NAIT Centre for Boreal Research

In-situ Electrokinetic Remediation of a Salt-Impacted Soil

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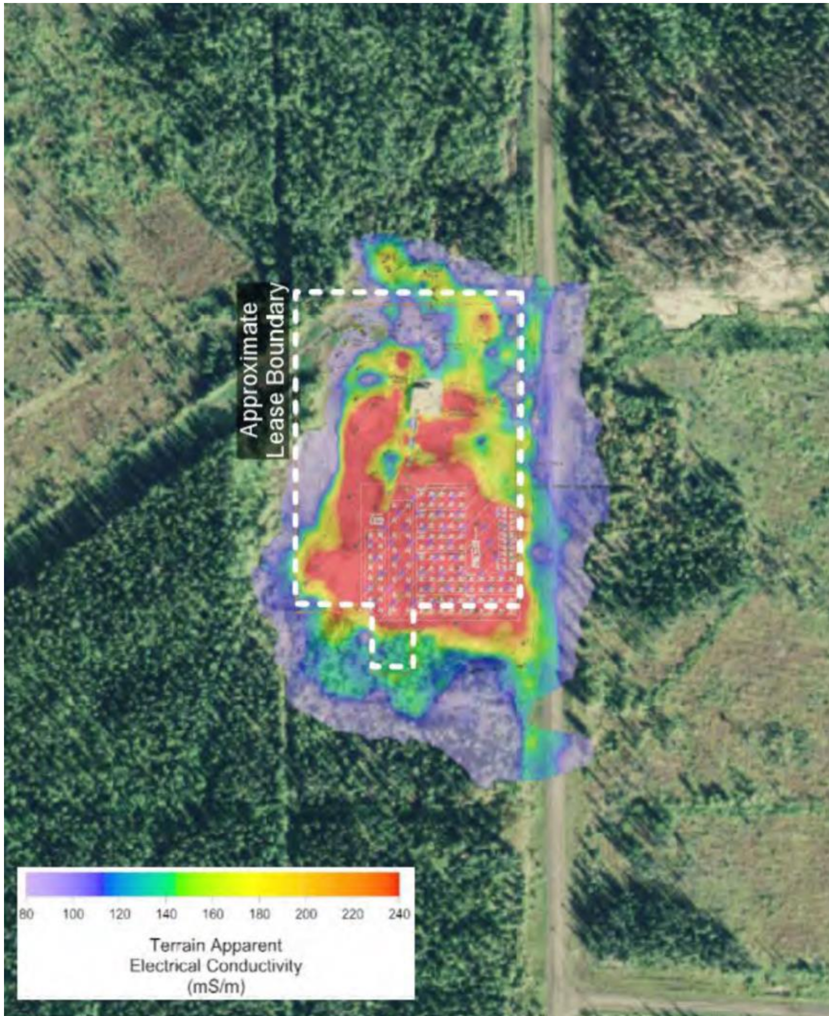
Background

- Produced water spills have occurred on the lease.
- Salinity levels on the site (measured by electrical conductivity) exceeded acceptable rating categories.

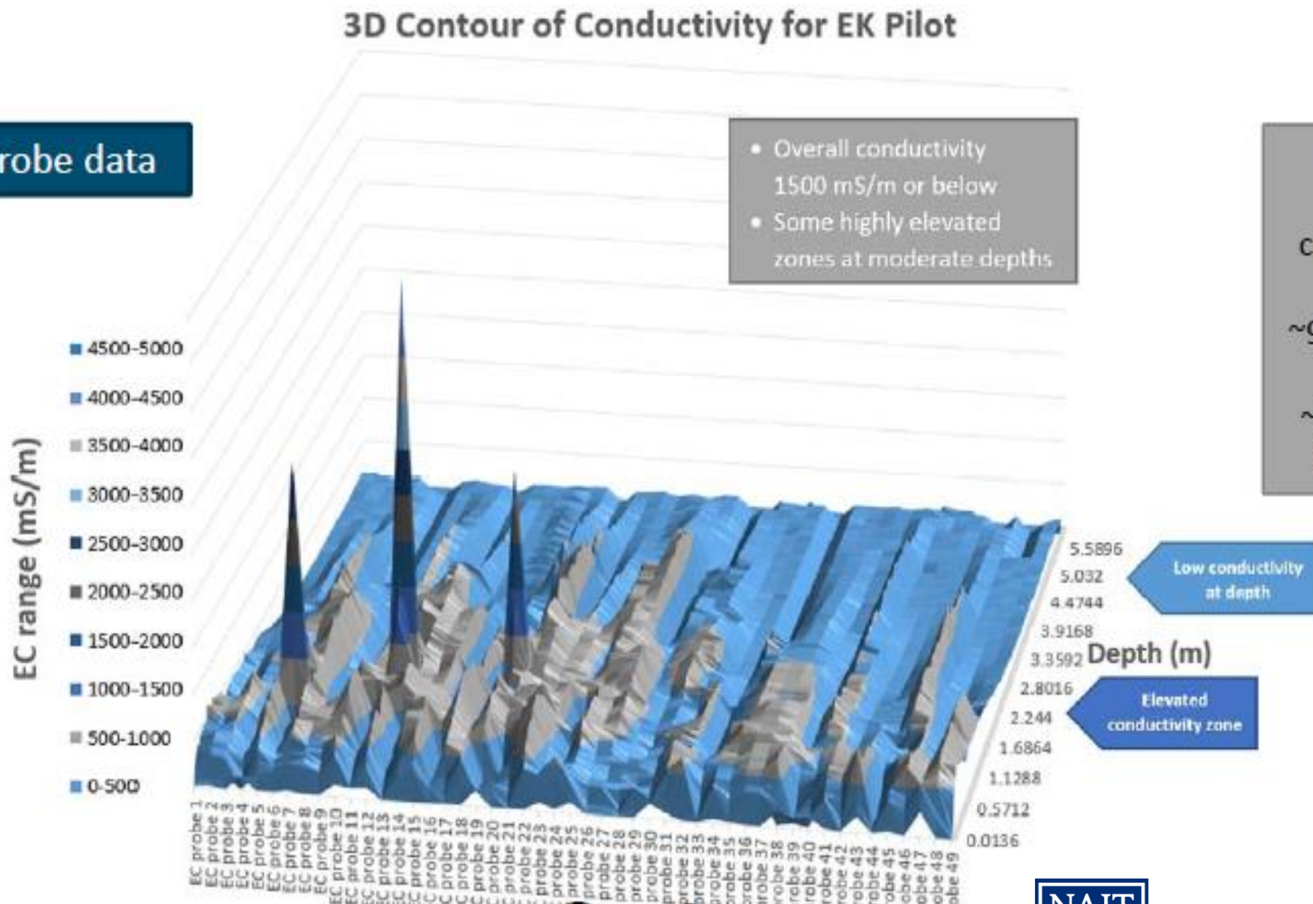
Ho, 2017

Equilibrium Environmental Inc., 2018



Initial Salinity Level

Baseline Geoprobe data



Correlating Geoprobe conductivity with soil samples
~95 tonnes of Cl in the ground
~50% of Cl in the top 2 m of soil

Ho, 2017

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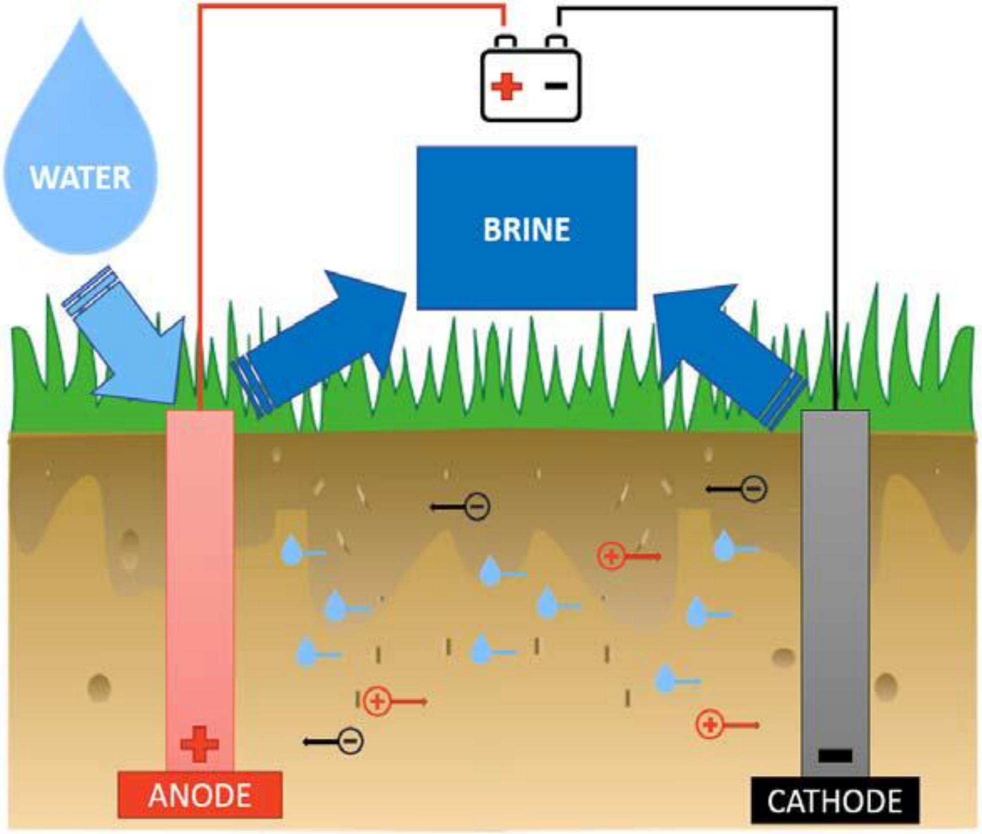
Electrokinetic (EK) Remediation

It involves the application of direct current electric fields of suitable intensity, through a soil matrix to cause the migration of charged ions towards the opposite electrode that has been properly inserted into the ground.

Ho, 2017

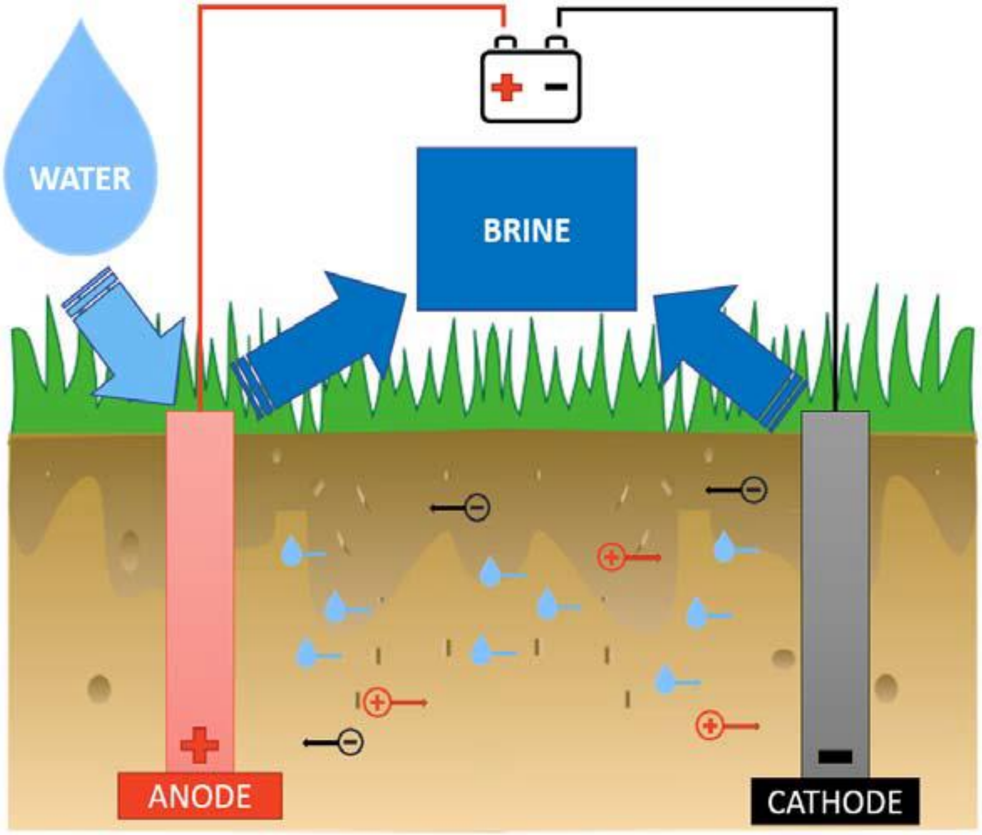


Electrokinetic (EK) Remediation

For salt remediation,
EK separates sodium (Na +) and chloride (Cl -).

The negatively-charged electrodes attract the Na + ions and the positively-charged electrodes attract the Cl -

Ho, 2017



Problem

In an attempt to find new technologies that reduce soil movement the company identified EK remediation as an enabling technology that may allow for the responsible and efficient remediation of the soil and groundwater.

- EK technology needed to demonstrate applicability and reproducibility.
- The technology needed to be optimized to make it cost-effective at large scale.

Objective

The goal of the project was to understand how to implement EK remediation and show if there is a repeatable treatment trend for salt-affected soil.

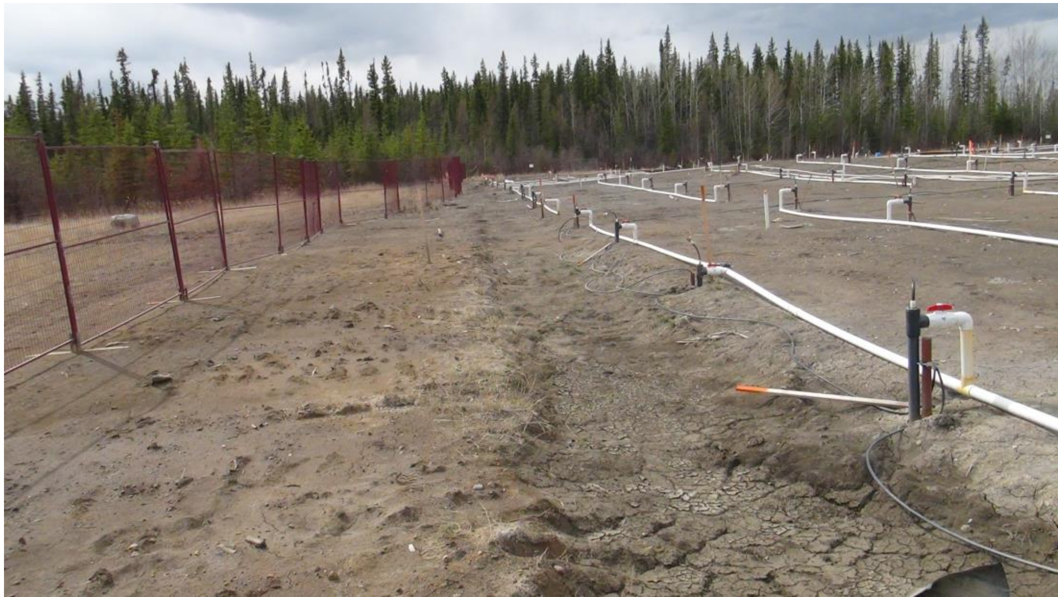
Specific objective:

- Development of cost-effective EK remediation technology for large scale implementation.

Electrokinetic Remediation Materials

Main materials and equipment:

- Source(s) of power
- Electrodes (cathodes and anodes)
- Storage tanks (for brine solution and fresh water)
- Fencing to control the access of wildlife and people



Equipment and Infrastructure Layout

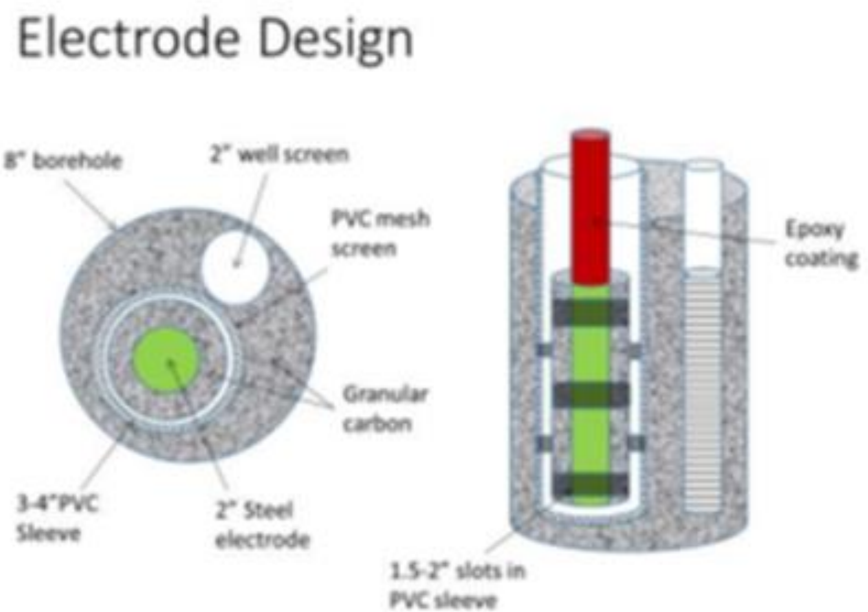
System Designed and operated by

Ground Effects
Environmental Services Inc.

Photo credit: Ground Effect Environmental Services

Equipment and Infrastructure

The system contains an injection pump for injecting fresh water into the electrode systems, as well as a vacuum extraction system to extract the contaminated water.



Ground Effect Environmental Services, 2017

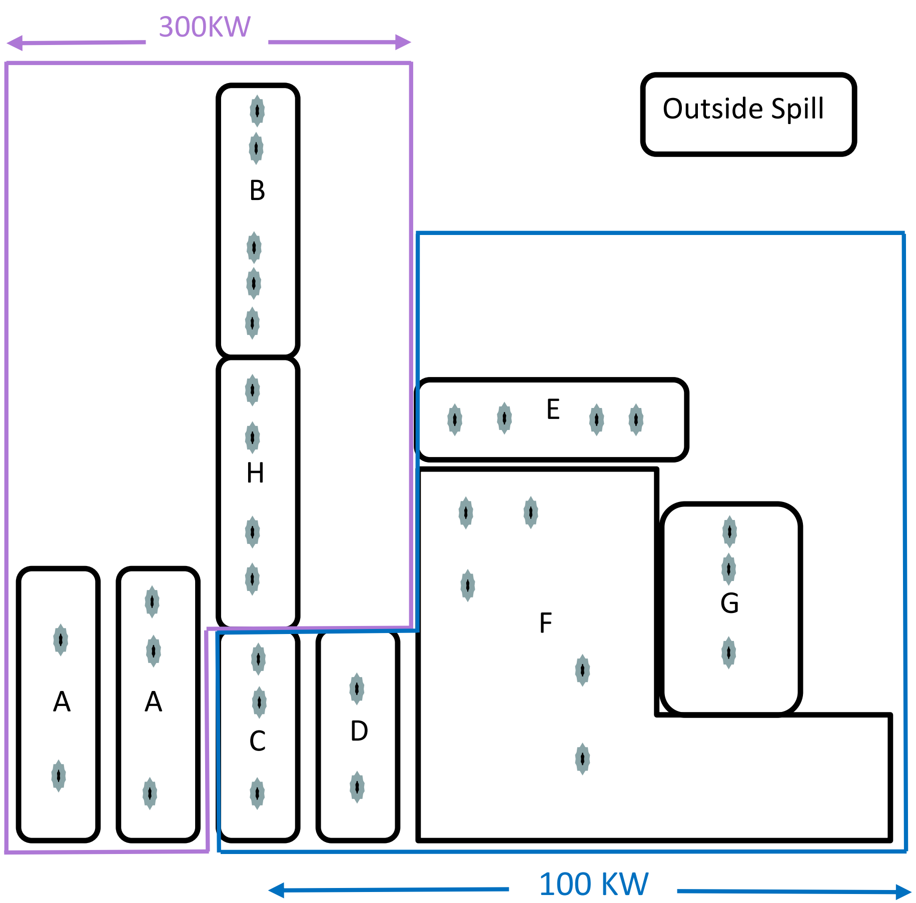
EK Treatment Combinations

Site was classified into zones based on:

- Duration of the electrokinetic process (1 or 2 years)
- Distance between the electrodes (5 or 7 m)
- Power supplied (100 or 300 KW)

These factors determined the major treatment combinations applied on site.

Treatments & Soil Sampling Post-remediation



Sampling Zones	Duration (Years)	Electrode Spacing (m)	Electrical Current (KW)
A	1	7	300
B	1	5	300
C	2	5	100
D	2	7	100
E	1	5	100
F	2	5	100
G	1	5	100
H	1	5	300

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Soil Sampling Post-remediation

- Soil sampling was done to a depth of 5 m.
- At each plot, soil cores were taken at the depths of 1, 2, 3, 4 and 5 m.
- 33 sampling plots were bored consisting of:
  - 27 treatment plots
  - 4 control grid plots
  - 2 untreated sampling plots
- Total of 165 samples were collected.

Conductivity

Differences in conductivity by zone

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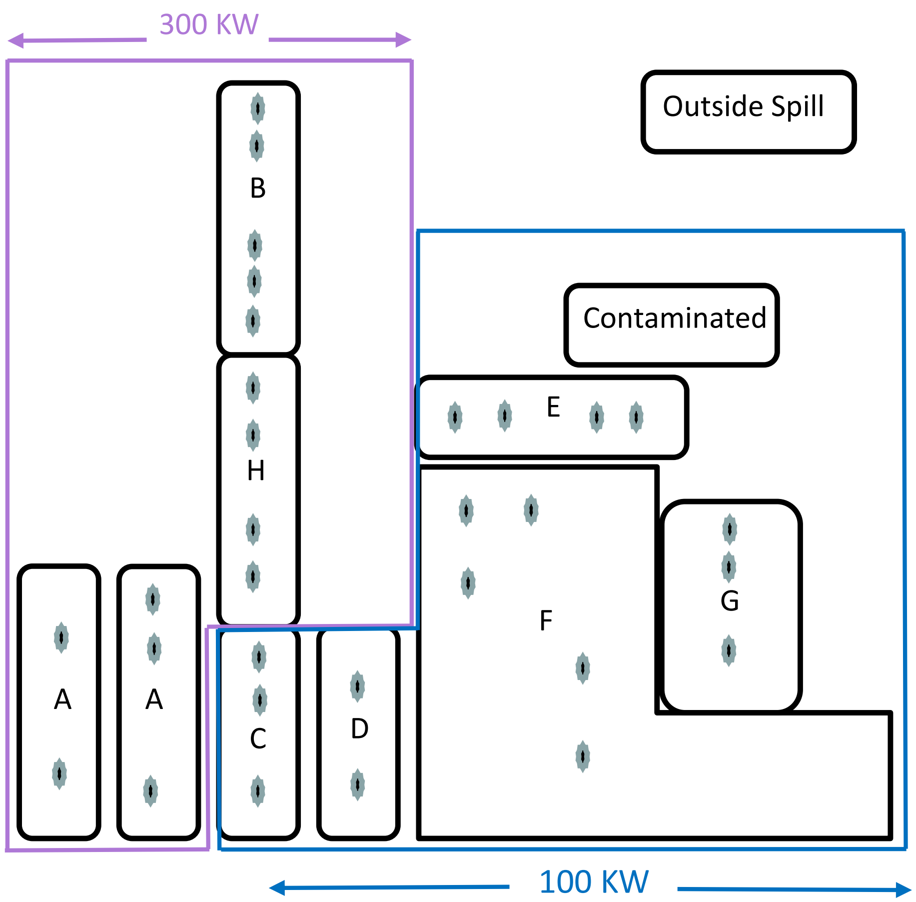
Conductivity by Zone



Conductivity ~ Zone
$F_{9,173} = 13$, $P < 0.001$

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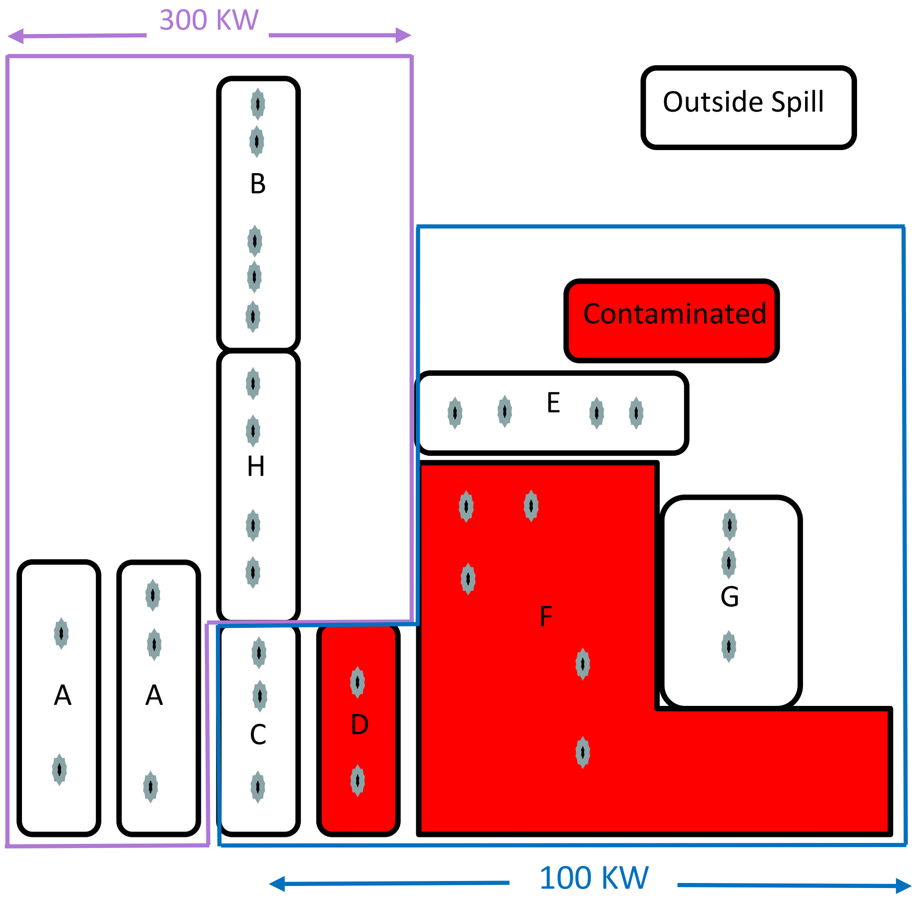
Conductivity by Zone



Red = Highest

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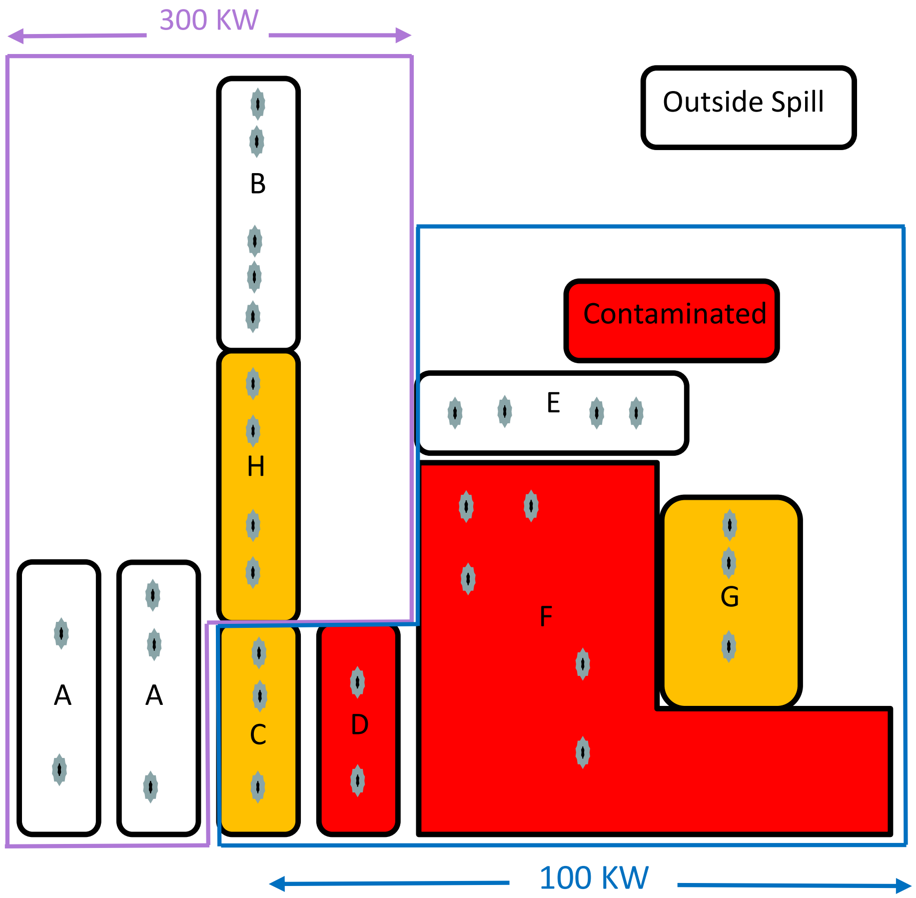
Conductivity by Zone



Red = Highest
Yellow = Moderate

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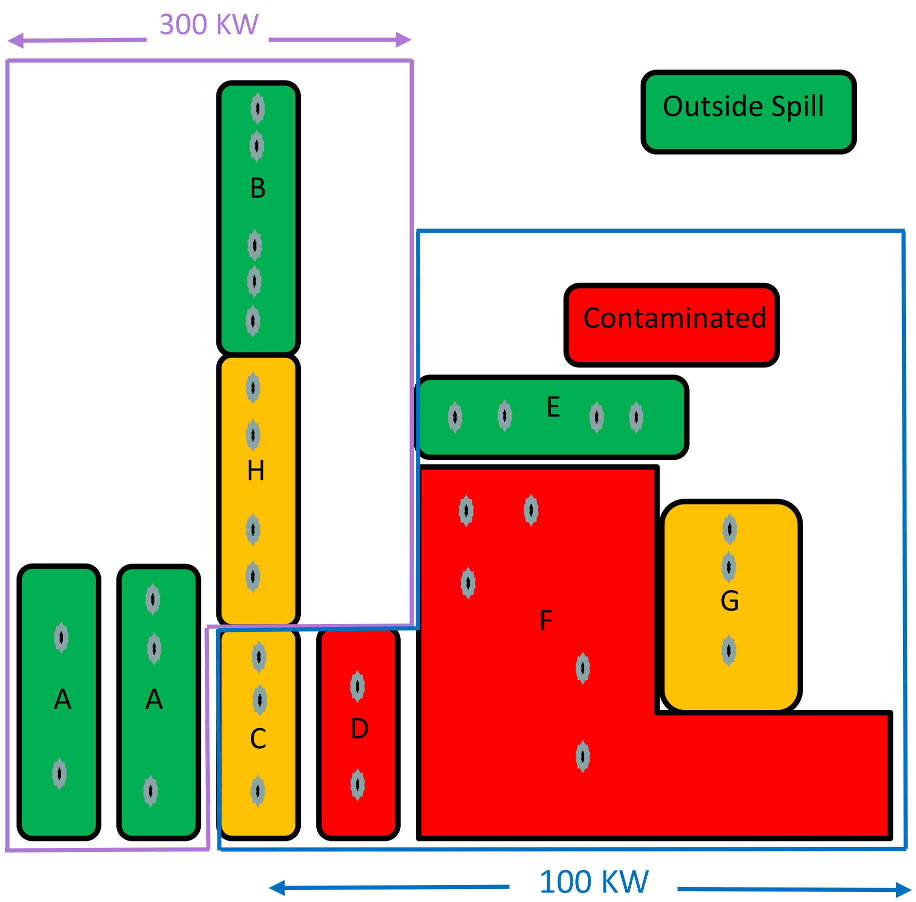
Conductivity by Zone



Red = Highest
Yellow = Moderate
Green = Lowest

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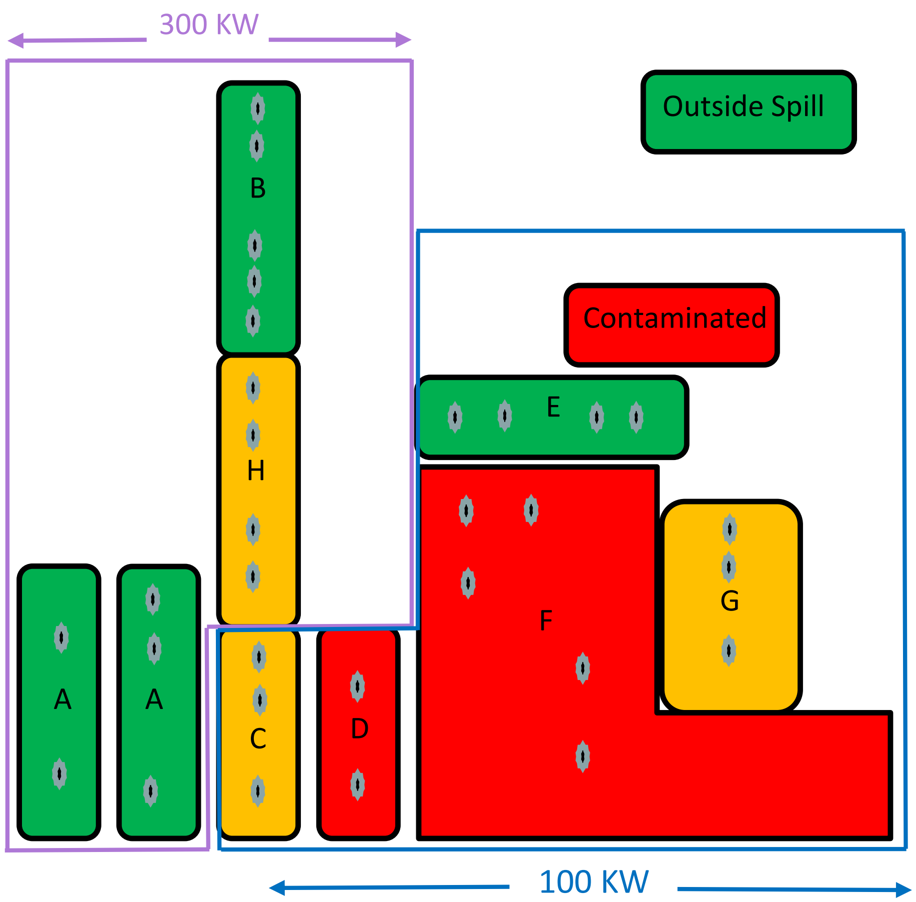
Conductivity by Zone



More high conductivity zones (red) in 100 KW area

Power effect?

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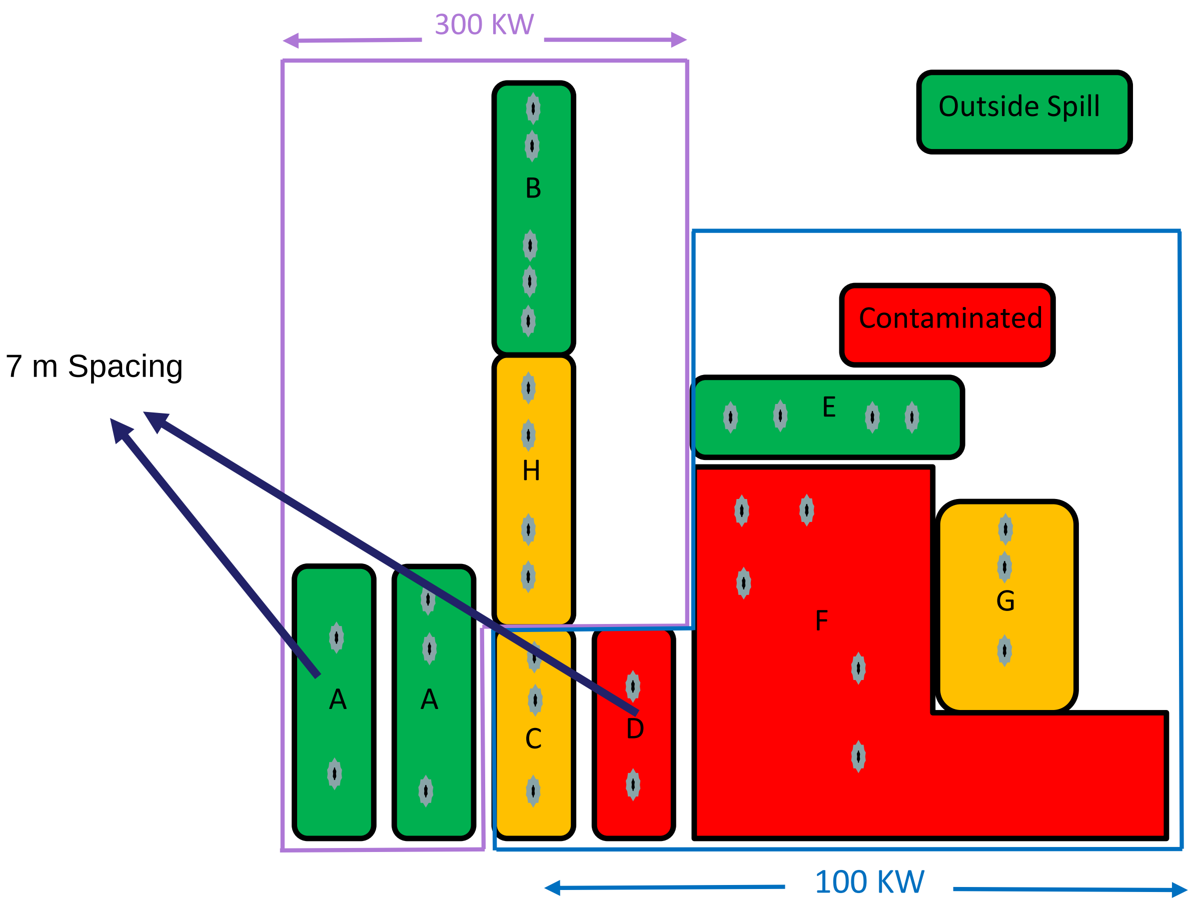
Conductivity by Zone



A and D have 7 m spacing

7 m associated with both low and high conductivity

No spacing effect?

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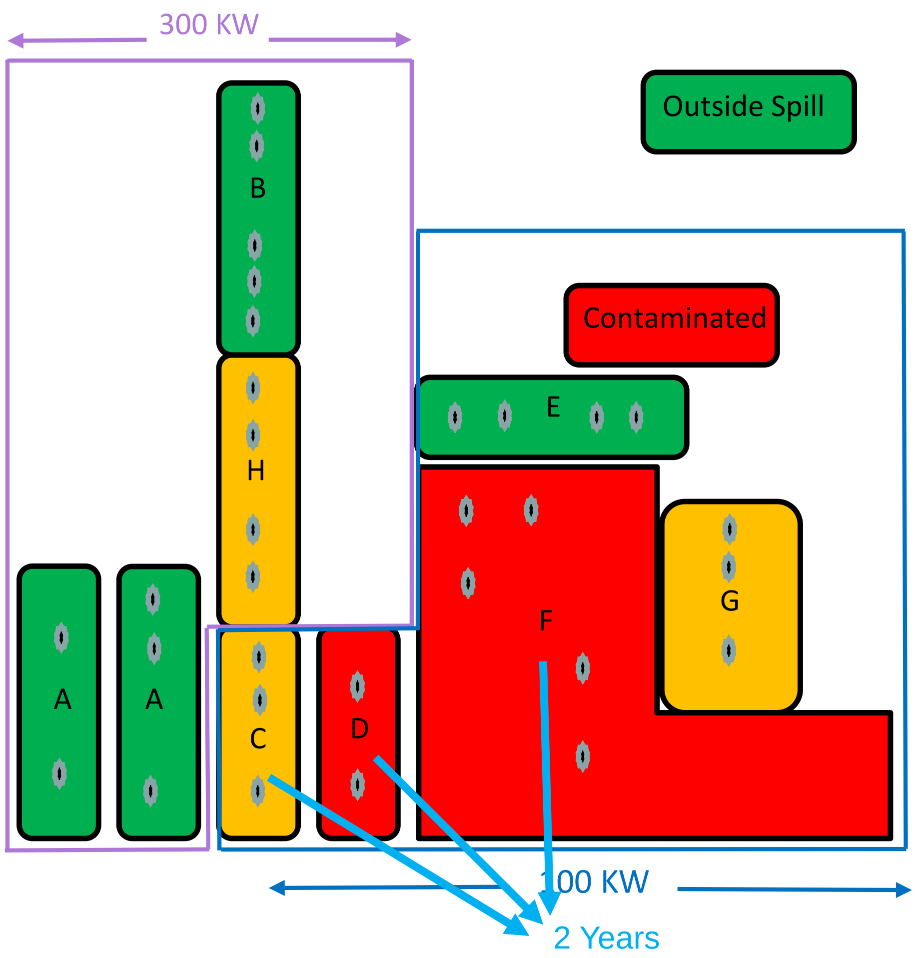
Conductivity by Zone



Zone C, D, F have 2 years of treatment

Year effect? 2 years have higher conductivity?

*Many other factors to consider

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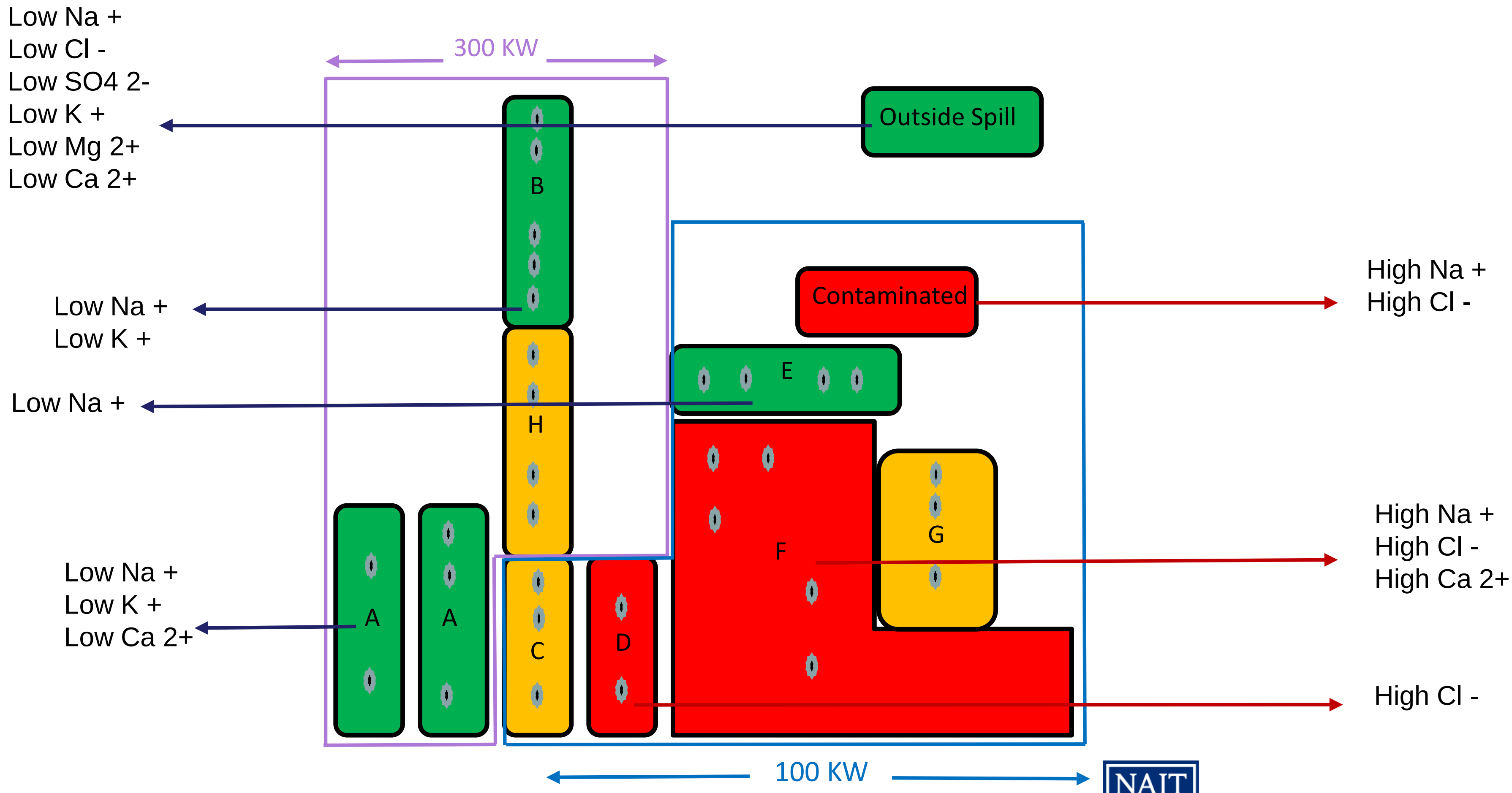
Conductivity

Differences in conductivity by zone &
Concentrations of various ions

Conductivity and Ions by Zone



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Conductivity

Linear Regression

Year, Electrode Spacing, Power, Depth used as predictors

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Conductivity Linear Model

- Not Significant

- Not Significant

Conductivity ~ Year + Electrode Spacing + Power + Depth

- Significant
- Increase in power resulted in decrease in conductivity

- Significant increase in conductivity at 2 m relative to 1 m
- 1 m and 3 m not different
- Lower conductivity at 4 m and 5 m

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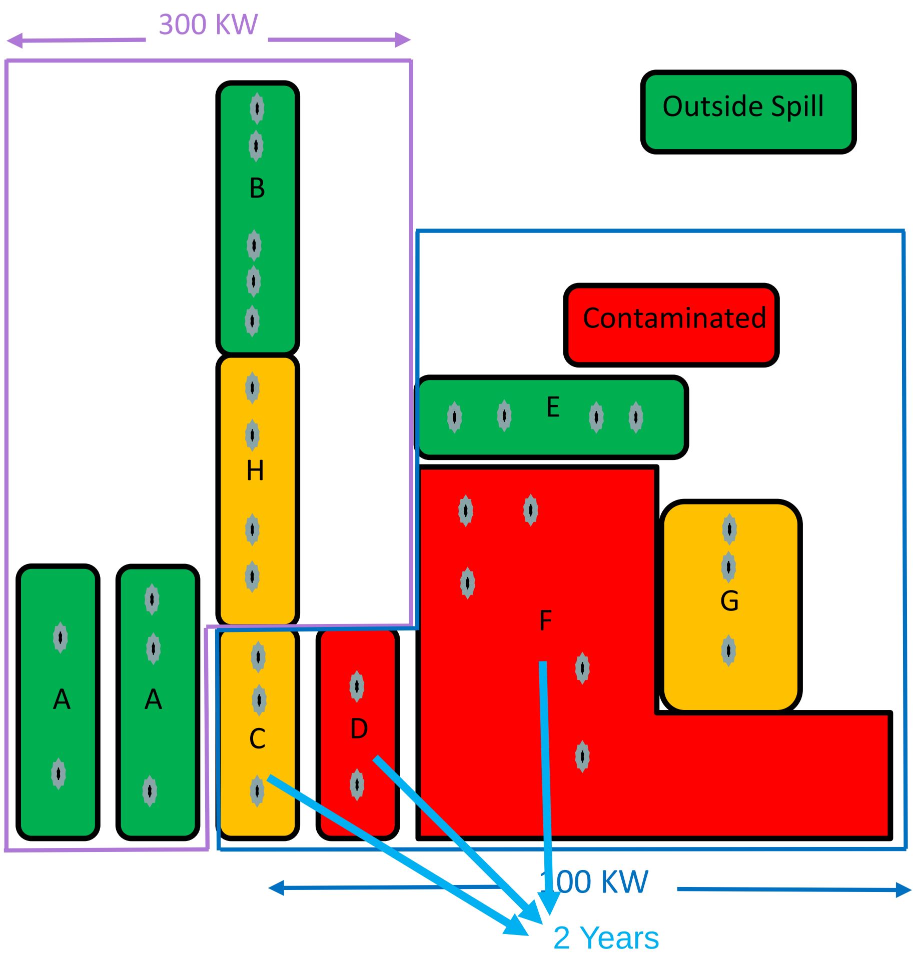
Conductivity Linear Model



- Zone C, D, F have higher conductivity
- Not related to the number of years the treatment was run

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Sodium [Na +]

Linear Regression

Year, Electrode Spacing, Power, Depth used as predictors

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Sodium Linear Model

- Not Significant

- Significant
- 5 m and 7 m similar
- Lower [Na +] without electrodes

$$[Na^{+}] \sim \text{Year} + \text{Electrode Spacing} + \text{Power} + \text{Depth}$$

- Significant
- Increase in power resulted in decrease in [Na +]

- Not Significant
- But generally higher [Na +] at 2 m depth

Chloride [Cl -]

Linear Regression

Year, Electrode Spacing, Power, Depth used as predictors

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Chloride Linear Model

- Marginally significant
- Decrease in [Cl -] Year 2

- Significant
- Lowest [Cl -] without electrodes

$[Cl^-]$ ~ Year + Electrode Spacing + Power + Depth

- Significant
- As power increases, there is a decline in [Cl -]

- Significant
- Lower concentrations at 4 m and 5 m

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Results Summary

- Year effect not significant for overall conductivity
  - Marginally less [Cl -] 2 years vs 1 year
- Spacing not important for overall conductivity
  - Lower [Na +] and [Cl -] when electrodes not present
- An increase in power resulted in lower conductivity
  - Lower [Na +] and [Cl -] in sample plots
- Depth was significant
  - Highest conductivity & ions at 2 m
  - [Na +], [Cl -], [SO4 2-], [K +], [Mg 2+], [Ca 2+]

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Discussion

- Non uniform spills
- Corrosion of electrodes
- Moisture differences across plots
  - Not measured for all plots, excluded from analysis

Discussion

- Less effective over time
  - Running for additional years may not be beneficial (need more research)
  - Treatments more efficient when there are more ions? Not as effective for small scale spills?
- Electrodes promote the movement of ions
  - No current means that NaCl isn't broken into ions
  - May explain why there was lower [Na^+] and [Cl^-] when electrodes not present
- 5 m vs 7 m spacing not different
- Higher power more effective
- Lower concentrations in plots when power was applied
  - Agrees with previous report where higher conductivity and [Cl^-] was observed at the electrodes
  - Movement of mostly [Na +] and [Cl –]
- Consider the depth. Understand where to focus efforts.

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Project Initiator

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Questions?

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