



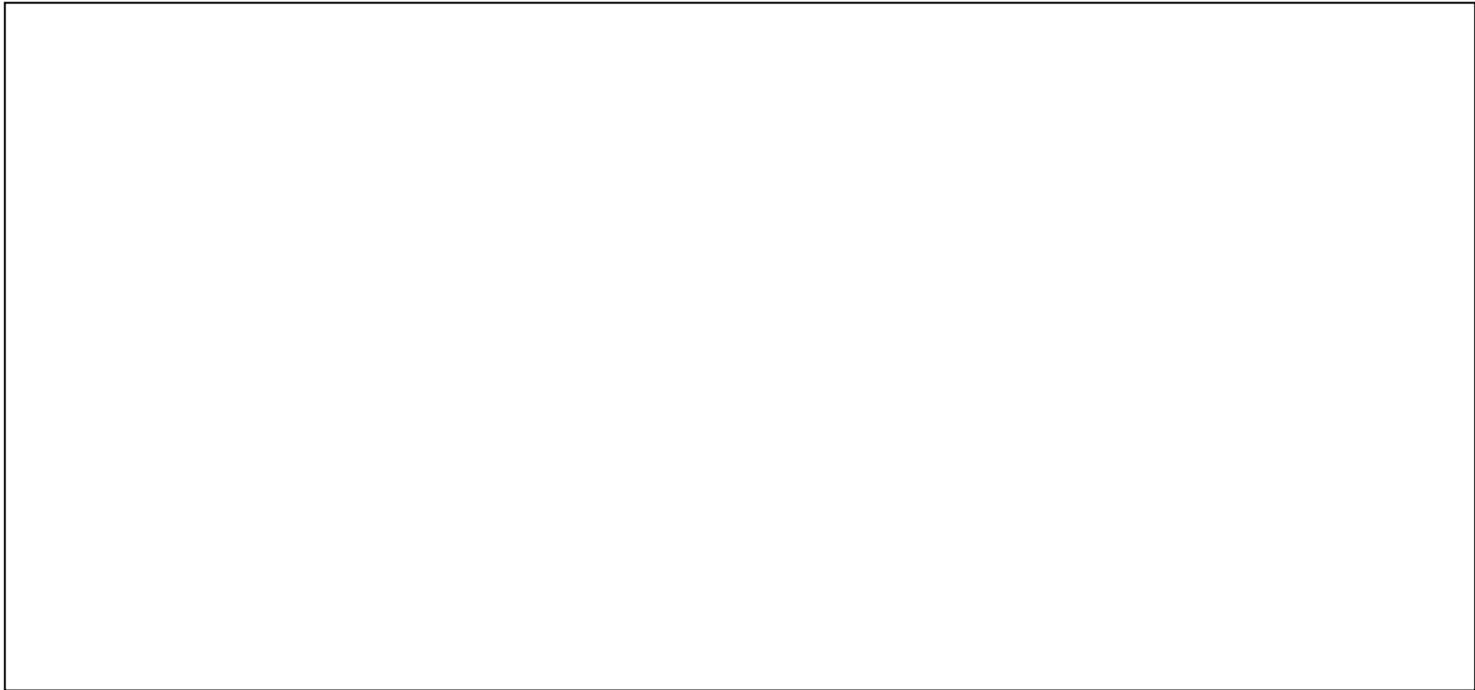
**Thermal Remediation
Services, Inc.**

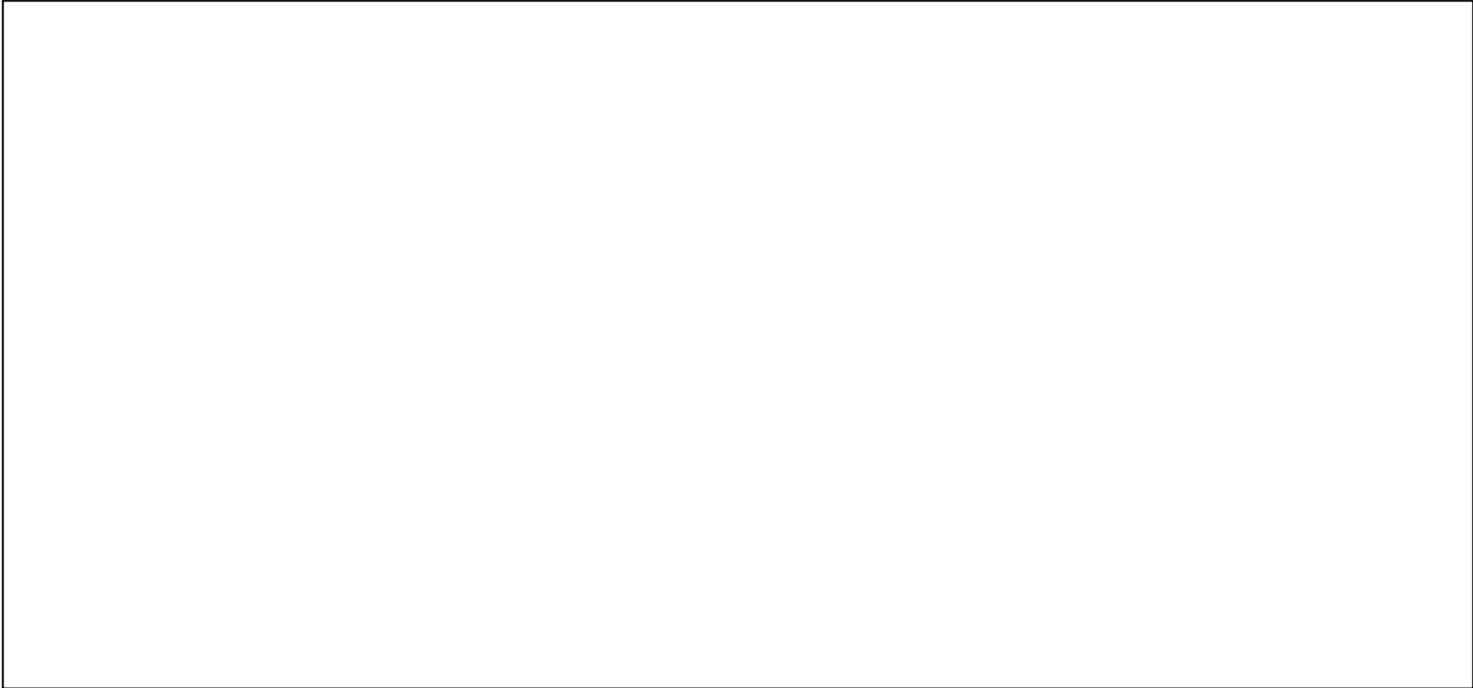
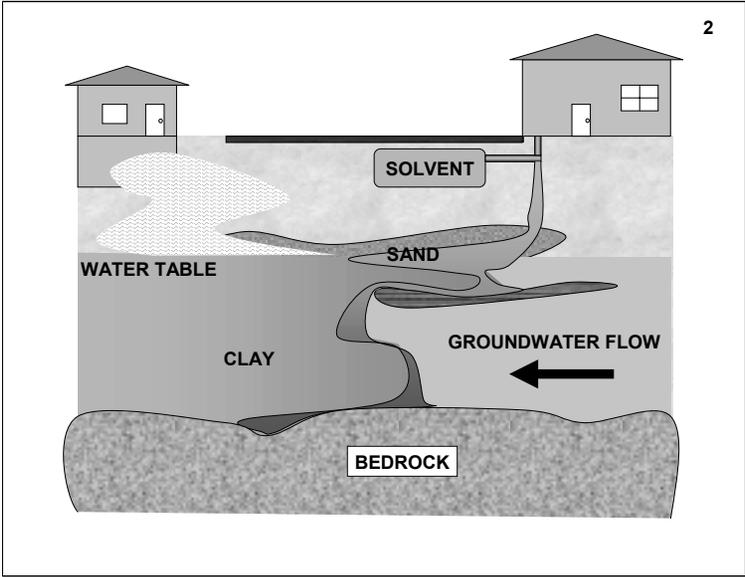
1

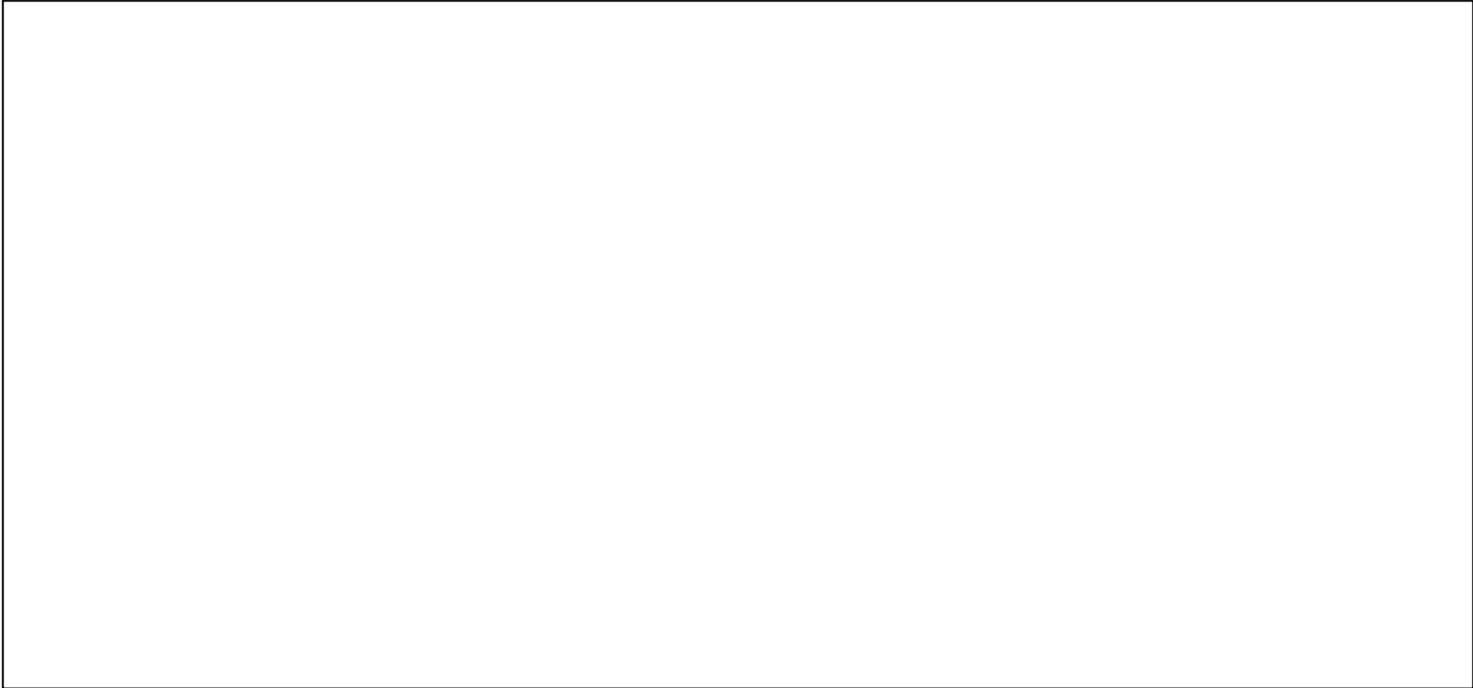
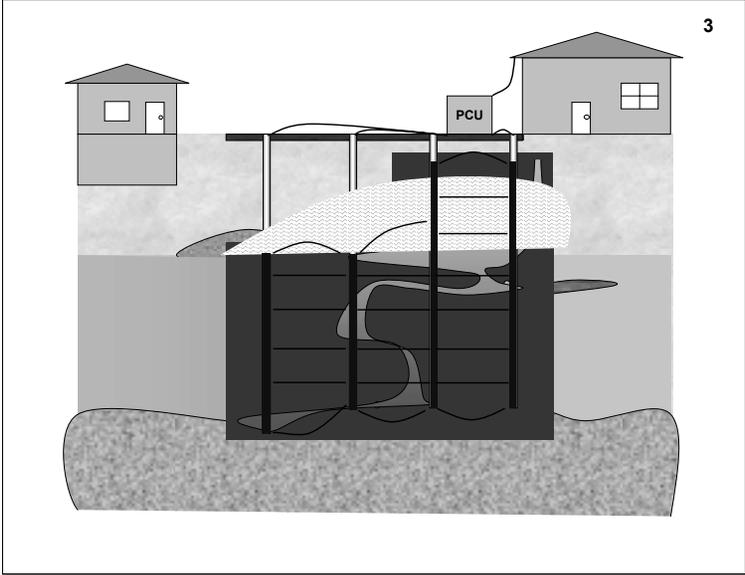
***Electrical Resistance Heating
for
In-Situ Remediation of Soil &
Groundwater***

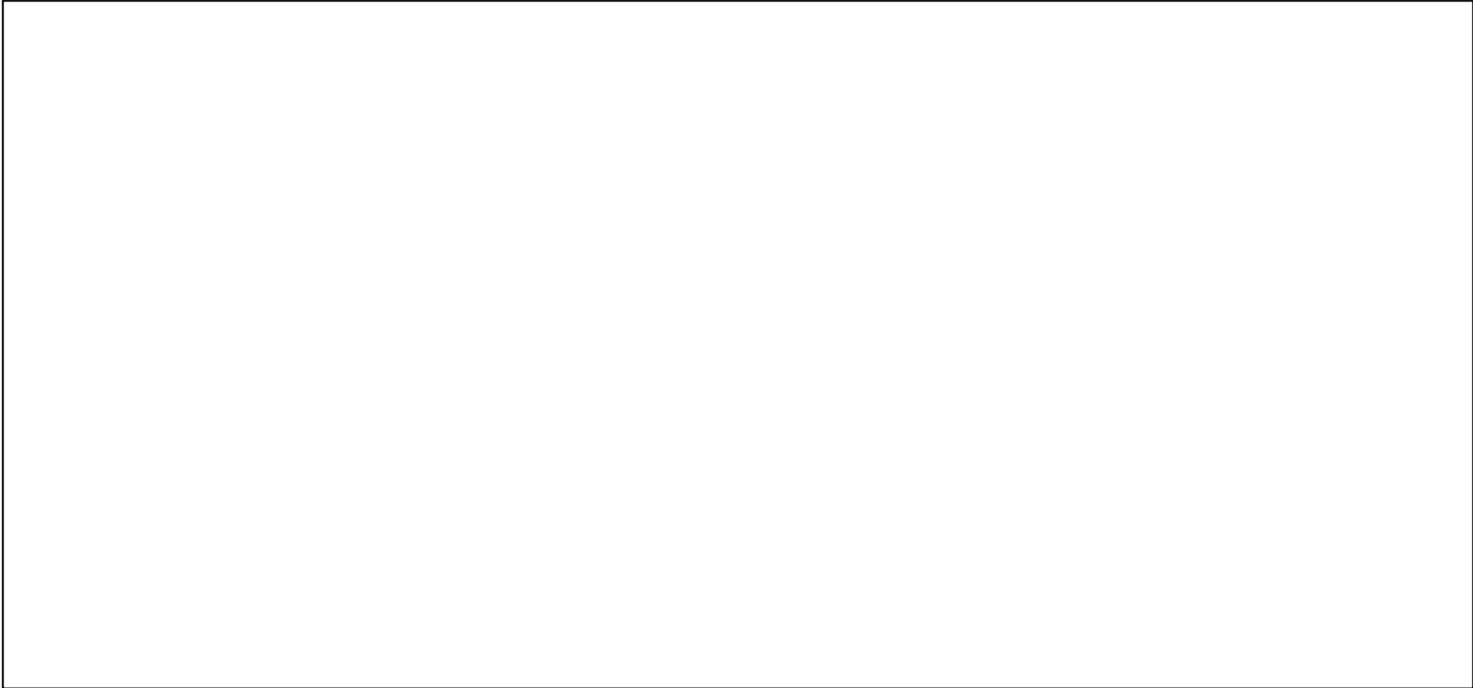
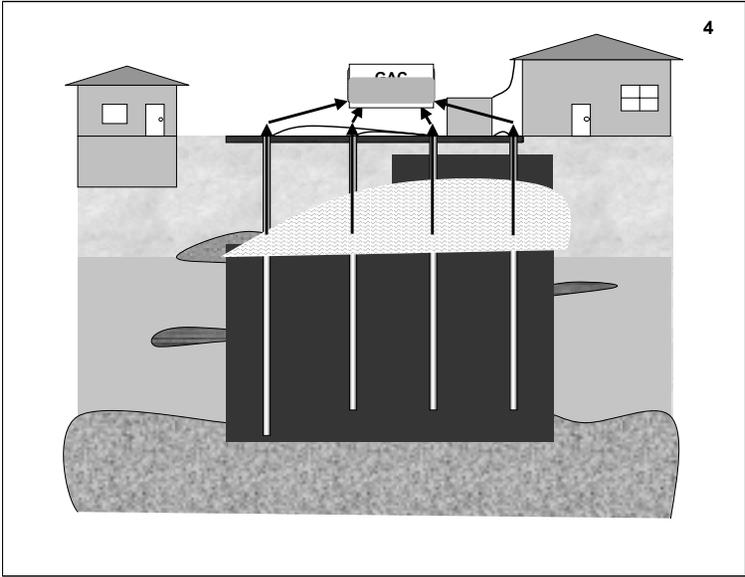
December 10, 2002

Greg Beyke
(770) 794-1168
gbeyke@thermalrs.com
www.thermalrs.com











Why Electrical Resistance Heating?

5

- 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 yds³



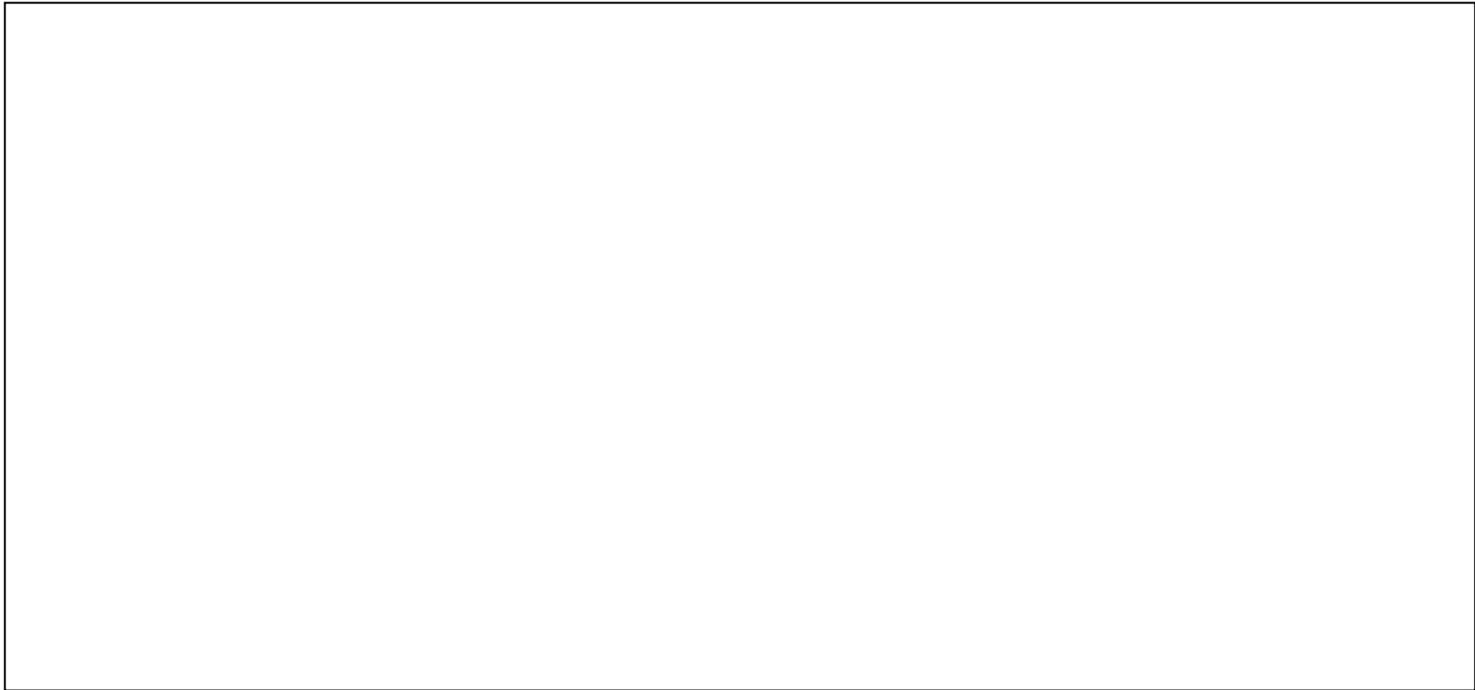
Applications

**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**



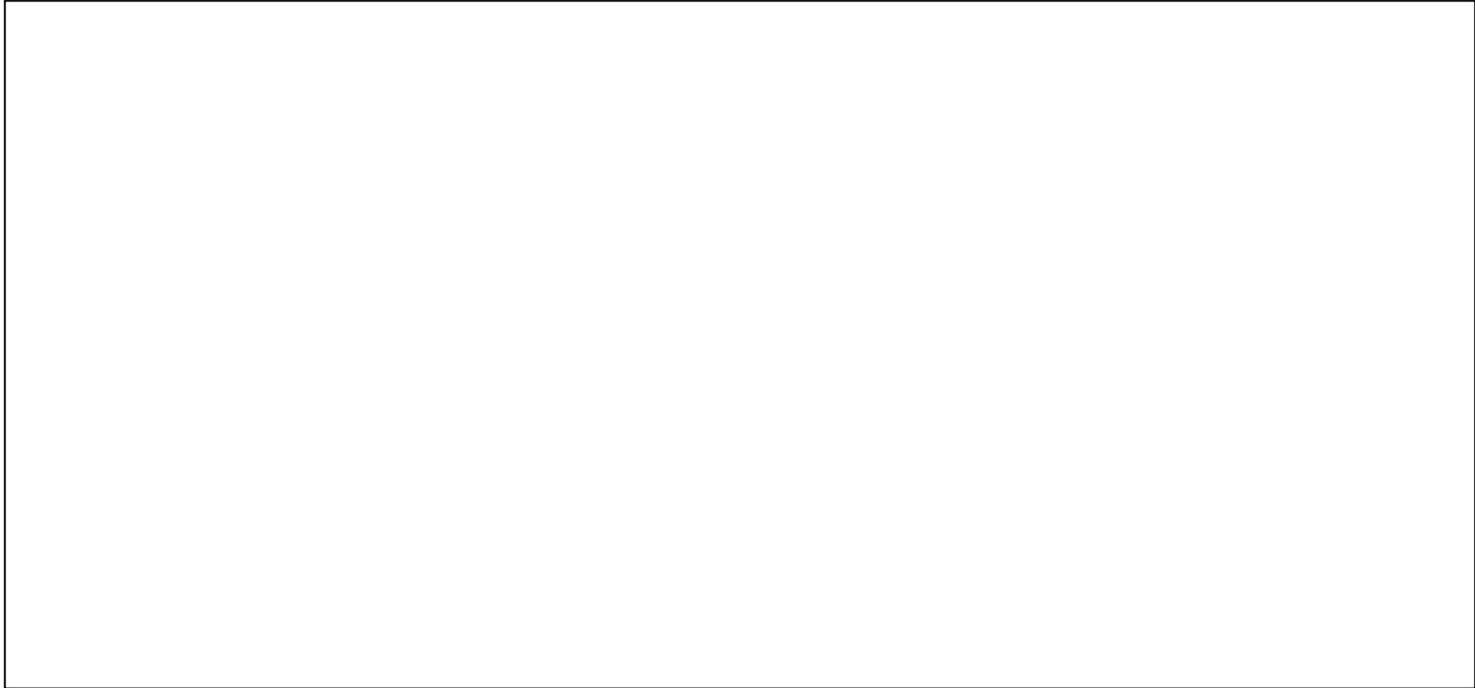
T S THERMAL REMEDIATION SERVICES, INC.

In-Situ Steam Generation

7

The diagram illustrates the In-Situ Steam Generation process. It shows a cross-section of the ground with a surface layer and a deeper soil layer. On the surface, there are three electrodes: two labeled 'ELECTRODE' and one in the center labeled 'NEUTRAL'. A person is standing between the two outer electrodes, with a voltage of '<15 V' indicated between them. Below the surface, three vertical electrodes are inserted into the soil. The voltage between these electrodes is labeled '150 V to 600 V'. A bracket on the right side of the soil layer indicates a 'HEATED ZONE' around the electrodes.

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





Surface Equipment

8

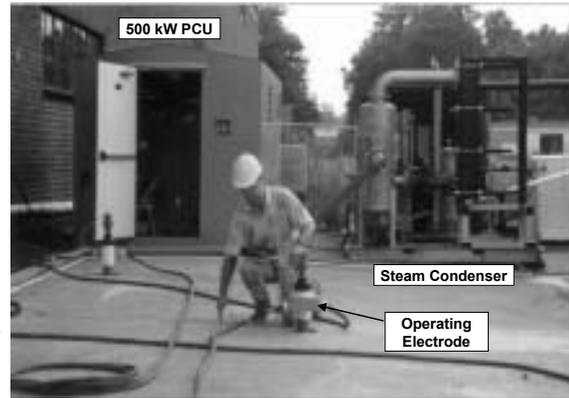
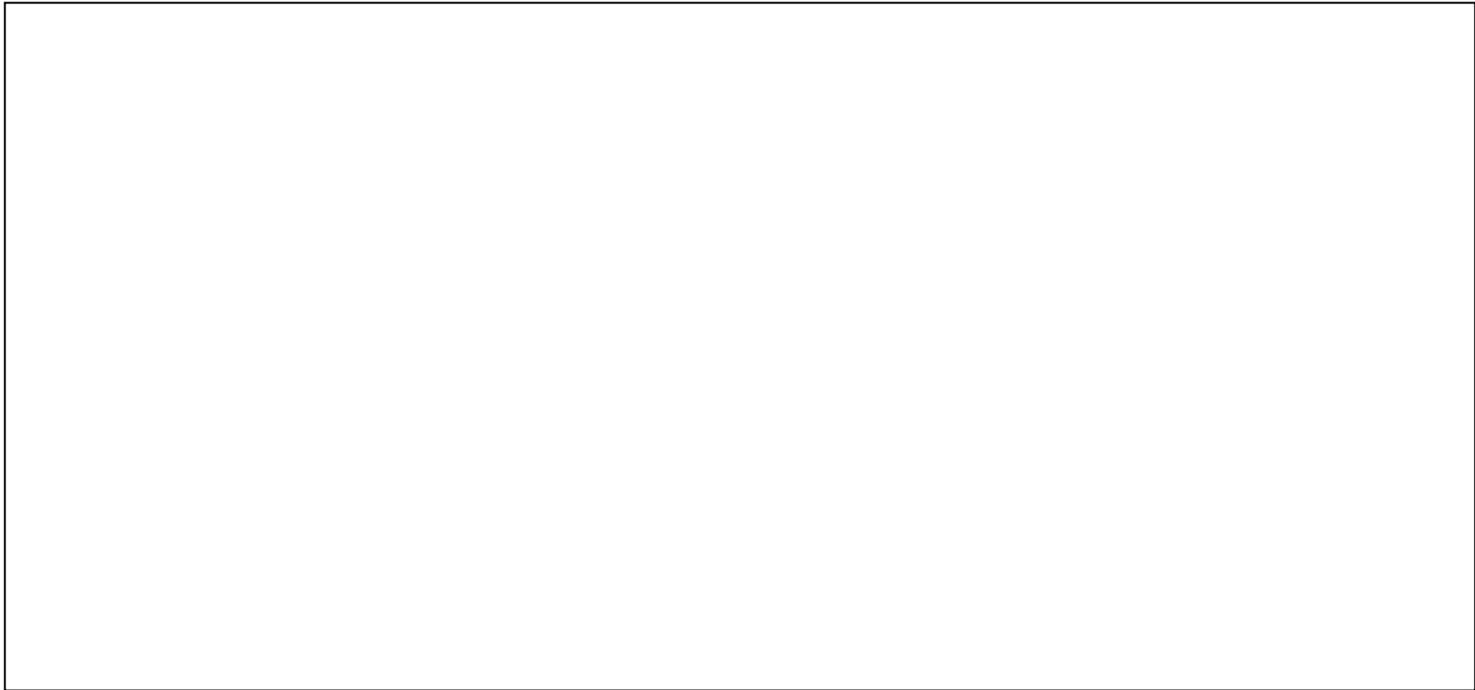
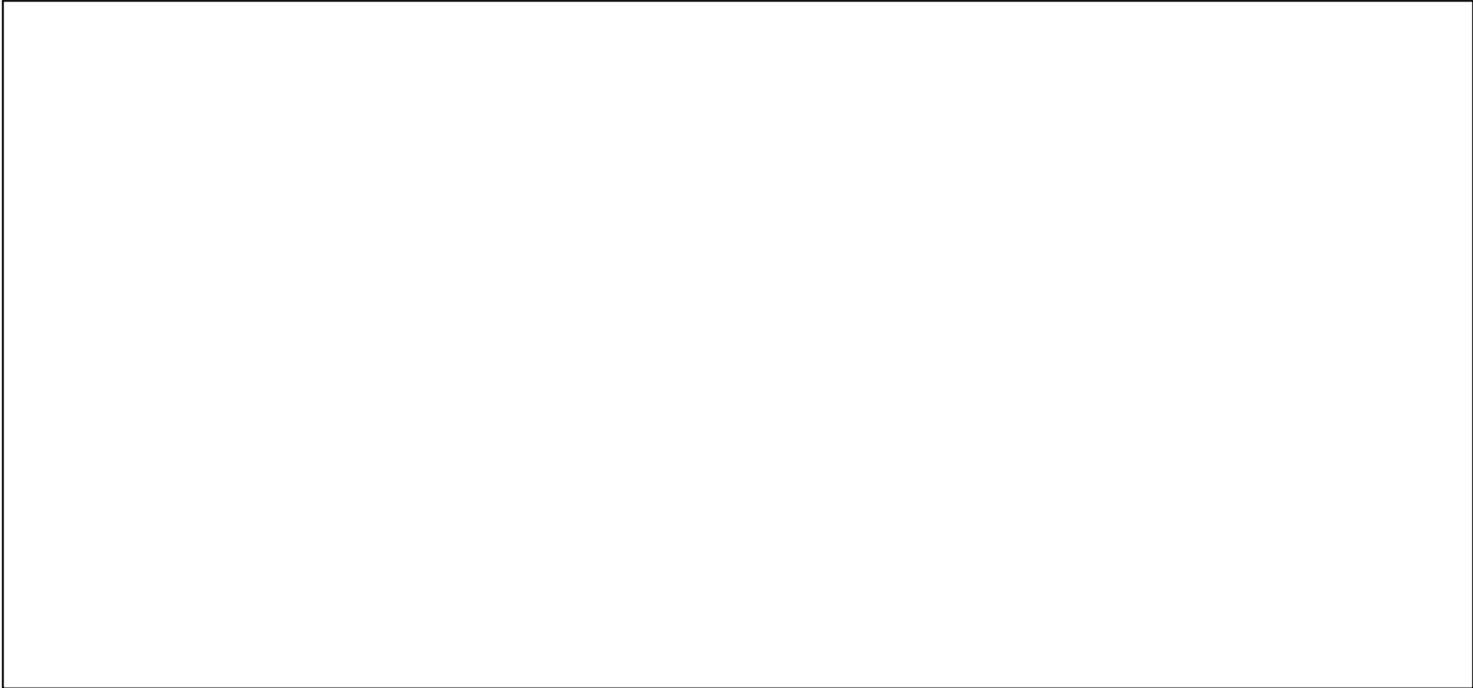
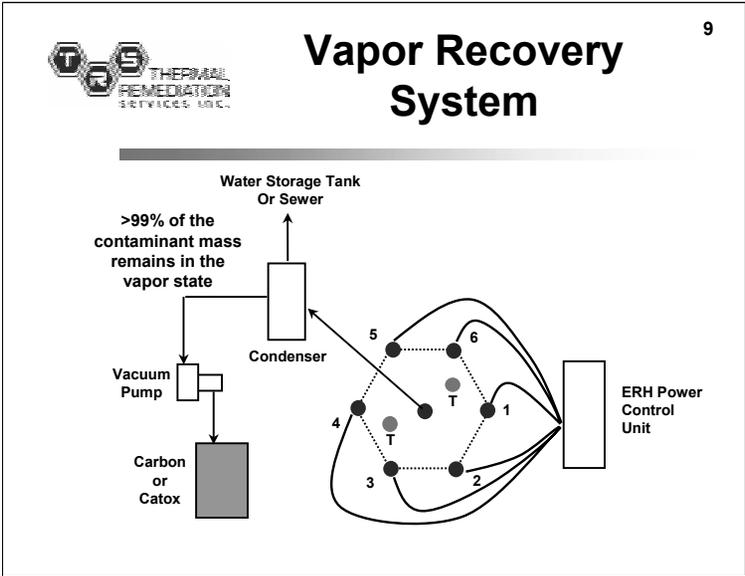


Photo
Courtesy of
Brown and
Caldwell

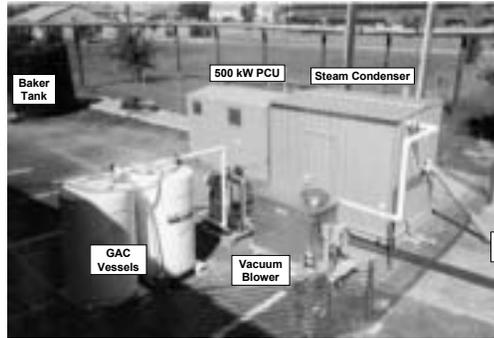






ERH Equipment Staging

10





Full-Scale DNAPL Cleanup the Problem*

11

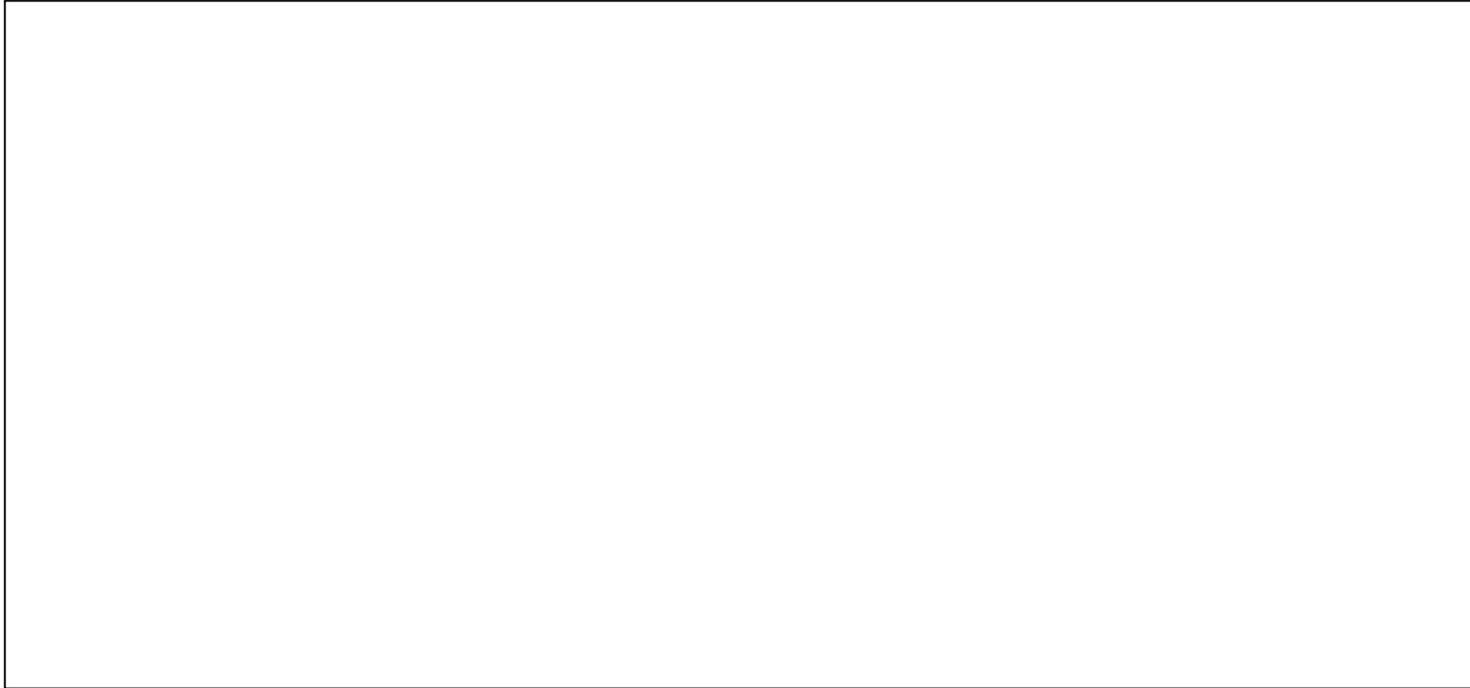
DNAPL (TCE & TCA) covering about 1 acre of an industrial site

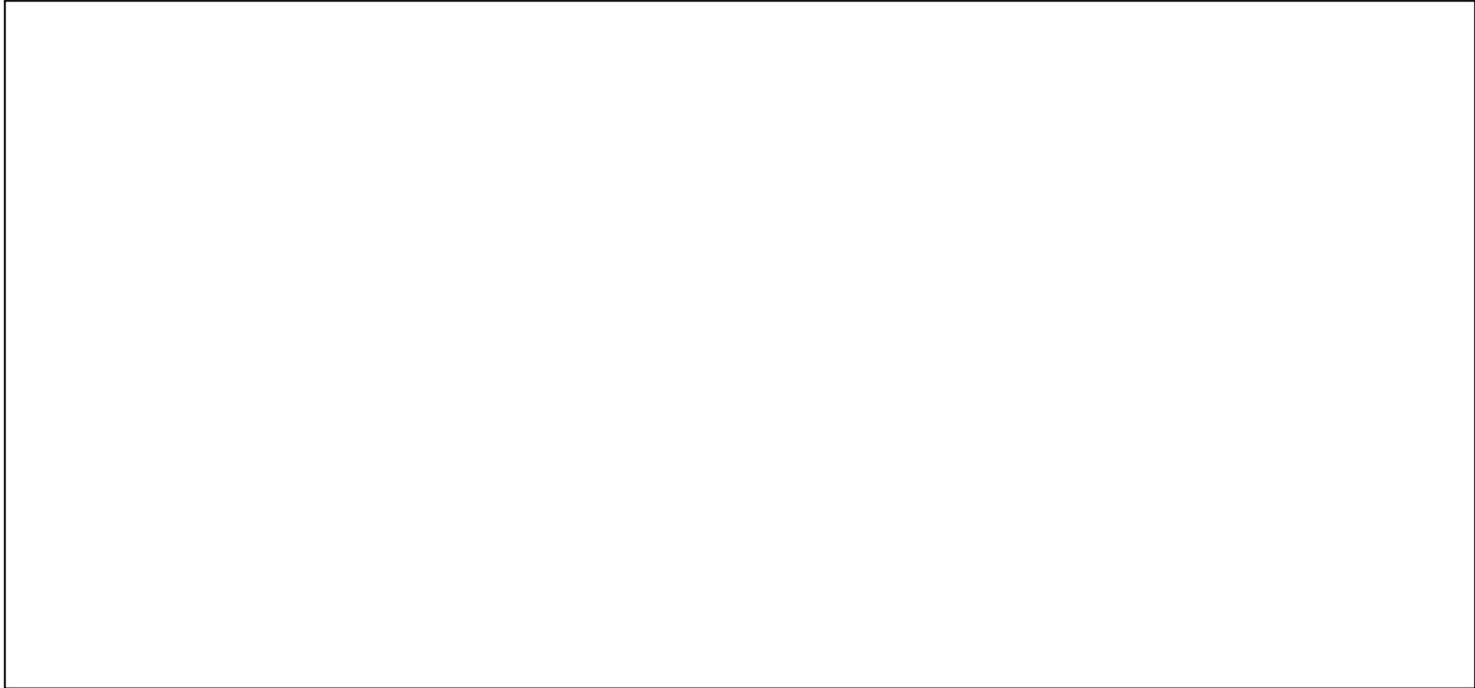
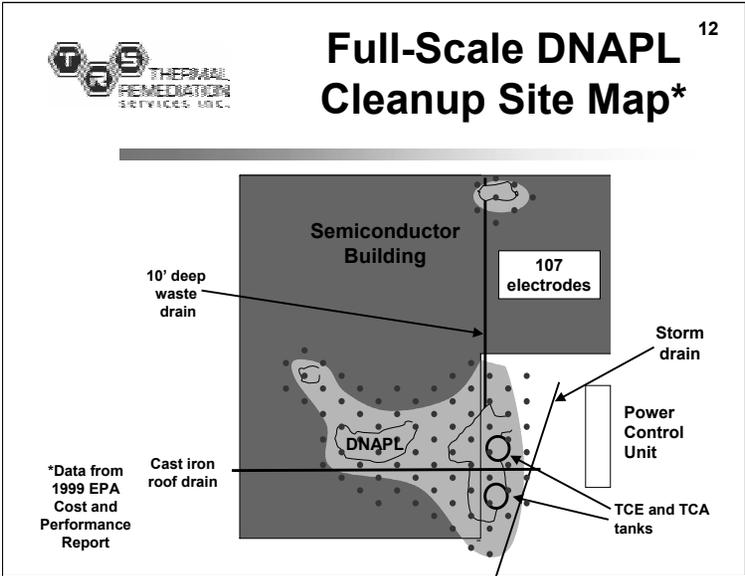
ENSR performed remediation for about 5 years and removed 30,000 pounds of TCE & TCA

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







ERH Remediation Beneath a Building

13

Limited
overhead
access

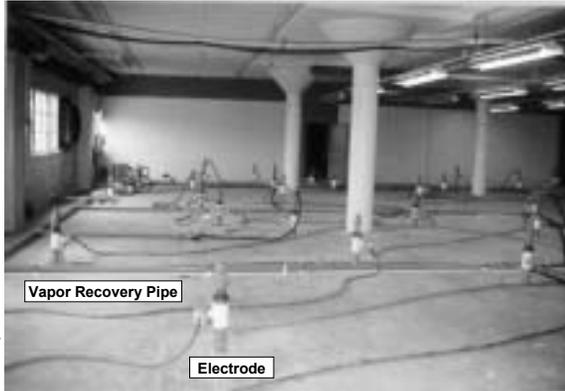
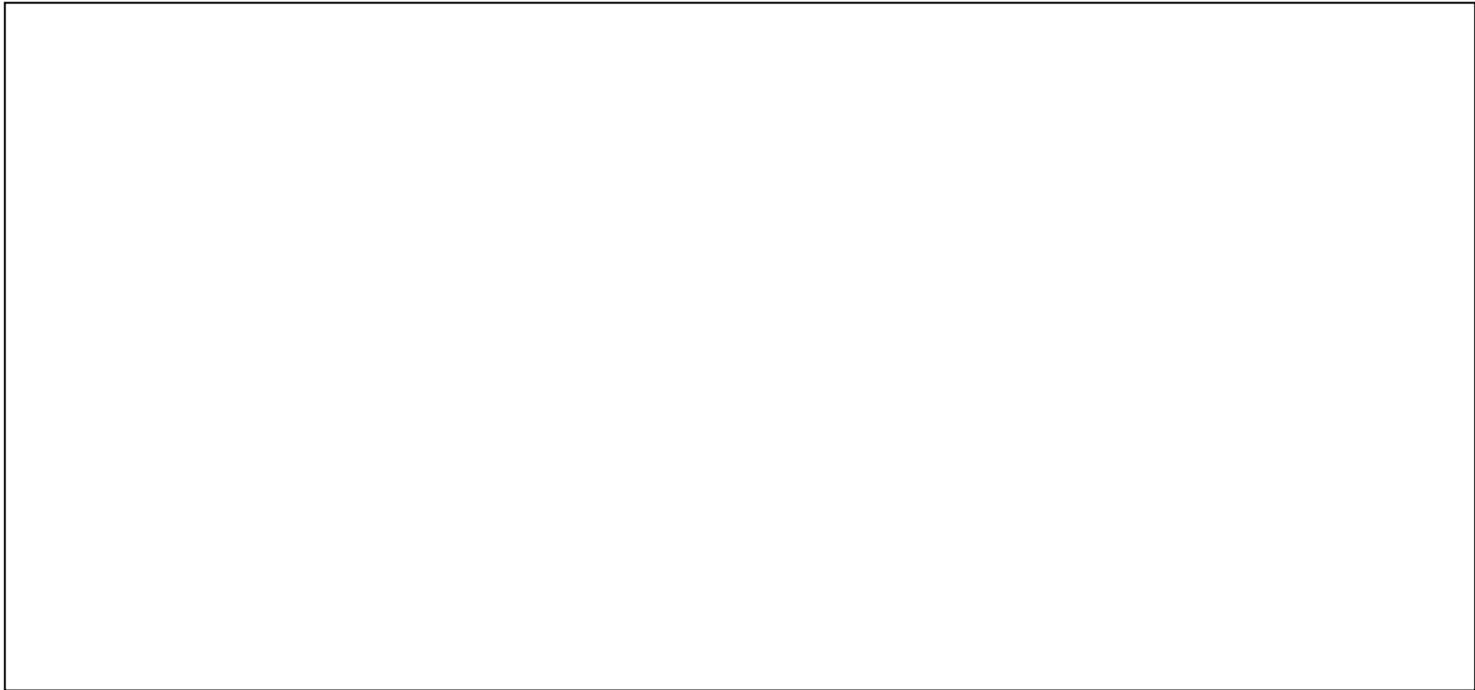
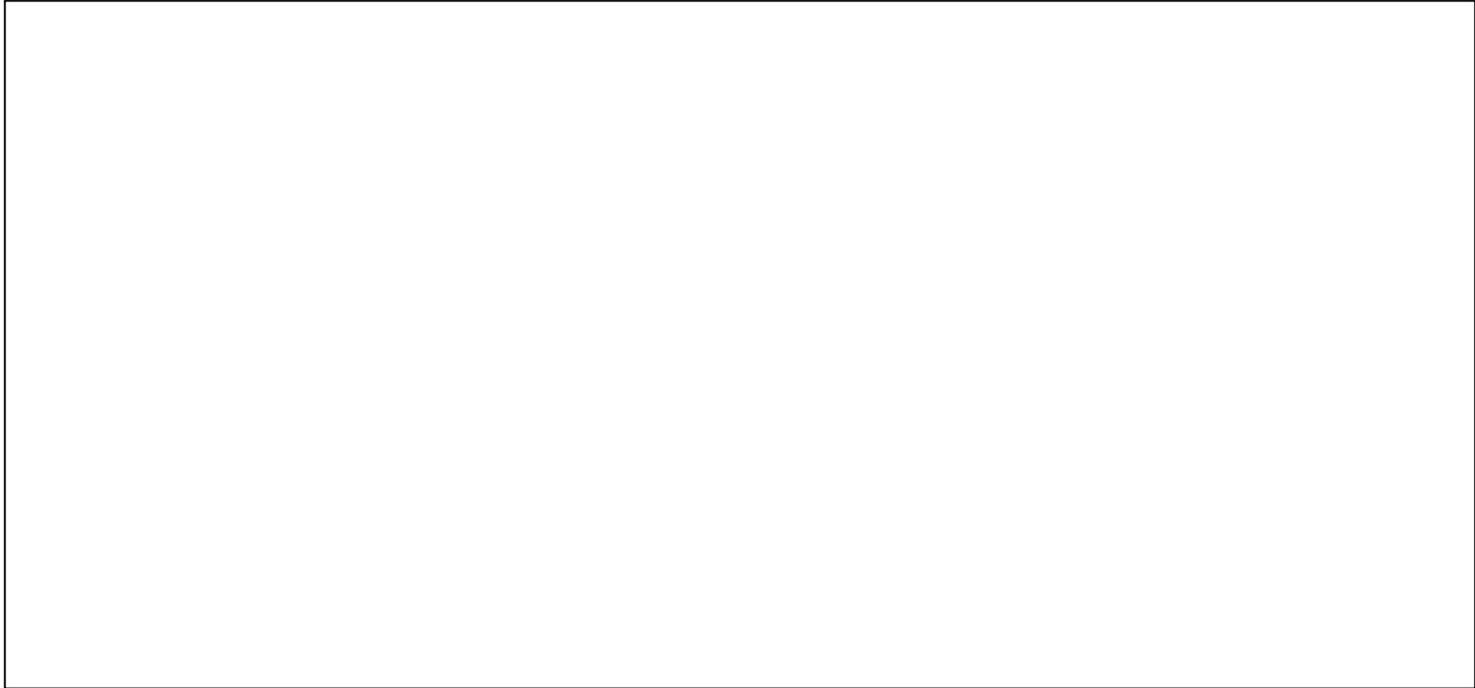
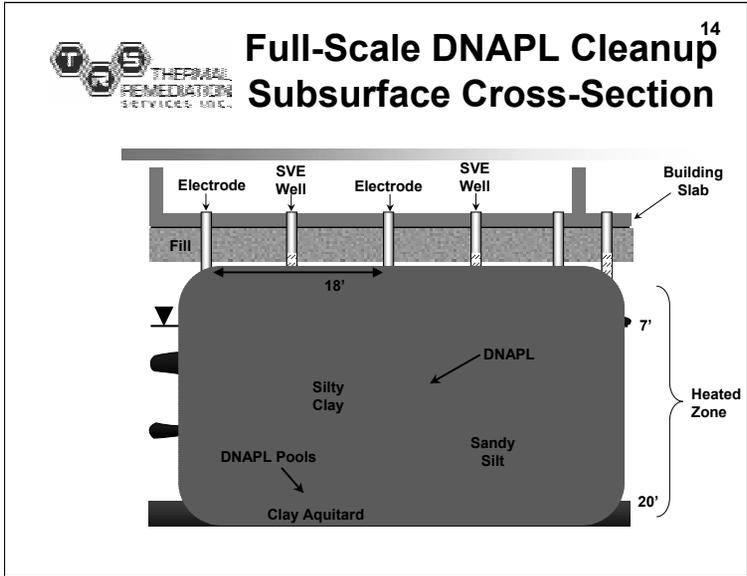


Photo Courtesy
of Brown and
Caldwell







Full-Scale DNAPL Cleanup¹⁵ Operations & Results*

Operations

Heating (107 electrodes) started June 4, 1998

Aquifer reached boiling in 60 days

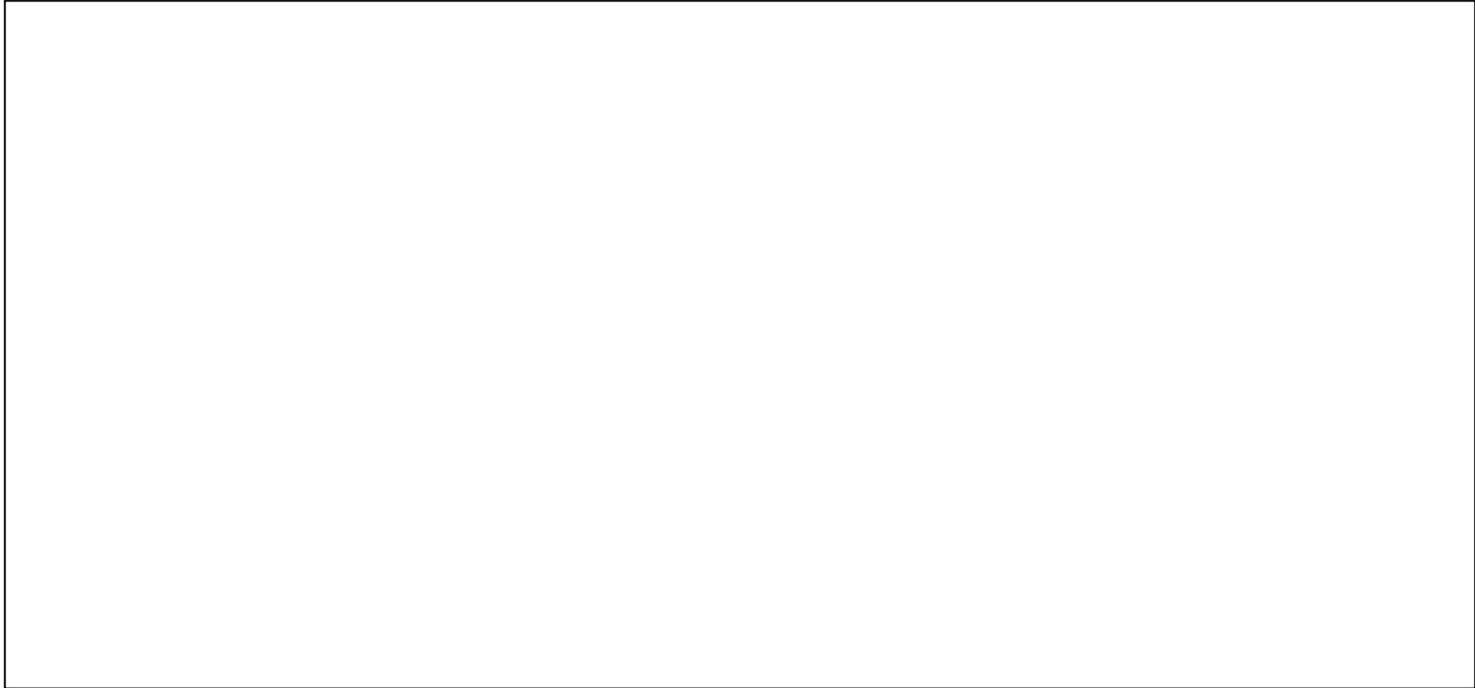
Maintained above the boiling point of TCE (73°C) for the next 3 months

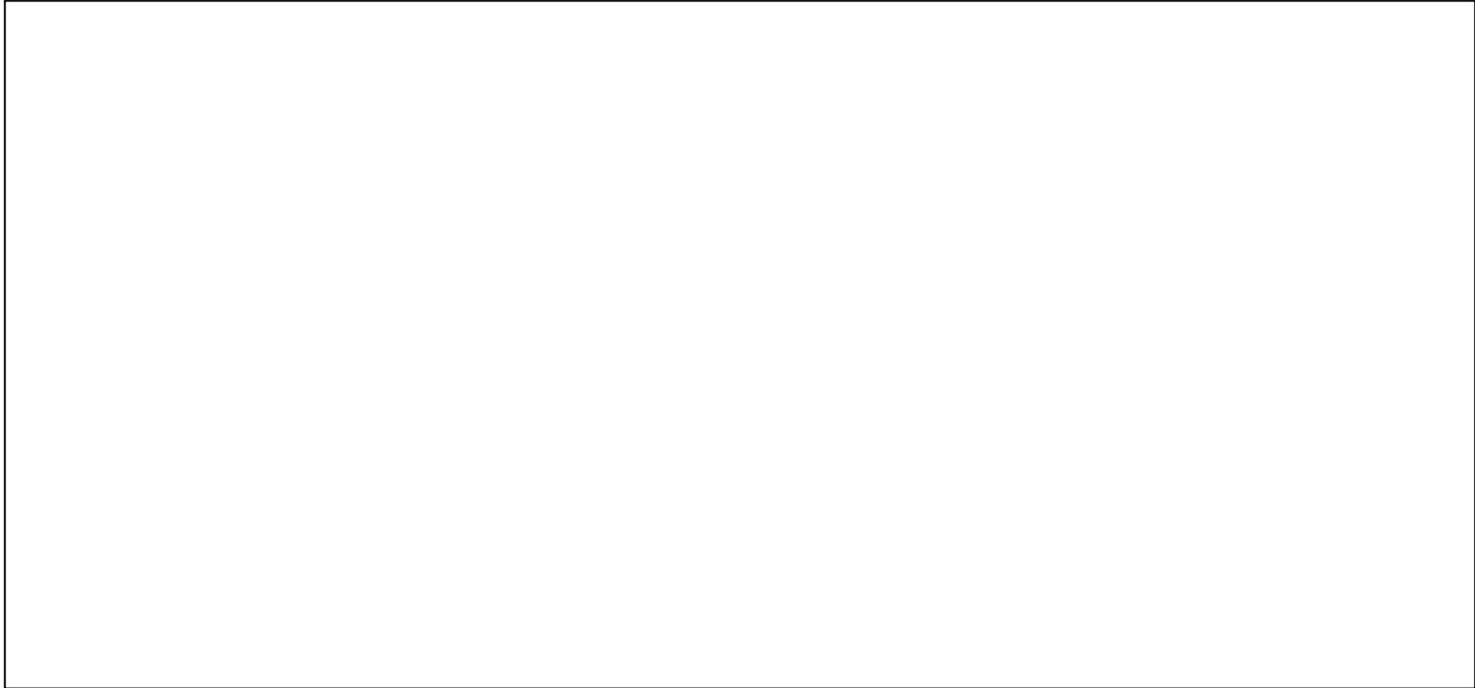
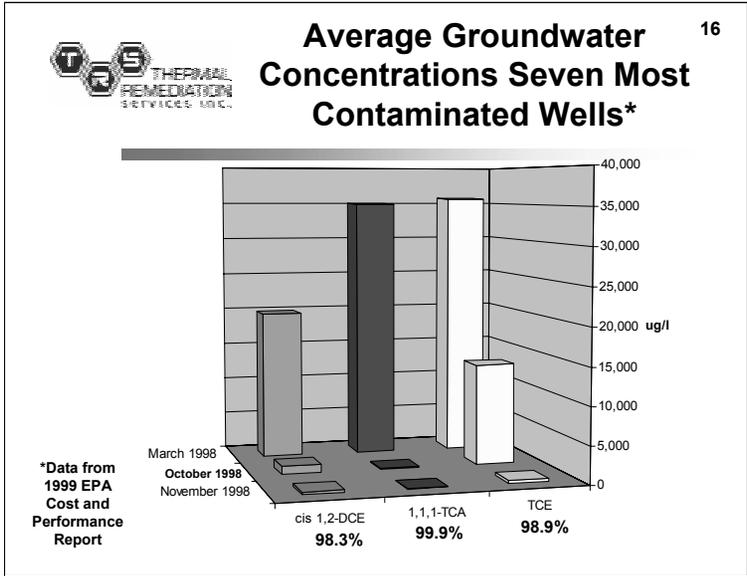
Results

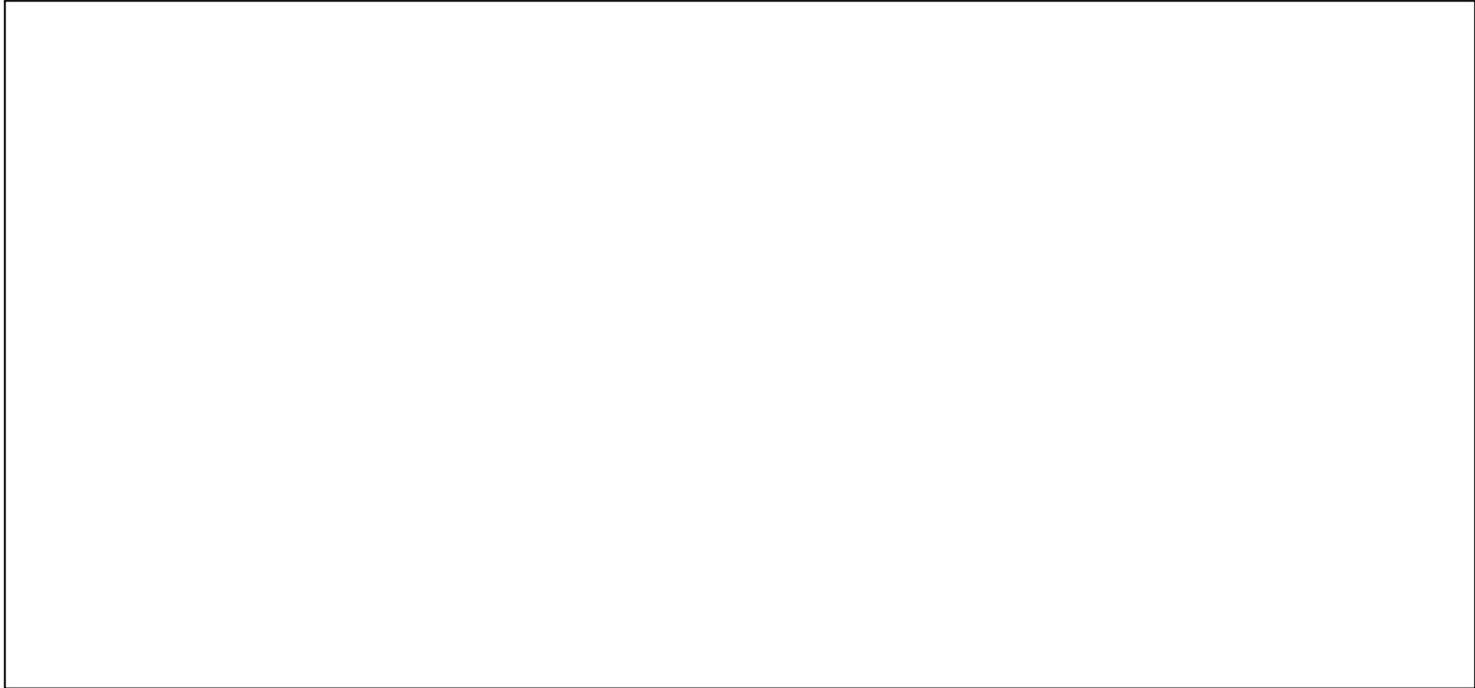
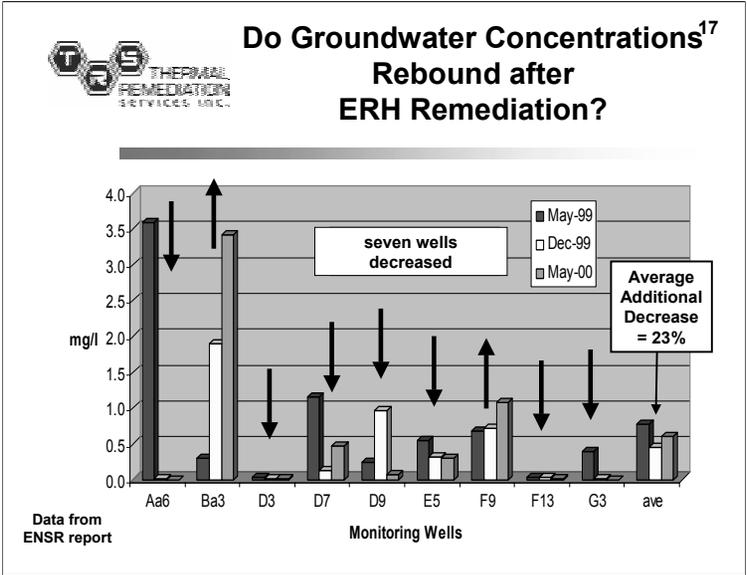
Tier III levels by late November 1998;
the site is now closed

>15,000 pounds of VOCs removed

*Data from 1999 EPA Cost and Performance Report









Polishing Mechanisms

18

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 Cleanup¹⁹ Cost & Performance Data*

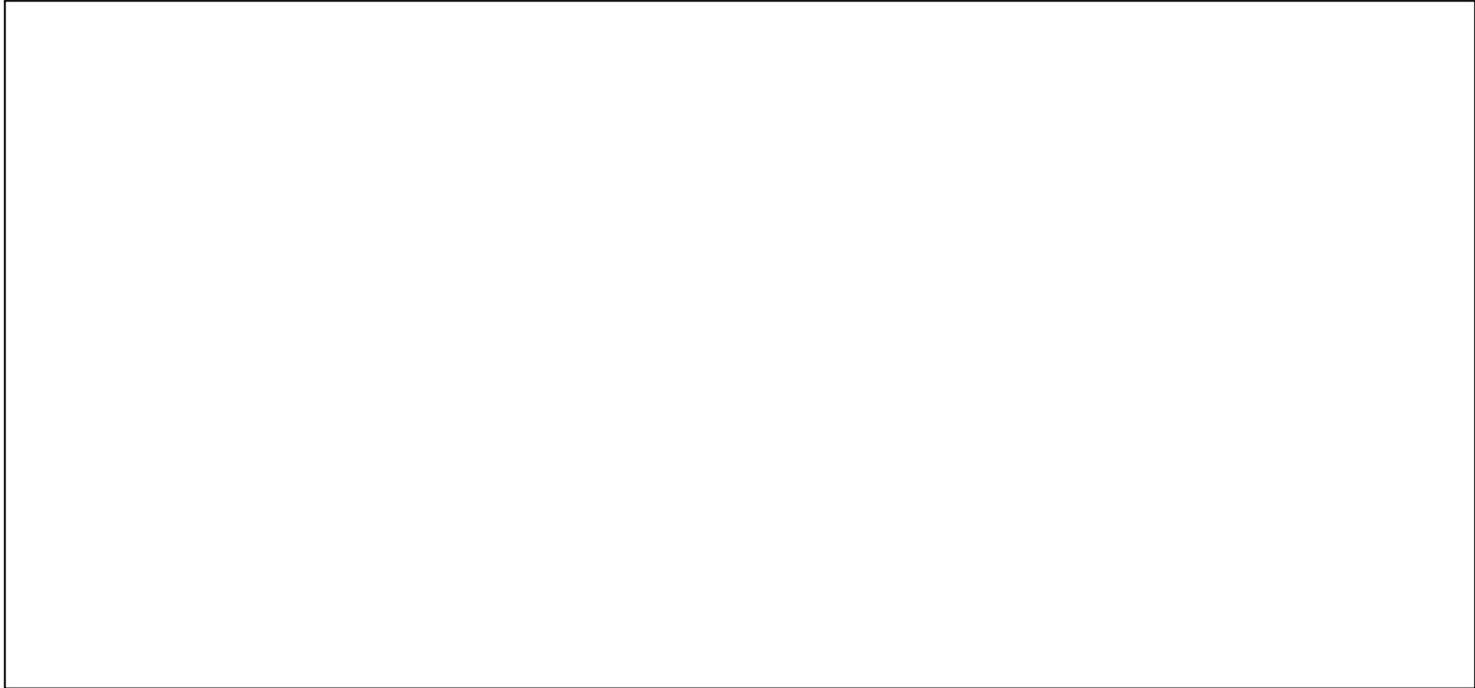
Effectiveness

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 20



Photo
Courtesy of
URS





ERH Remediation Beneath²¹ Air Force Plant Four

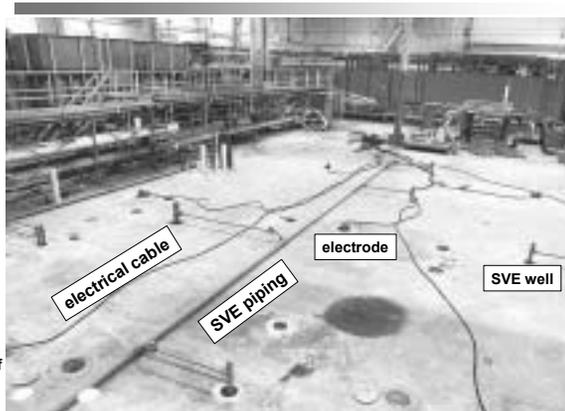
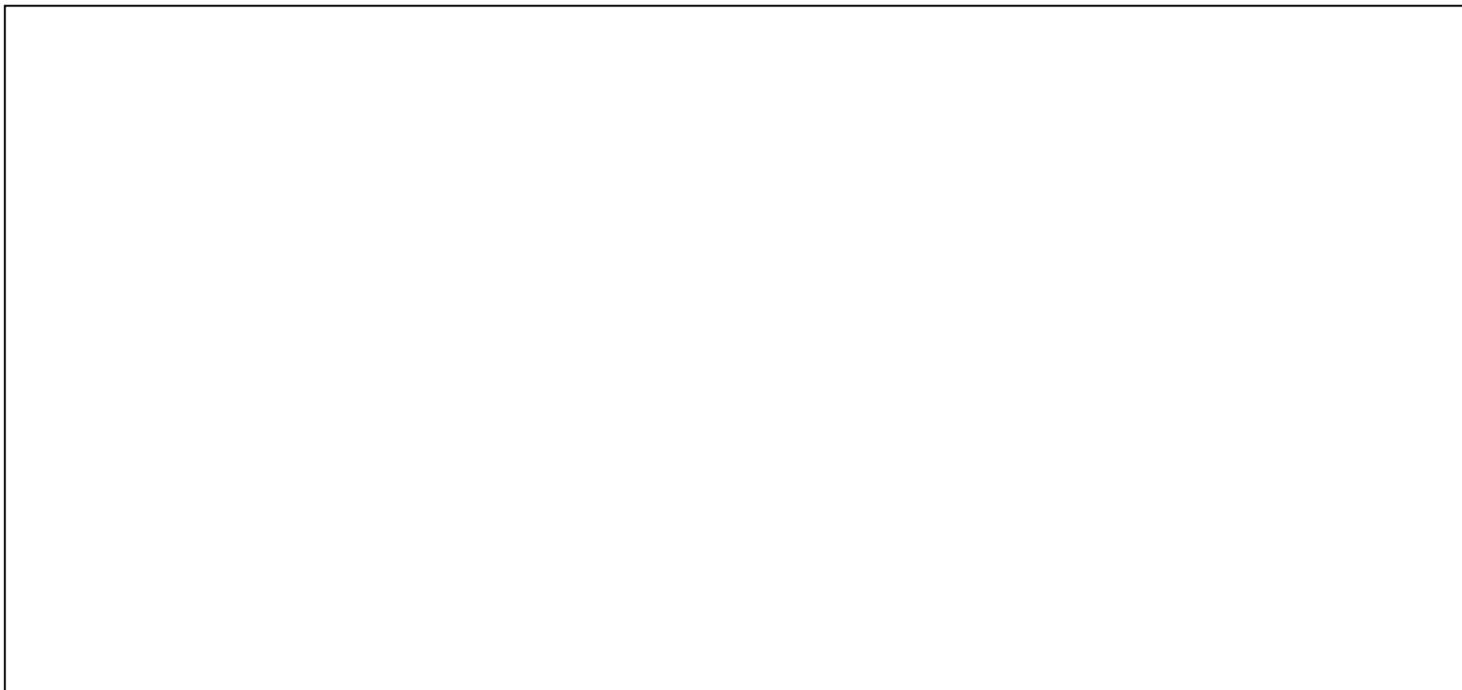


Photo
Courtesy of
URS

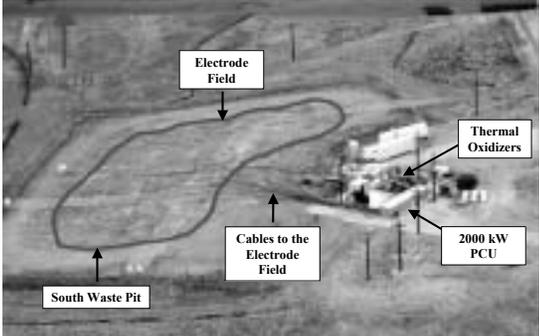


22



THERMAL
REMEDICATION
SERVICES, INC.

Lowry Landfill System Layout



Electrode
Field

Thermal
Oxidizers

2000 kW
PCU

Cables to the
Electrode
Field

South Waste Pit

The image is an aerial photograph showing the layout of the Lowry Landfill System. It features several key components labeled with text boxes and arrows: a large, irregularly shaped area labeled 'Electrode Field' in the upper center; a cluster of industrial buildings labeled 'Thermal Oxidizers' on the right; a power unit labeled '2000 kW PCU' below the thermal oxidizers; a network of lines labeled 'Cables to the Electrode Field' connecting the power unit to the electrode field; and a rectangular area in the lower left labeled 'South Waste Pit'.

