Downgradient Thermal Front Migration and Enhancement of Plume Area In-Situ Bioremediation after Thermal Source Area Remedy

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Outline

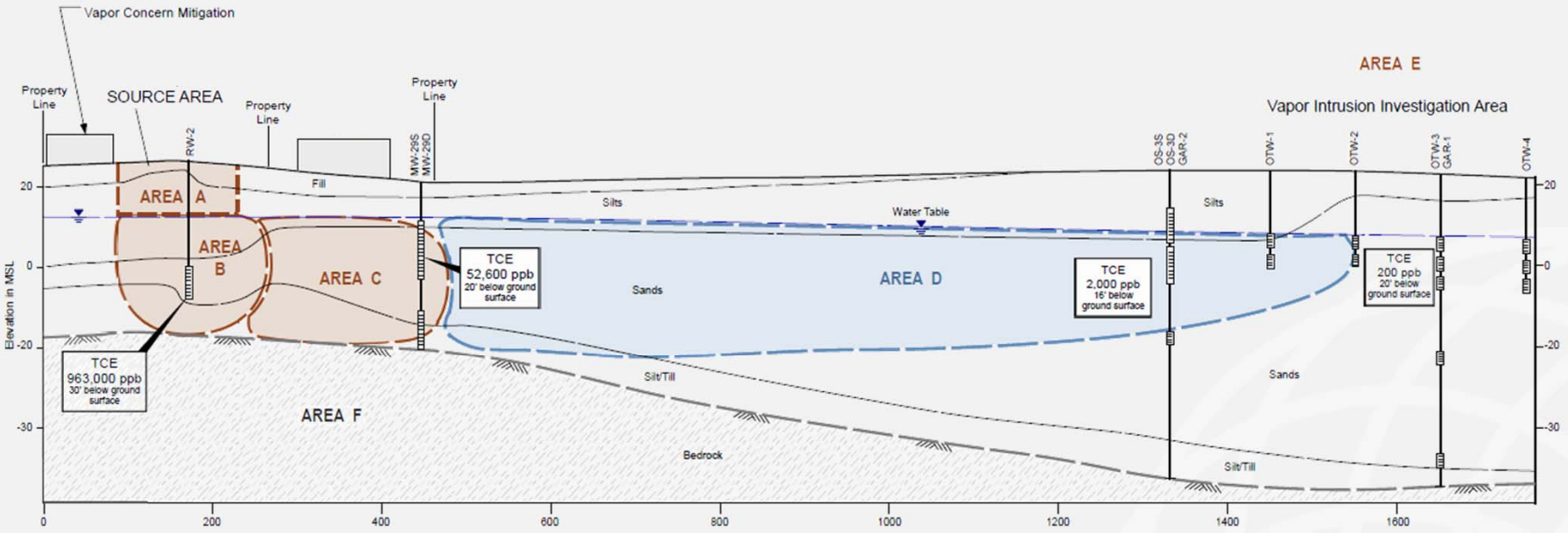
- Site background and conceptual site model
- Selected remedies and objectives
- Groundwater flow and transport model description
- Current evaluation of source area thermal remedy and downgradient temperature monitoring
- Modeling changes under consideration
- Summary

Site Background

- Site located in commercial / residential area
- Complicated site-use history
  - Manufacture of household appliance controls
  - Manufacture of home decorating products
  - Metal grinding and polishing
  - Warehousing and distribution of various products
- Geologic setting
  - Fill
  - Upper glacial till
  - Glacial and glacio-lacustrine deposits
  - Lower glacial till
  - Bedrock is siltstone/mudstone
- Primary COC is cVOCs



Conceptual Site Model

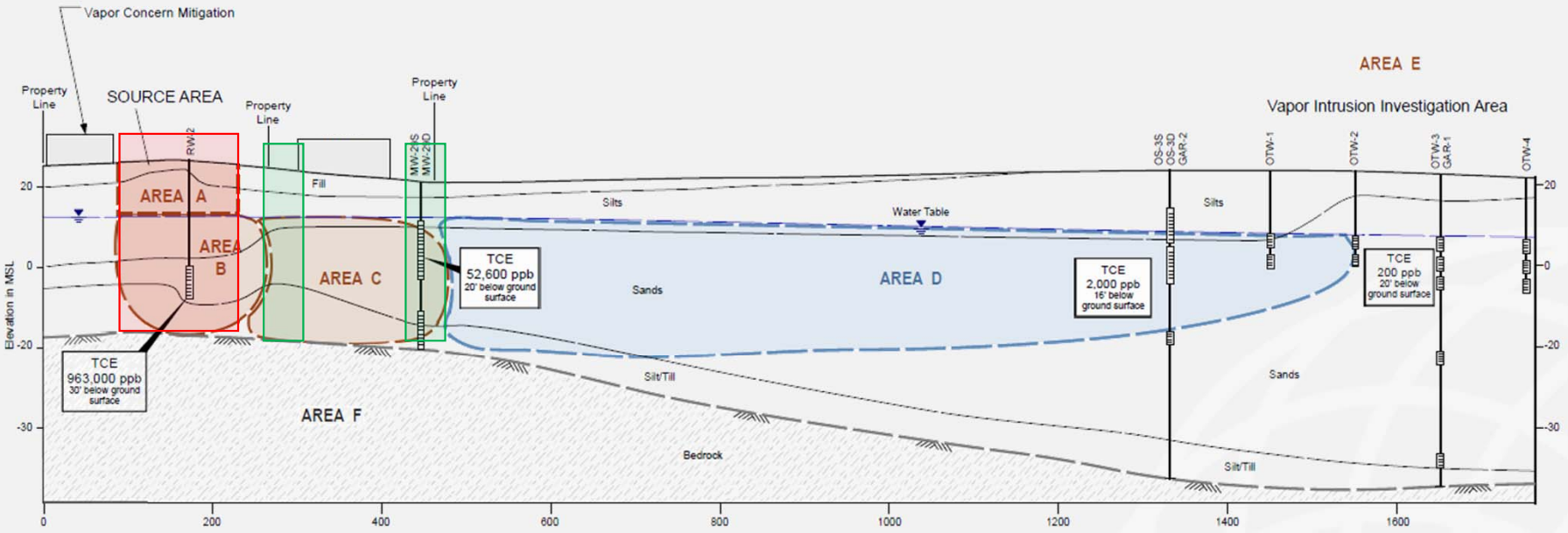


AREA	REMEDIAL AREA
A	Onsite Soil Remediation Area
B	Onsite Groundwater Source Remediation Area
C	Offsite Concentrated Groundwater Remediation Area
D	Downgradient Dissolved Groundwater Impact Area
E	Residential Vapor Intrusion Investigation Area
F	Bedrock Aquifer System

NOTE:

Groundwater Quality Standard for TCE - 1 ppb
Vapor Intrusion Groundwater Screening Level for TCE - 2 ppb

Treatment Technology Selection



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Thermal Treatment Area

Provect-IR Barriers

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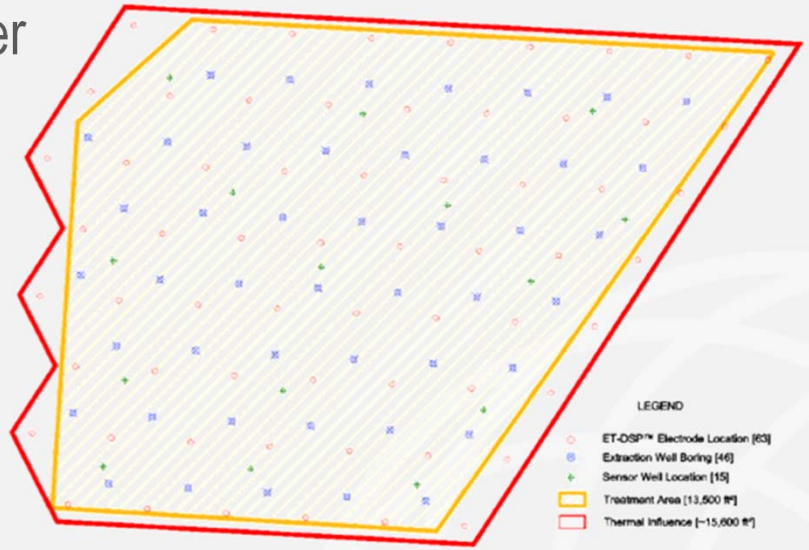
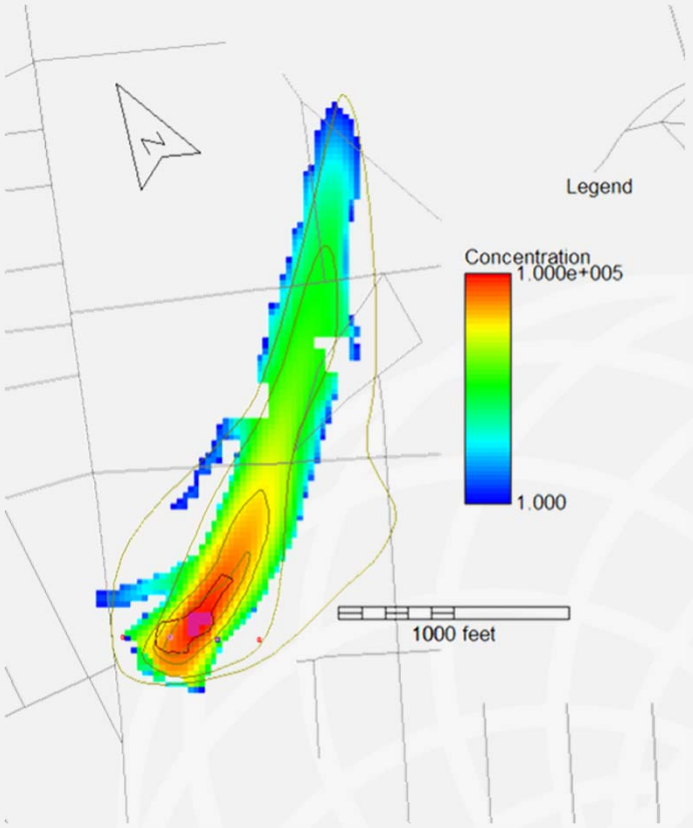
Selected Remedies and Objectives

- Source Soils and On-site Groundwater
  - Thermal treatment –
    - ET-DSP™ (McMillan-McGee)
- Off-site Groundwater Area
  - Provect IR barriers
    - 60% ZVI
    - 40% fermentable substrate
    - Long-lifetime source for bioremediation
    - Abiotic degradation in event of temperature excursions
- Downgradient Dissolved Plume
  - Manage with Classification Exception Area (CEA)
  - Evaluate long-term attenuation of the dissolved plume



A Calibrated Site Flow and Transport Served as the Basis for Subsequent Thermal Modeling

- Groundwater model developed to support and streamline investigation activities
- Calibrated to groundwater heads
- Subsequently calibrated to contaminant transport
- Subtleties in modeled versus observed suggested offsite, non-related source areas



Adapted MODFLOW and MT3DMS Models to Simulate Heat-Flow at the Site

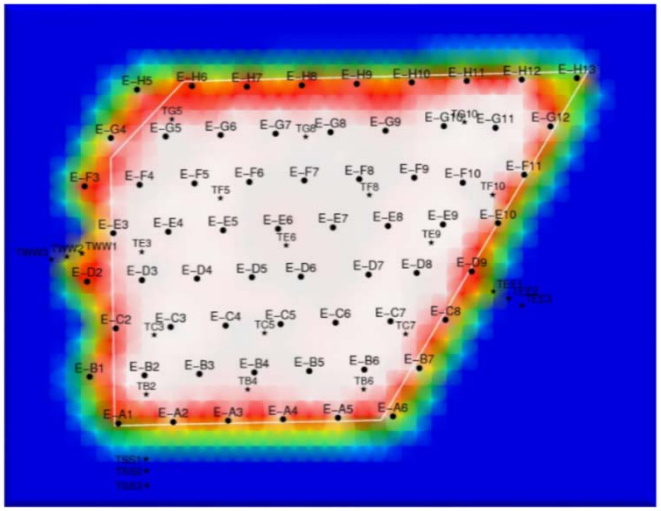
- Used heat-flow equation's analogous structure to simulate transport using MT3DMS
- Previous studies used methodology to model ground-source heat pumps, geothermal resource modeling, and heat-flow in/across complicated geologic structures
  - Hecht-Méndez et al. 2010, in Groundwater V48 N5.
  - Baier et al. 2013, in International Journal of Engineering Research & Technology
  - Plummer et al 2016, in Proceedings, 41st Workshop on Geothermal Reservoir Engineering

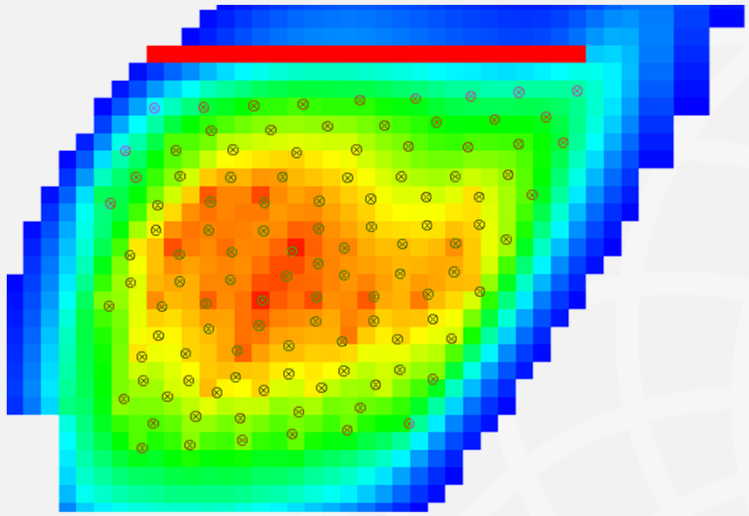
Similarities in Heat-Flow and Contaminant Transport Equations

- Contaminant Transport
  - $\left(1+\frac{\rho_b K_d}{n}\right)\frac{\delta C^k}{\delta t} = div\,[(D_m + \alpha v_a)\,gradC^k] - div(v_a C^k) + \frac{q_{ss}C_{ss}}{n}$
- Heat-flow
  - $\left(\frac{p_m c_m}{np_w c_w}\right)\delta T/\delta t = div\left[\left(\frac{\lambda_m}{npwcw} + \alpha v_a\right)\,gradT\right] - div(v_a T) + \frac{q_h}{np_w c_w}$
  - In MT3DMS, the first term in the heat-flow equation is R the retardation factor and K_d is the ratio of the specific heat capacity of the solids to the volumetric heat capacity of the water

Site Thermal Modeling Parameters

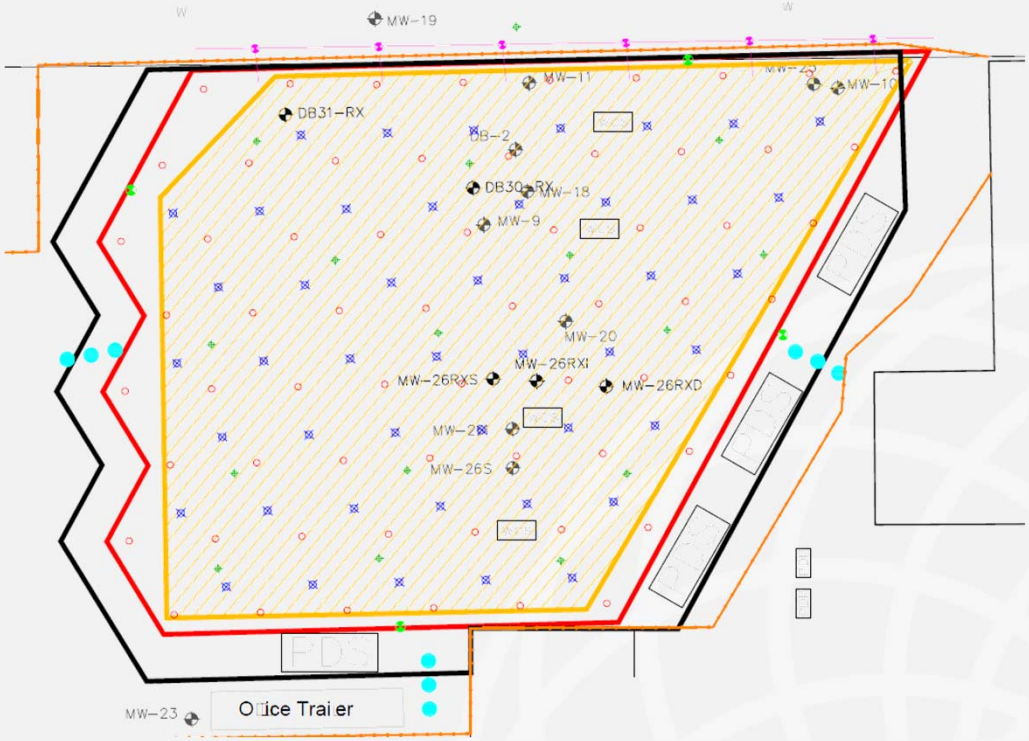
- Parameters match those from ISTR pre-design
- Averaged values used in less vertically discretized MT3DMS model
- Values adjusted during modeling



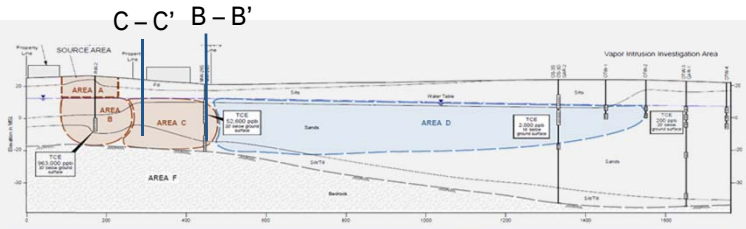


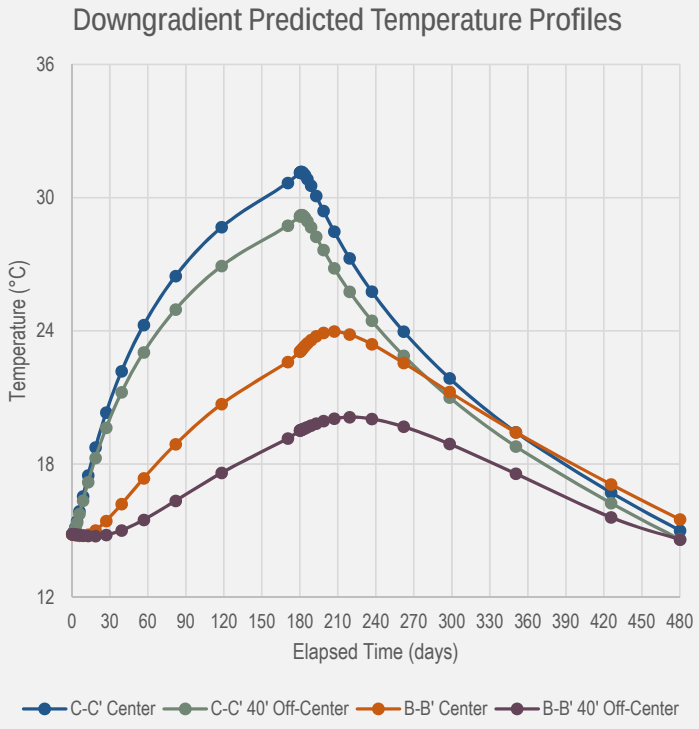
Current Status of ISTR

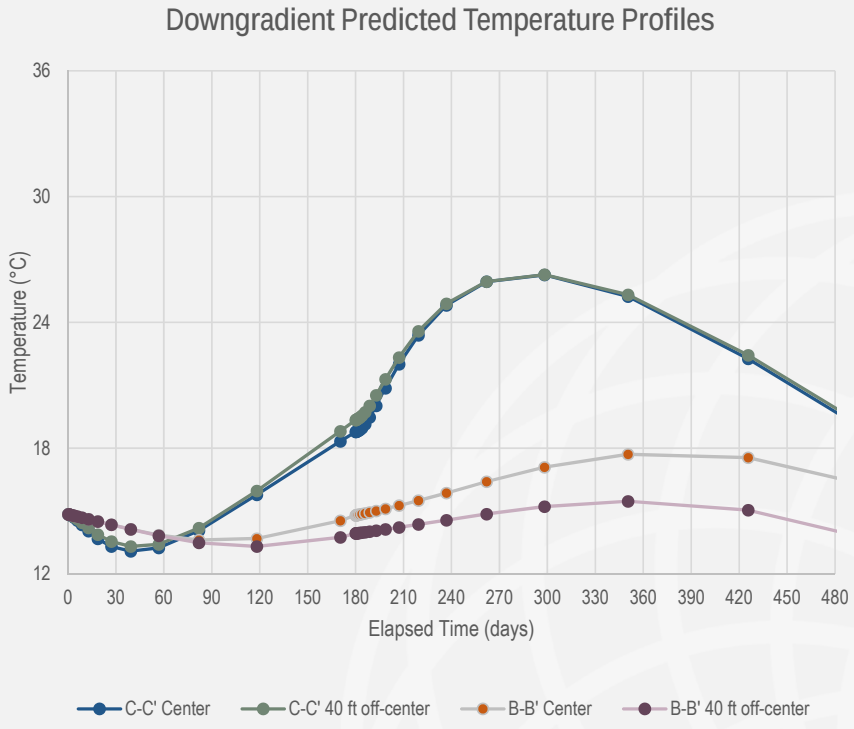
- ISTR construction – Autumn 2017
- Quench line added to protect utilities
- Heating begins – December 2017
- Temps within target range 100° to 110°C in source



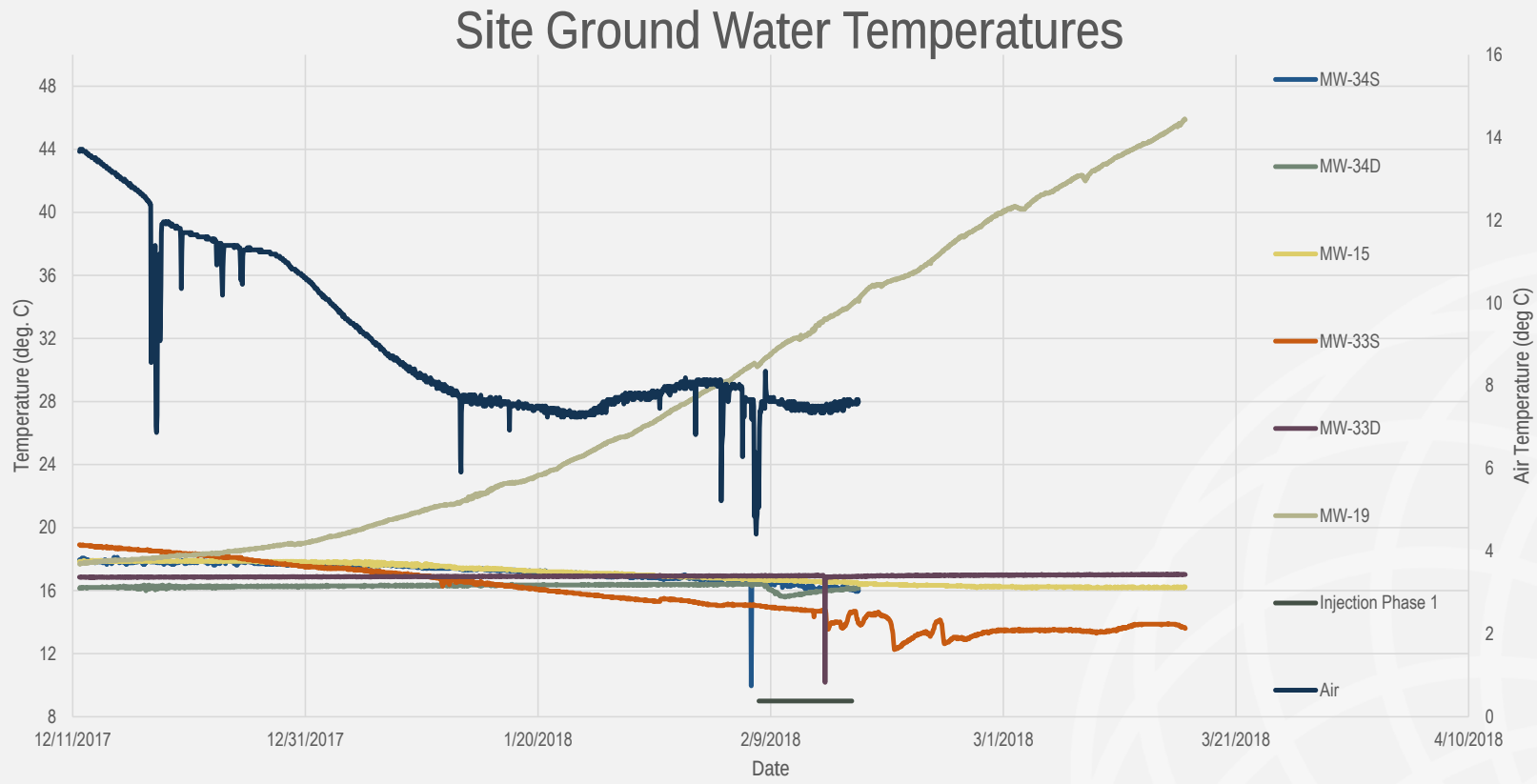
Quench Line Reduces Downgradient Temperatures







Current Data Suggests we are not Seeing Thermal Effects Downgradient . . . Yet



Next Steps

- Continue monitoring groundwater temperatures
- Complete installation of Provect-IR barriers downgradient
- Monitor downgradient groundwater chemistry changes and observe effects of barrier installation on groundwater and cVOC concentrations
- Re-evaluate for presence of thermally enhanced bioremediation