In Situ Thermal Approaches to NAPL Remediation for RCRA Corrective Action

Jim Cummings

OSRTI/OSWER/USEPA

Why *In Situ* Treatment?

- Avoid cost/risk of excavation/transportation
- Address contamination not readily amenable to excavation
  - Beneath buildings/structure
  - Beneath water table
  - At Depth

Beneficial Effects of Increased Temperature

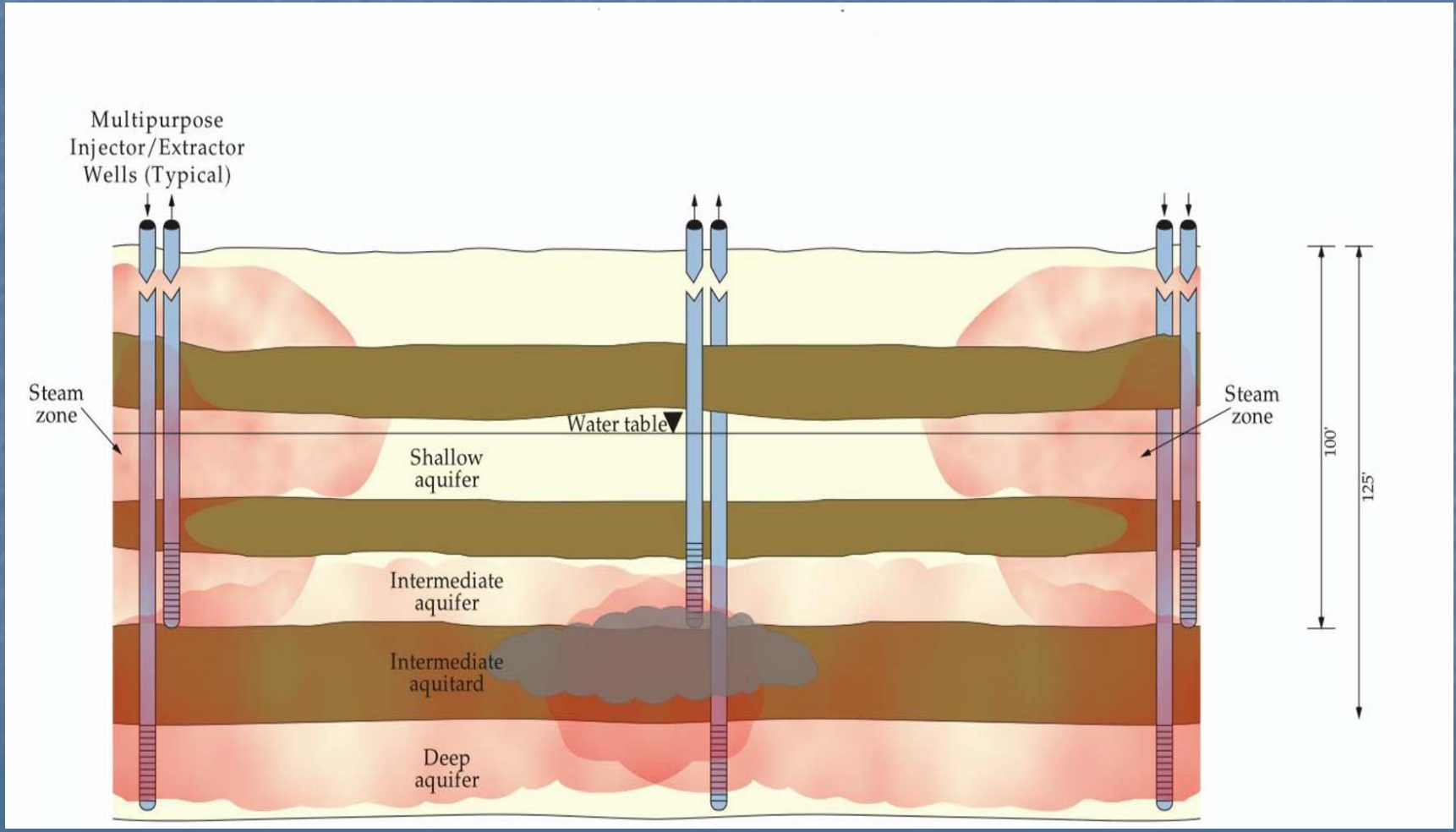
- Increased Volatility
- Reduced Viscosity
- (Slightly) Increased Solubility
- Mixture of Water and Contaminants boil at lower temperature than normal contaminant boiling point
- Increased hydrolysis rates
- Thermal processes less affected by heterogeneity

Heating Approaches

- Steam Enhanced Extraction (SEE)
- Electrical Resistive Heating (ERH)
- Thermal Conductive Heating/In Situ Thermal Desorption)ISTD

STEAM ENHANCED EXTRACTION (SEE)

Steam Injection Cross-Section – Visalia, Ca Pole Yard NPL Site



Visalia 1995-97: *1.2M lb Creosote Removed*

- A yield equivalent to 3500 years of pump-and-treat

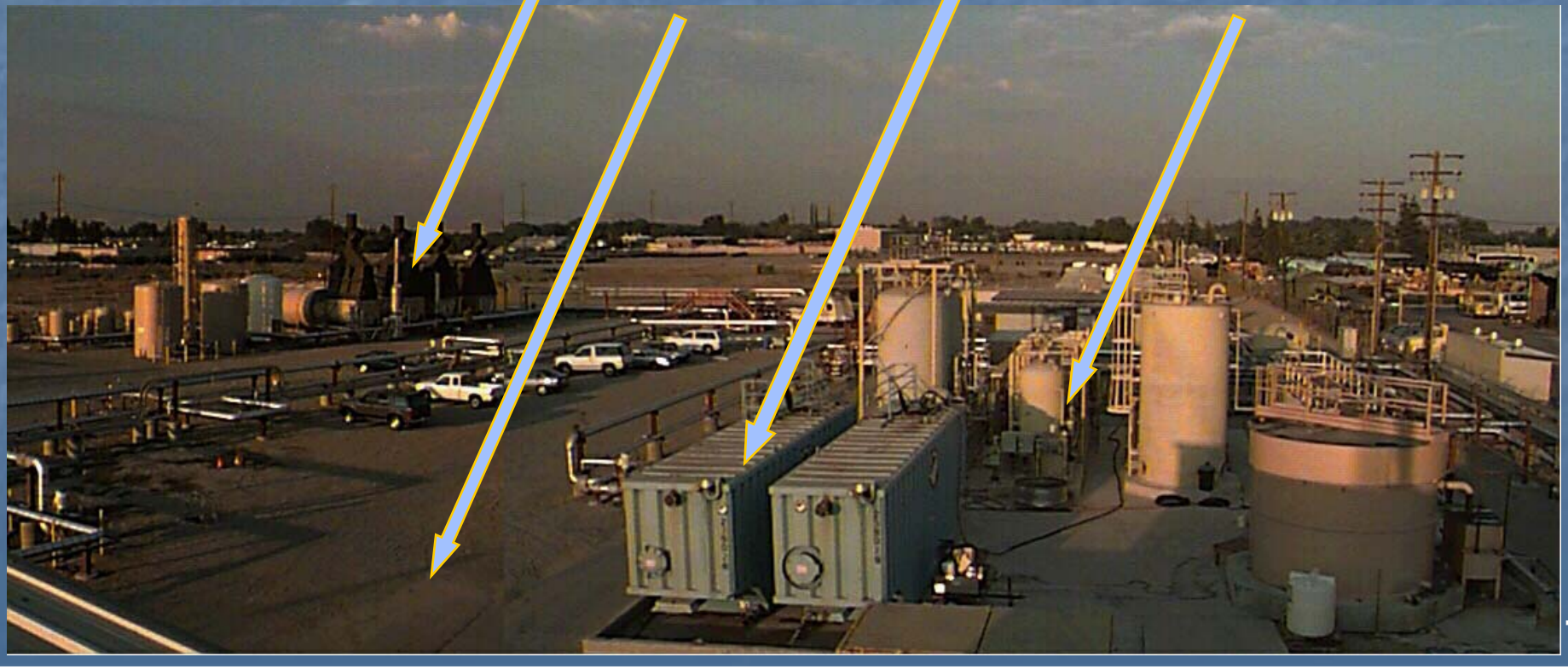
Prior to steam injection the removal rate was approximately 10 lb per week

204,000 lb
Vapor Hydrocarbon
Burned In Boilers

607,000 lb
Free Product
LNAPL & DNAPL

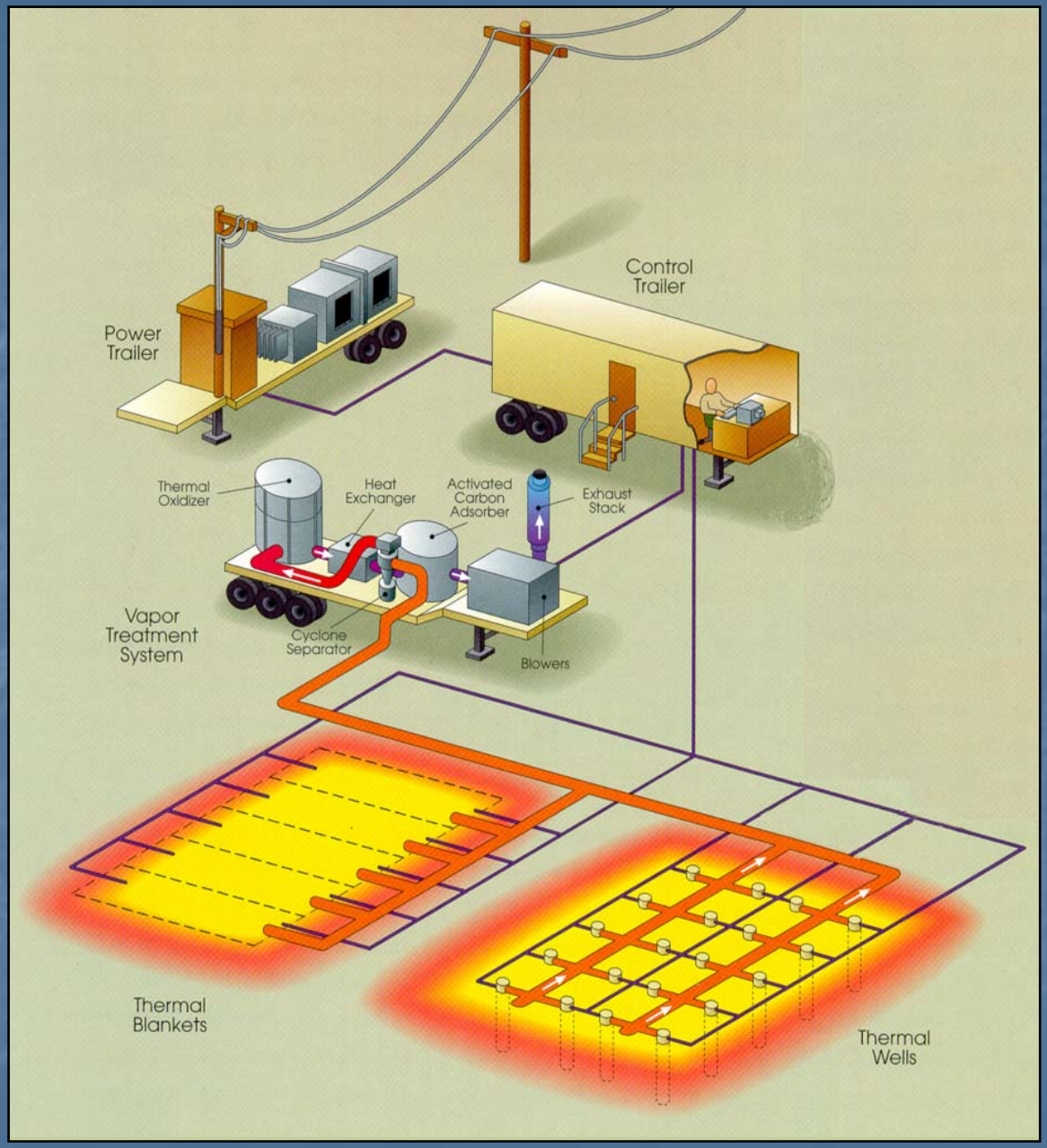
210,000 lb
In Situ Destruction
(Removed CO_2)

195,000 lb
Dissolved Hydrocarbon
Activated Carbon Filtration

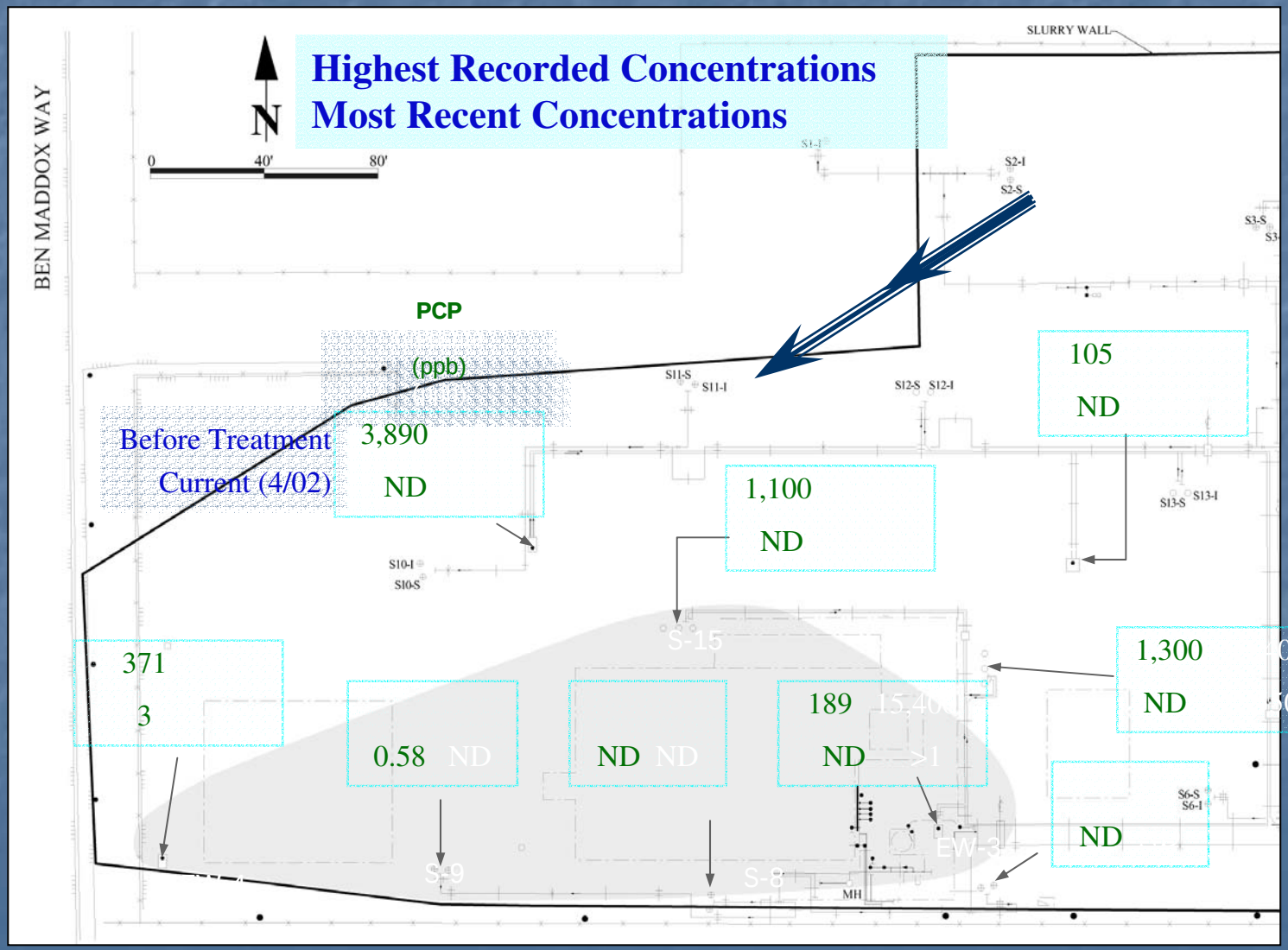


ISTD Processes

- Thermal Conduction into Soil
- Vaporization of Fluids and Contaminants within Soil
- Collection of Vapors
- In-Situ Oxidation and Pyrolysis - >95-99% In-Situ Destruction
- Aboveground Treatment of Vapors (may be simpler than illustrated)



Visalia Progress Groundwater Quality - Pentachlorophenol & Creosote

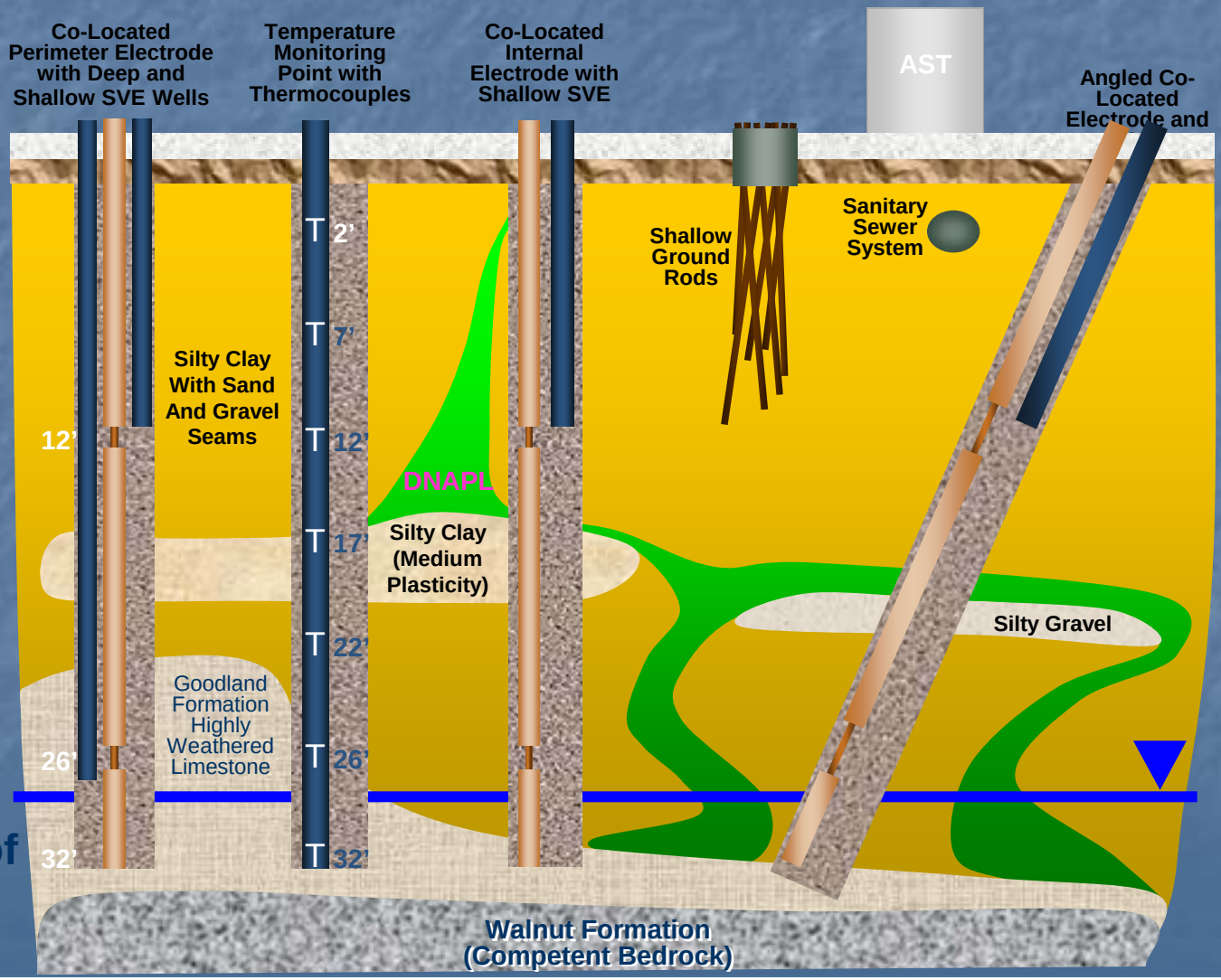


Costs at Visalia

- Total Project Cost - $21.5 million 1996 through mid-2001
- Unit Cost per Cubic Yard of Soil Treated
  - Actual Costs $57
  - With Lessons Learned $38
- Comparative Cost per Gallon of Creosote Removed
  - Pump and Treat $26,000
  - Steam $130
- Estimated Time to Remove 1.2 Million Pounds of Creosote
  - Pump and Treat 3,250 years
  - Steam 3 years

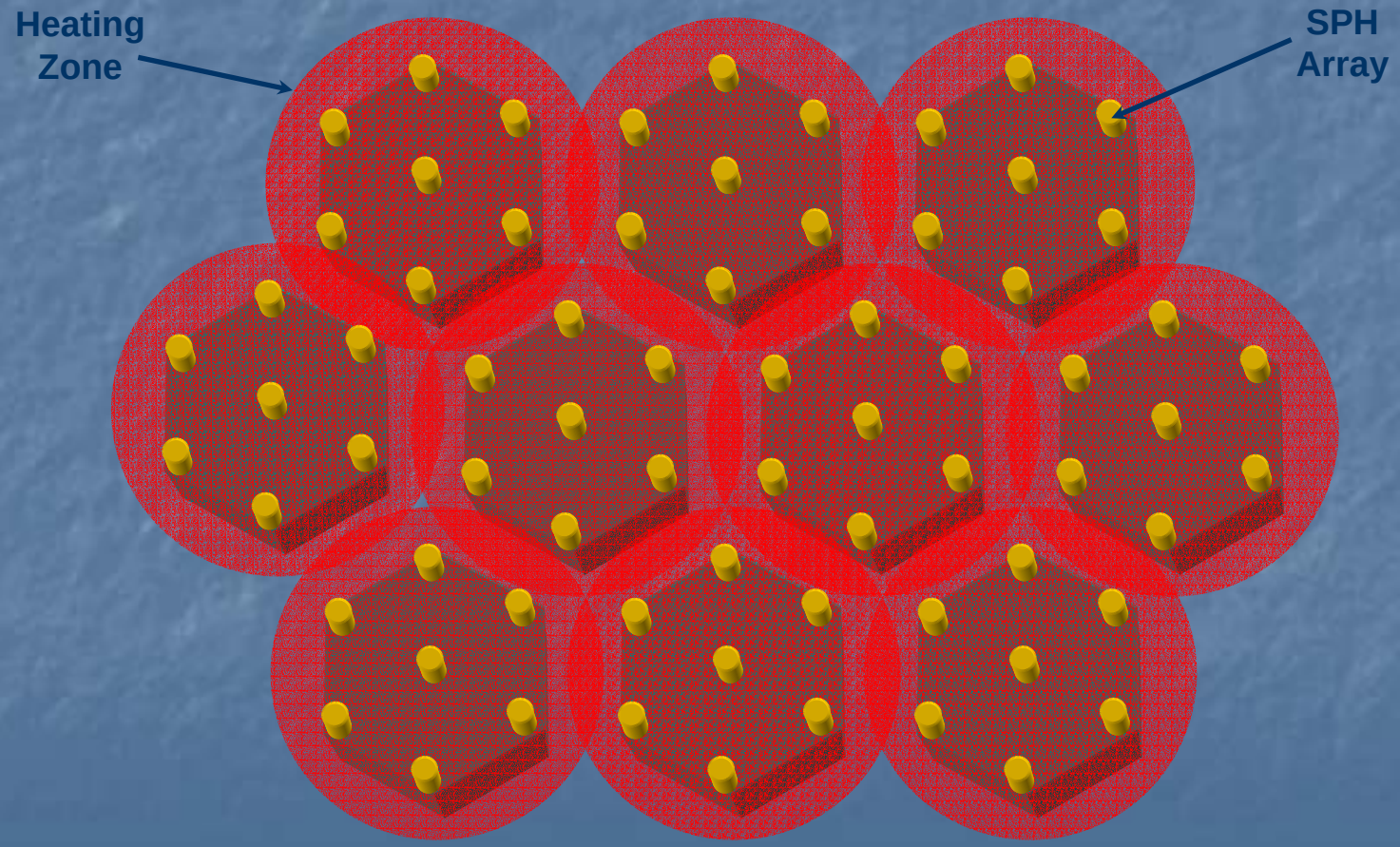
ELECTRICAL RESISTIVE HEATING (ERH)

Full-Scale ERH Subsurface X-Section



Courtesy of URS

Full-Scale Implementation Multiple Arrays



ERH - TCE DNAPL Remediation
Air Force Plant Four
Fort Worth, Texas

Photo Courtesy of URS

Full-Scale ERH at AF Plant 4

- 1/2 acre area inside/outside of Bldg. 181 -manufacturing opns 24/7
- 70 electrodes and co-located Vapor Recovery wells in and around existing tanks/ piping/equipment (32° angles)
- Heterogeneous silt, clay and gravel with a highly weathered limestone, competent bedrock at 32 ft bg
- Groundwater at 27 ft bg
- ERH operations May to Aug 2002; reduced – Dec '02
- Goal – Avg 90% reduction based on a 95% UCL

Angled Electrode Boring

Courtesy of URS

ERH Remediation Beneath Air Force Plant Four

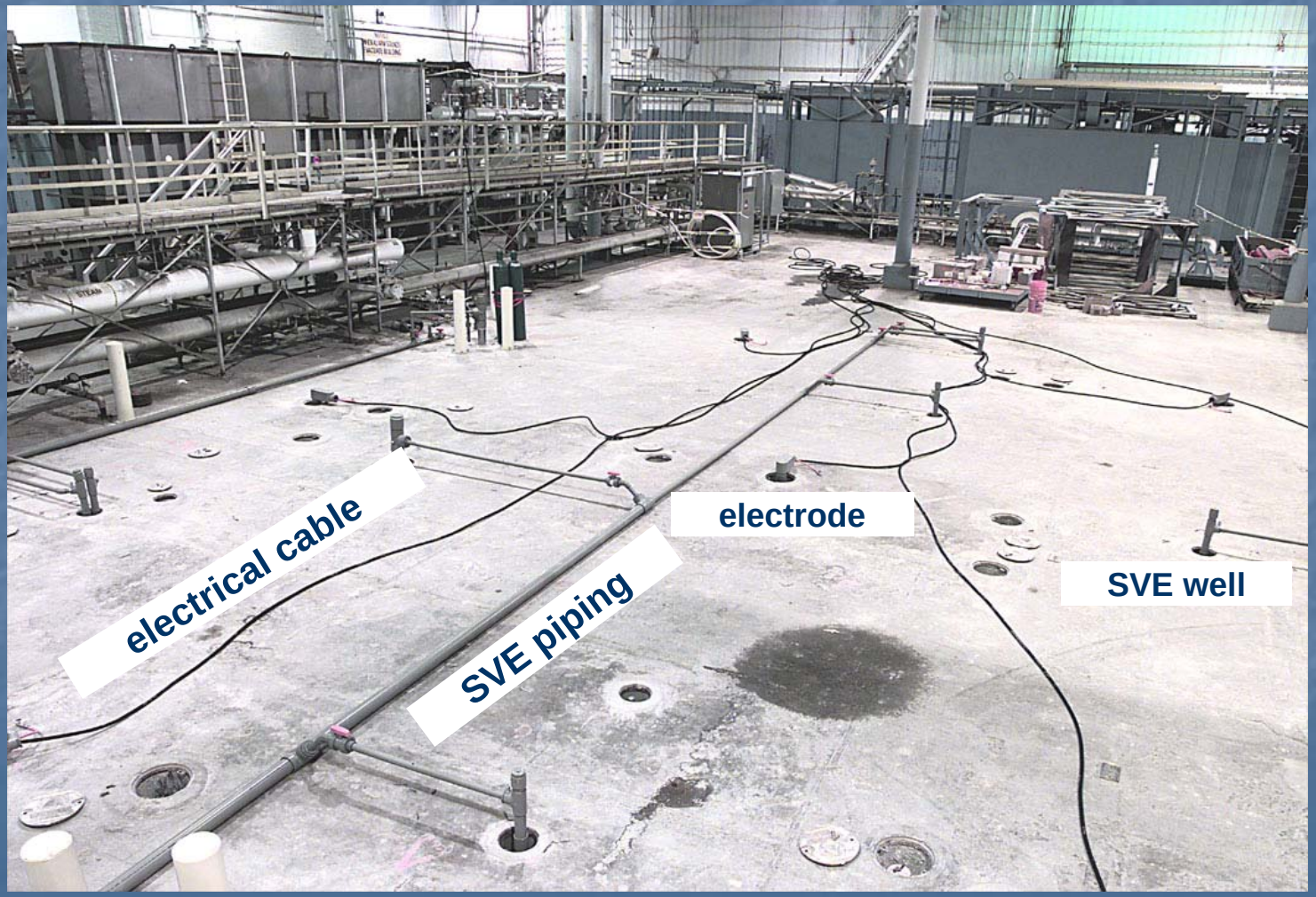


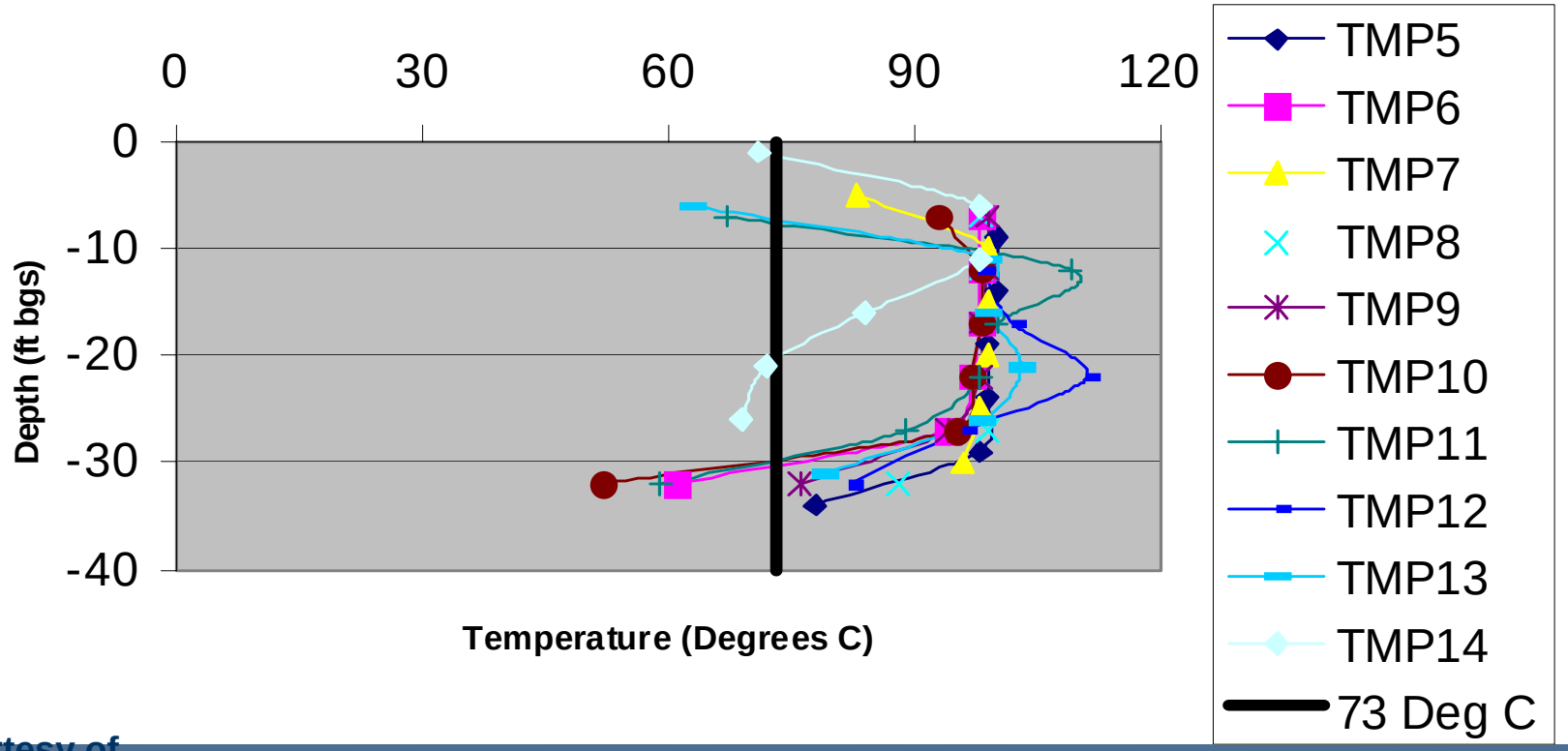
Photo Courtesy of URS

Continuous Indoor Air Monitoring

- INNOVA System sampled air for TCE every 5 minutes
- Would shutdown ERH system if TCE >3 ppm
- Online remote monitoring
- Never exceeded background TCE concentrations inside Bldg. 181

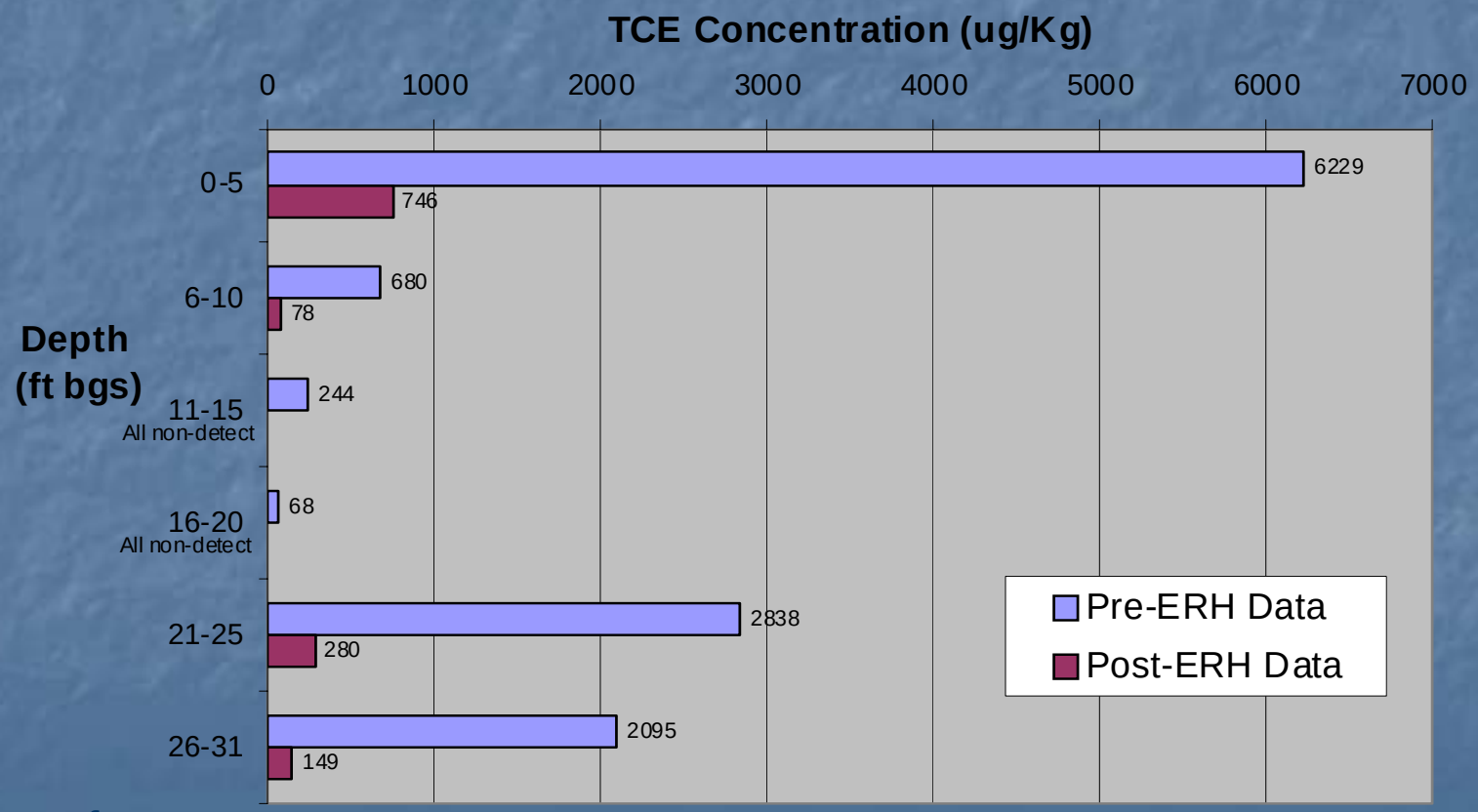
Courtesy of URS

Maximum Subsurface Temperatures Achieved



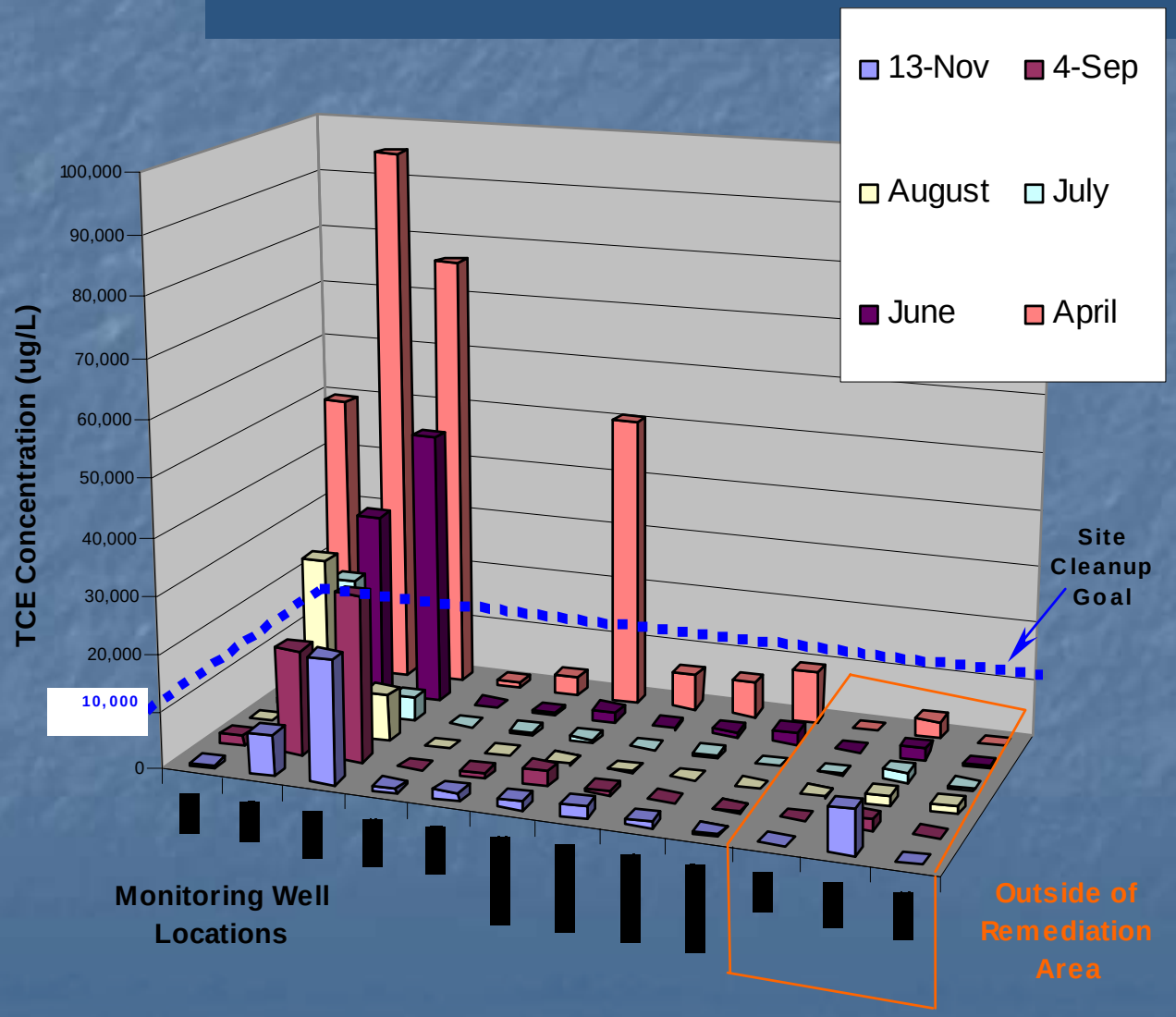
Courtesy of URS

Pre and Post Soil Data with Depth



Courtesy of URS

Final TCE Concentrations in Groundwater



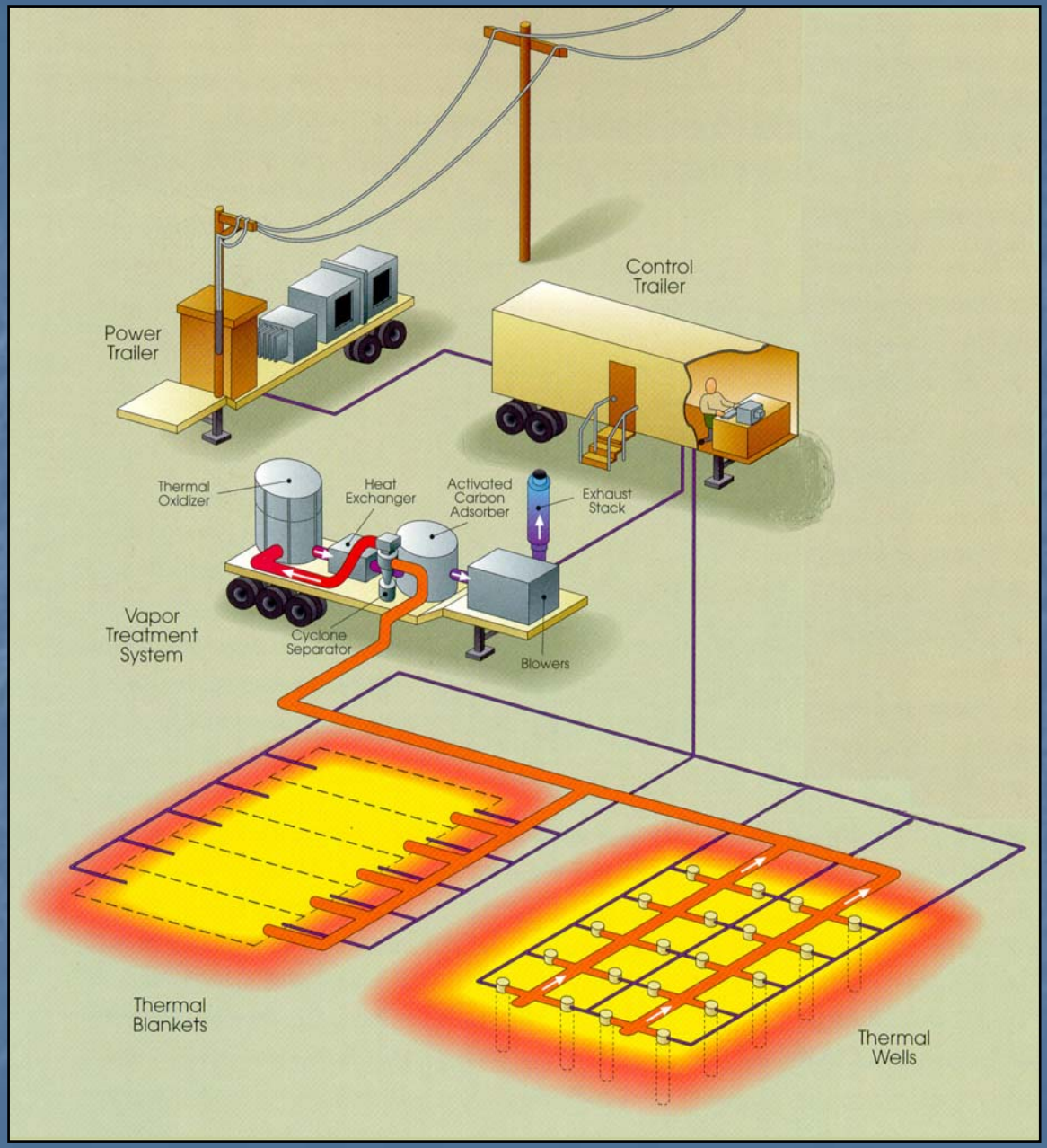
Results at AF Plant 4

- Area/Vol. treated: 22,000 sq. ft./27,400 c. yds
- Average weekly power input – 563 kW
- Recovered ~ 1,600 lbs. TCE
- Met GW goal following 4 months of opns - ~ 93% avg reduction in TCE GW conc.
- Met soil goal - 90% average reduction
- TCE levels never exceeded background in indoor breathing space
- No impacts on manufacturing opns
- $57 per cubic yard
- Evidence of heat enhanced biodegradation

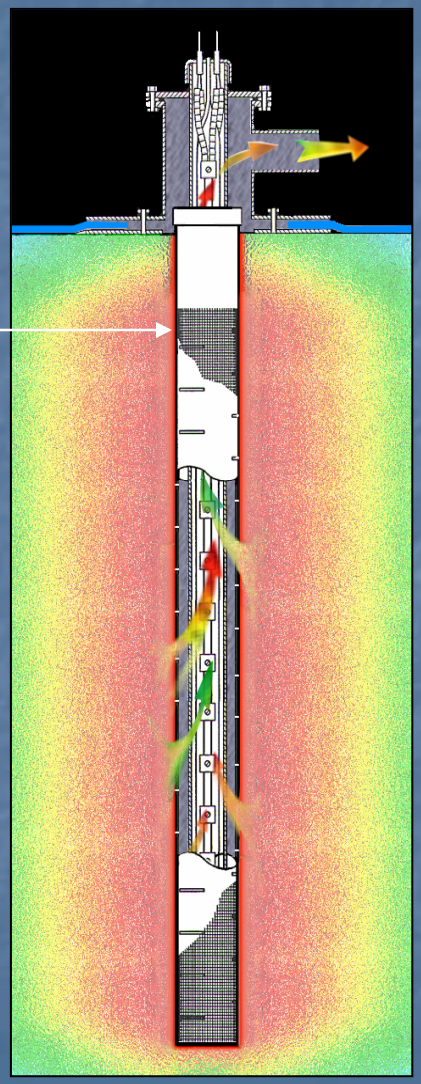
THERMAL CONDUCTIVE HEATING/IN SITU THERMAL DESORPTION (ISTD)

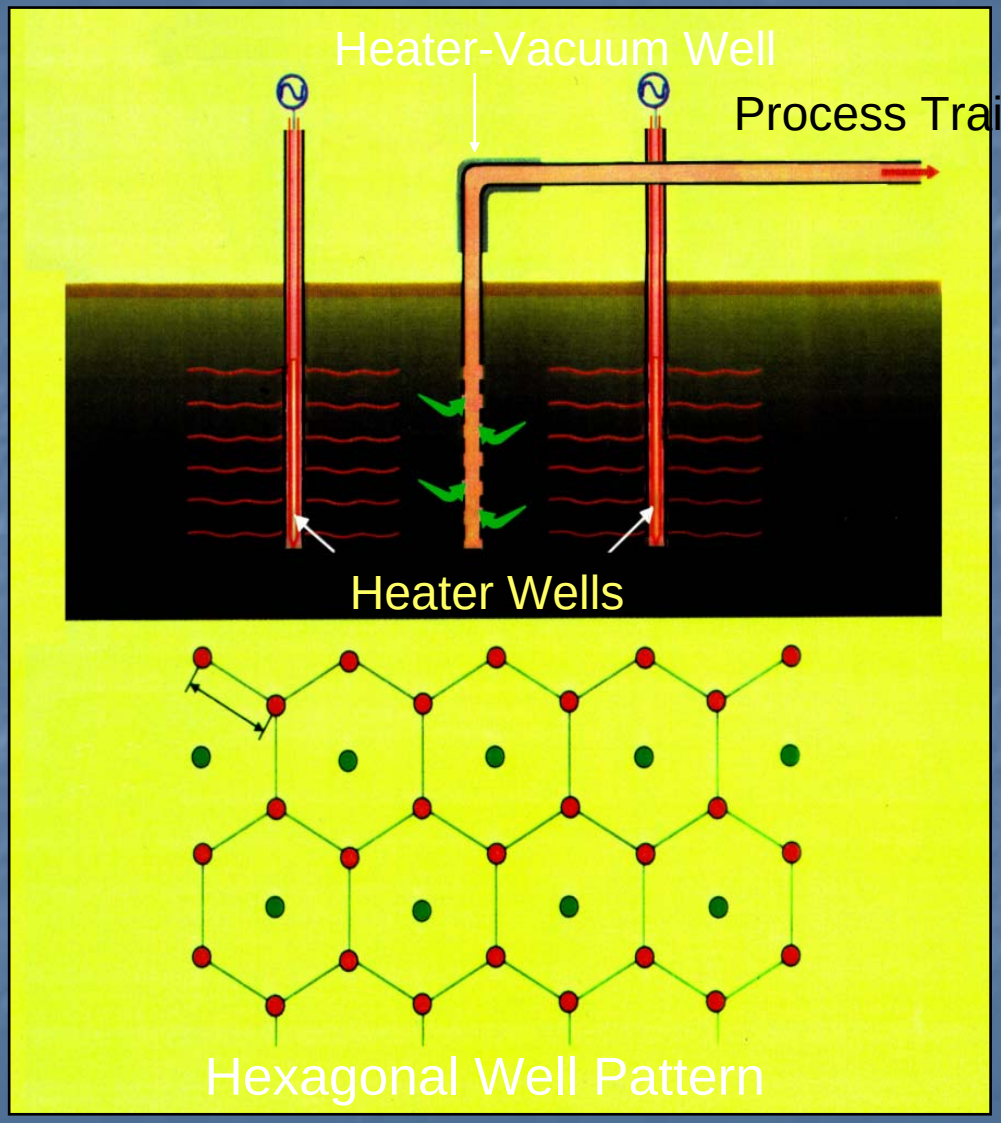
ISTD Processes

- Thermal Conduction into Soil
- Vaporization of Fluids and Contaminants within Soil
- Collection of Vapors
- In-Situ Oxidation and Pyrolysis - >95-99% In-Situ Destruction
- Aboveground Treatment of Vapors (may be simpler than illustrated)



ISTD: Simultaneous Application of Heat and Vacuum





S. Glens Falls, NY Drag Strip (PCBs)

Adjacent Residences, Portland, IN

ISTD Well Field

ISTD at Former Shell Bulk Storage Terminal, Eugene OR

ISTD at Eugene, OR (cont.)

- Maximum soil concentrations of 9,300 mg/kg (DRO), 3,500 mg/kg (gasoline); GW 1,300 µg/l (benzene);
  - as much as 7.9 ft of free product in monitoring wells.
  - Gravel layer 1-4', over silt to ~11-16' bgs.
- Project goals:
  - Removal of free product and benzene
  - Closure of site under Oregon DEQ RBCA UST program

Eugene, OR ISTD Project Results

- Free phase LNAPL removed from the 1-acre site
- Estimated 200,000 lbs of hydrocarbons removed and treated during 120-day heating
- Post-remediation soil and GW samples below the ODEQ's Tier 1 Risk-Based Concentrations:
  - Benzene concentrations in GW w/in treatment area reduced from 1,300 µg/L to ≤2.50 µg/L.
  - Post-treatment off-site GW samples below the analytical detection limit (i.e., <0.5 µg/L)
- Oregon DEQ issued a "No Further Action" letter for the site on March 14, 2000

Information Resources

- Jim Cummings
  - 703- 603-7197
  - cummings.james@epa.gov
- Database: *cluin.org/products/thermal*
- Archived web-based seminar: *cluin.org/studio/napl*