =
  - 1000 µS/cm =
  - 0.01 mS/m



Brine Soil Impacts – Salinity

EC (mS/cm)	Salt Rank	Effect on Plants
0 - 2	Low	Very little
2 - 4	Moderate	Salt-sensitive plants and some other seedlings may show injury
4 - 8	High	Most non-salt tolerant plants will show injury; Salt-sensitive plants will show severe injury
8 - 12	Excessive	Salt-tolerant plants will grow; Most others show severe injury
12+	Very excessive	Very few plants will grow

Objectives

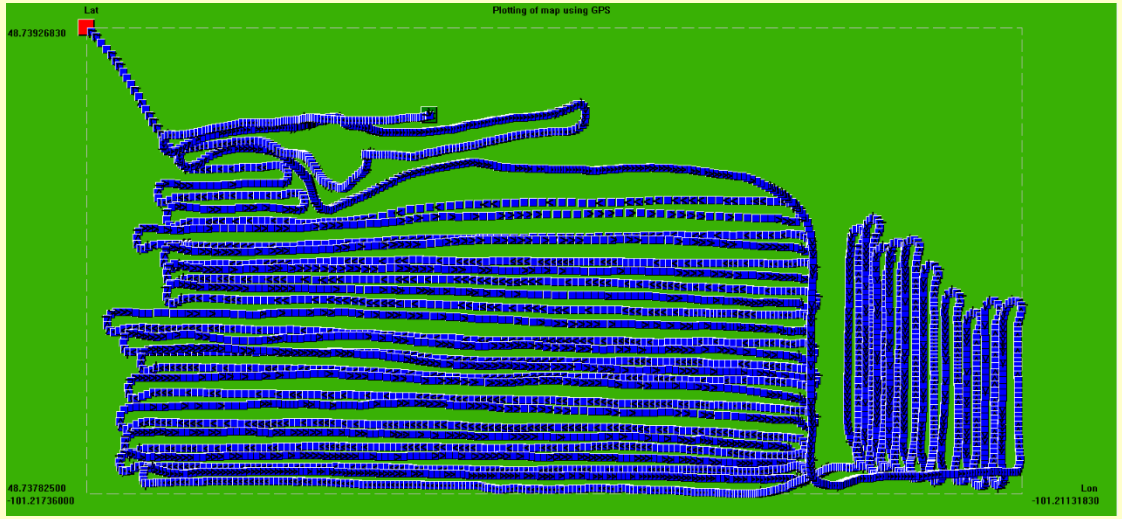
- Test 3 methods for field determination of soil EC at 3 legacy brine sites in Bottineau County, North Dakota
- Determine which, if any, field screening method best predicts laboratory EC
- Determine if predictive models from one site can be transferable to other sites.

Method for Measuring Salinity

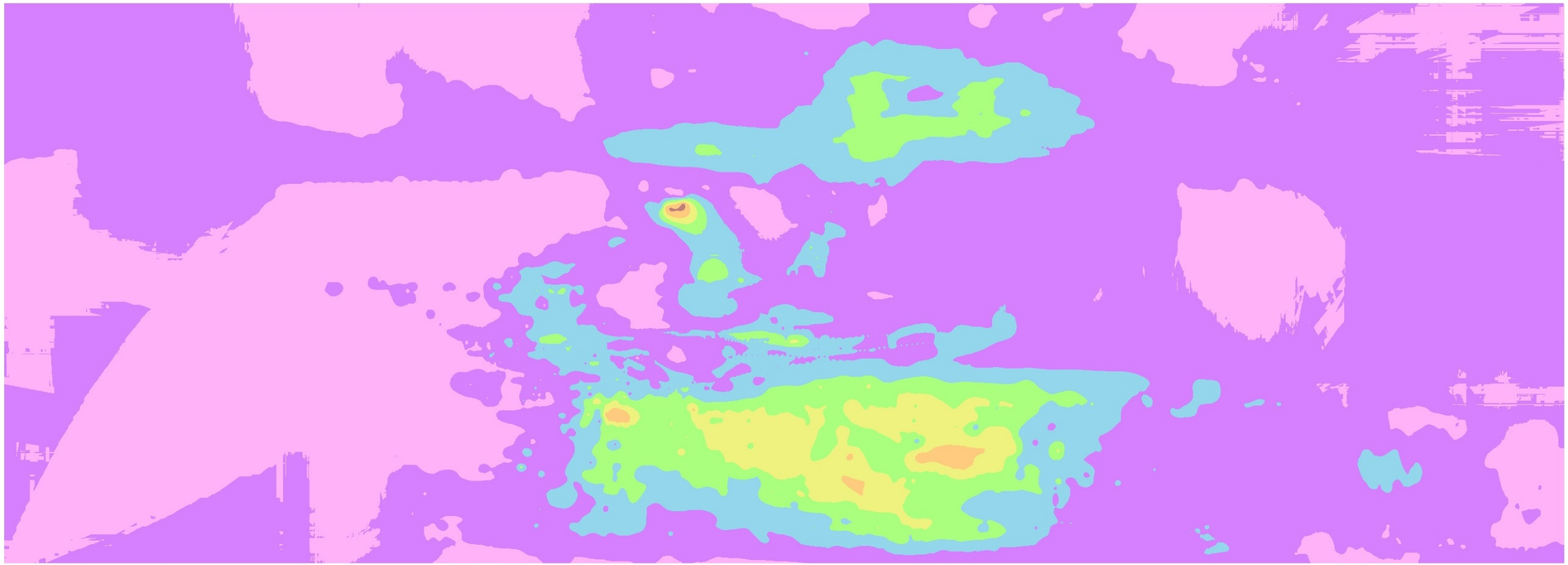
- Electromagnetic Survey
- Hydraulic Profiling Tool (Geoprobe)
- Field-Tested Soil Samples
- Lab-Tested Soil Samples

Electromagnetic Survey (EM)

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



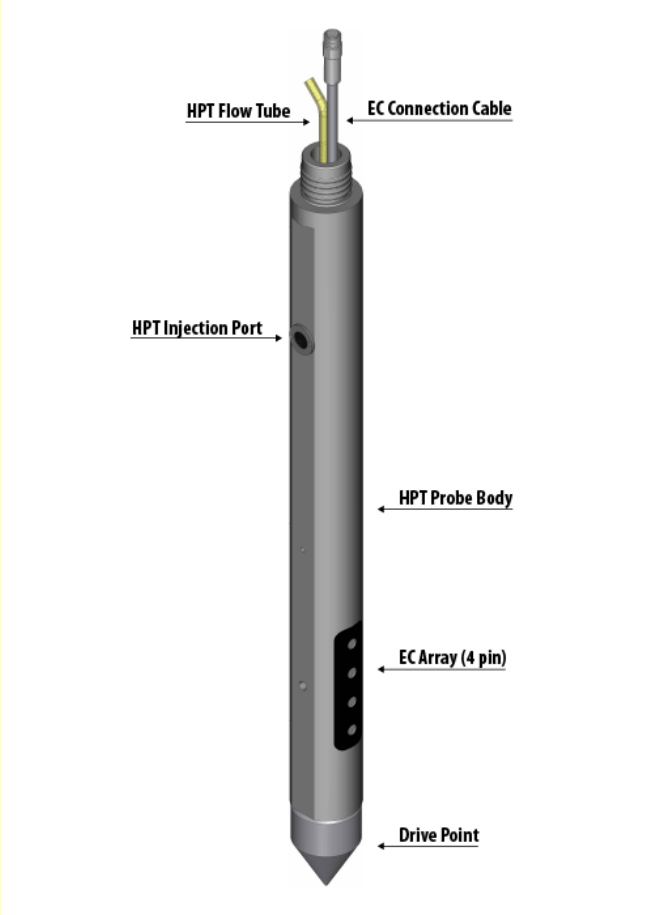
Electromagnetic Survey



1,200 - 1,300

Geoprobe HPT

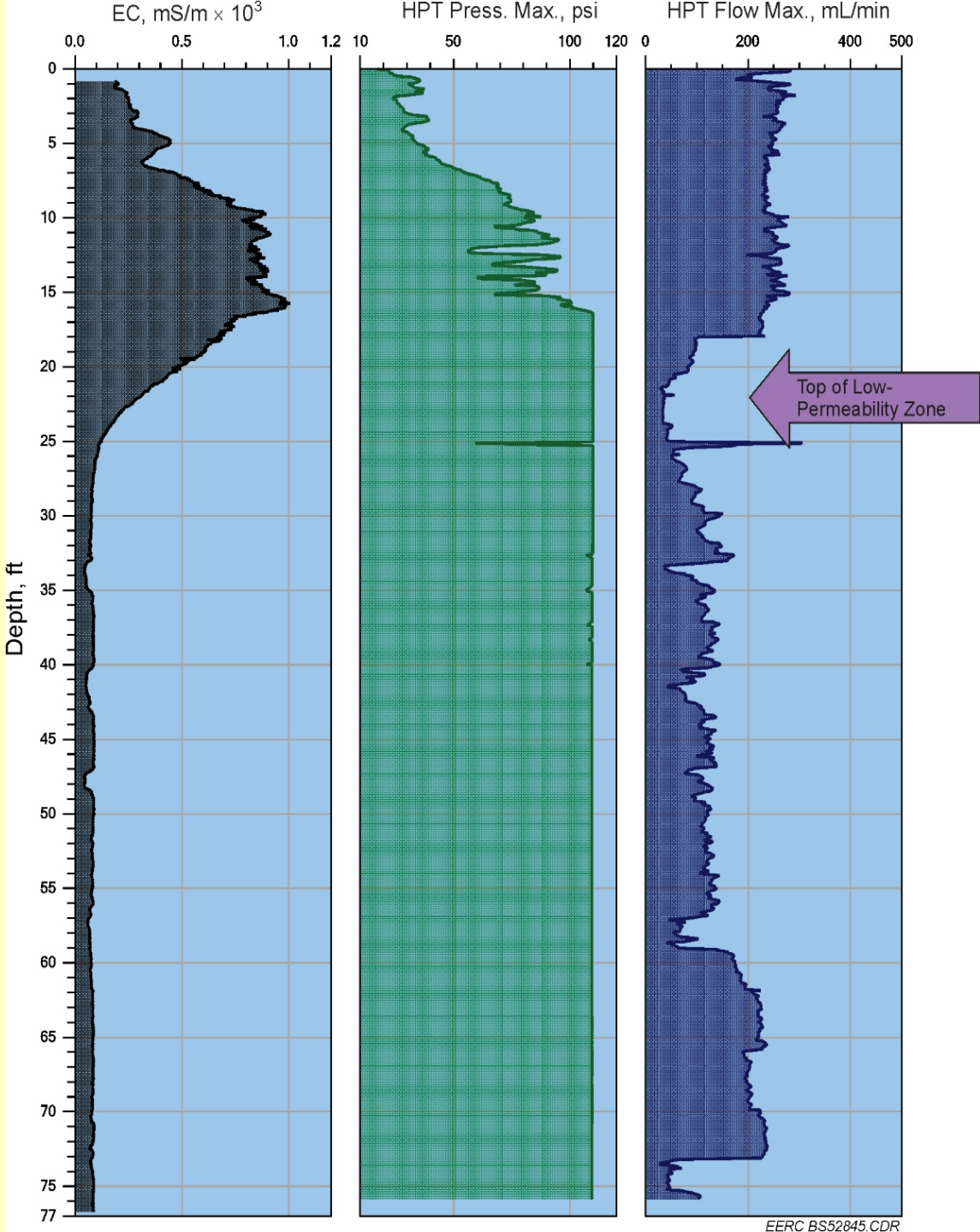
- Data
  - EC
  - Injection Pressure
  - Flow Rate
- 1-inch diameter recoverable sample



Geoprobe HPT

- 2-inch intervals
- Depth to refusal or where EC decreased

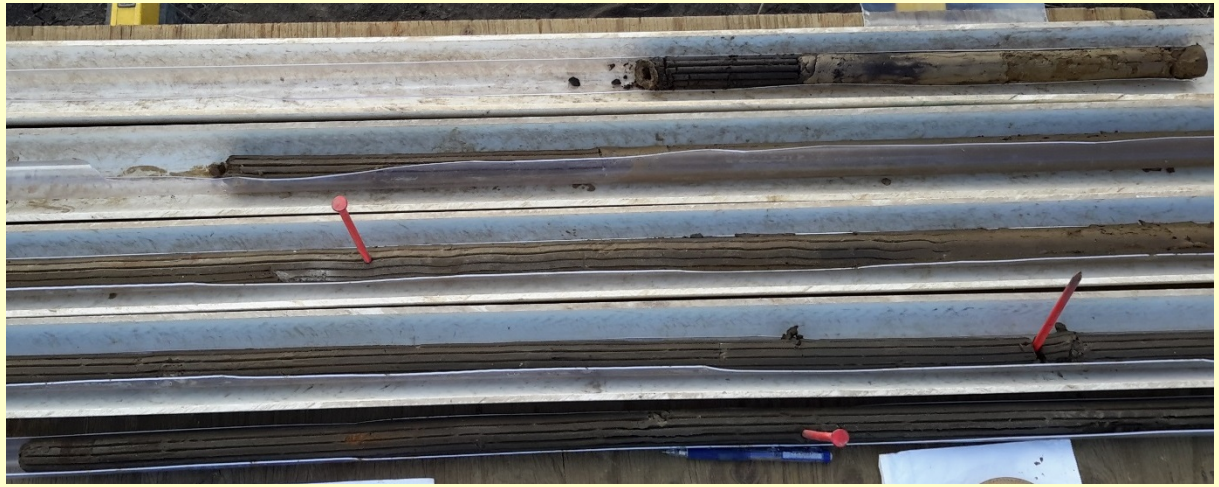
- Low permeability zones in the soil profile
- Depth of EC contamination



Soil Sampling

- Continuous cores at 2-ft intervals
  - Giddings Probe: < 6 ft
  - Geoprobe: > 6 ft

- Split for Field and Lab analysis



Soil Sampling

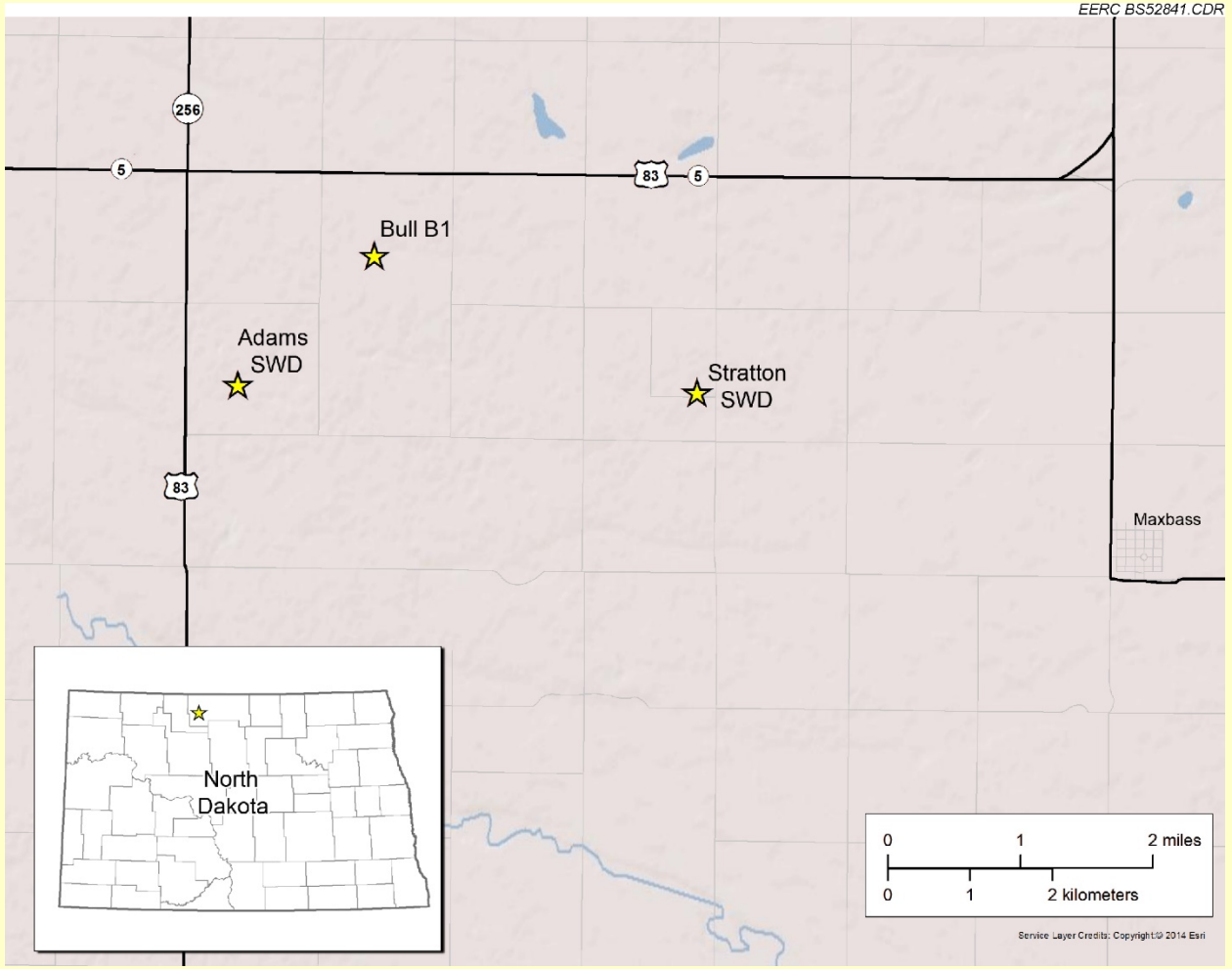
- Field Testing
  - 1:1 soil:water ratio by field weight
  - Filtered for two sites
    - Not filtered for Bull site
  - Oakton Con 6+ Conductivity Meter

- Lab Analysis
  - 1:1 soil:water ratio by dry weight*

* Lab Saturated Paste Extract will provide a more accurate EC for additional cost.

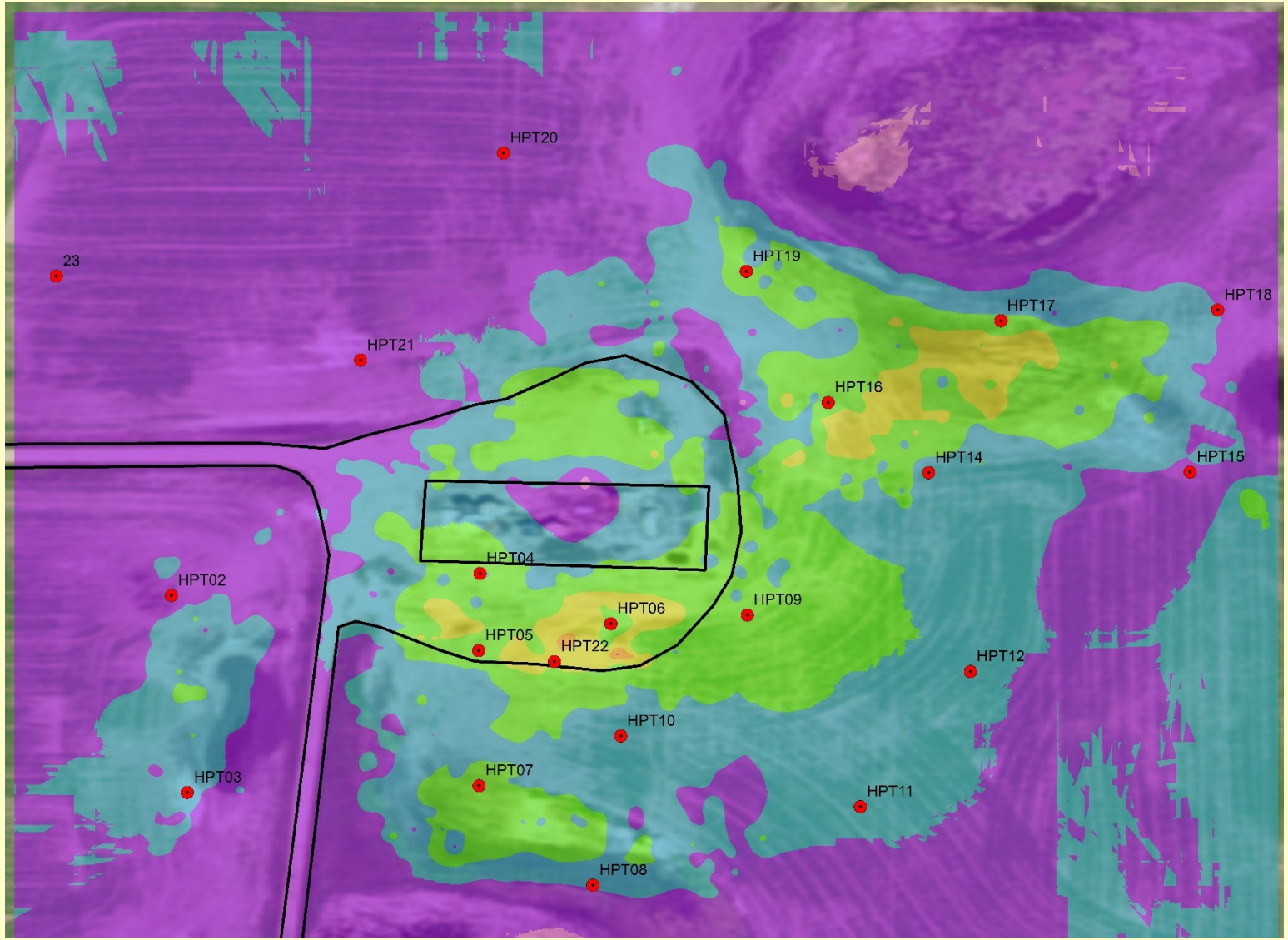
Location

- 3 legacy brine pits
- Bottineau County, ND
- Prairie Pothole Region
  - Shallow ground water
  - Clay soils with low permeability
- Precipitation = 15 – 19”
- Study Dates:
  - September 2015
  - August – October 2016



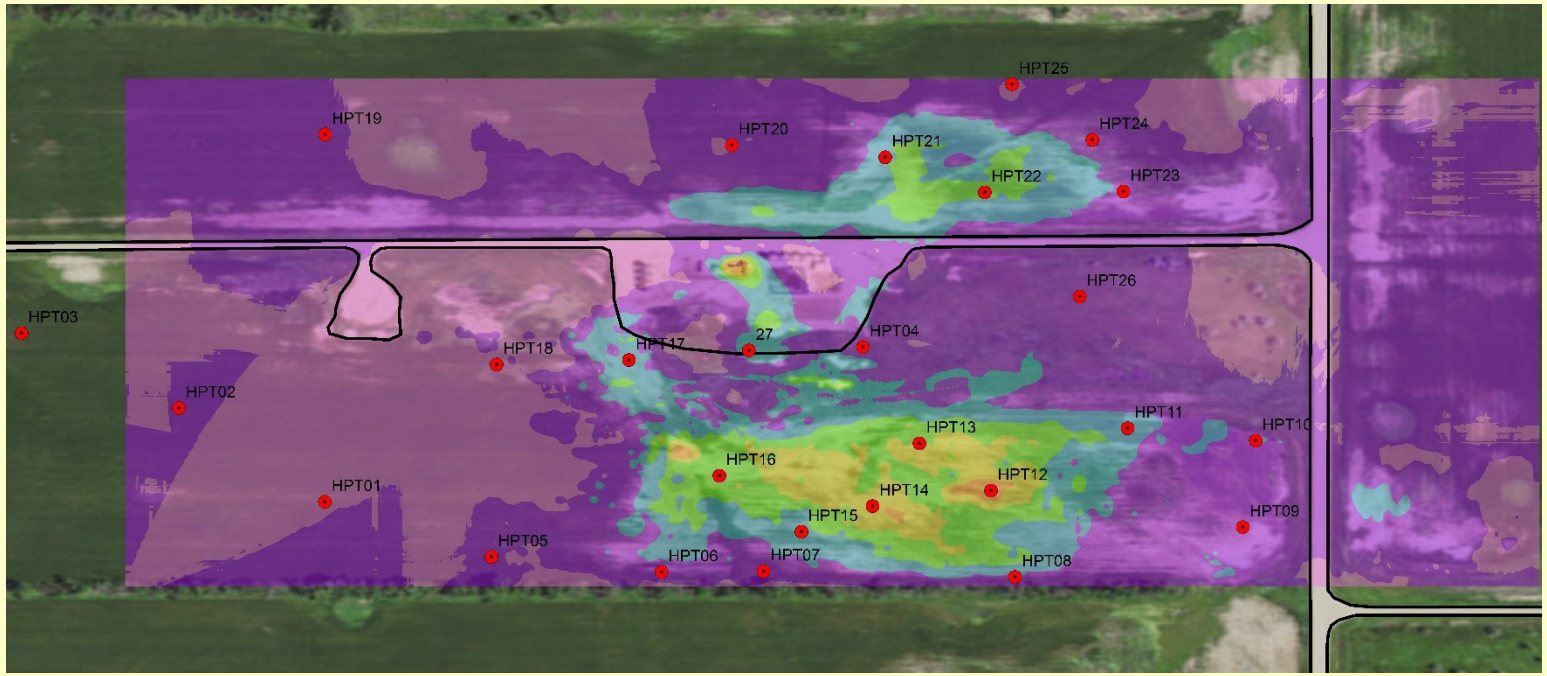
Location – Adams

- Brine Area: ~ 2.5 acres
- EM Survey
  - 9.5 acres
  - 2,139 points
  - 3,000 Hz (0-3meters)
- Geoprobe
  - 20 locations
  - 10-25 ft deep
- Field & Lab Analysis
  - 20 samples



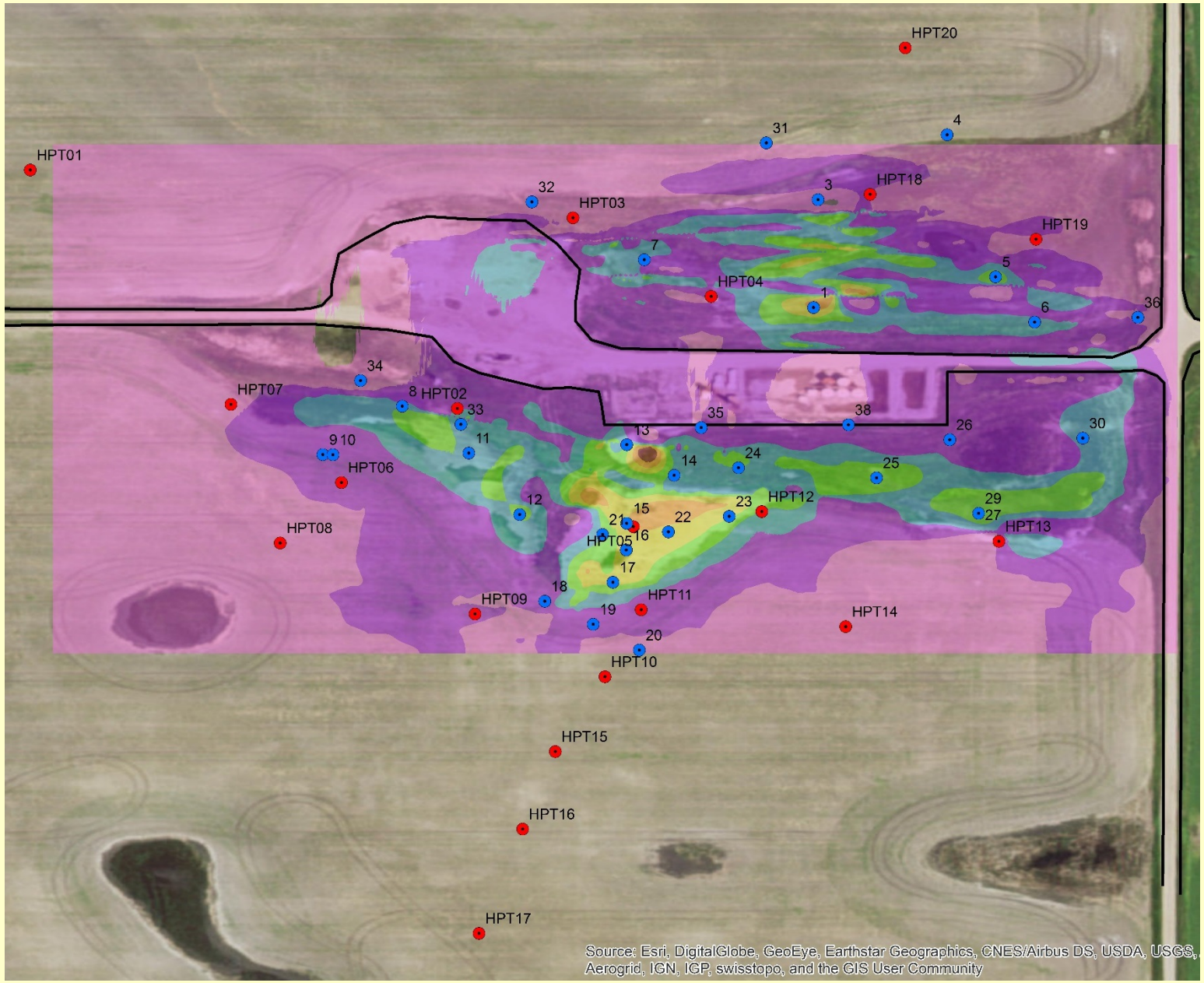
Location – Stratton

- Brine Area: ~ 7.5 acres
- EM Survey
  - 28 acres
  - 11,580 points
  - 3,000 Hz (0-3meters)
- Geoprobe
  - 27 locations
  - 16-77 ft deep
- Field & Lab Analysis
  - 25 samples



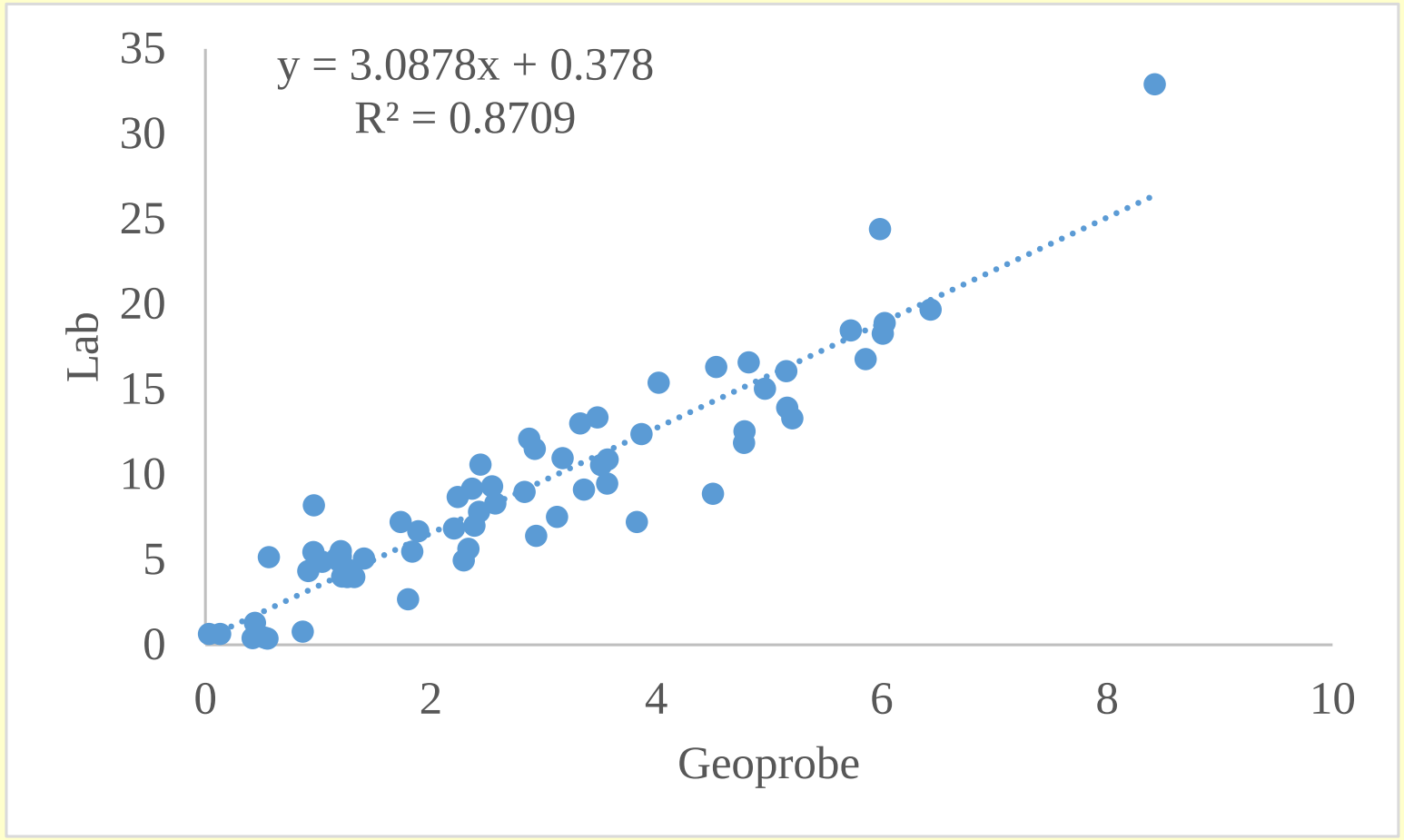
Location – Bull

- Brine Area: ~ 6 acres
- EM Survey
  - 15.3 acres
  - 11,163 points
  - 3,000 Hz (0-3meters)
- Geoprobe
  - 20 locations (red)
  - 10-25 ft
- Field & Lab Analysis
  - 35 samples (blue)



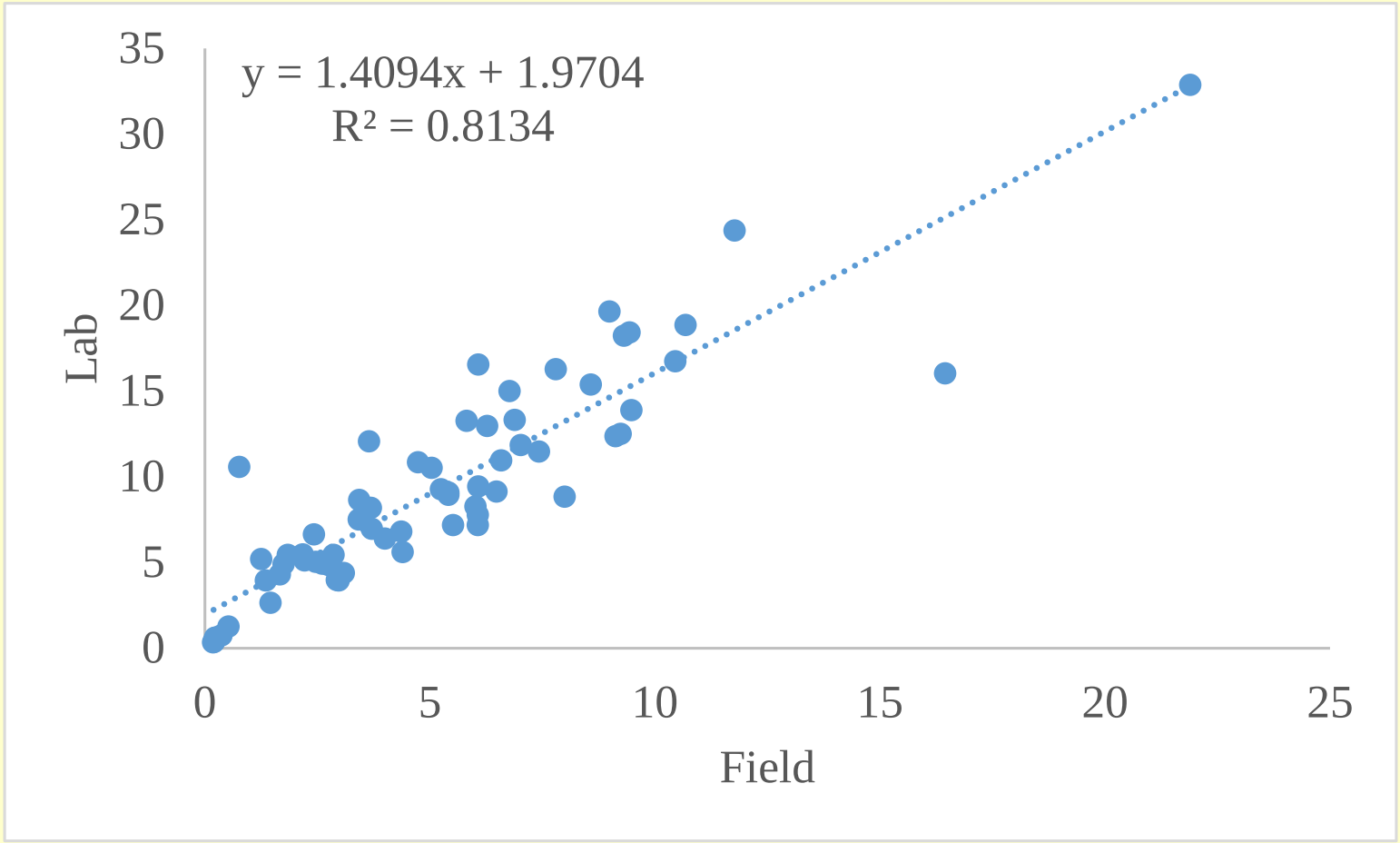
Results – Adams

- Highly correlated
  - R = 0.933
- Highly predictive
  - R^2 = 0.871
  - P < 0.001
- Underestimates lab EC



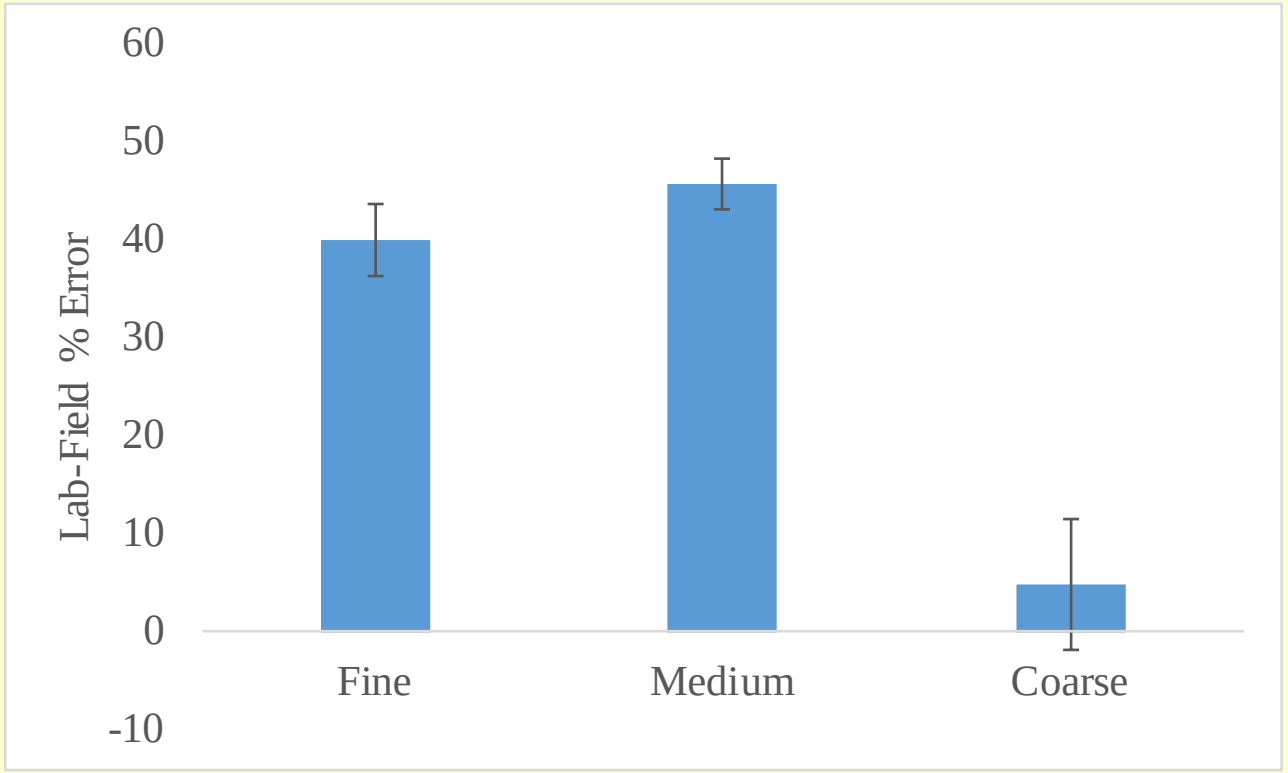
Results – Adams

- Highly correlated
  - R = 0.902
- Highly predictive
  - R^2 = 0.813
  - P < 0.001
- Slightly underestimates lab EC



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

- Moisture
  - Field EC – field weight
  - Lab EC – oven dried weight
- Mixing
  - Difficult to mix field soils completely especially when fine textured

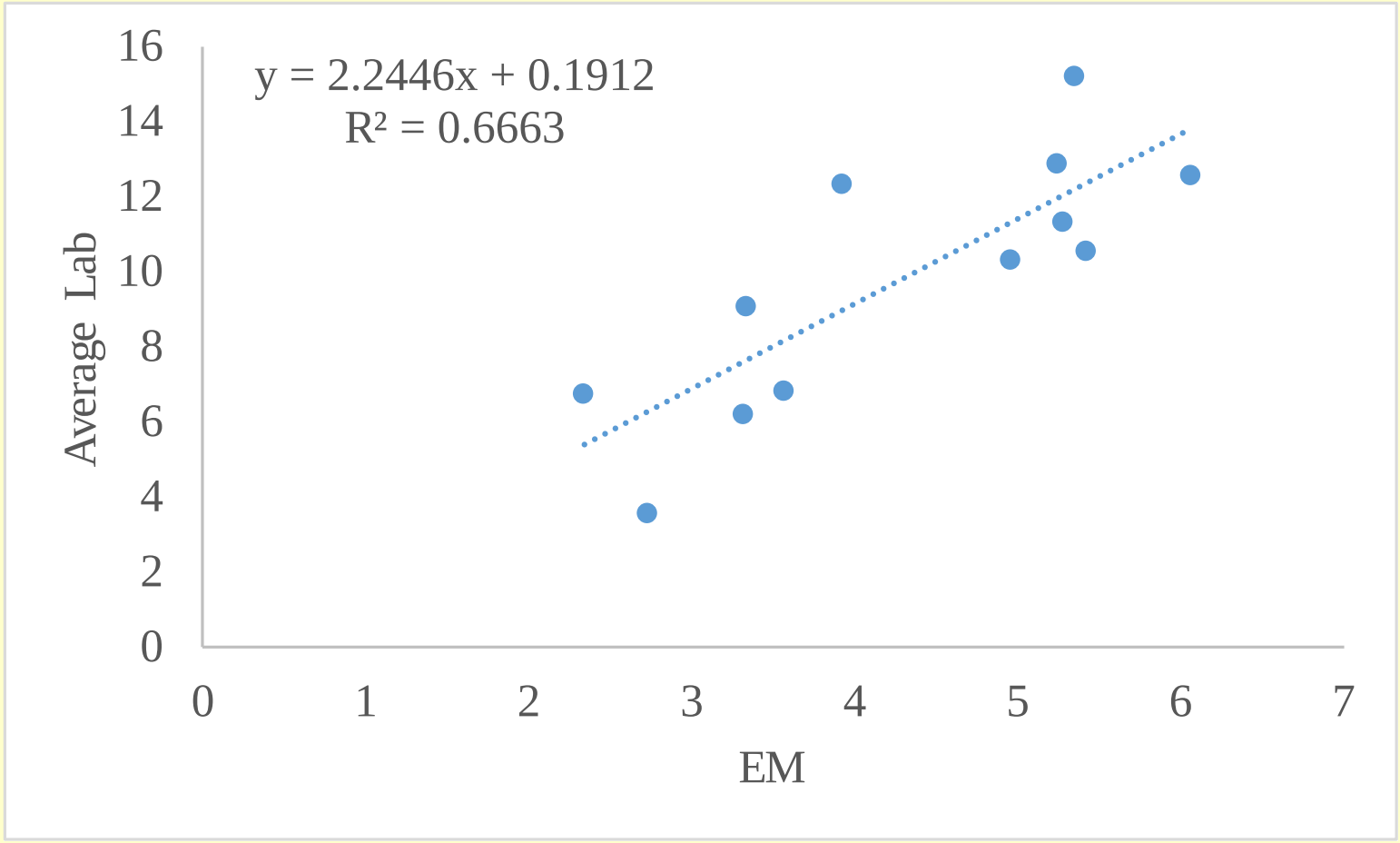


Lab-Field % Error = ((Lab EC - Field EC)/Lab EC)*100

Results – Adams

- Correlated
  - R = 0.816
- Somewhat predictive
  - R^2 = 0.666
  - P = 0.001
- Underestimates lab EC

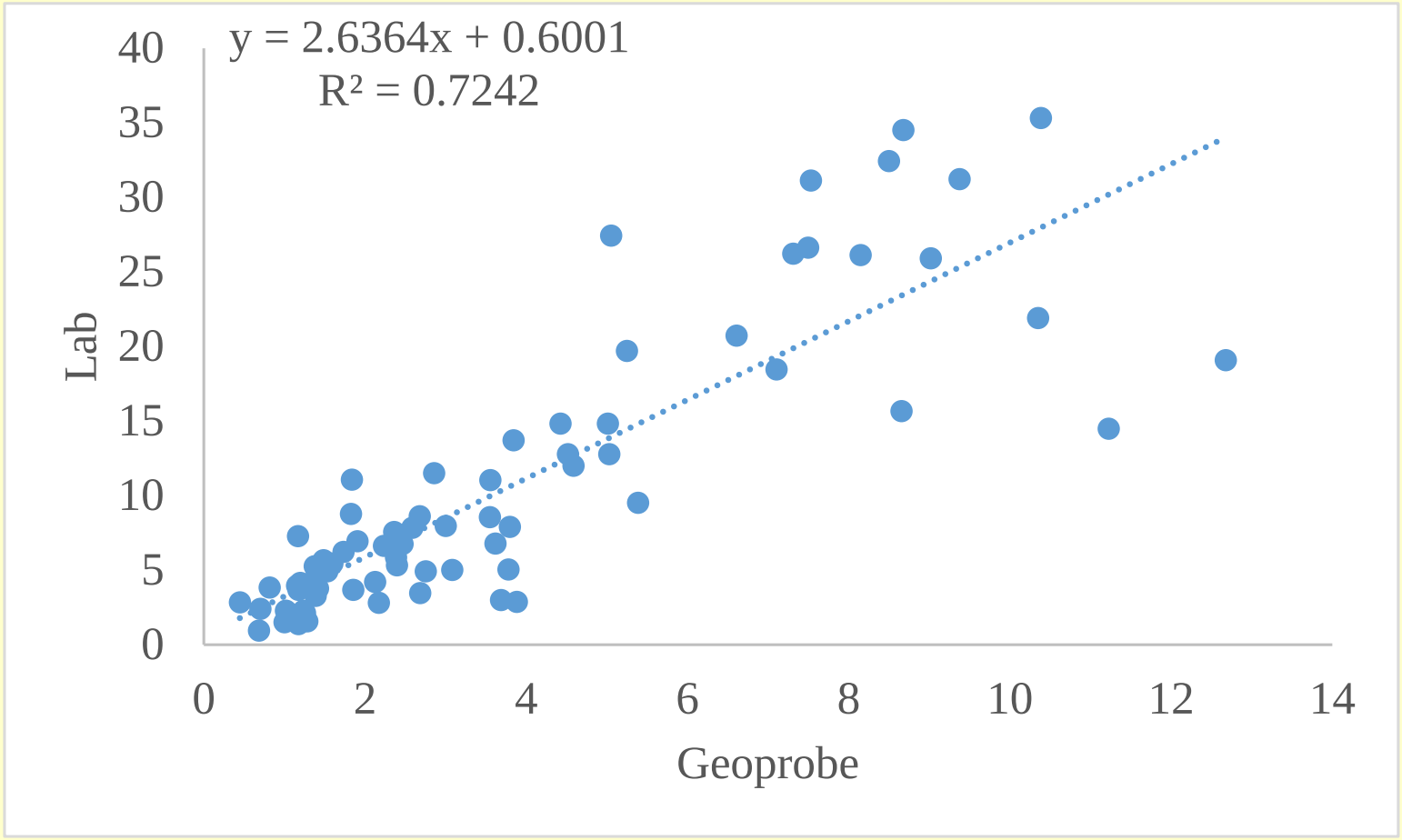
Kriged EM Survey EC



Results – Stratton

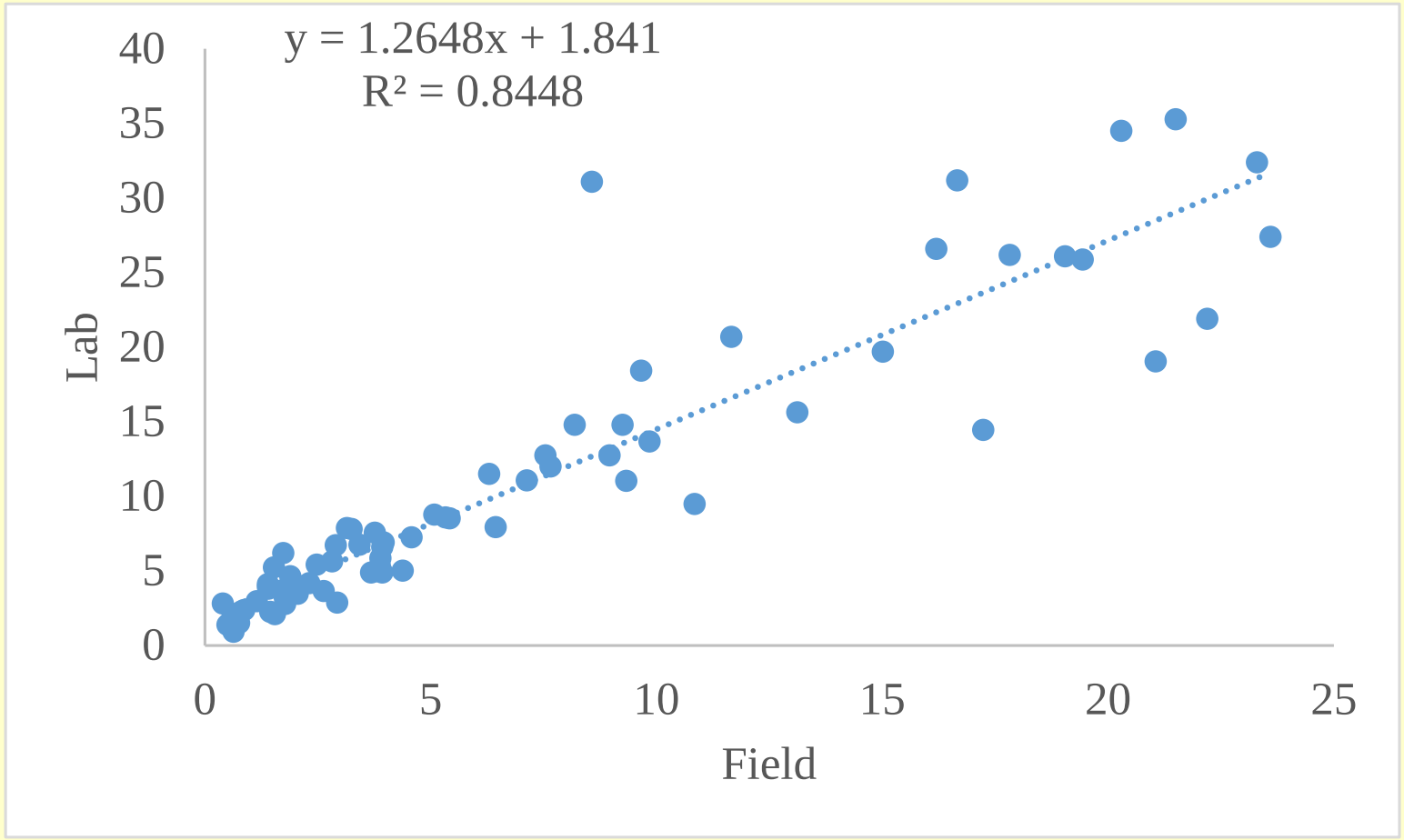
- Correlated
  - R = 0.851
- Somewhat predictive
  - R^2 = 0.724
  - P < 0.001
- Underestimates lab EC

Geoprobe EC



Results – Stratton

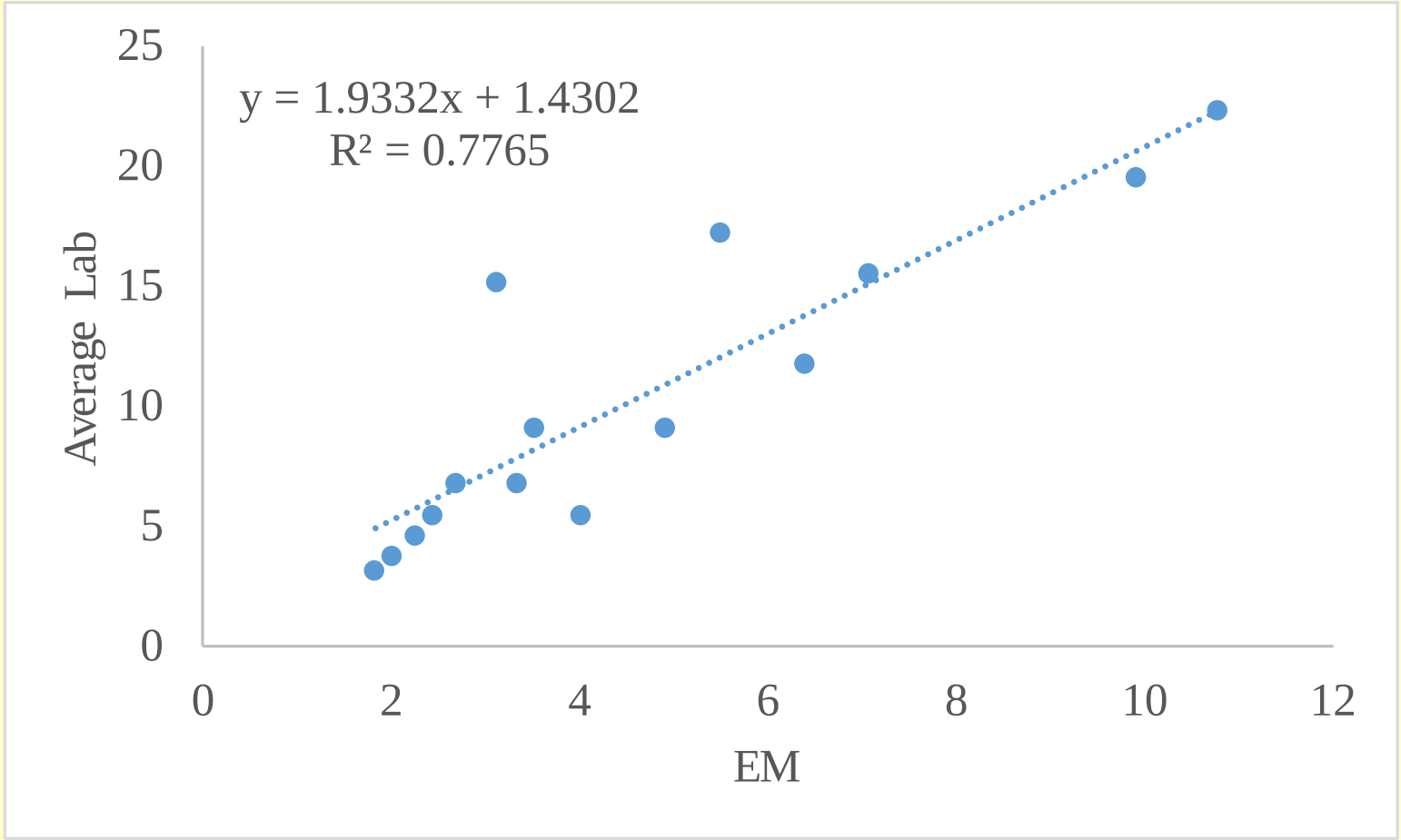
- Highly correlated
  - R = 0.919
- Highly predictive
  - R^2 = 0.845
  - P < 0.001
- Slightly underestimates lab EC



Results – Stratton

- Highly correlated
  - R = 0.881
- Somewhat predictive
  - R^2 = 0.777
  - P < 0.001
- Underestimates lab EC

Kriged EM Survey EC



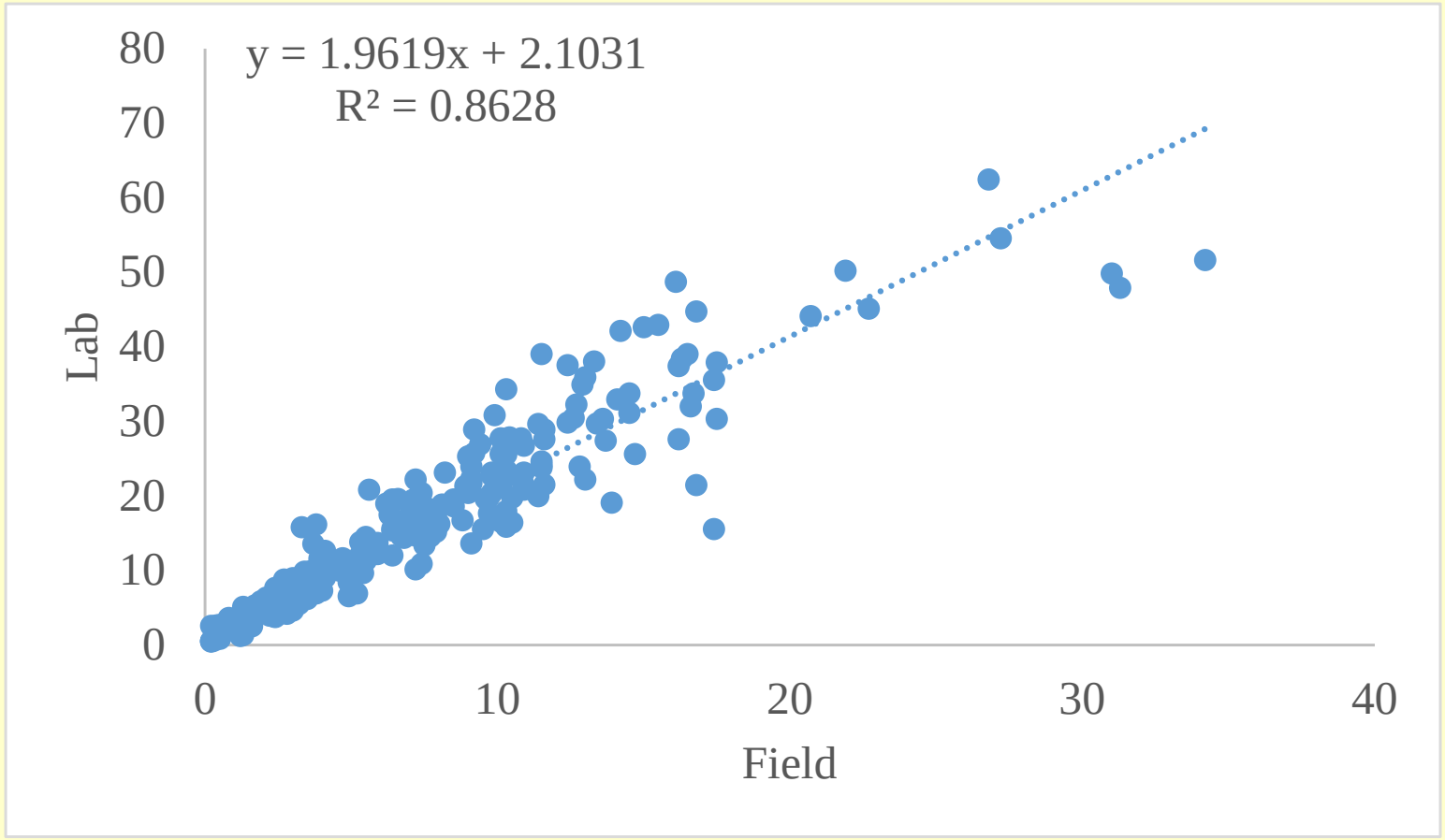
Results – Adams & Stratton

Location	Independent Variable(s)	Dependent Variable	R	R^2	P-value	Regression Equation
Adams	Geoprobe Data + Field Testing Data	Lab Data	0.946	0.895	<0.001	$y = 2.079x_1 + 0.535x_2 + 0.516$
Stratton	Geoprobe Data + Field Testing Data	Lab Data	0.920	0.847	<0.001	$y = 0.352x_1 + 1.123x_2 + 1.483$

Results – Bull

- Highly correlated
  - R = 0.928
- Highly predictive
  - R^2 = 0.862
  - P < 0.001
- Underestimates lab EC

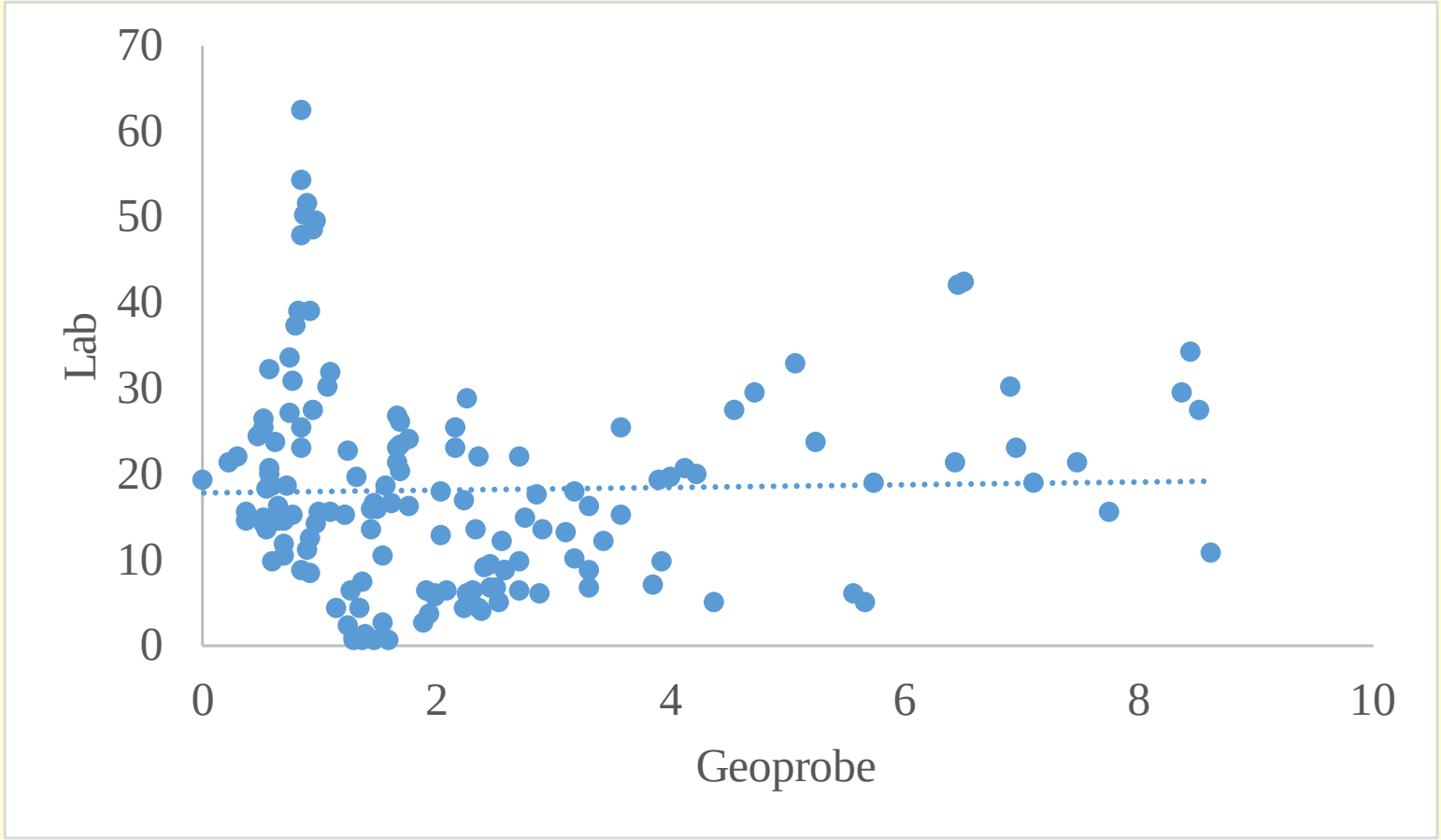
Field Testing EC



Results – Bull

- Not correlated
  - R = 0.022
- Not predictive
  - R^2 = 0.0005
  - P = 0.795

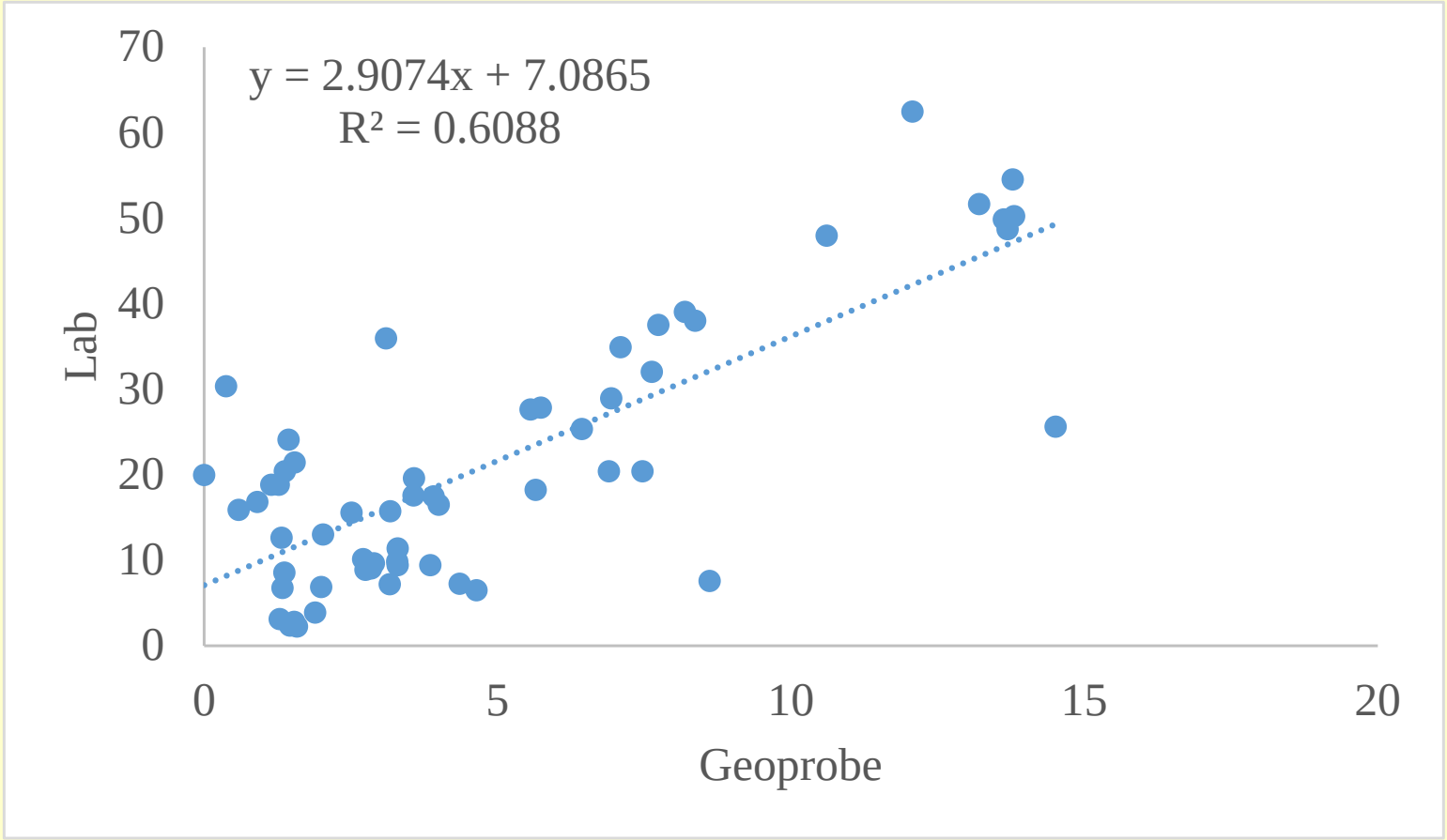
Geoprobe EC



Results – Bull

- Correlated
  - R = 0.780
- Not predictive
  - R^2 = 0.609
  - P < 0.001
- Underestimates lab EC

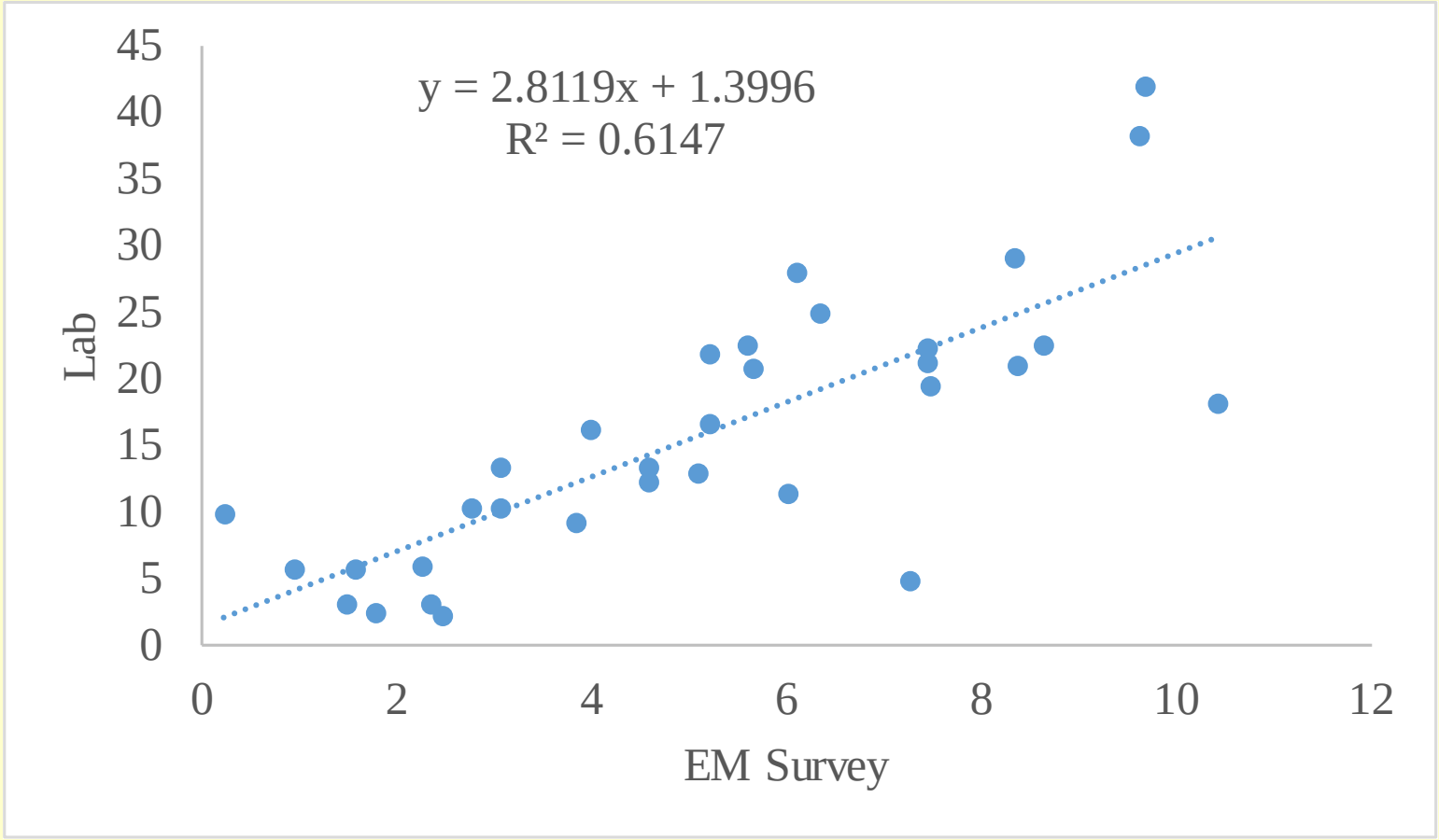
Geoprobe EC (within 50 ft)



Results – Bull

- Correlated
  - R = 0.784
- Somewhat predictive
  - R^2 = 0.615
  - P < 0.001
- Underestimates lab EC

Kriged EM Survey EC



Model Transferability – Adams

Descriptive Statistics	Actual Lab Data	Predicted Values				
		Adams (Geoprobe +Field)	Stratton (Geoprobe +Field)	Stratton (Geoprobe)	Stratton (Field)	Bull (Field)
Mean	9.20	9.20	8.25	8.13	8.32	12.19
Standard Deviation	6.16	5.83	5.02	4.91	4.99	7.75
Maximum	32.90	29.74	29.04	22.80	29.54	45.13
Minimum	0.36	0.72	1.78	0.69	2.08	2.49
P-value		1.000	0.333	0.273	0.374	.008

Model Transferability – Stratton

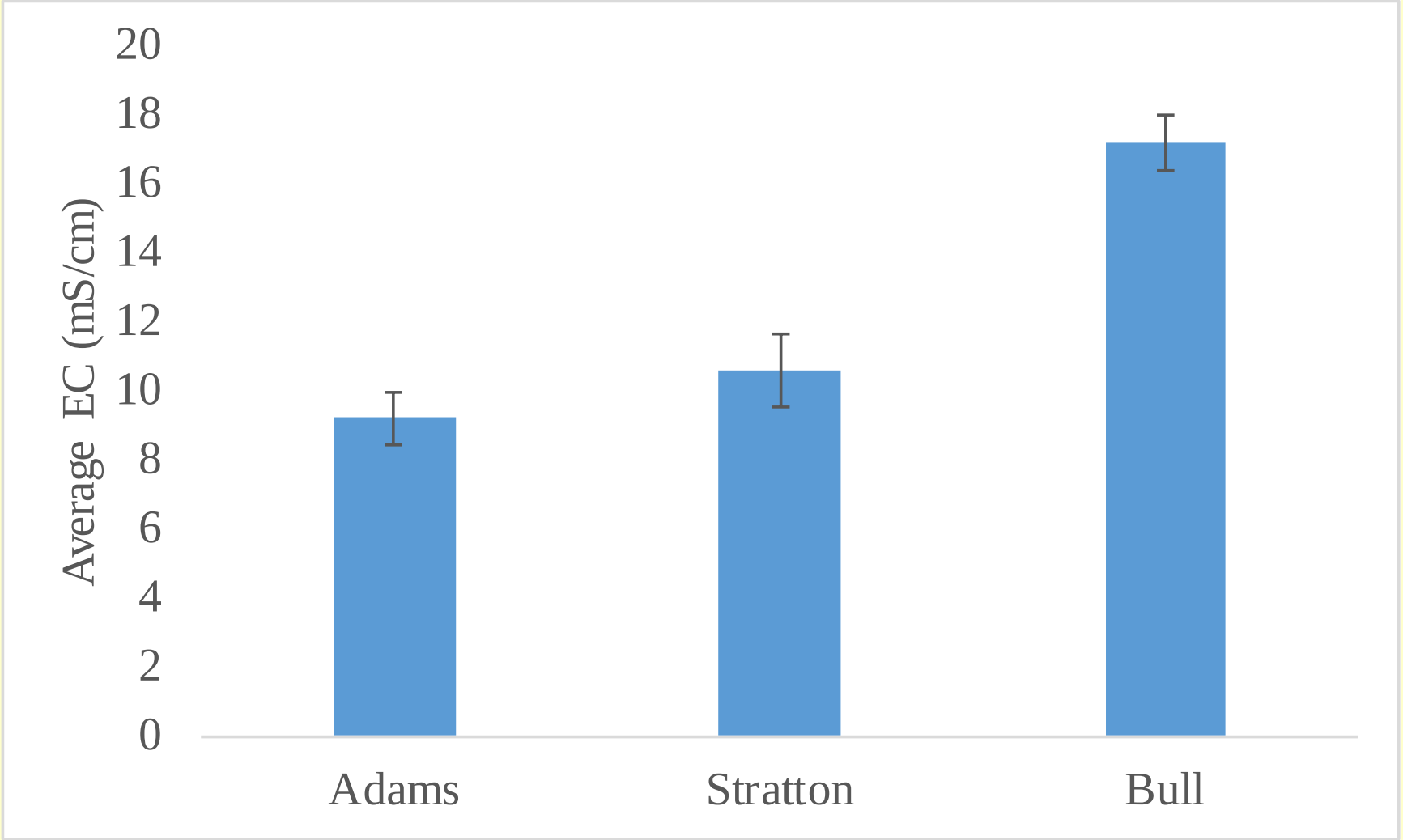
Descriptive Statistics	Actual Lab Data	Predicted Values				
		Stratton (Geoprobe +Field)	Adams (Geoprobe +Field)	Adams (Geoprobe)	Adams (Field)	Bull (Field)
Mean	10.58	10.58	12.09	12.07	11.71	15.69
Standard Deviation	9.26	8.51	9.59	9.22	9.48	13.21
Maximum	35.30	30.64	38.14	39.52	35.23	48.47
Minimum	0.93	2.09	1.66	1.76	2.54	2.91
P-value		0.997	0.340	0.336	0.471	0.021

Model Transferability – Bull

Descriptive Statistics	Actual Lab Data	Predicted Values			
		Bull (Field)	Adams (Field)	Stratton (Field)	Adams/Stratton Combined (Field)
Mean	17.15	17.08	12.70	11.47	11.92
Standard Deviation	12.21	11.41	8.19	7.35	7.47
Maximum	62.40	69.29	50.17	45.10	46.12
Minimum	0.44	2.12	1.97	1.84	2.13
P-value		0.969	<0.001	<0.001	<0.001

Model Transferability – Bull

- More similar sites are more transferable



Conclusions

- All 3 field methods correlate to lab EC, but do not correspond.
  - All underestimate lab EC
- Field testing produces most consistent model
  - Geoprobe also good
- EM survey data provides a generalized representation of the relative concentrations of EC
- Regression models were somewhat transferable between similar sites

Applications

- EM survey provides good basis for selecting sample locations
- Regression models developed from field testing or Geoprobe data can reduce quantity of lab samples
- Still need to send some sample to lab for verification of actual EC for reclamation designs

Thank You!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