Thermal Remediation Services, Inc.

Electrical Resistance Heating for In-Situ Remediation of Soil & Groundwater

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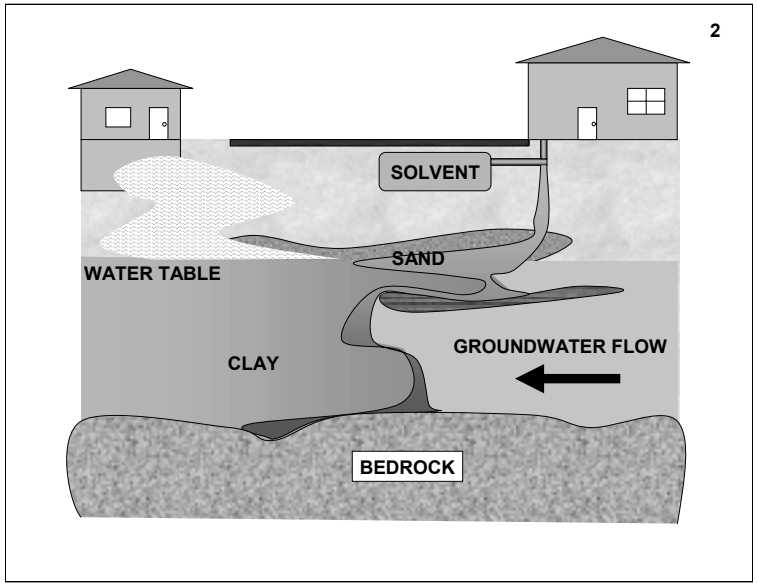
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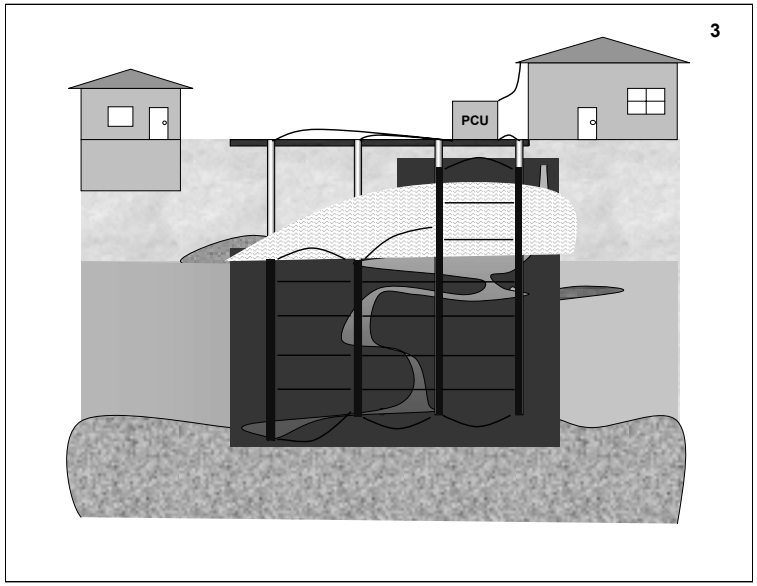
SOLVENT
SAND
WATER TABLE
GROUNDWATER FLOW
CLAY
BEDROCK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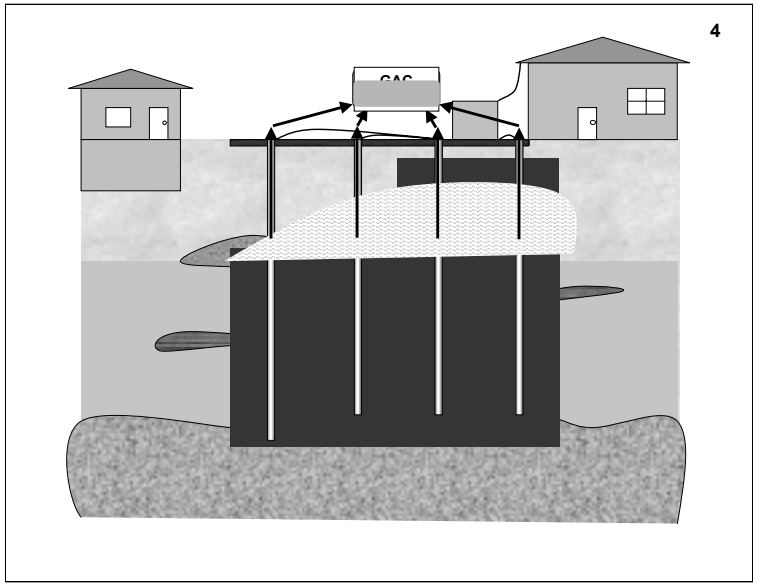
PCU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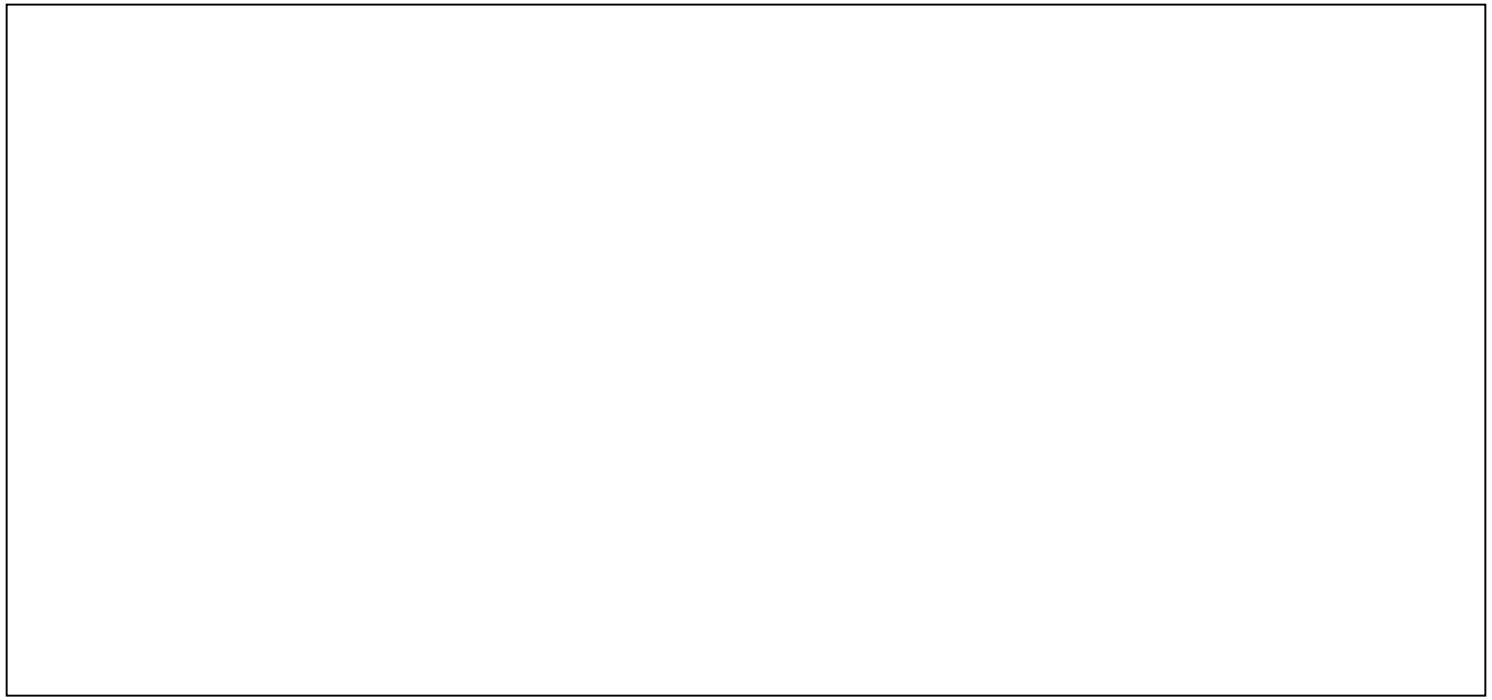
Why Electrical Resistance Heating?

- Heating is uniform with no bypassed regions
- Heating is rapid – months vs. years
- Steam is produced *in-situ*
- Preferentially heats tight soil lenses and DNAPL hot spots
- Cost effective: most commercial, full-scale sites range from $40-$100 per yds^3



Applications

- Low permeability & heterogeneous lithologies
- DNAPL & LNAPL cleanups by aquifer and smear zone heating
- Heavy hydrocarbon mobilization
- Degradation enhancement (hydrolysis, bio)
- Remediation underneath operating facilities, in the presence of buried utilities and hazardous waste drums

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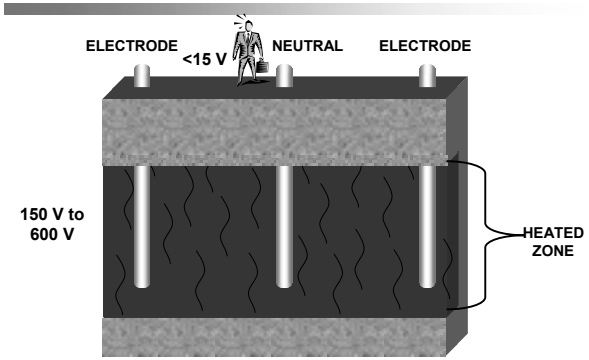
In-Situ Steam Generation



1. Soil grains act as electrical resistors
2. Steam generation is uniform through the heated zone
3. Discrete intervals can be heated

Surface Equipment

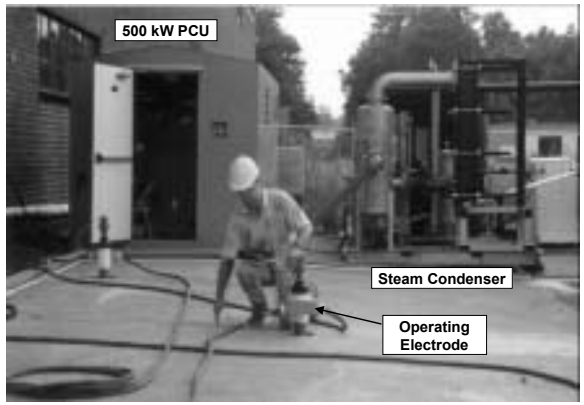
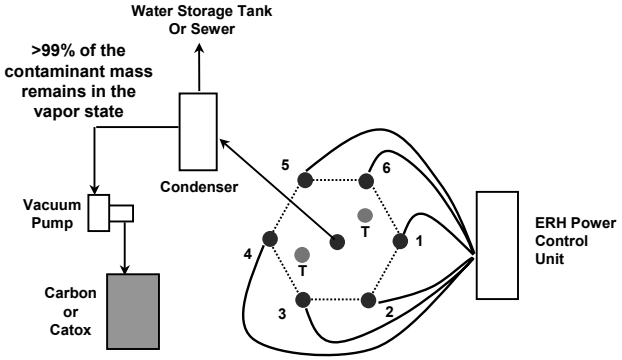
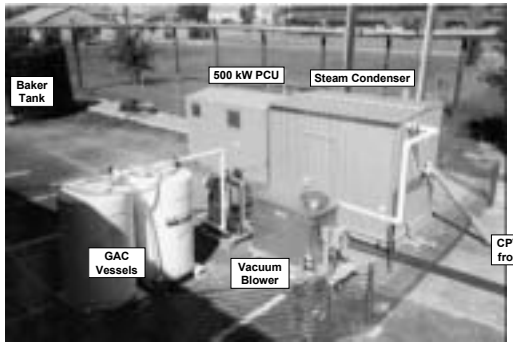


Photo Courtesy of Brown and Caldwell

Vapor Recovery System



ERH Equipment Staging



Full-Scale DNAPL Cleanup the Problem*

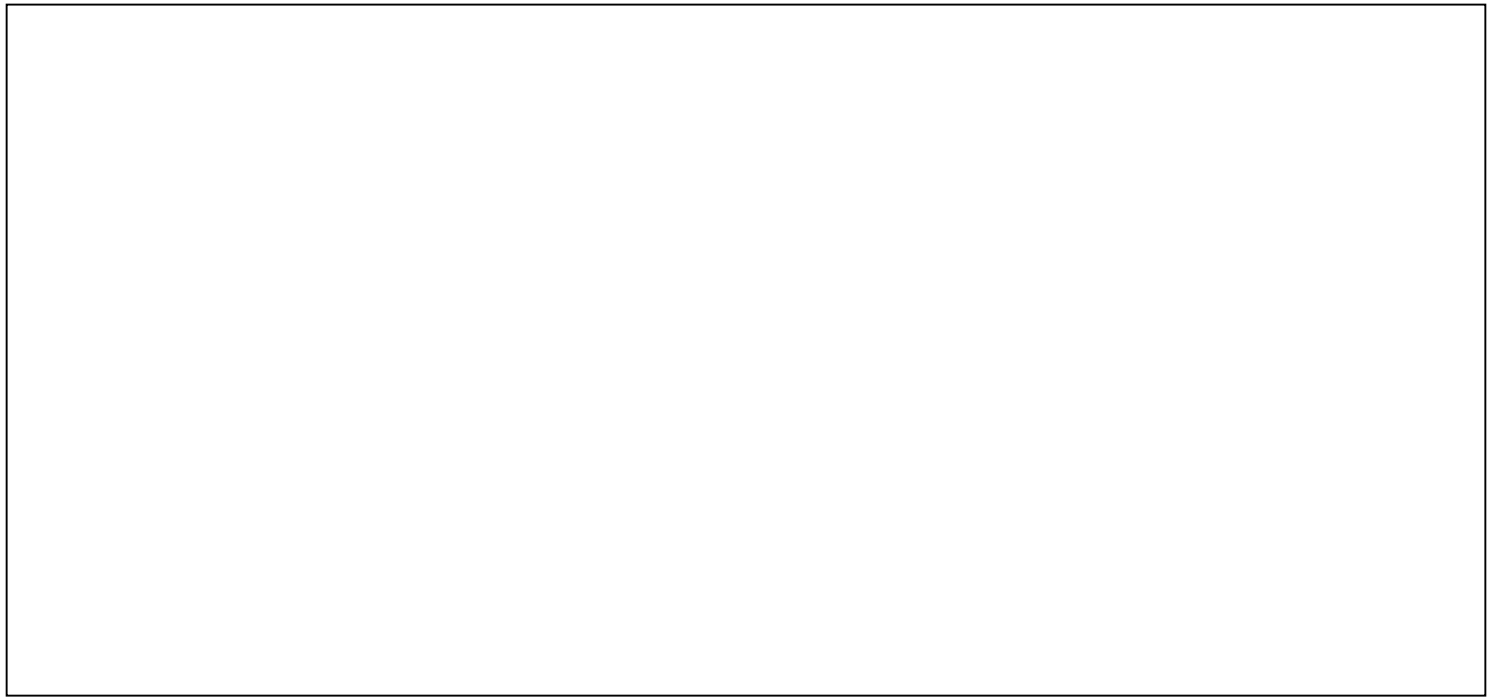
DNAPL (TCE & TCA) covering about 1 acre of an industrial site

ENSR performed remediation for about 5 years and removed 30,000 pounds of TCE & TCA

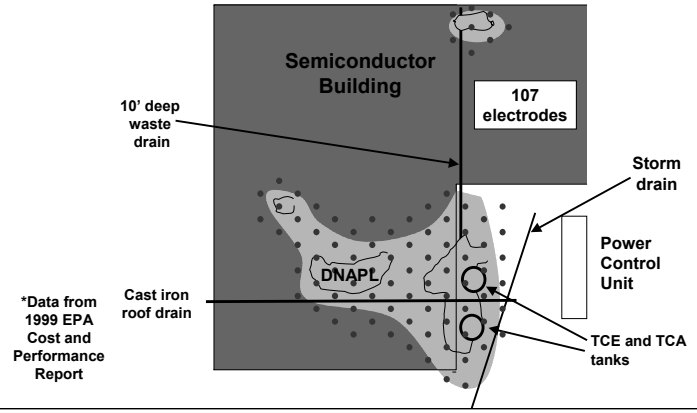
DNAPL remained in four areas, mostly under a large warehouse building

Goal: Reach Tier III RBCA Cleanup Levels over entire site

*Data from the 1999 EPA Cost and Performance Report



Full-Scale DNAPL Cleanup Site Map*



*Data from 1999 EPA Cost and Performance Report

ERH Remediation Beneath a Building

Limited overhead access

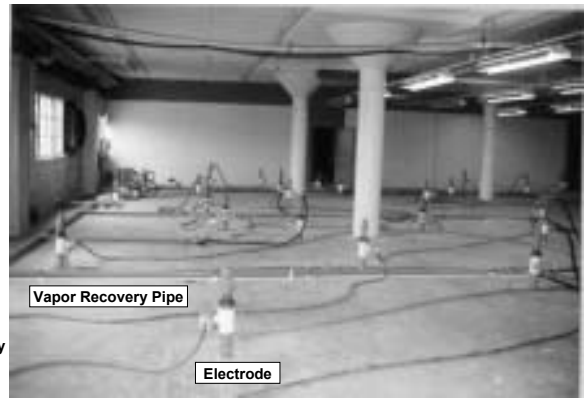
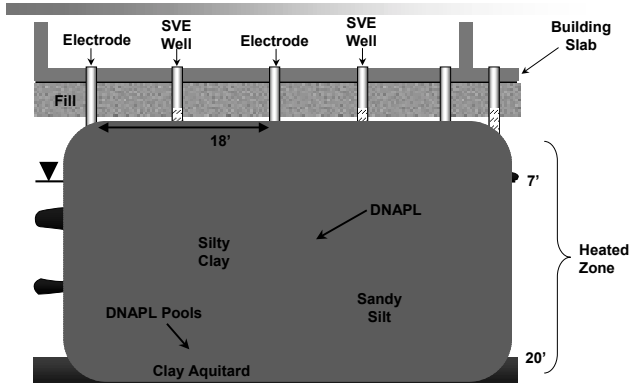


Photo Courtesy of Brown and Caldwell

Full-Scale DNAPL Cleanup Subsurface Cross-Section



Full-Scale DNAPL Cleanup Operations & Results*

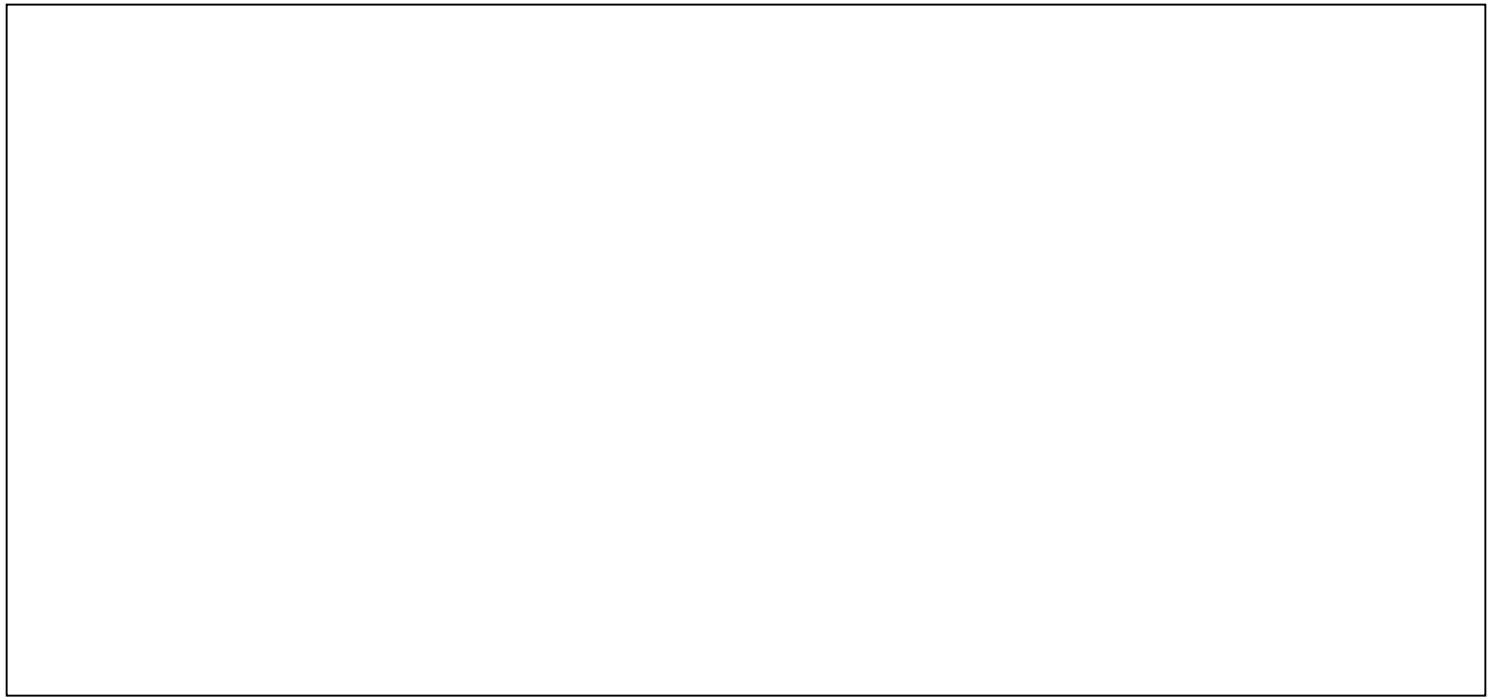
Operations

- Heating (107 electrodes) started June 4, 1998
- Aquifer reached boiling in 60 days
- Maintained above the boiling point of TCE (73ºC) for the next 3 months

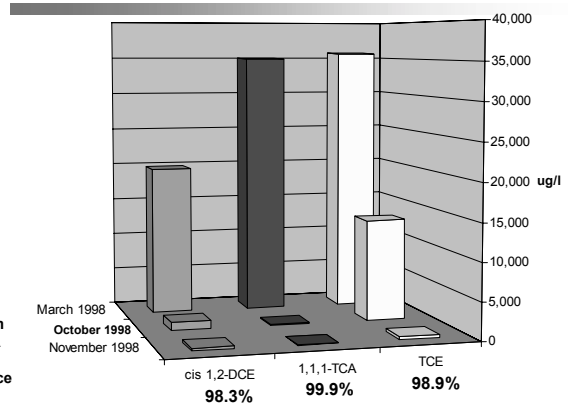
Results

- Tier III levels by late November 1998; the site is now closed
- >15,000 pounds of VOCs removed

*Data from 1999 EPA Cost and Performance Report

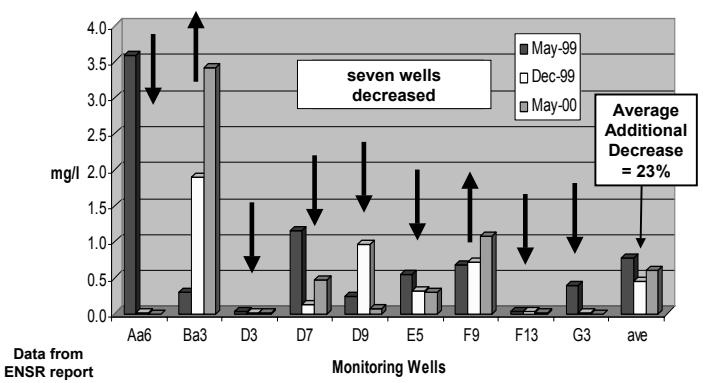


Average Groundwater Concentrations Seven Most Contaminated Wells*



*Data from 1999 EPA Cost and Performance Report

Do Groundwater Concentrations Rebound after ERH Remediation?



Polishing Mechanisms

Hydrolysis of Halogenated Alkanes

Compounds such as TCA have a hydrolysis half-life of less than one day at steam temperatures.

Iron Reductive Dehalogenation

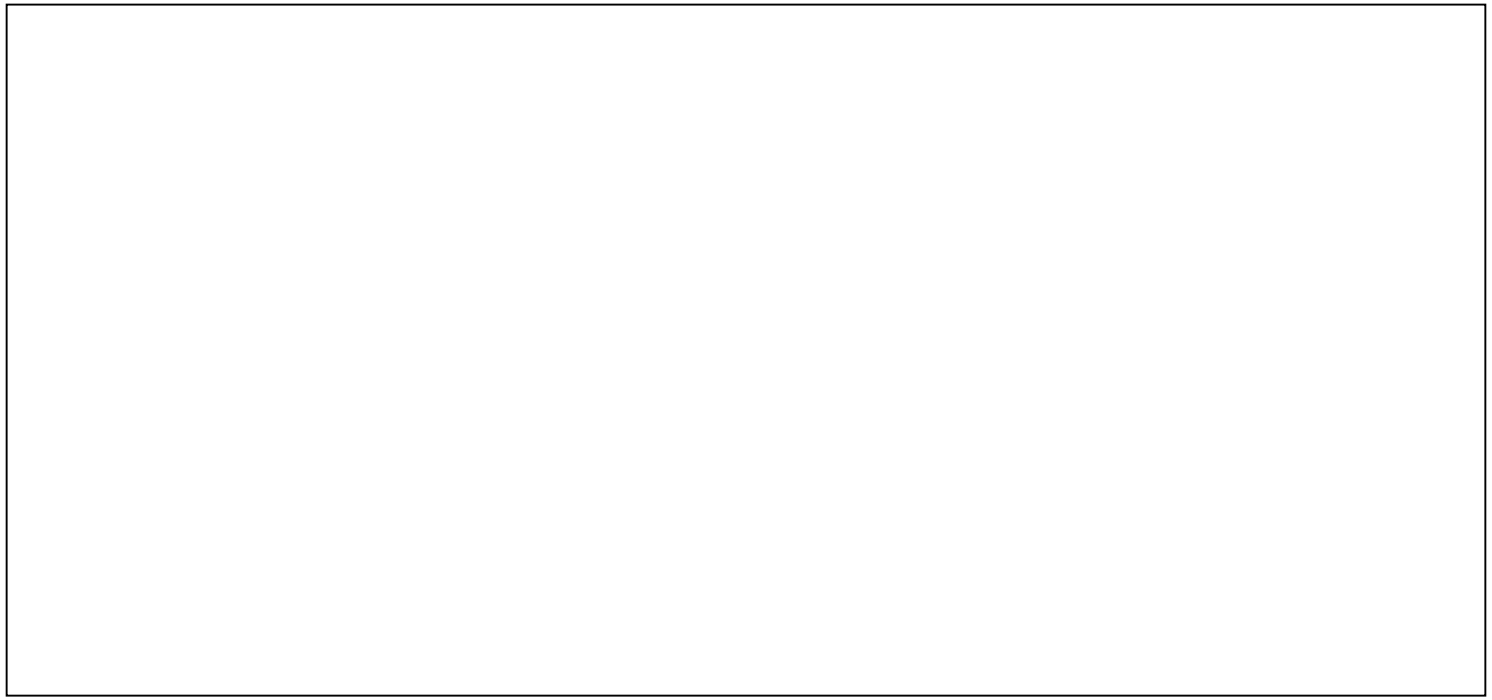
Steel shot used as electrode backfill provides an iron source for reductive dehalogenation (iron filing wall)

Temperature Accelerates Reactions

The above reaction rates are increased by factor of thousands at 100°C (Arrhenius Equation)

Bioremediation by Thermophiles

Thermophilic bacteria are the most effective solvent dehalogenators and prefer 40-70°C



Full Scale DNAPL Cleanup Cost & Performance Data*

Effectiveness

- Total operations took 18 weeks, five days
- Treated approximately 30,000 cubic yards
- Since completing, average groundwater VOC concentrations have continued to decrease

Costs

- Total project costs were $32/cubic yard
- The total includes electrical costs of $6.50/cubic yard
- Vapor treatment was not required. If vapor treatment had been required, the cost would have been about $41 per cubic yard.

***Data from the 1999 EPA Cost and Performance Report**

TCE DNAPL Remediation
Air Force Plant Four
Fort Worth, Texas

Photo Courtesy of URS

ERH Remediation Beneath Air Force Plant Four

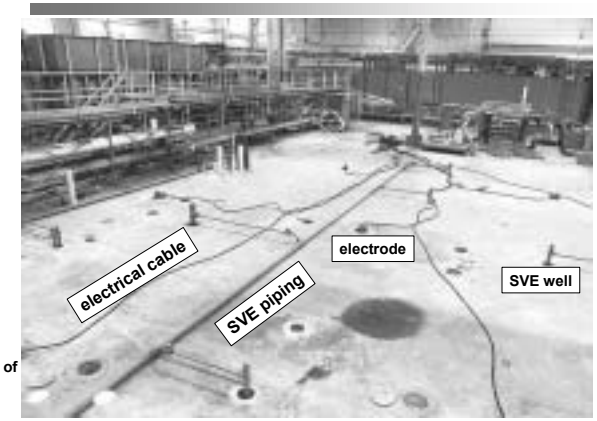


Photo Courtesy of URS

Lowry Landfill System Layout