

Assessing the Performance of Thermal Conductive Heating for Remediation of Chlorinated VOCs in Saturated and Unsaturated Settings

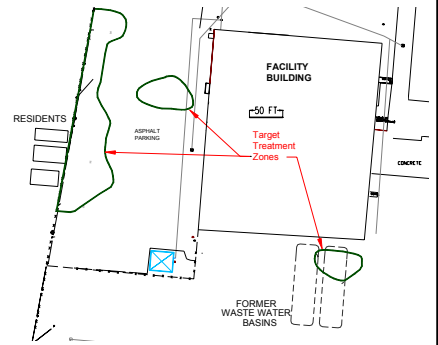
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TerraTherm, Inc.,
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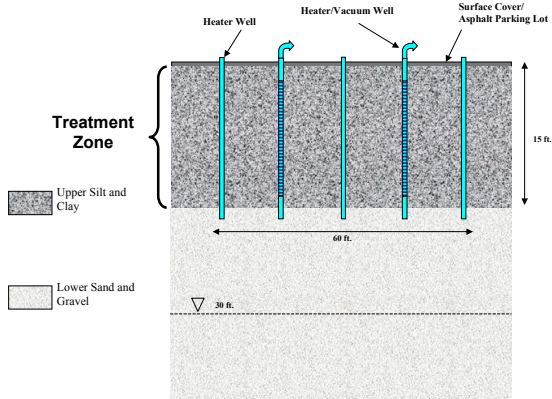
Uwe Hiester, reconsite TTI GmbH, D



- Active mfg. Facility
- Dense, saturated clays
- 10,950 cy PCE- & TCE-contaminated soil
- TCE max = 4,500 mg/kg
- 0 to 15 ft BGS
- Treatment goal 1 mg/kg TCE



Cross-Section Through Treatment Zones – Parking Lot Areas



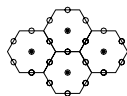
Dense Clayey Till – ~1 to 12 ft BGS



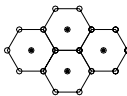
Numerical Simulation of ISTD

- Simulations used to evaluate:
 - Effectiveness of layout and pattern,
 - Potential for contaminant redistribution
 - Time required for treatment,
 - Need/benefit of surface insulation,
 - Power application rate vs operational time and effectiveness, and
 - Off-gas treatment requirements.

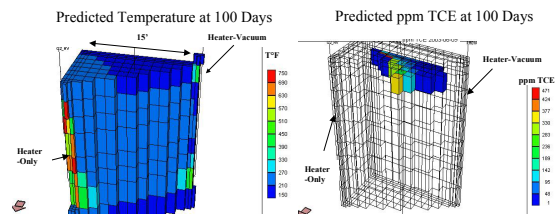
Side Centered



Apex Centered



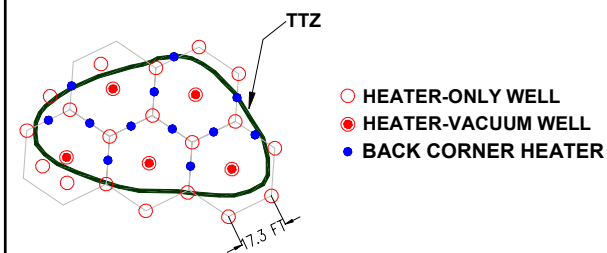
The Problem - Getting The Shallow Layers Hot at Midwest Site



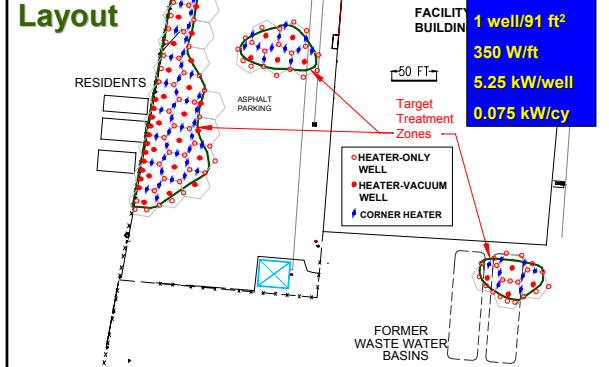
- Numerical Simulations Predict that TCE Condenses and Concentrates in Shallow, Cooler Layer
- Decided to install additional heaters at "back corners"

(M.K. Tech Solutions)

Detail Showing ISTD Heater Well Pattern in Parking Lot Area 2 TTZ



Final Well Layout

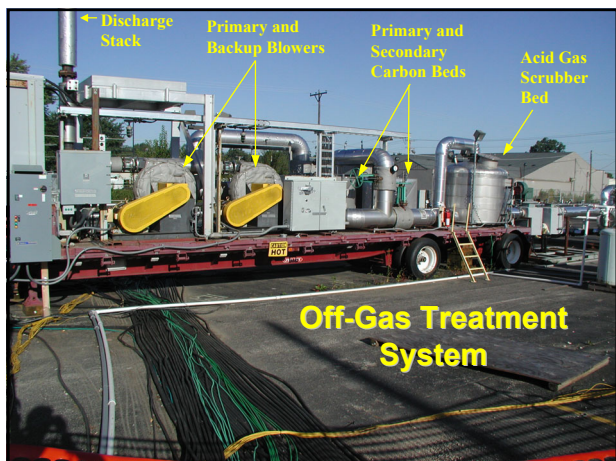


Residents
Immediately
Adjacent to
Treatment
Zone

Completed ISTD Well Field

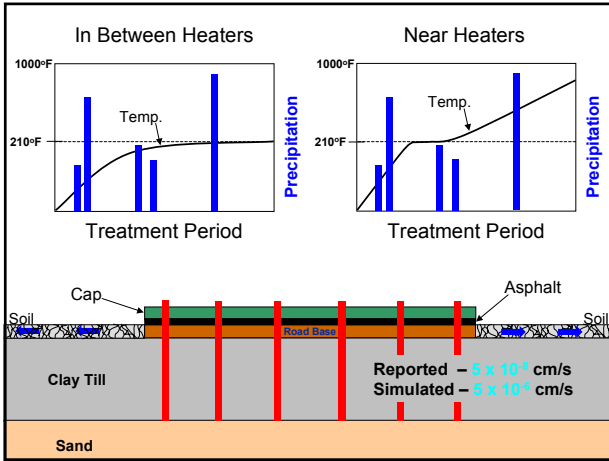


Off-Gas Treatment System



Expected Performance

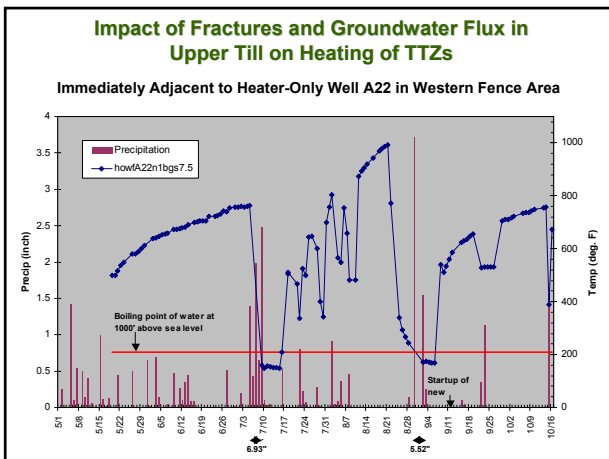
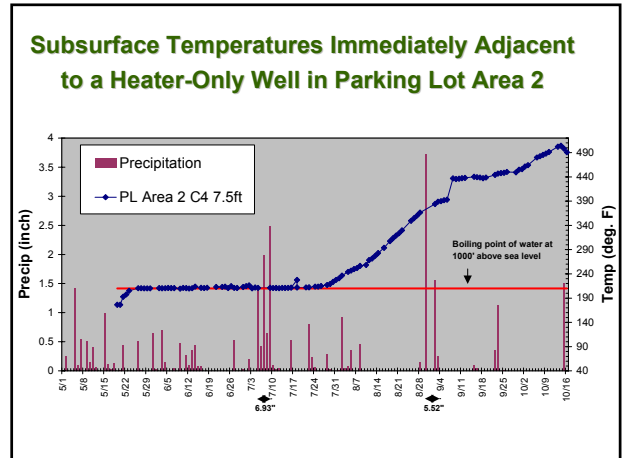
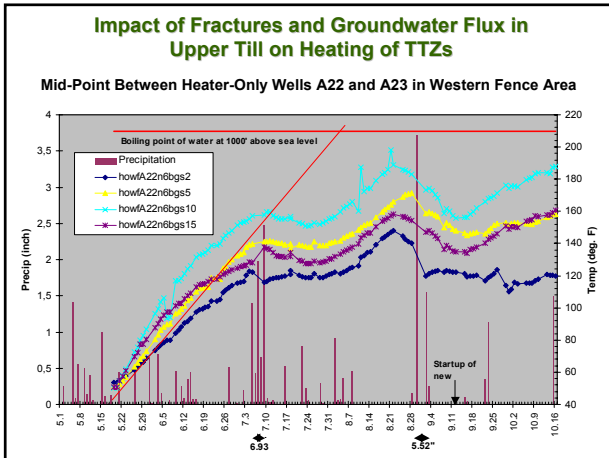




Observed Performance

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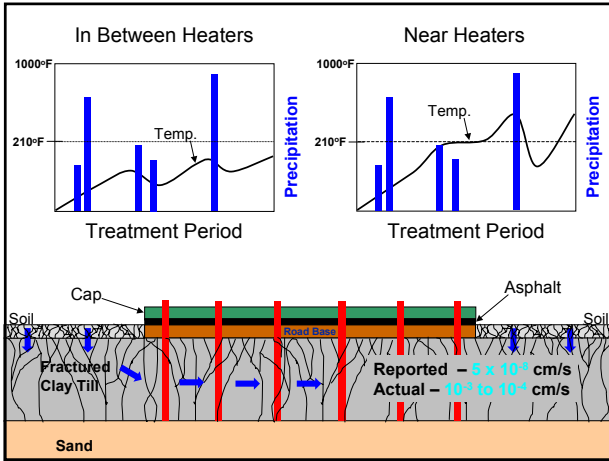
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remediation concepts for sites and urban areas



Revised Conceptual Model of Hydrogeology

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Modifications to Address Groundwater Flux

- Replace short corner heaters with full-length heaters
 - 38% increase in power input density: from 0.075 kW per cy to 0.1 kW per cy
- Operate longer



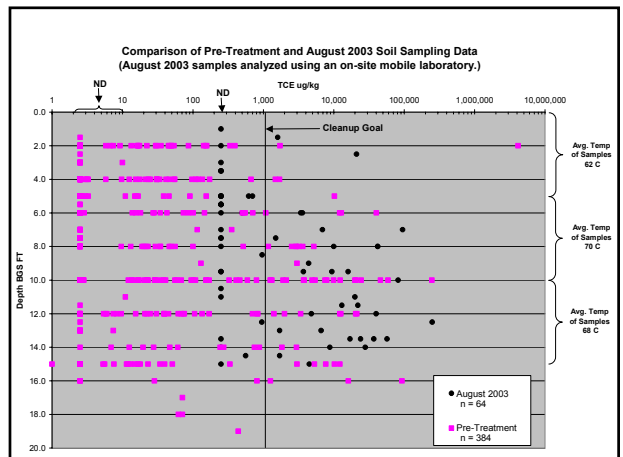
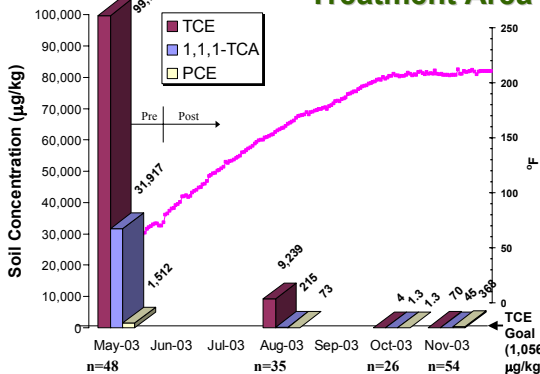
Final Results

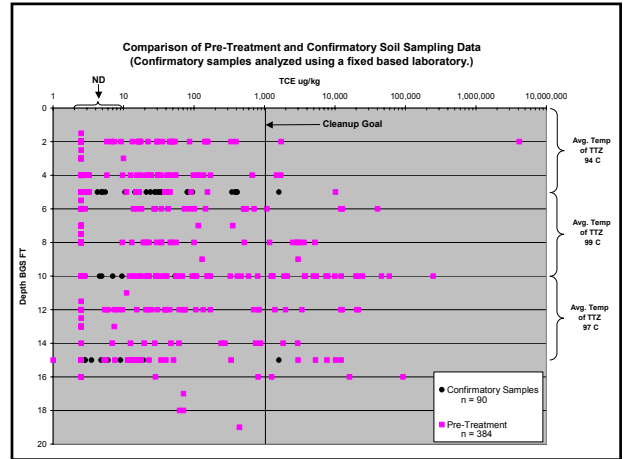
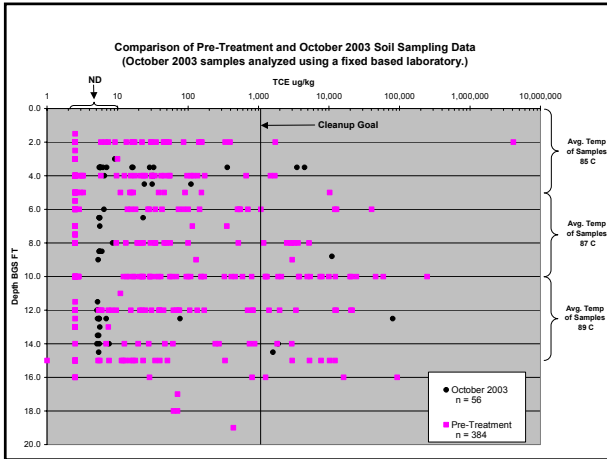


Surface Temperatures Immediately Beneath Cover



Results – PL 1 Treatment Area



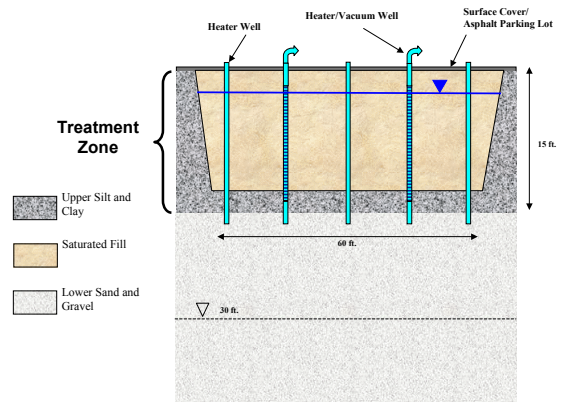


Percent Reductions in Average Concentrations - Parking Lot Area 1

	Average PreTreatment Concentration µg/kg	August 80 Days of Heating		October 150 Days of Heating		November 180 Days of Heating	
		Avg. Conc. µg/kg	% Reduction	Avg. Conc. µg/kg	% Reduction	Avg. Conc. µg/kg	% Reduction
TCE	99,744	9,239	90.737%	4	99.996%	70	99.930%
TCA	31,917	215	99.326%	1.3	99.996%	45	99.859%
PCE	1,512	73	95.172%	1.3	99.914%	363	75.992%
No. of Samples	48	35		26		54	



Cross-Section Through Treatment Zone – FWWB



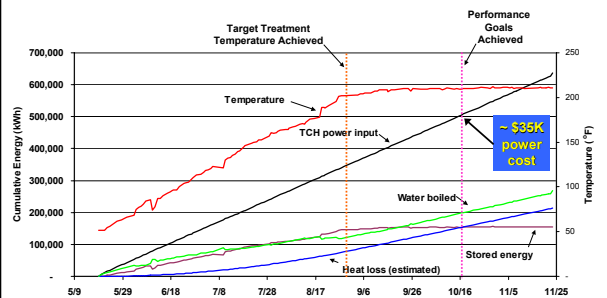
Energy Balance

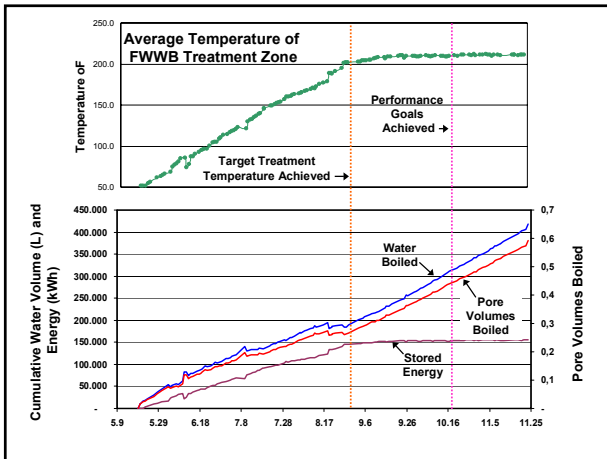
Energy Input =

- Energy Stored (heat capacity of soil and water)
- Energy for Boiling Water (Steam)
- Extraction of Heated Water and Air
- Heat Losses



Energy Balance FWWB Treatment Area





Summary

- Met guaranteed performance goals for dense clayey soils in all three treatment areas:
 - 150 to 180 days
 - < 1 mg/kg TCE (95% UCL)
- Achieved results below the water table without boiling off all of the water
- Flexible design and operation addressed excess groundwater flux
- Cost effective above and below the water table:
 - \$150/cy for guaranteed results (~\$1.65M total)
- Problem-free implementation immediately adjacent to residences
- Client submitted No Further Action letter



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