



# Monitoring the Impacts & Effectiveness of Electrical Resistance Heating with Enhanced Bioremediation



# Heating Technologies

## **Thermal Conduction Heating (TCH)**

Electrically powered thermal conduction heating

20 - 400 °C

## **Steam Enhanced Extraction**

Steam injected through screen wells

100 °C

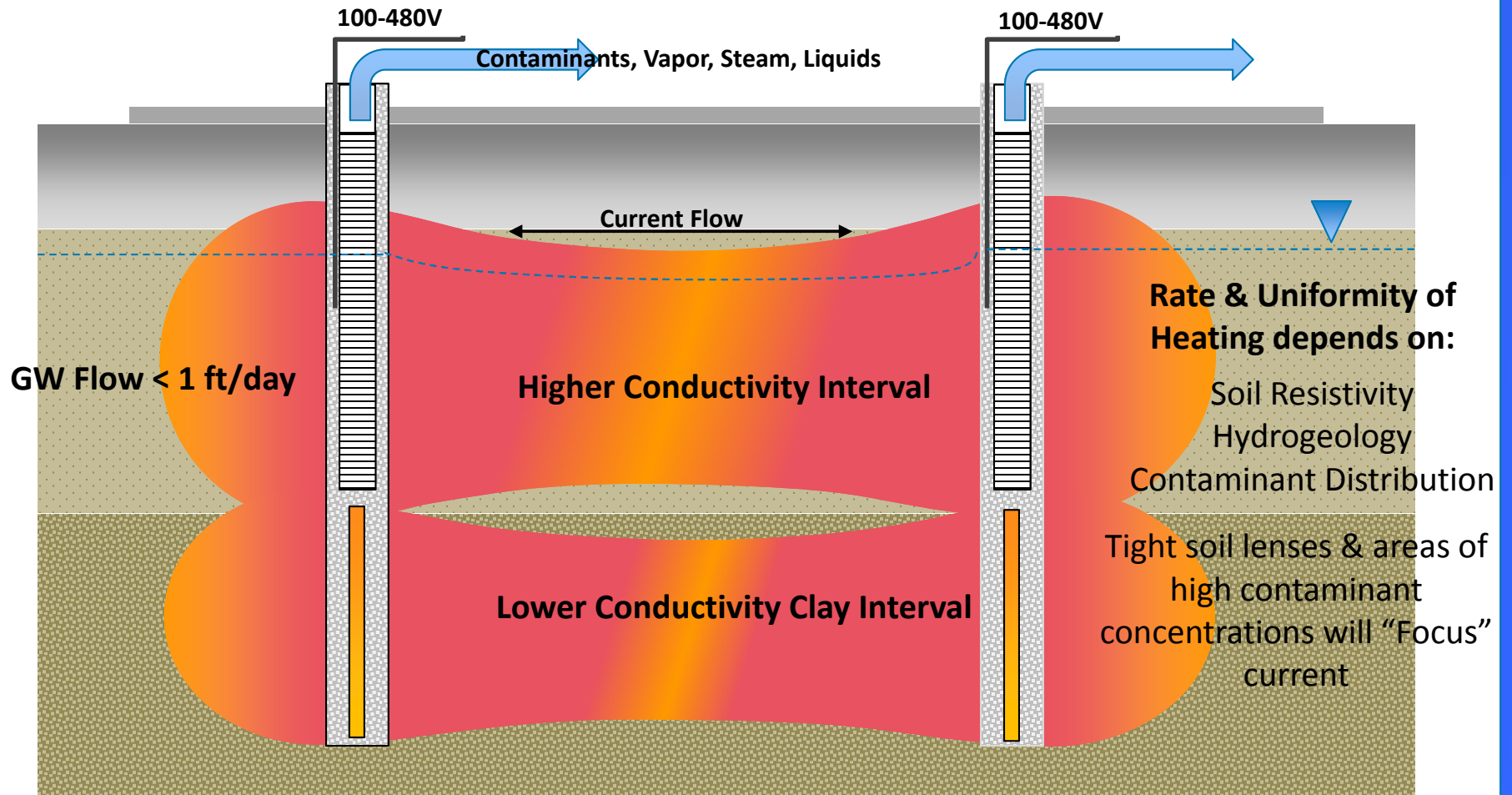
## **Electrical Resistance Heating (ERH)**

Passes current between electrodes in the subsurface

Electrical resistance of soil generates heat

20 - 100 °C

# Electrical Resistance Heating (ERH)



# Advantages of Thermal Technologies

## Reduce source mass & overall lifetime project cost

- Multiple removal mechanisms work in concert:
- Direct volatilization, steam stripping, enhanced evaporation
- Dissolution rates increase
- Desorption rates increase
- Abiotic degradation rates increase
- Biotic degradation rates increase (moderate heating)

# Combining with Bioremediation

## Bio-Polishing

- Residual energy from completed ISTR system
- Enhanced degradation

## Low Temp Heat Enhanced Bioremediation

- ISTR system with operational temps of 30 to 35°C
- Maximize degradation rates
- Increase free product extraction (if present)

## Source – ISTR Downgradient – Heat Enhanced Bioremediation

- ISTR system with operational temps of 100°C
- Downgradient moderate heating (recirculation system)
- Enhance degradation rates

## Background

- Dry cleaning facility operating for 67 years
- Contaminants
  - Tetrachloroethene (PCE)
  - Some daughter products
  - Stoddard solvent
  - HMW hydrocarbons (DRO, ORO)
- No discernable groundwater flow direction
- Ongoing SVE system (modified for ERH operations)

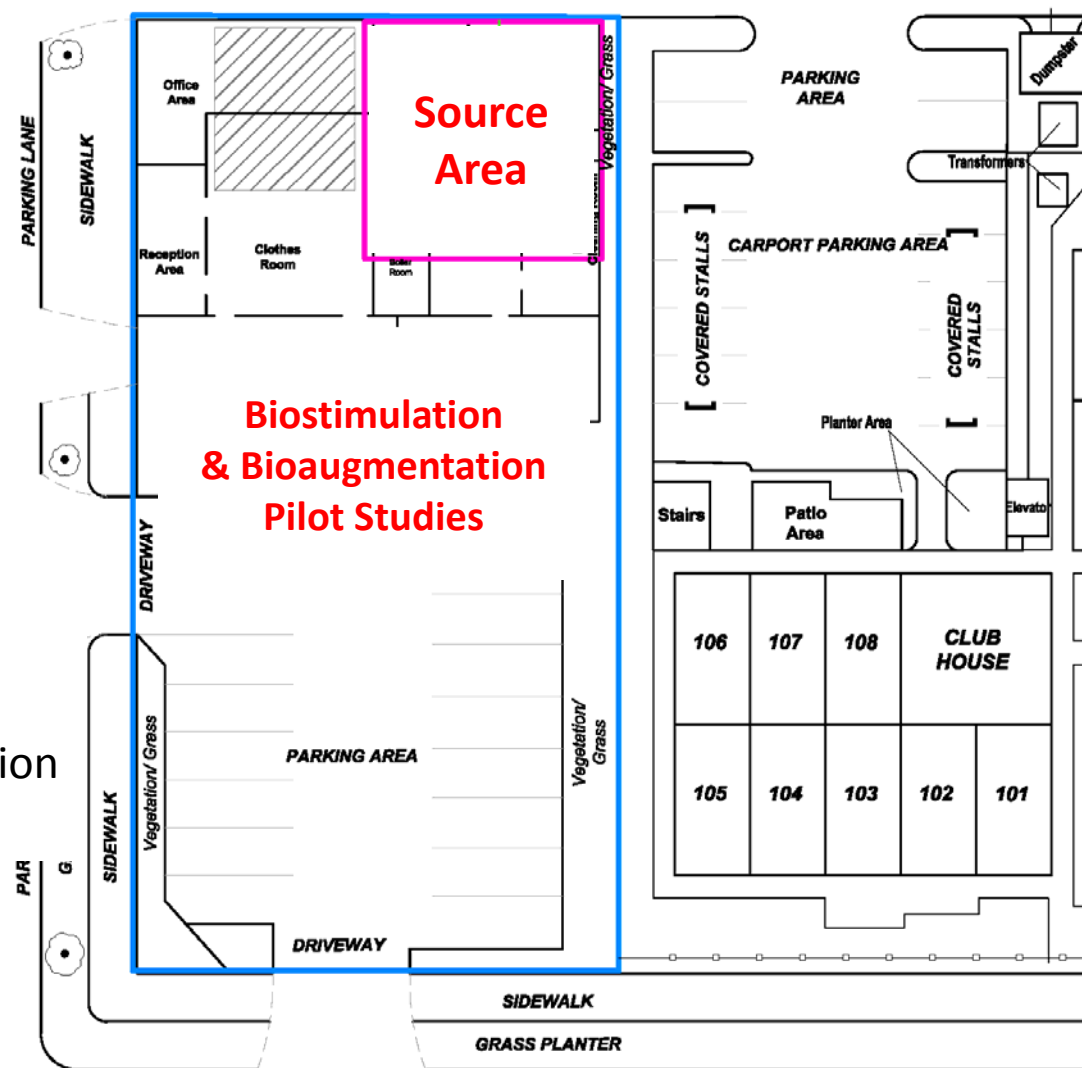
# Site Layout

## Source Area

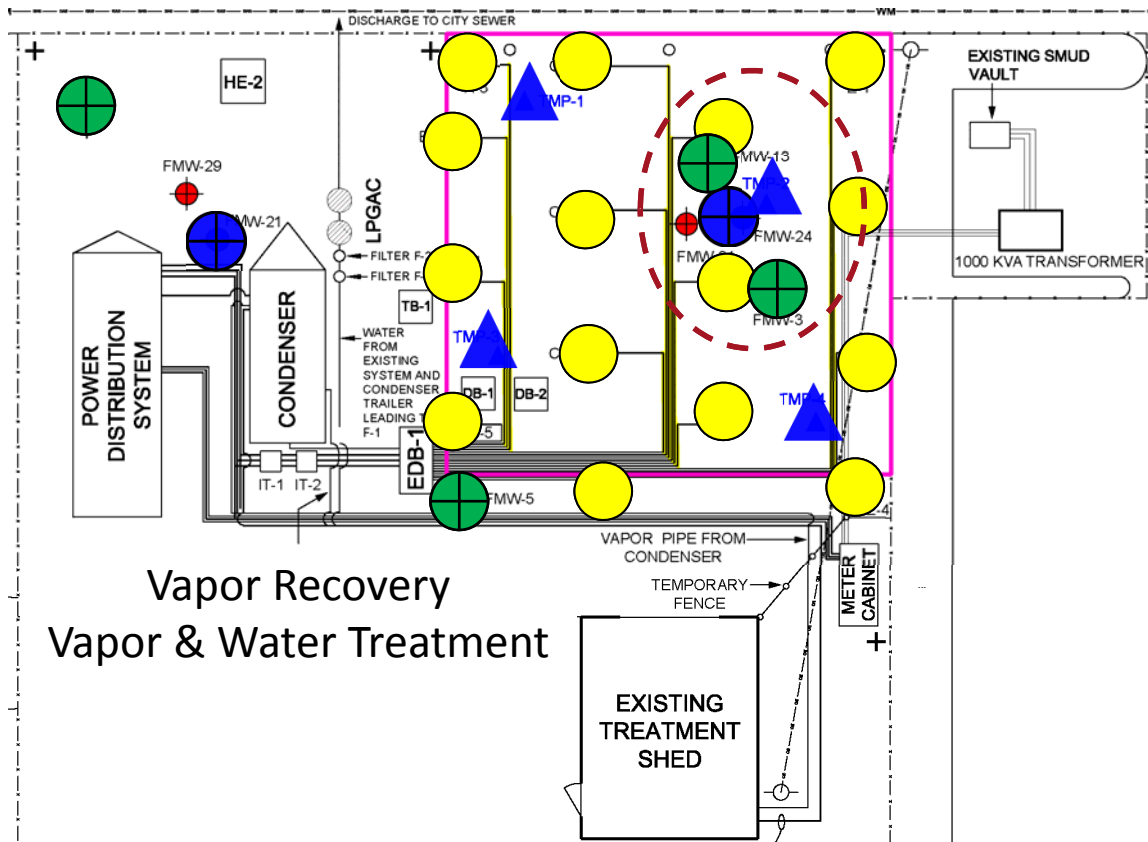
USTs  
Dry Cleaning Rooms  
ERH Treatment System

## Plume





Biostimulation/Bioaugmentation  
Pilot studies



# Source Area ERH System

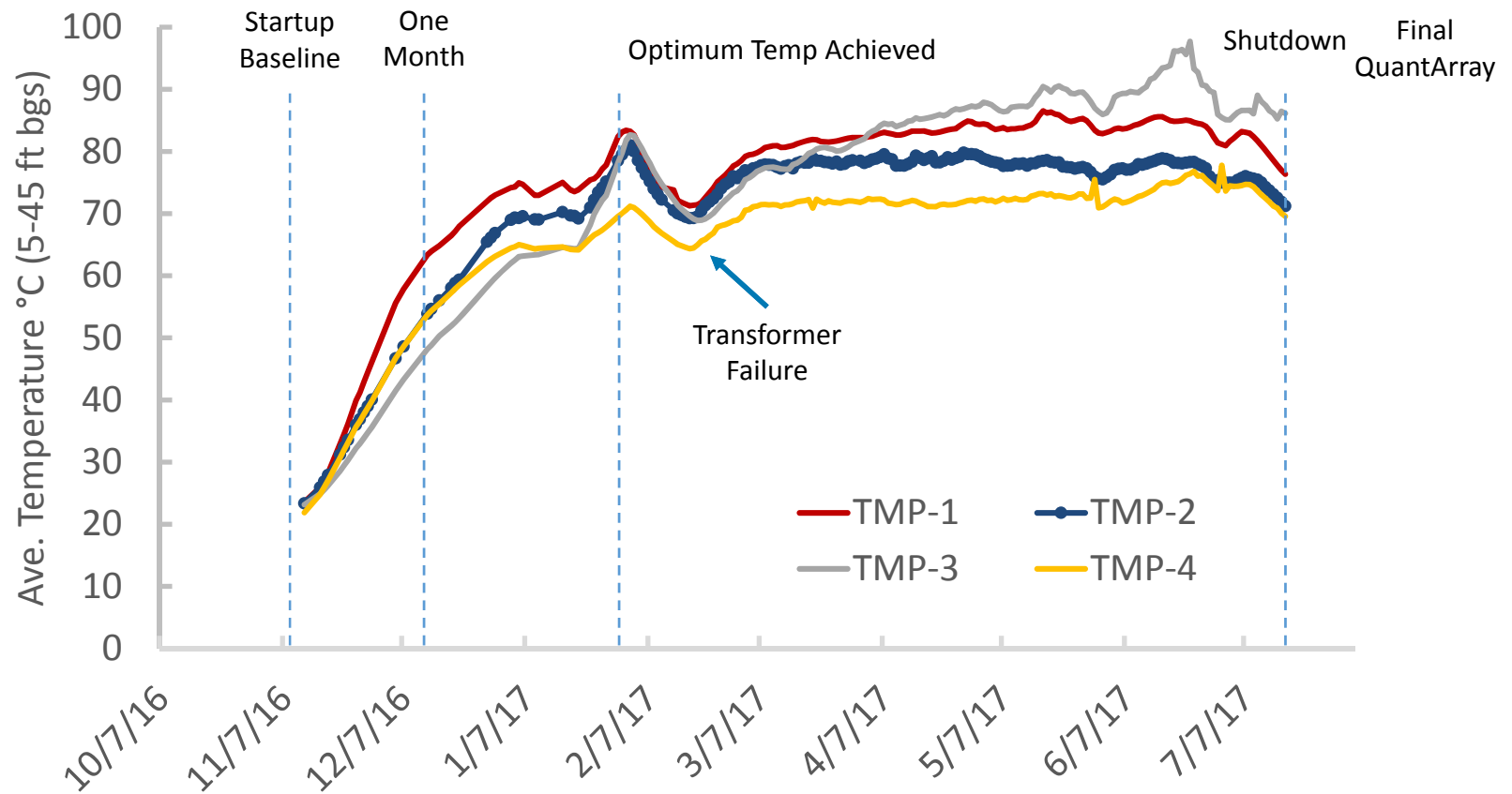


Vapor Recovery  
Vapor & Water Treatment

-  Total of 15 combined electrode/vapor recovery wells
-  Shallow monitoring wells (FMW-3)
-  Intermediate monitoring wells (FMW-24)
-  Temperature probes (TMP-2)



# ERH Operation



## ERH Performance - Soil

Contaminant	Highest Pre-ERH Concentration (mg/kg)	Highest Post-ERH Concentration (mg/kg)	Average Post-ERH Concentration (mg/kg)	Percent Reduction (%)
PCE	26	0.054	0.0052	>99.9%
TCE	11	0.002	0.0003	>99.9%
Stoddard Solvent	3100	2600	246	~ 93%

## ERH Performance - Groundwater

Contaminant	Highest Pre-ERH Concentration (µg/L)	Highest Post-ERH Concentration (µg/L)	Average Post-ERH Concentration (µg/L)	Percent Reduction (%)
PCE	6,600	98	51.3	>99%
TCE	5,900	7.5	4.6	>99%
cDCE	28,000	ND	ND	~ 100%
Vinyl chloride	4.1	ND	ND	~ 100%

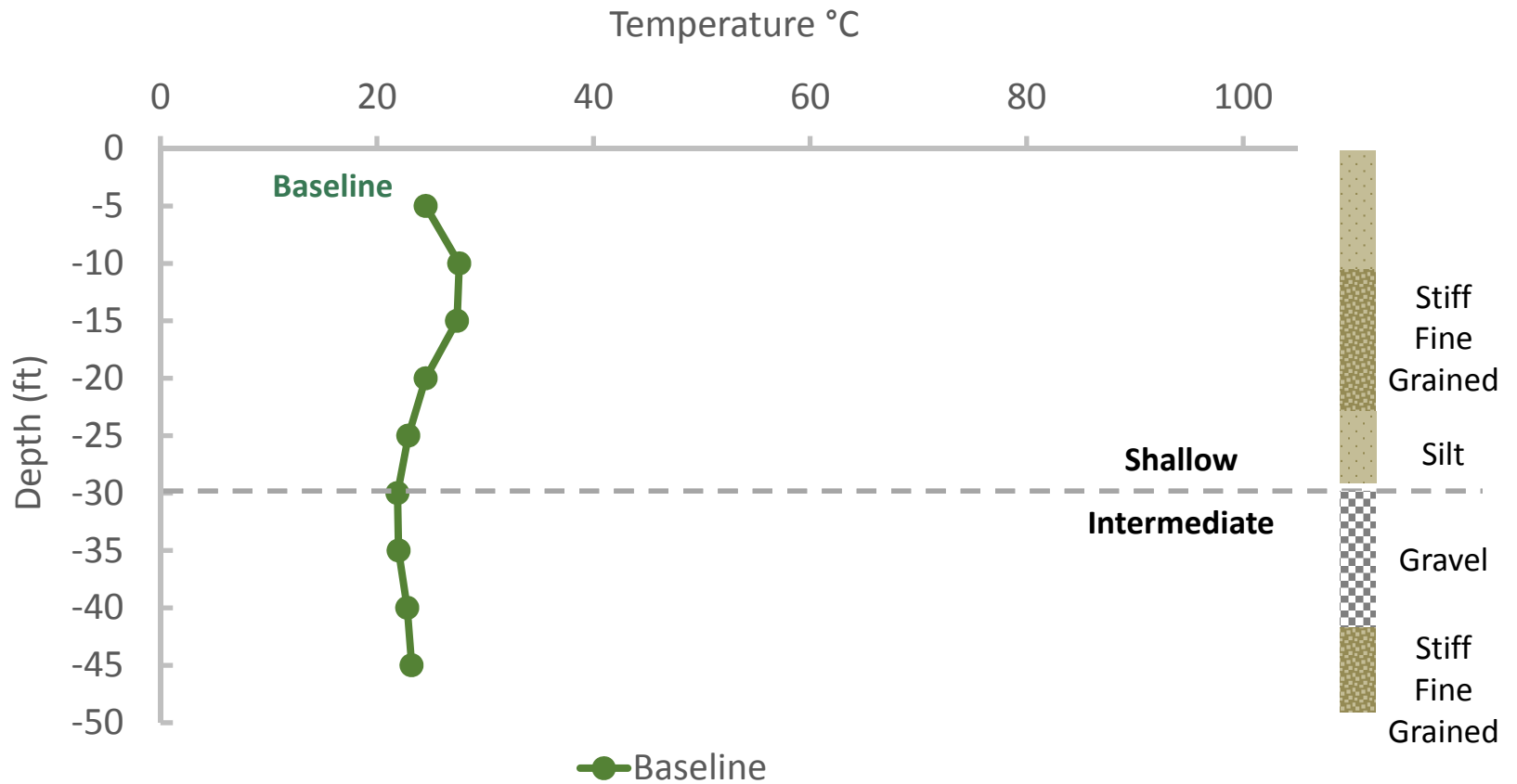
## ERH Conclusions

- Highly effective contaminant mass removal
  - Greater than 99% decrease in soil CVOCs
  - 99% decrease in groundwater CVOCs
  - Approximately 93% decrease in soil SS concentration
- Temperatures achieved
  - 80° C reached at 75% of treatment volume
  - 90° C reached at 58% of treatment volume
- Heterogeneity of subsurface soils impacted heating

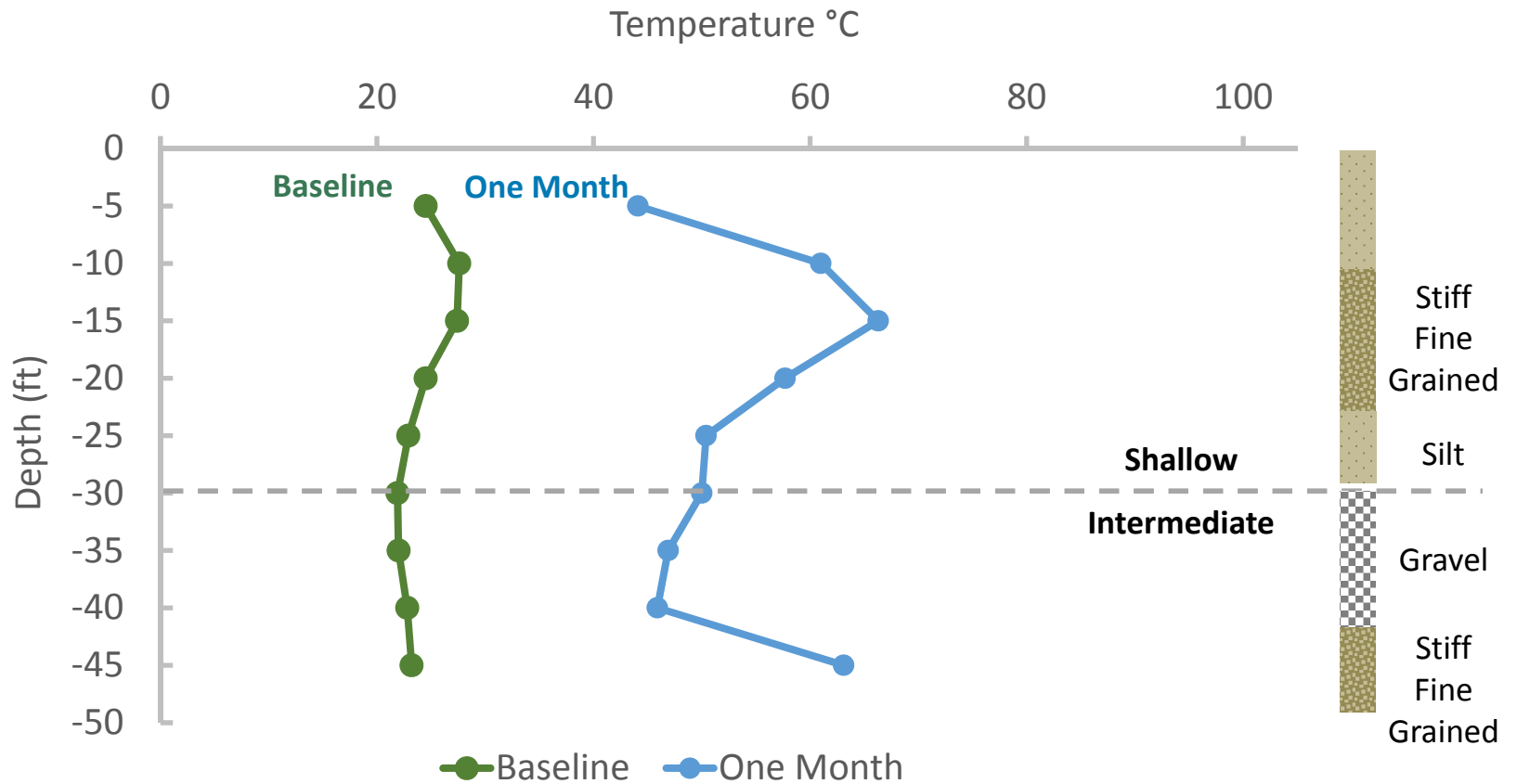
## Goals - Microbiology

- Evaluate potential for
  - Post-ERH bioremediation in source zone
  - Enhanced biodegradation in downgradient areas
- QuantArray analysis of groundwater samples
  - Baseline
  - One month after startup
  - Following ERH shutdown

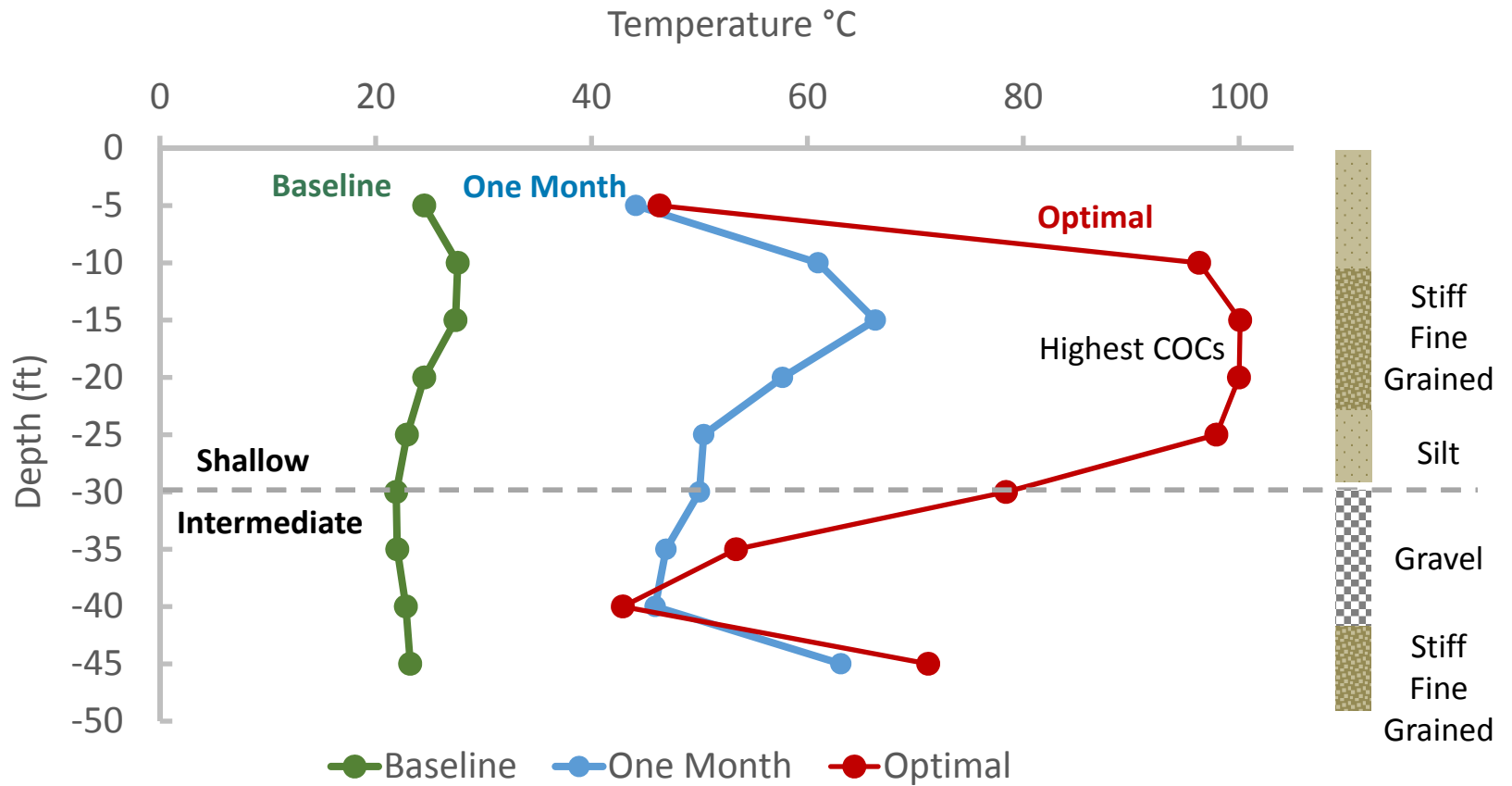
# Temperature with Depth (Baseline)



# Temperature with Depth (One Month)

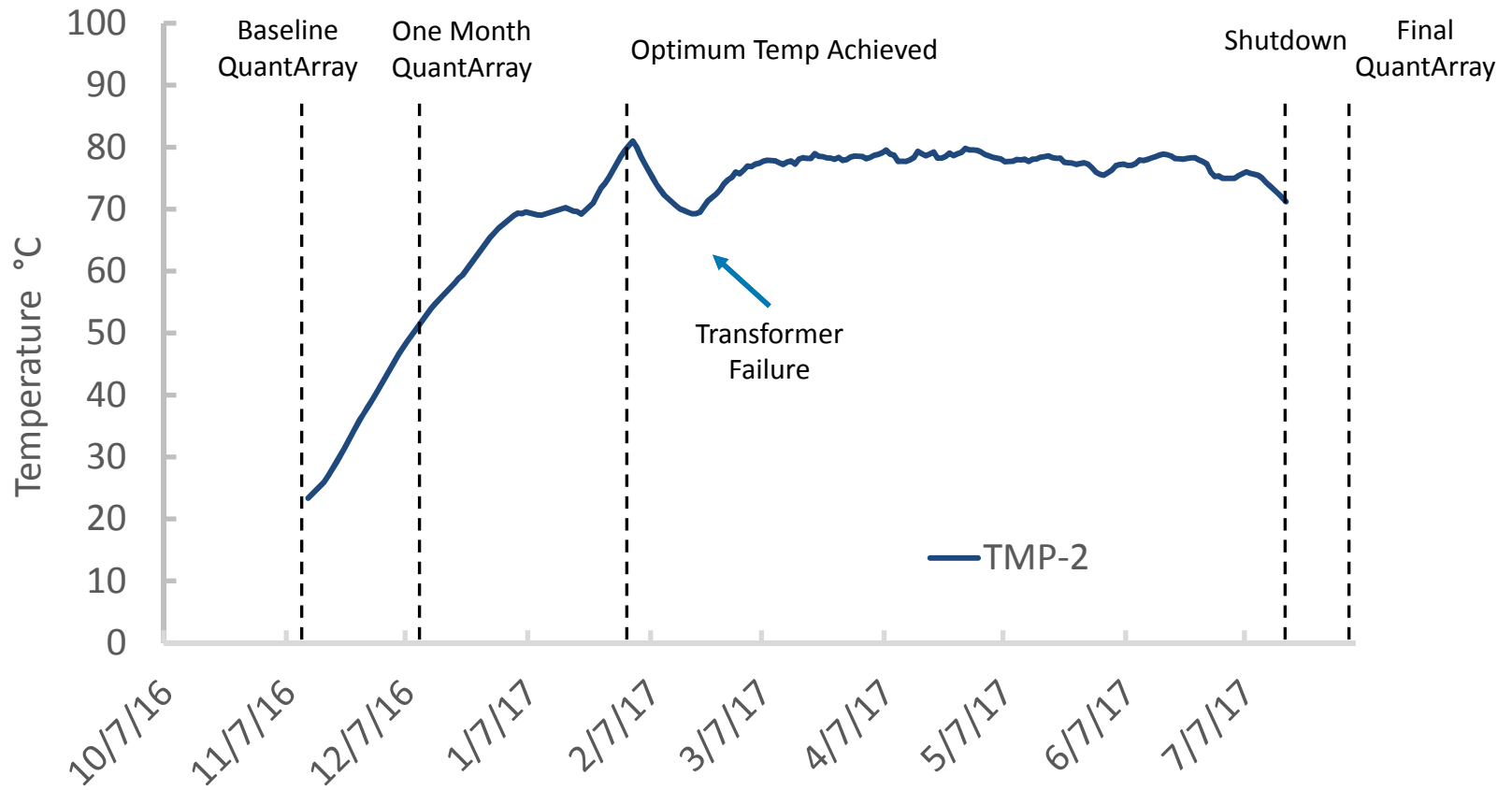


# Temperature with Depth (Optimal)

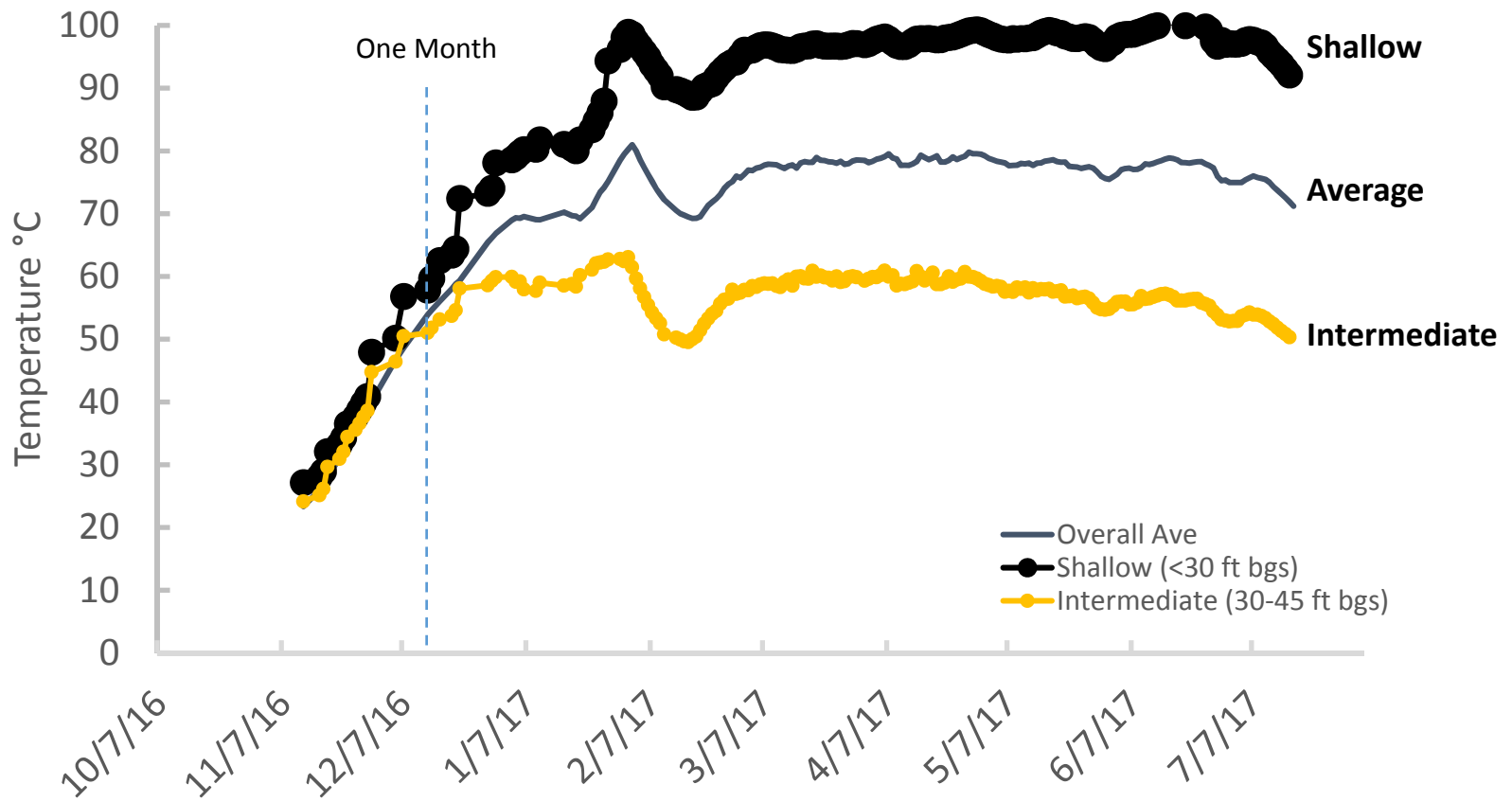




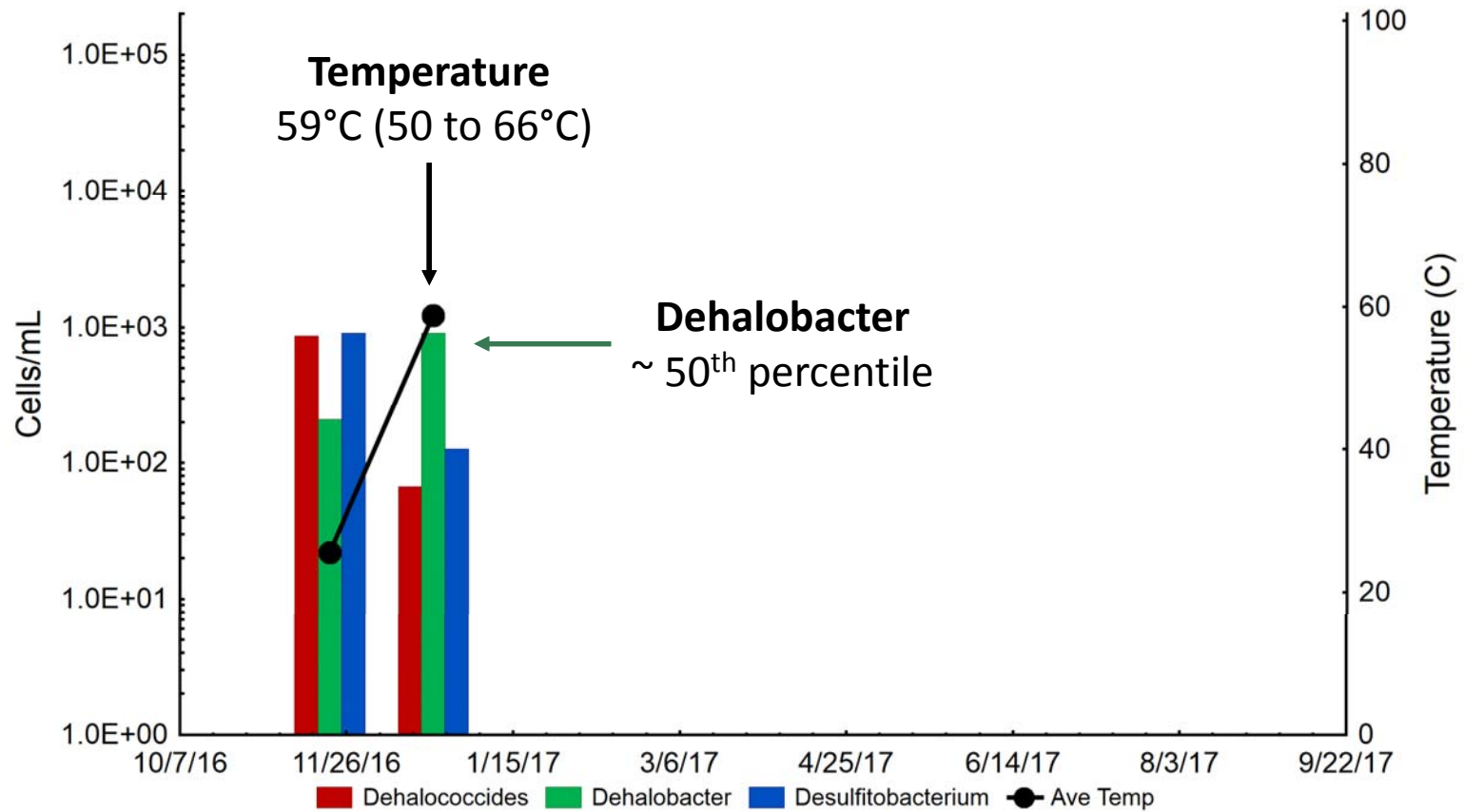
# Temperature over Time



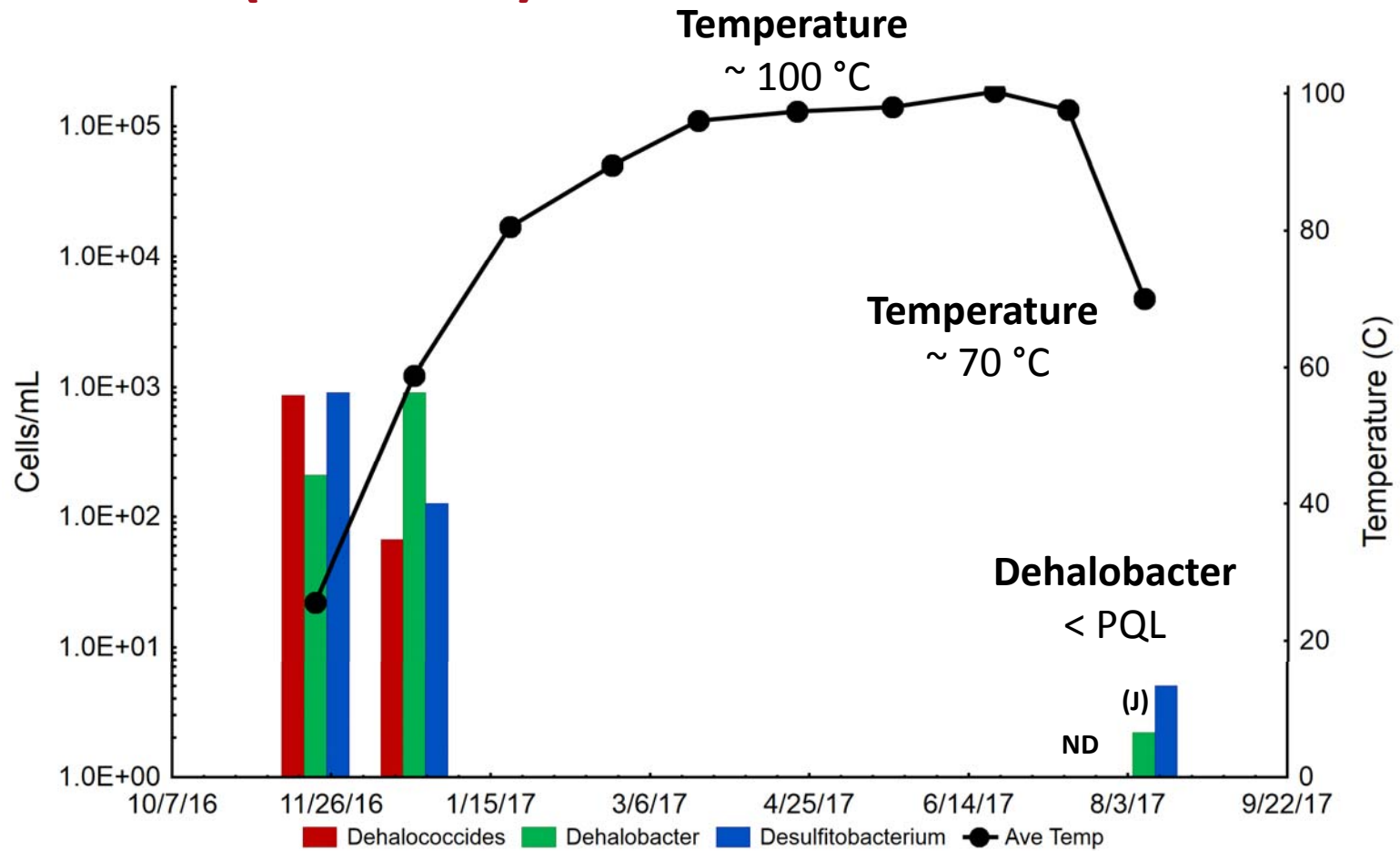
# Temperature over Time



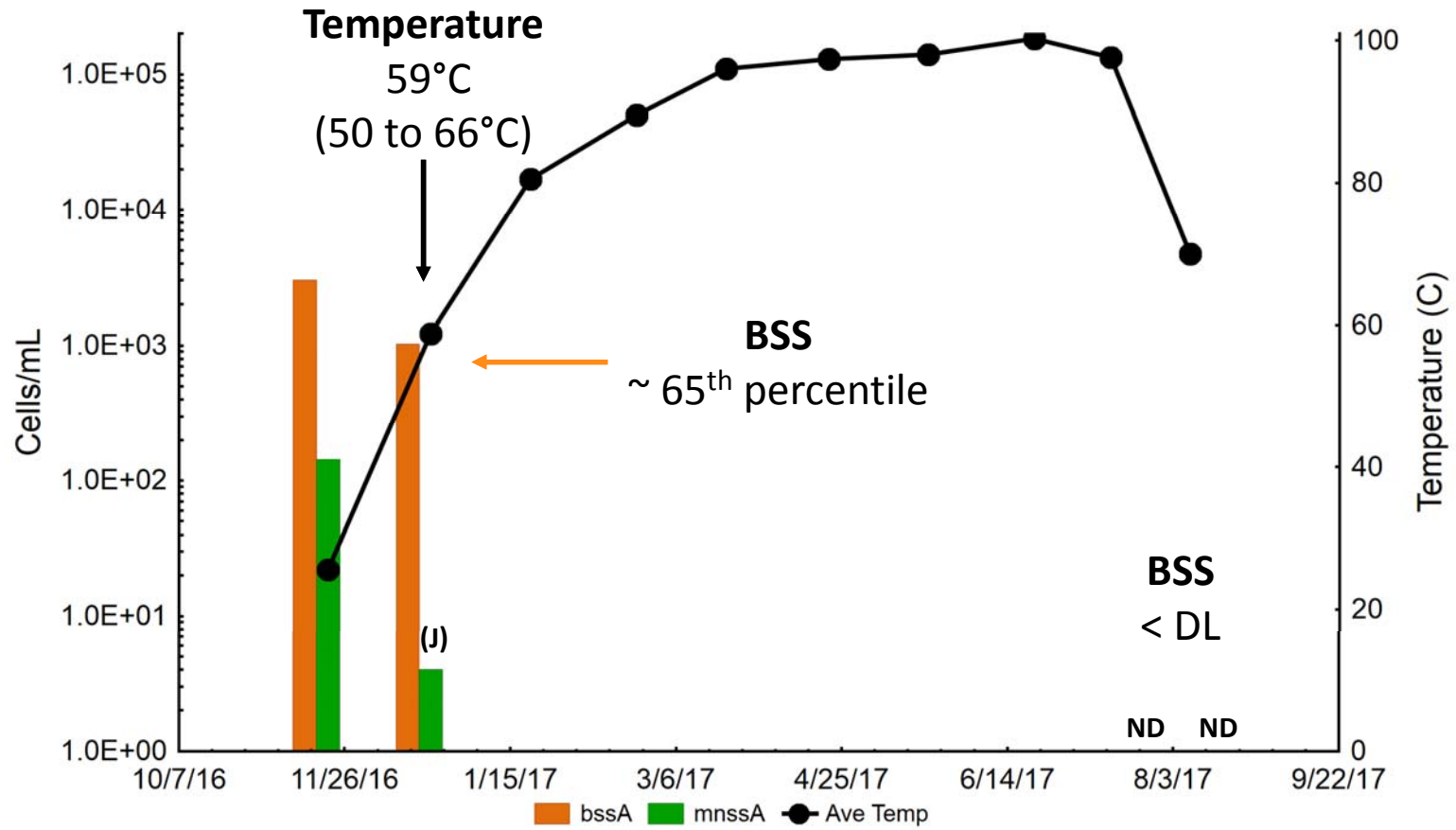
# Baseline vs One Month (Shallow)



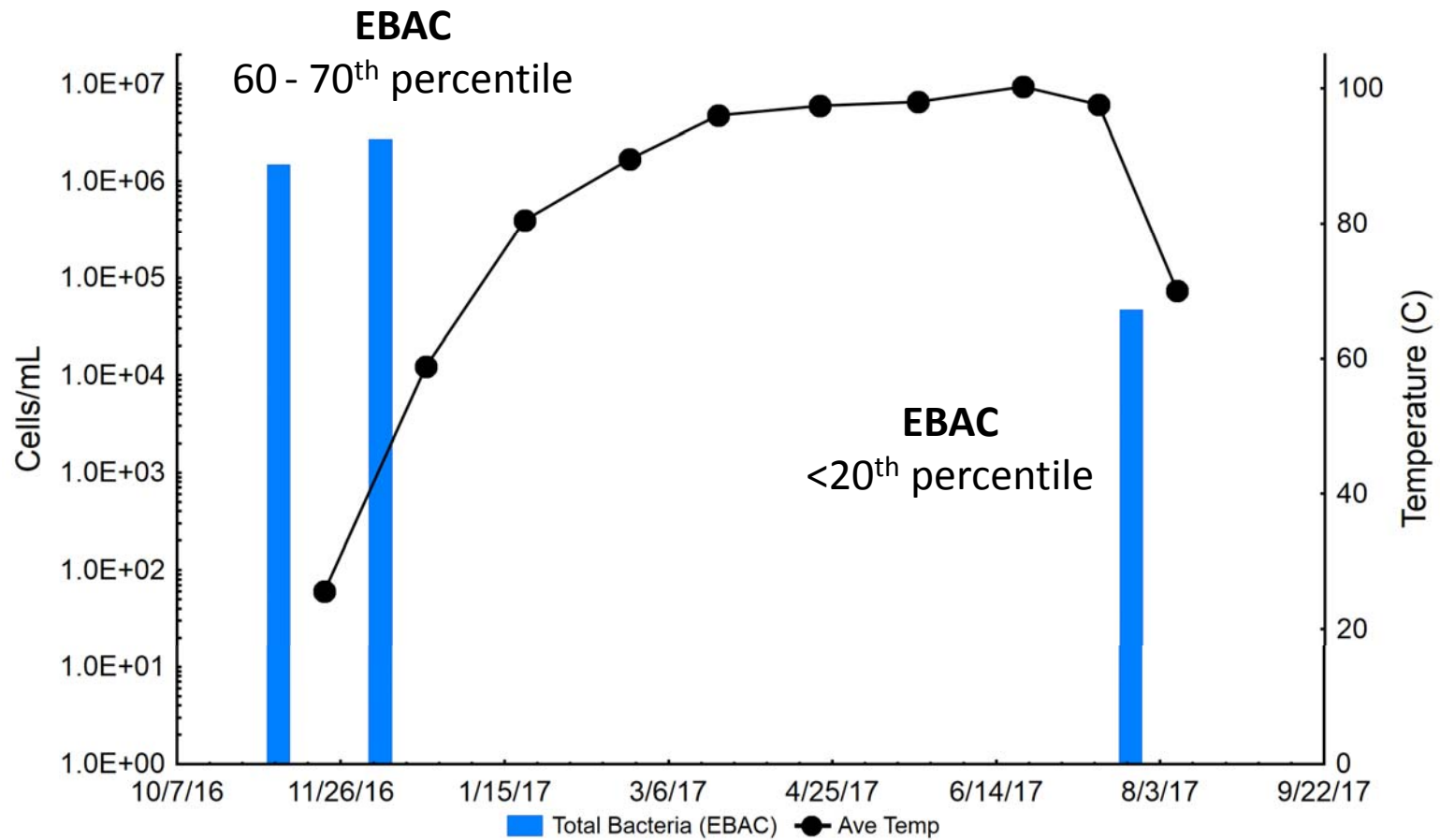
# Post ERH (Shallow)



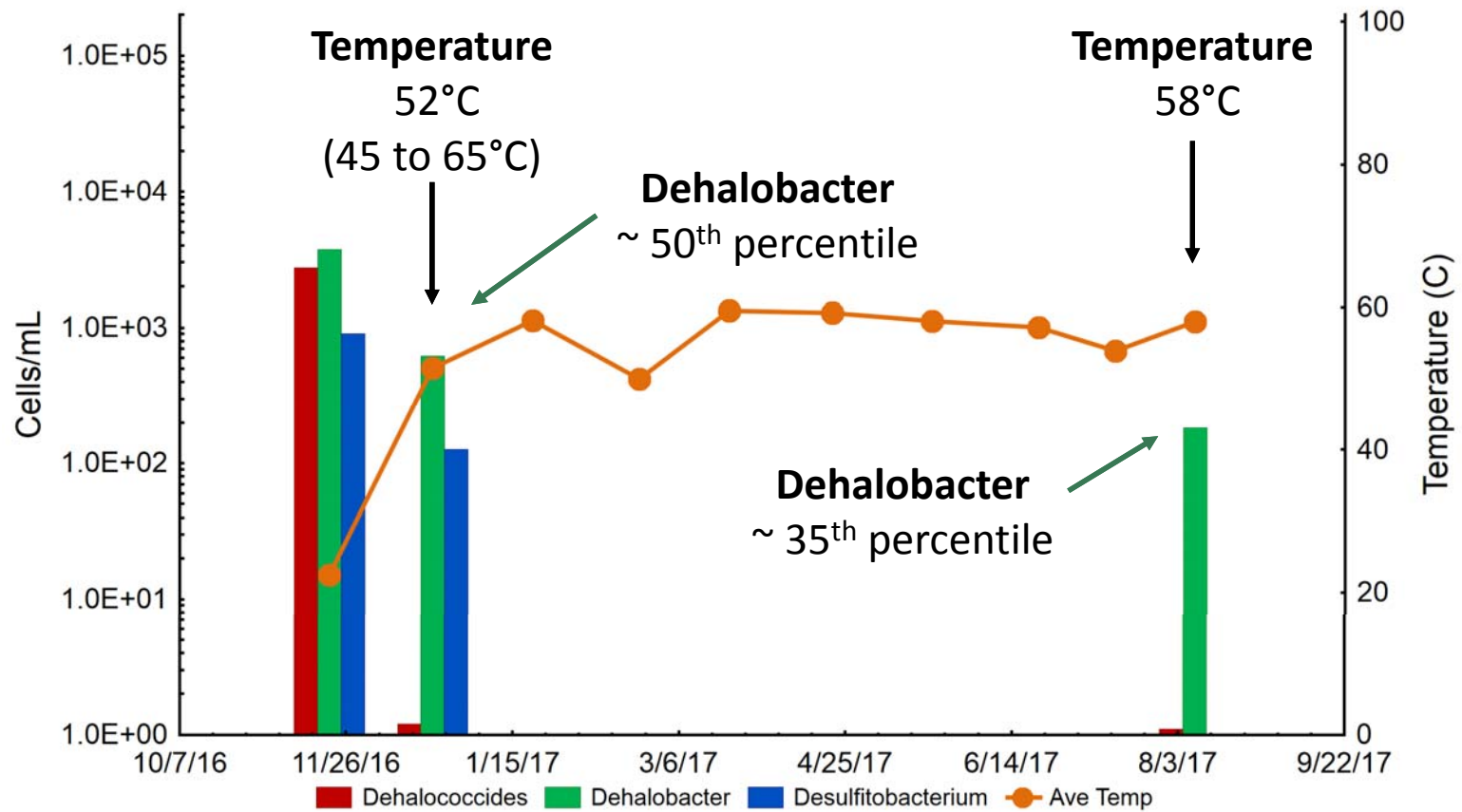
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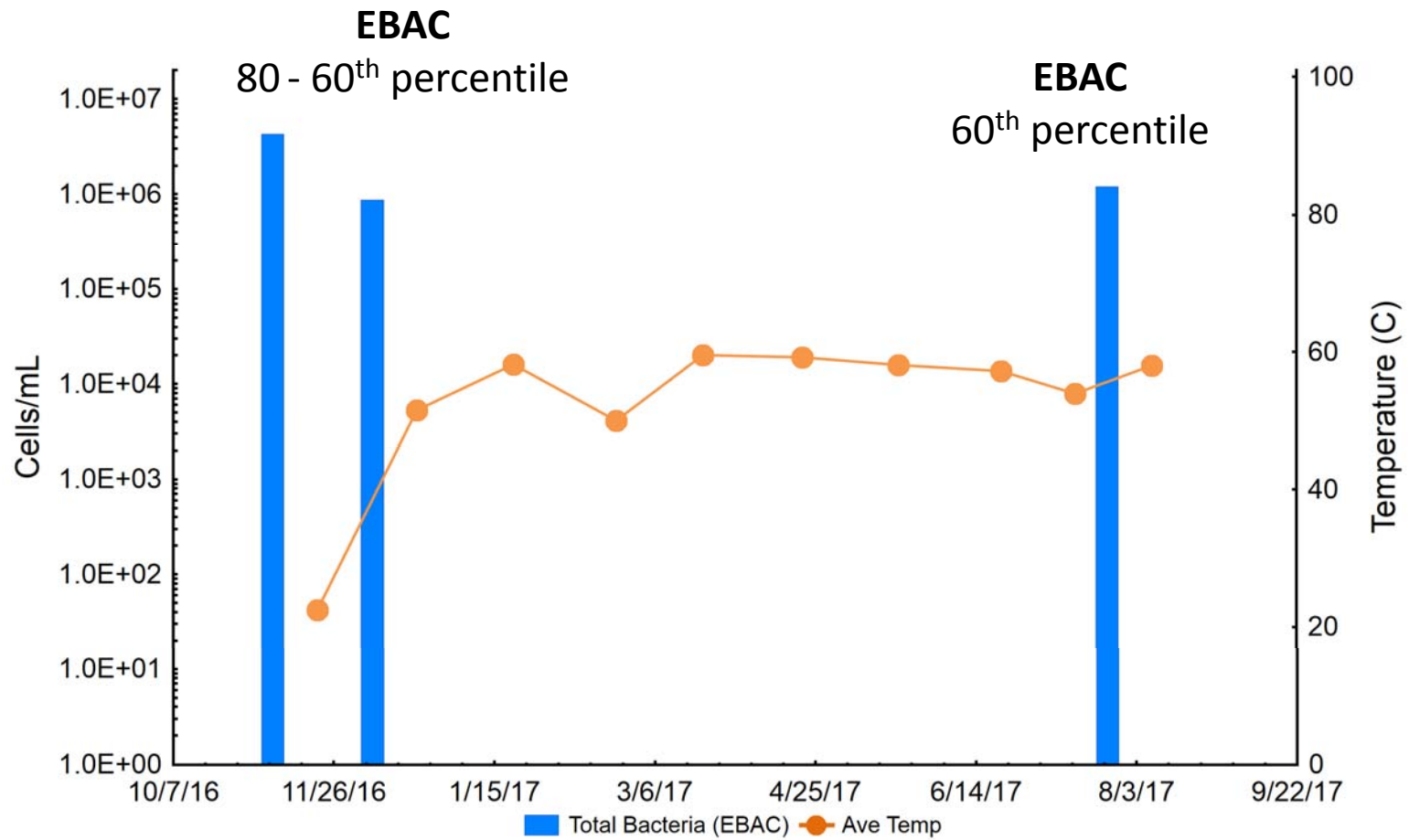
# Post ERH (Shallow)



# Intermediate



# Intermediate





# Microbiology Conclusions

ERH was operated for mass removal & destruction (~ 100° C)

No additional electron donor in ERH (source) area

- However, halorespiring bacteria survived at 40 - 50° C
- Anaerobic & aerobic BTEX degraders also survived
- Survival in lower temperature zones after 8 months of ERH

Indicate the Potential for

- Post-ERH Bio-Polishing or Biostimulation
- Enhanced biodegradation downgradient during ERH
- Low Temperature ERH with concurrent biodegradation

**More Comprehensive Sampling Plans are Needed**

# Recommendations

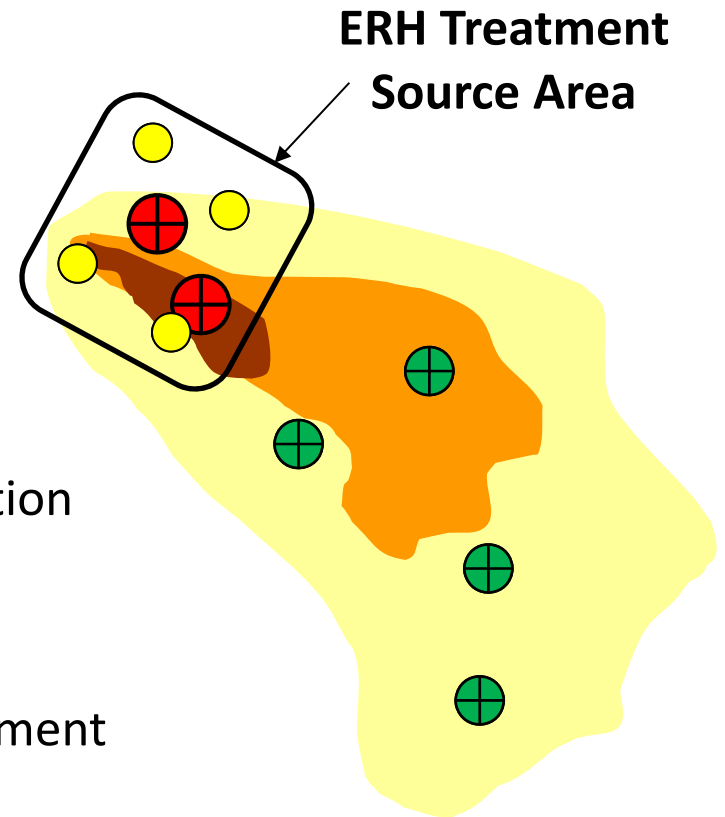
## Conventional ERH (100° C)

- ⊕ Source wells after ERH treatment
- ⊕ Assess Bio-Polishing
- ⊕ Downgradient wells throughout treatment
- ⊕ “Halo Effect” of heat enhanced biodegradation

## Low Temperature ERH (30-35° C)

- ⊕ ERH treatment zone wells throughout treatment
- ⊕ Downgradient wells throughout treatment

**Full chemical, geochemical and microbial analyses**



Questions???

