Bioaugmentation After Thermal Conductive Heating in Overburden and Bedrock

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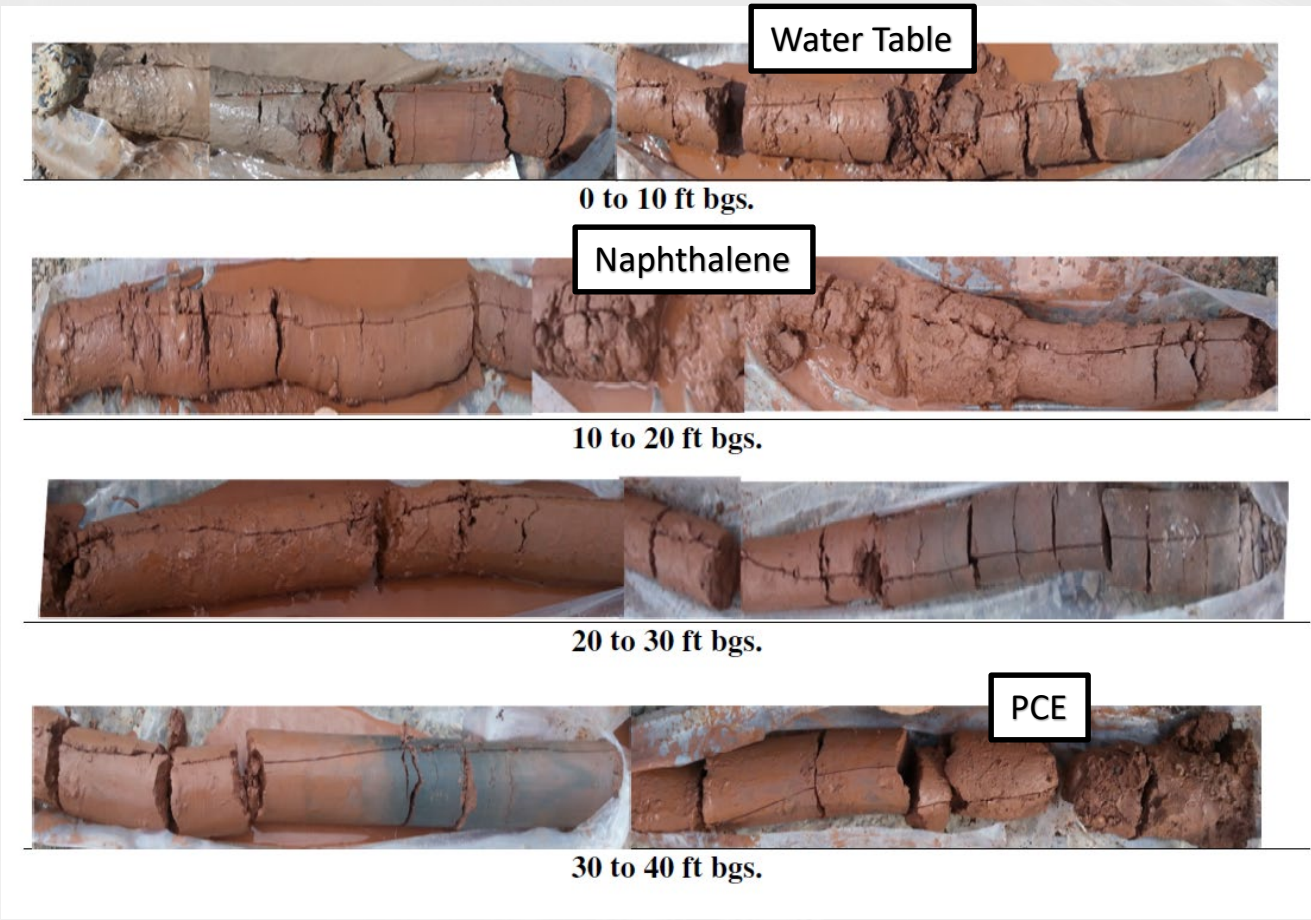
Outline

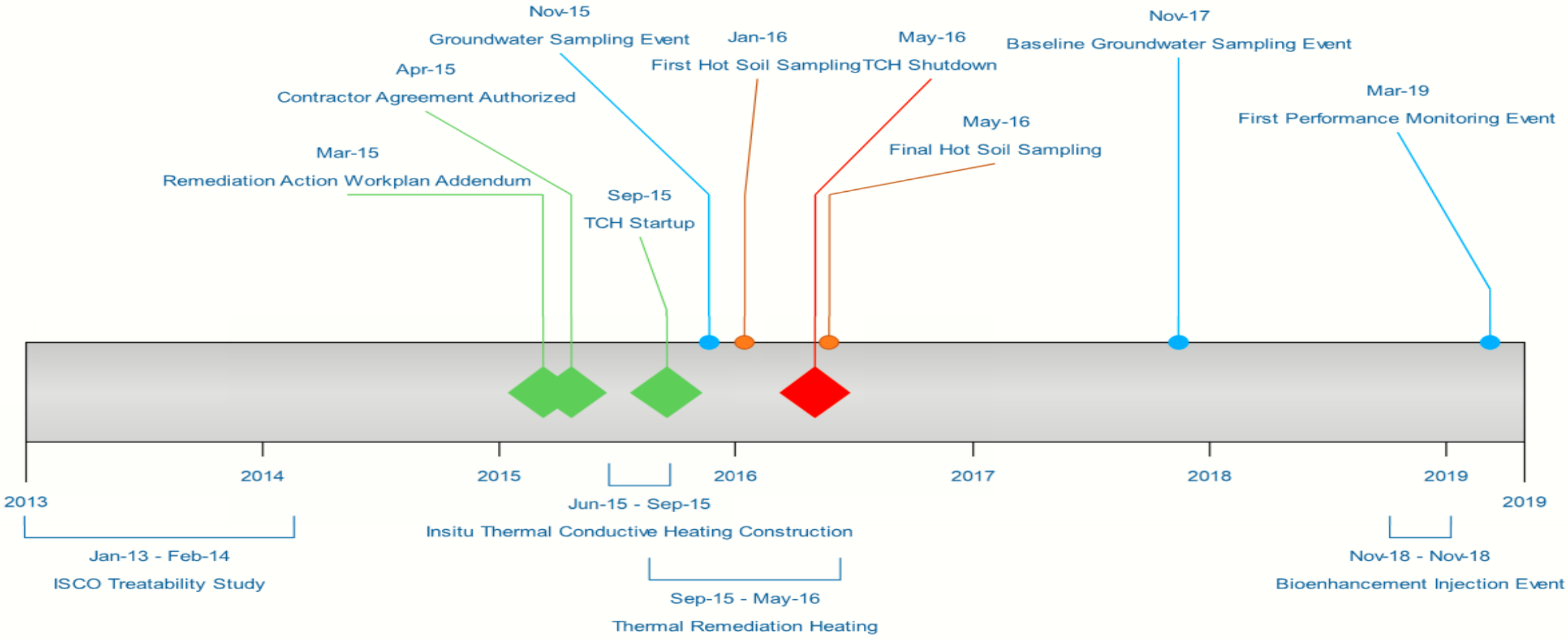
- Background
- Remediation
  - Thermal Conductive Heating
  - Bioremediation Post-Treatment
- Implications and Conclusions

Background

- CVOC and SVOC impacted overburden and bedrock in Northern New Jersey
- Historical soil concentrations:
  - PCE up to 1,600 mg/kg
  - Naphthalene up to 14,000 mg/kg
- Geology
  - Glacial till (consolidated red silt) overburden and Passaic formation bedrock



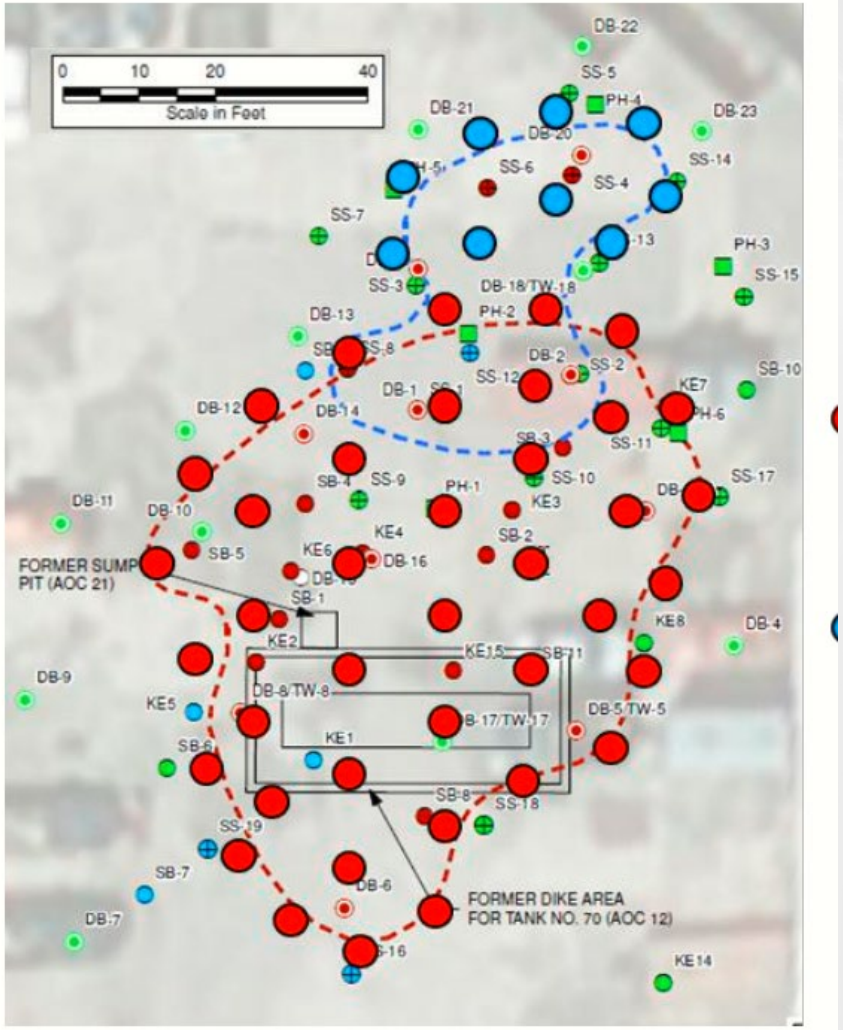
Remediation Timeline



Thermal Conductive Remediation - Installation

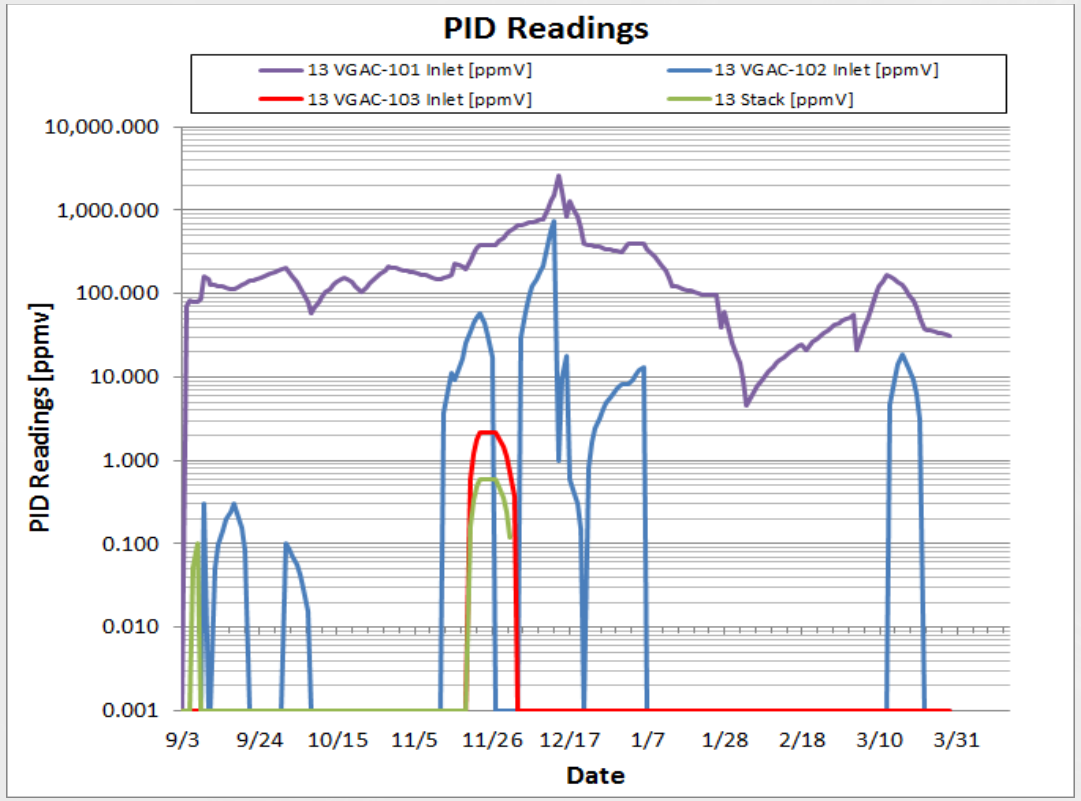
Constituents of Concern	NJDEP Non-Residential Direct Contact Soil Remediation Standards (mg/kg)	Impact to Groundwater Alternative Remediation Standards (mg/kg)
Tetrachloroethene	5	0.03
Naphthalene	17	150

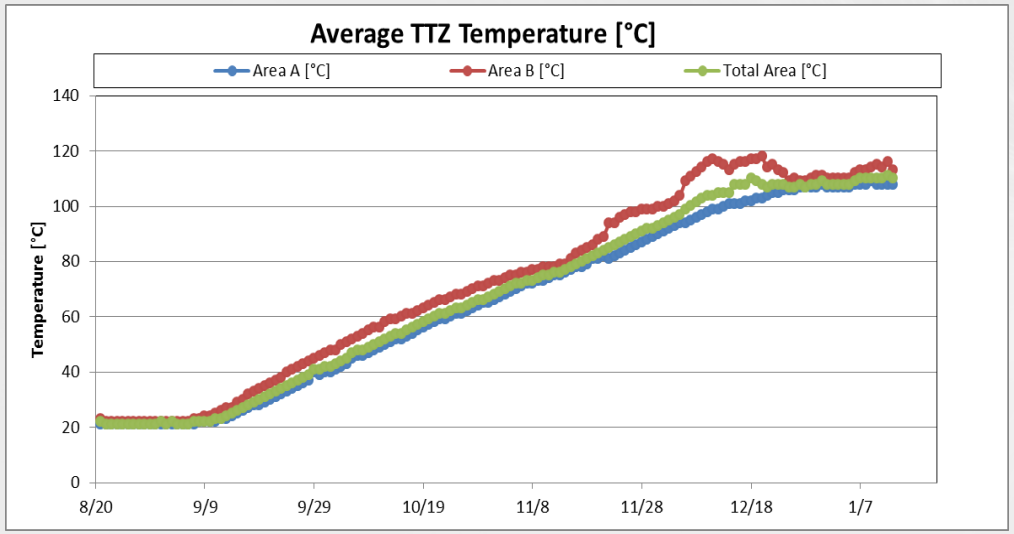
- Well Installation -
  - 40 heater/vapor-extraction wells to 45 ft bgs (PCE and comingled)
  - 9 heater wells to 35 ft bgs (naphthalene)
  - 10 temperature monitoring wells to 45 feet
  - 3 shallow pressure monitoring points

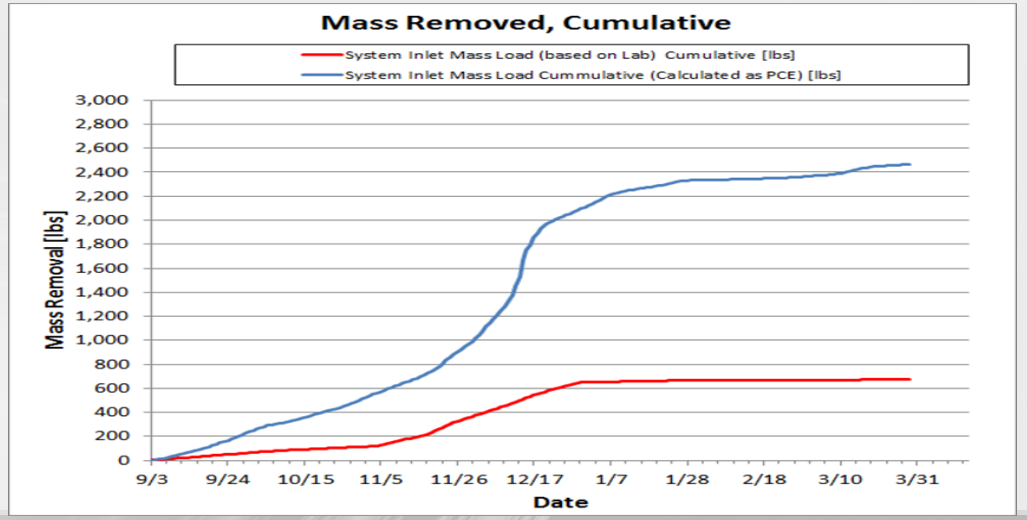


Thermal Conductive Remediation - Installation

Thermal Results





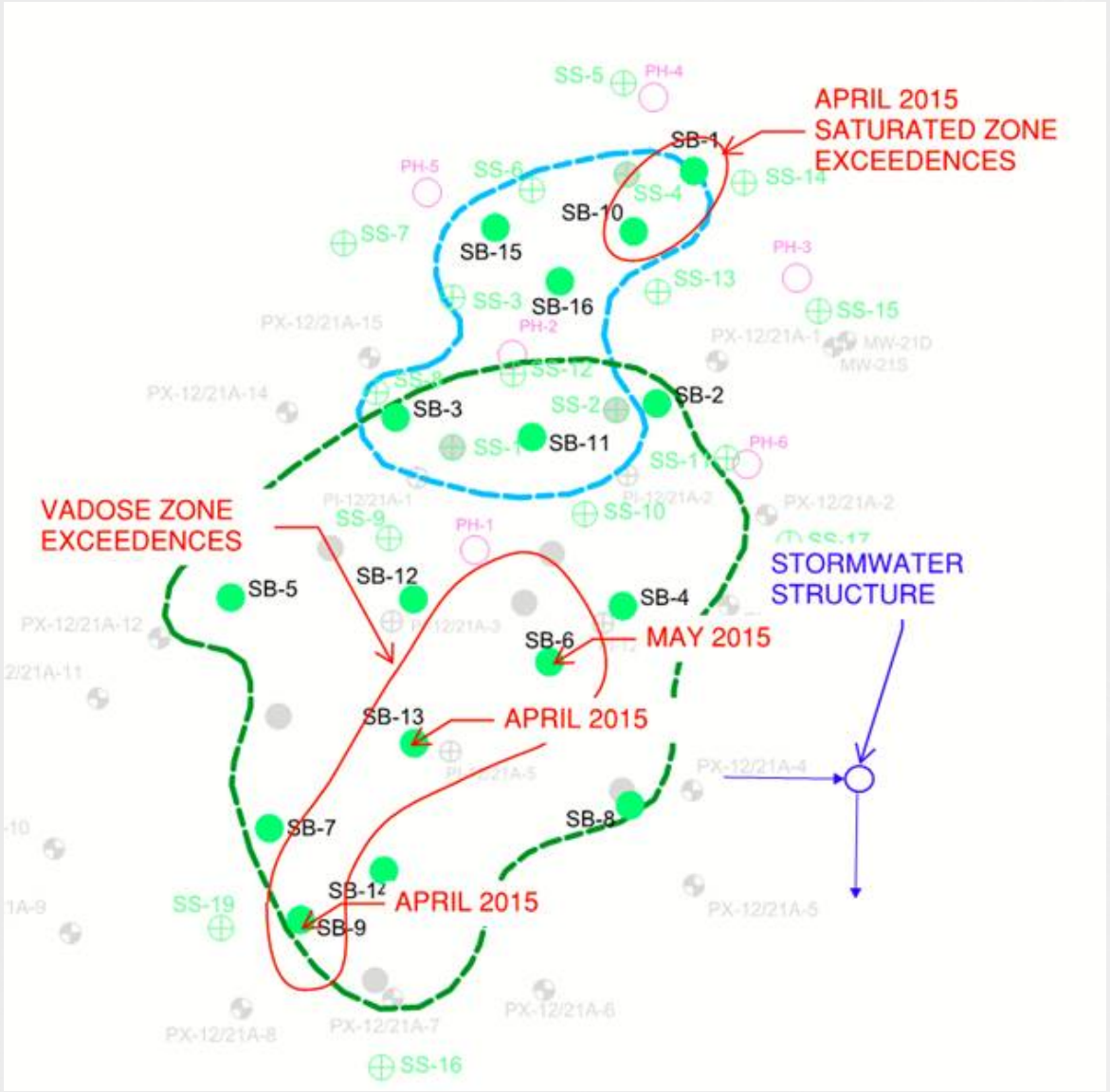


- 60% mass was removed in one month.
- Target temperatures were near the boring point of water.

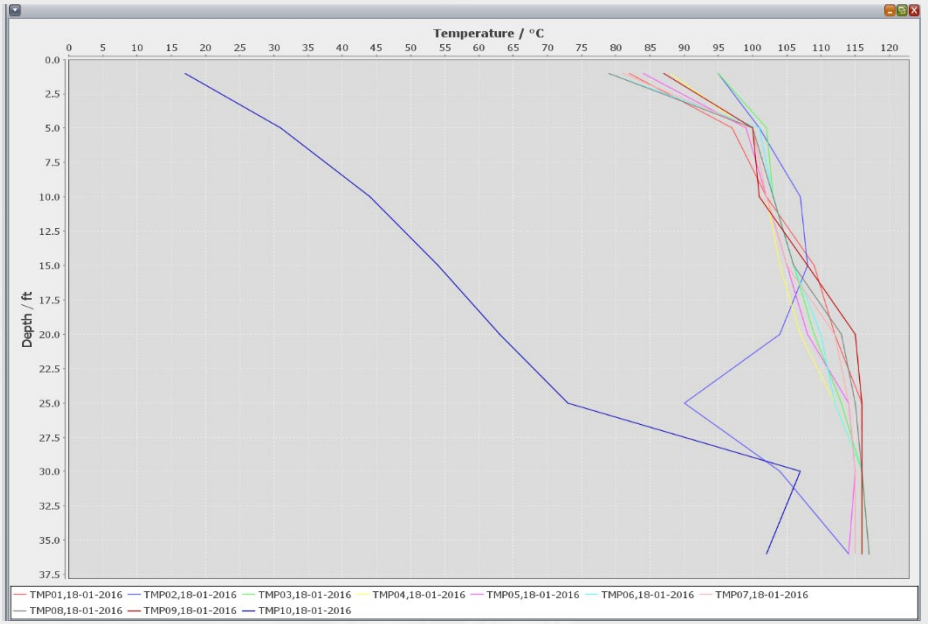
Thermal Results

- Heating desiccated soil to <10% moisture content.
- Moisture contents were correlate to contaminant levels

Thermal Results



- Achieved NJ IGW and non-residential standards
- Only limited locations exceeded residential standards
- Additional heating time was required to meet the standards.



Thermal Conductive Remediation – Lessons Learned

- Water flux significantly affected the heating and treatment efficiency.
- Contaminant can be mobilized in groundwater during heating (see groundwater result discussion).
- SVOC treatment did not require temperatures much higher than the boiling point of water.
- Naphthalene was detected at low levels in the vapor or condensate.

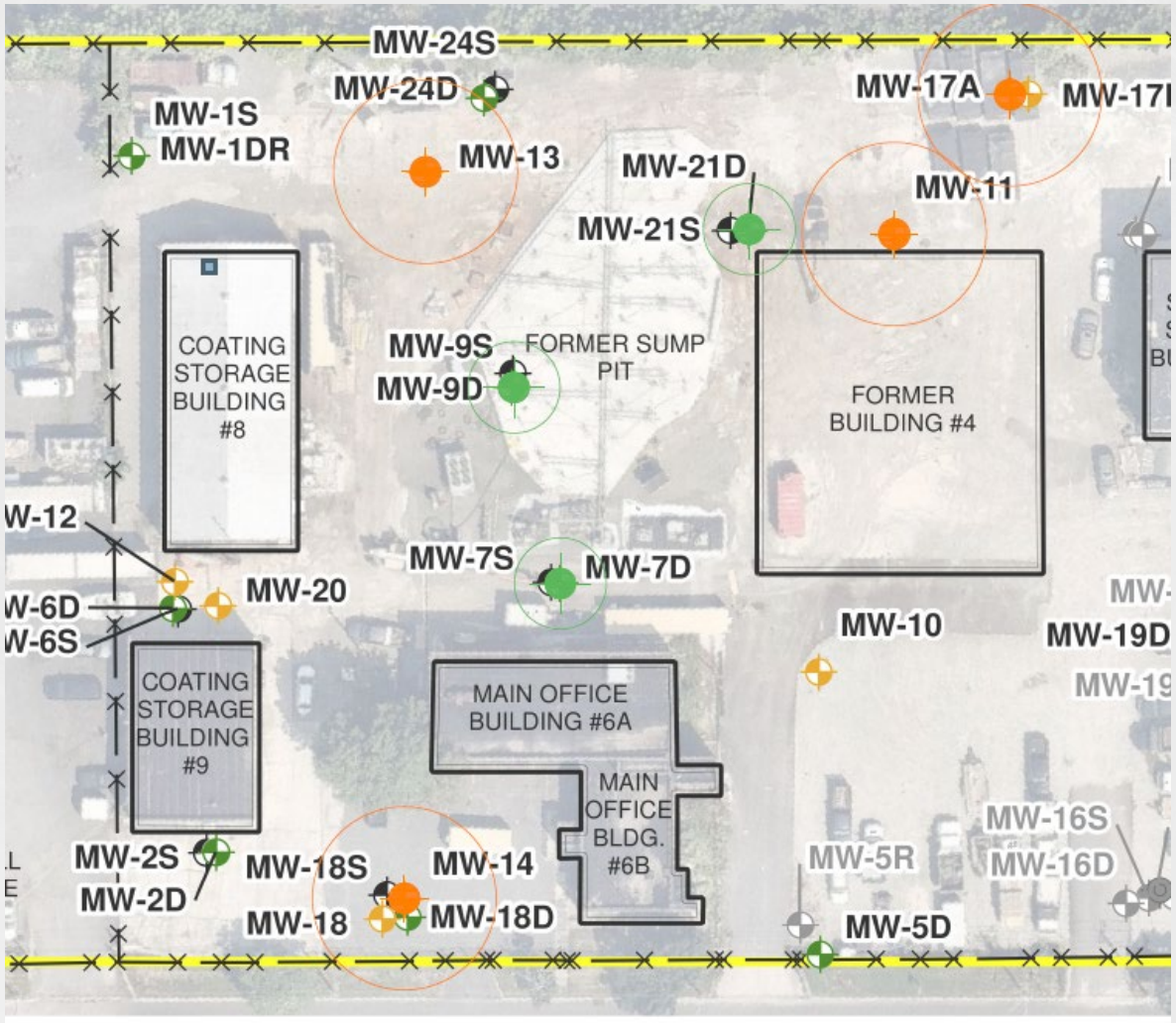
Bioremediation Implementation

- Bioremediation for Groundwater
- 2.5 years after thermal remediation

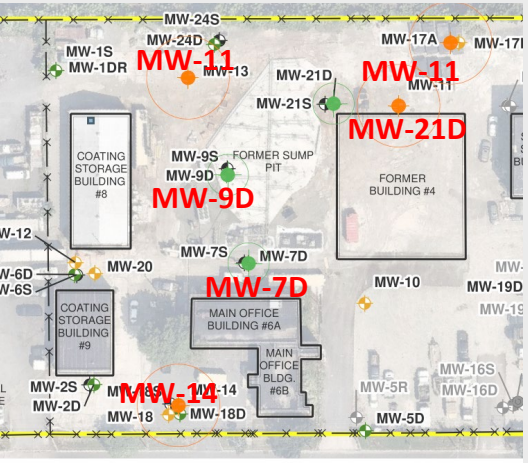
Bioremediation Implementation

- 7 – locations (3 Overburden + 4 Bedrock)
- Reagent -

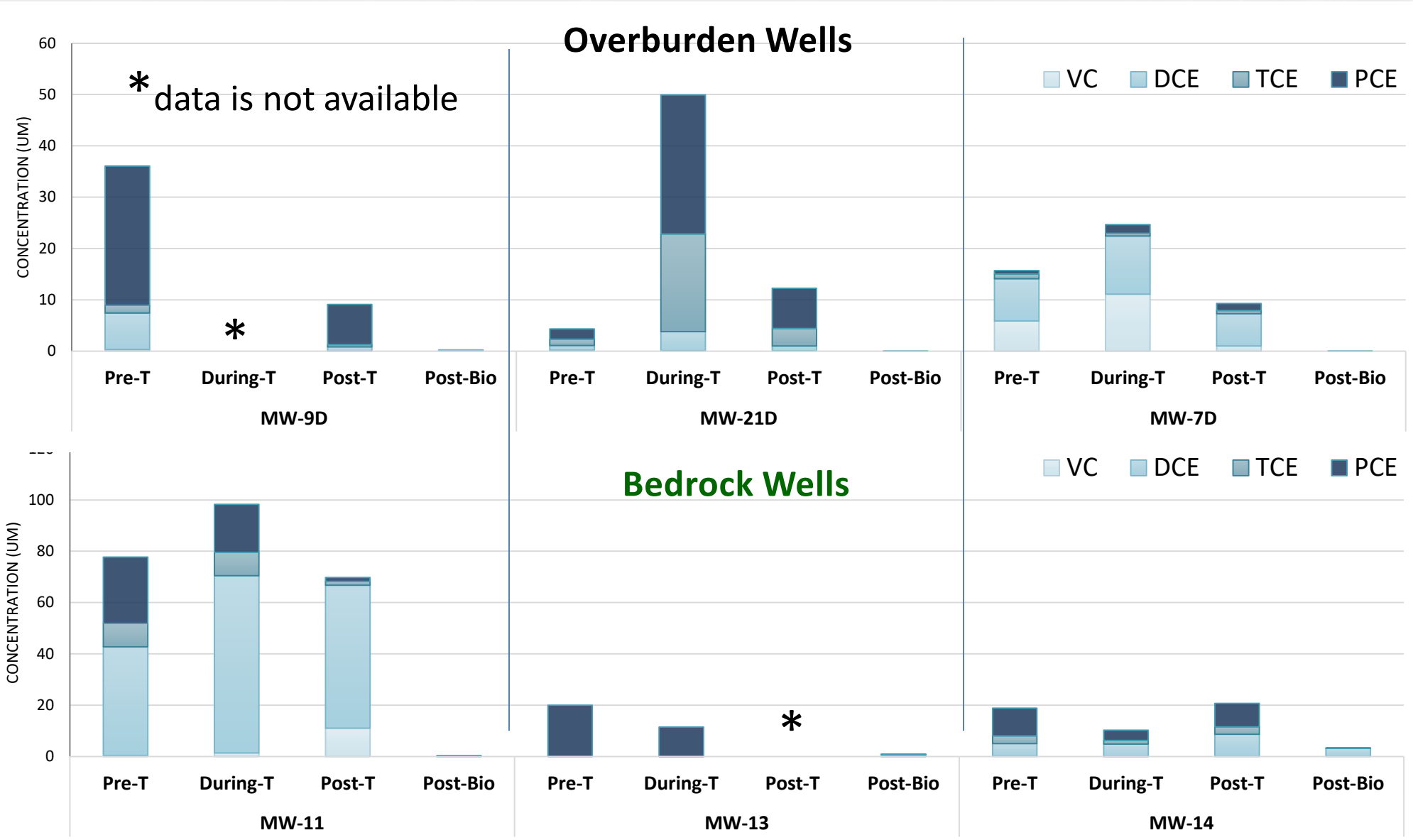
- Bedrock - SRS-FRL™ +DS™ (EVO from Terra Systems, Inc.) at 15,000 lbs
- Overburden – ELS™ (Peroxychem) at 7,800lbs
- Ammonium phosphate at 300 lbs
- Yeast extract at 300 lbs
- Sodium bicarbonate at 800 lbs
- SDC-9 at 138 L



Bioremediation Results - VOC

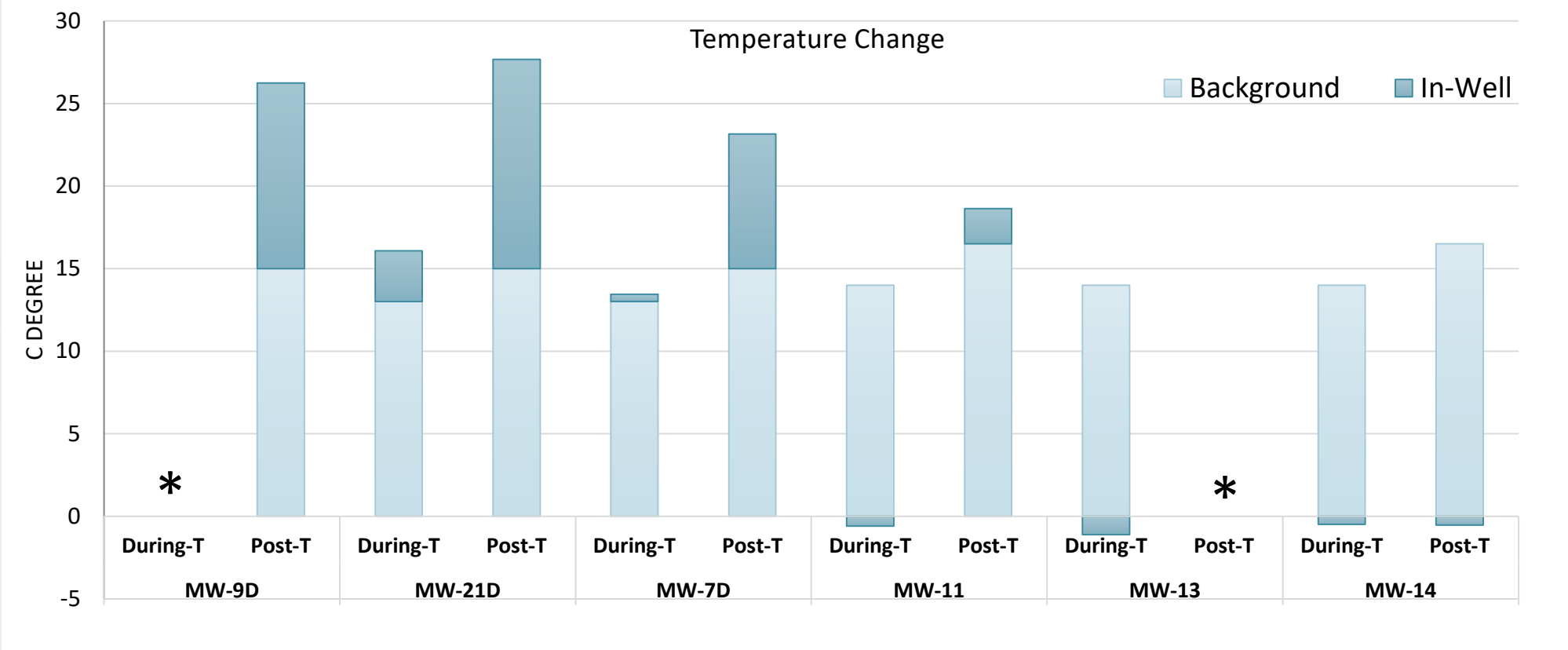


Pre-T	Apr-11
During-T	Nov-15 (2 months from heating start)
Post-T	Sep-17 (18 months after heat)
Post-Bio	Mar-19



Bioremediation Results – Geochemical Conditions

- 18 months after the heating ceased, the temperature is 10 to 15 °C higher than background in overburden
- No difference between bedrock wells and background

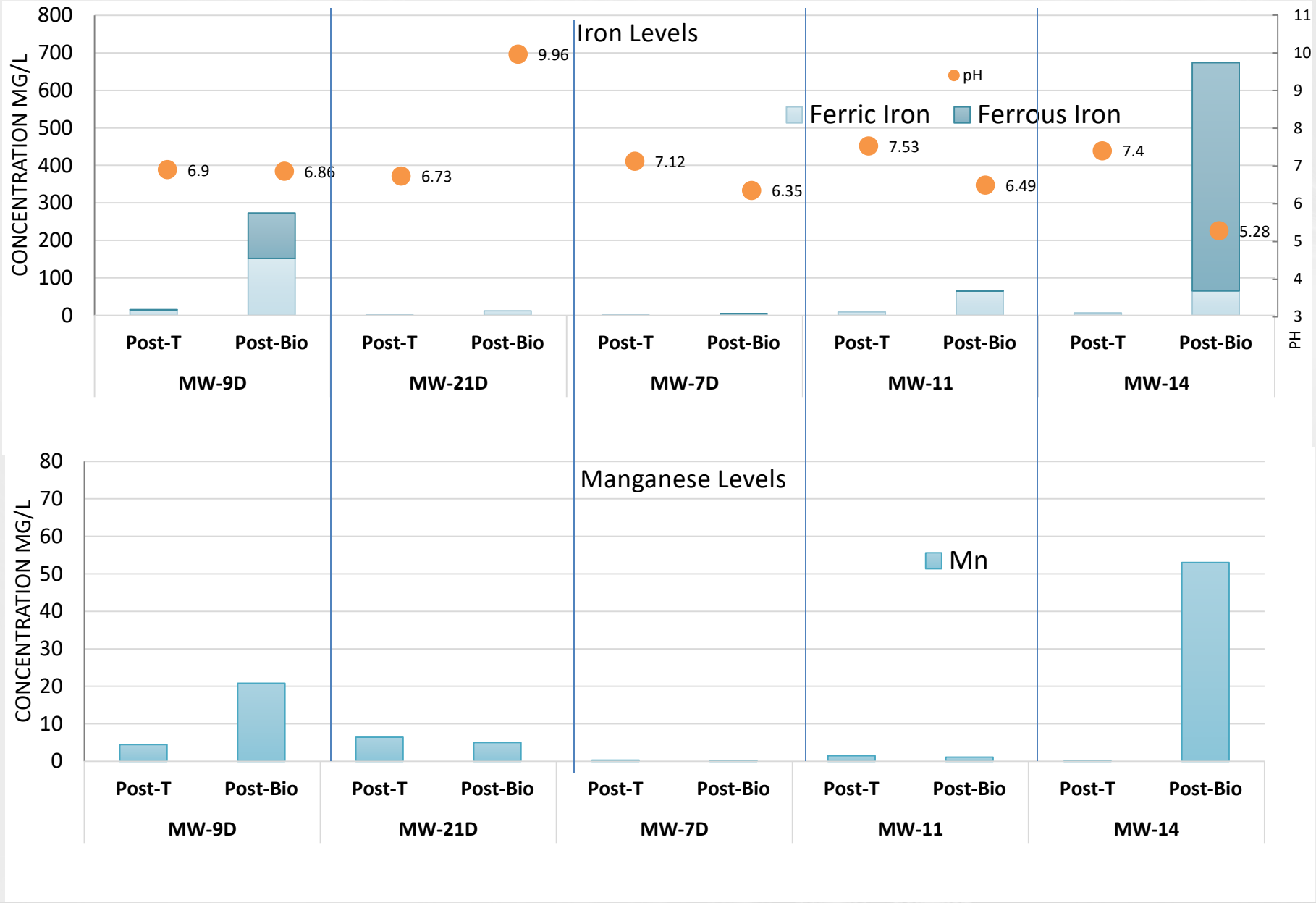


*data is not available

Metals and pH

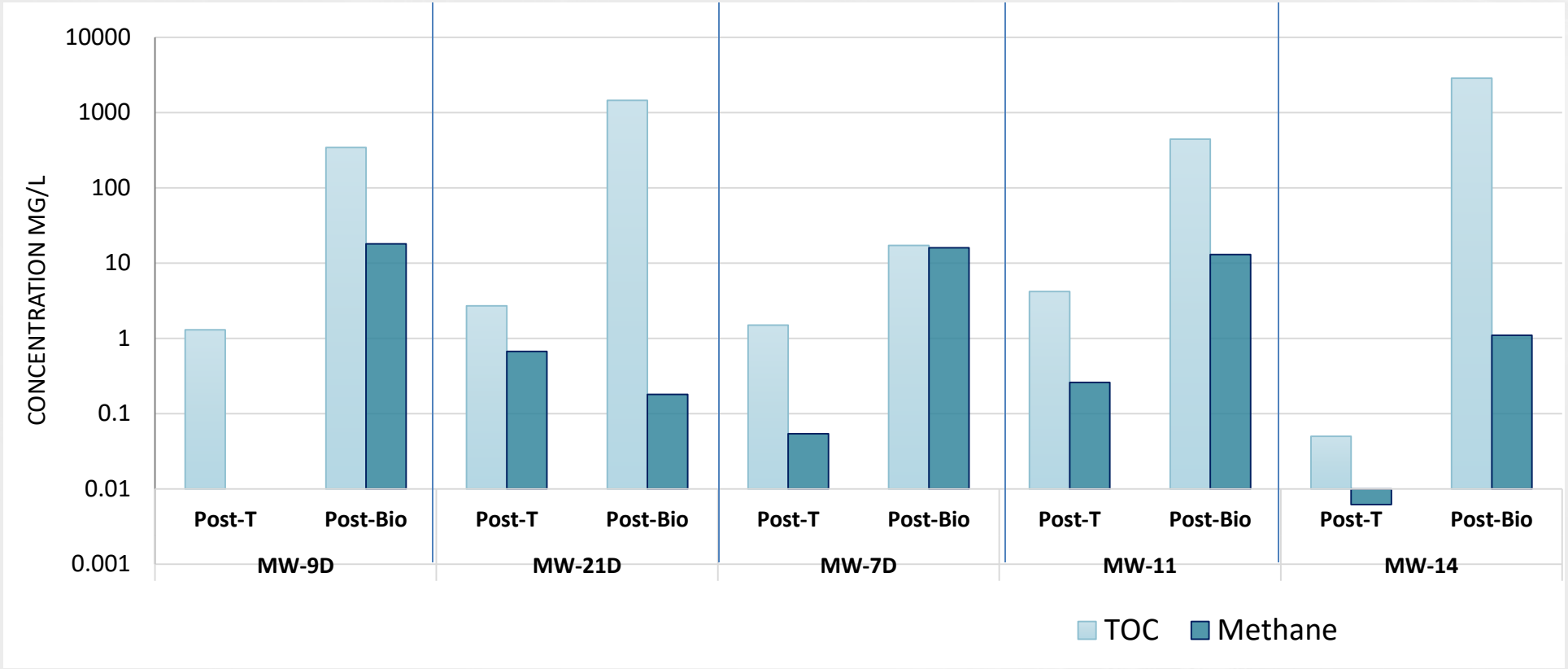
- Rapid and extensive metal mobilization within thermal treatment area and downgradient (vertically and horizontally).
- pH correlated to metal mobilization
- Optimal pH maintained at thermal treatment area (MW-9D).

Can ZVI from well casing contributed to the metal mobilization?



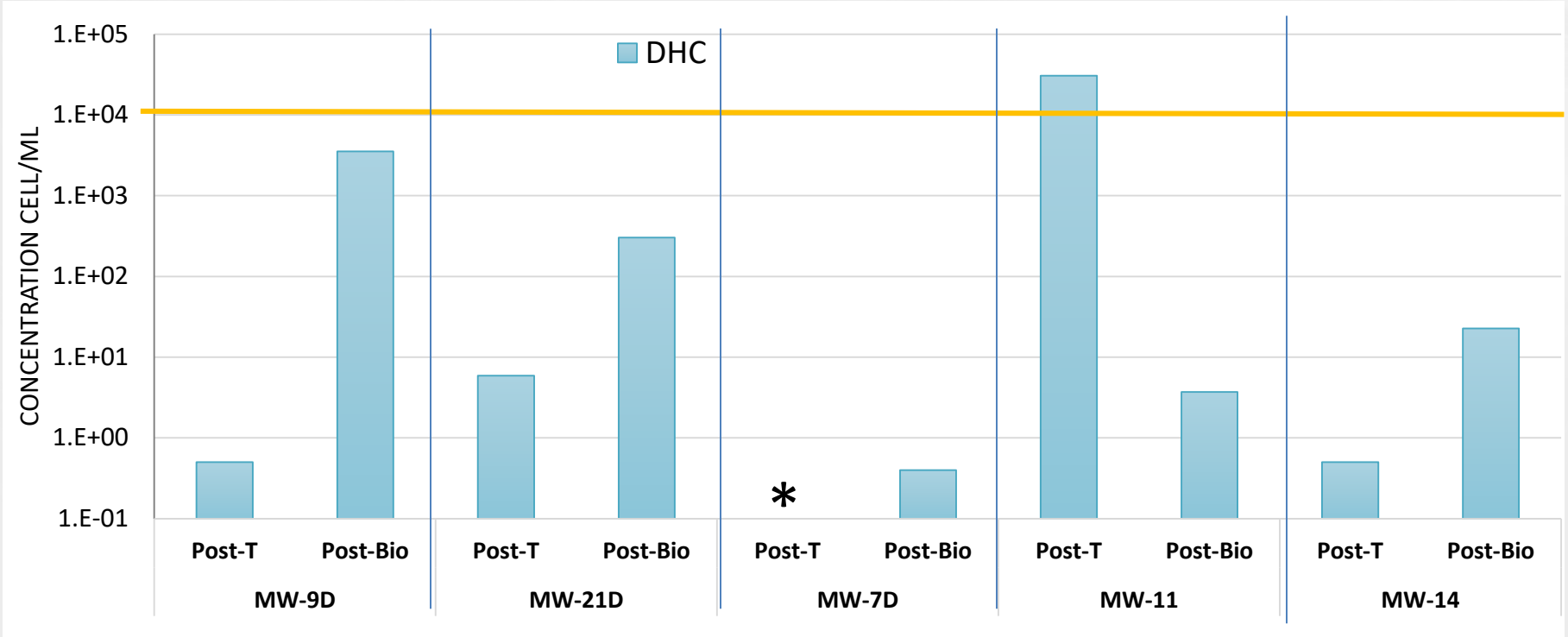
Bioremediation Results – Geochemical Conditions

- Relatively rapid methane production.
- Methane levels were elevated at the areas near thermal treatment area



Bioremediation Results – Geochemical Conditions

- Bioremediation injection enhanced DHC growth in overburden
- Bioremediation injection could decrease DHC levels in the bedrock wells near thermal treatment area.



Lesson Learned

- Aquifer temperature could be elevated for years after the termination of thermal heating.
- Iron reduction from thermal well casing contributed to decline in CVOC concentrations.
- Thermal treatment seemed to eliminate the electron acceptor competition.
  - Potential via iron reduction?
  - Soil characteristics/chemistry changes?
- Bioremediation after thermal treatment is a effective technology with a significant cost savings
  - 5% of the total thermal cost
  - Effective as a polishing step after thermal treatment removed bulk mass in source