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McMillan-McGee Corp.

ET-DSP™ for In-Situ Remediation Under an Inhabited Residential Apartment Building

Bruce C. W. McGee, McMillan-McGee Corp.

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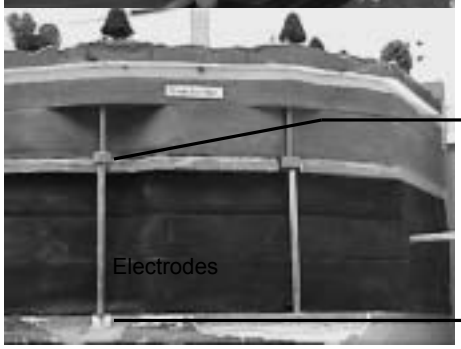
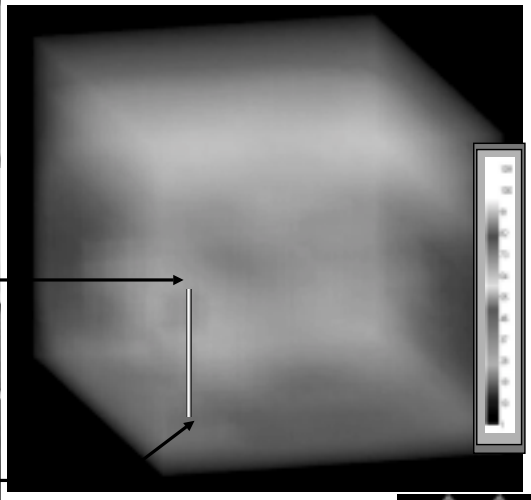
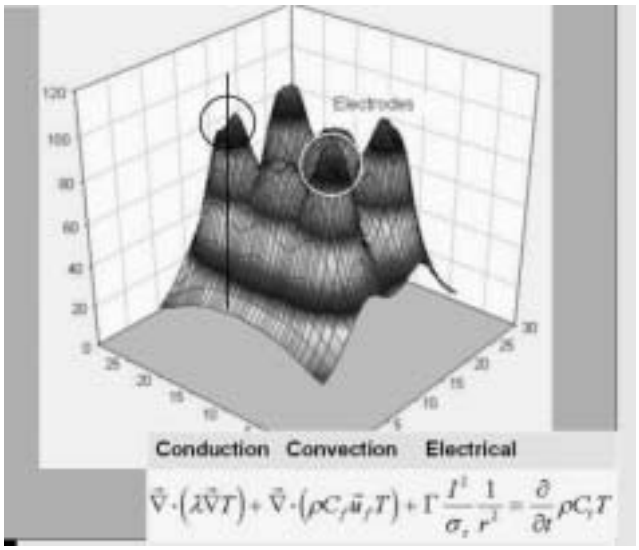
Electro-Thermal Dynamic Stripping Process: A Three Phase Electrical Soil Heating Strategy





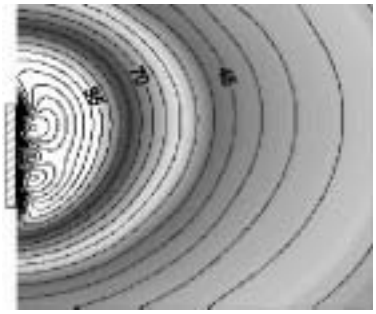
ET-DSP Heat Transfer Mechanisms

The heat is directed into the target volume from the electrode wells that are designed to balance the heat transfer mechanisms of electrical heating with convection to achieve rapid and uniform heating. Notice that heat flow outside the target volume has been minimized.



ET-DSP™: Electrode Design

ET-DSP™ Electrode



- ET-DSPTM has addressed this by circulating cooling water through the electrode, resulting in even resistive heating, and additional heating by convection.

Thermally Enhanced Remediation Mechanisms

- ***V*apourization** of volatile and semi-volatile organic compounds (*Dalton's Law of partial pressures*)
- ***D*ynamic Stripping** (*Henry's Law Constant*)
- ***S***olubility of PAH Increases With Temperature (remove more mass with the water phase).
- ***A*ccelerated Bioremediation** (*Thermophilic metabolism*).
- ***M*obility Improvement** (*Viscosity reduction and thermally enhanced absolute permeability*)
- ***T*hermal Hydrolysis** (*Arrhenius temperature rate.*)

Why Heat Helps

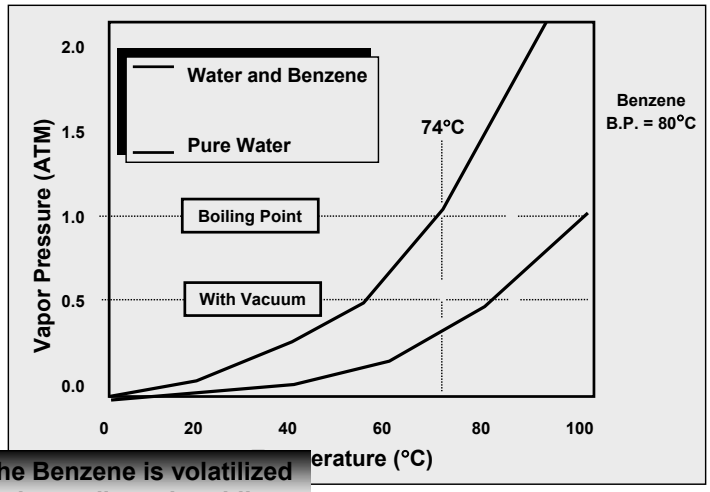
Thermal Characteristics of Contaminants

- Benzene has a high vapour pressure that increases exponentially with temperature.
- Henry's Law Constant for Benzene (air-water partitioning coefficient) increases by 15 to 20 times as temperatures rise from 10 to 100 degrees Celsius.
- The biodegradation rate of Benzene approximately doubles for every 10 °C increase in temperature.

Heat Will Help . . .

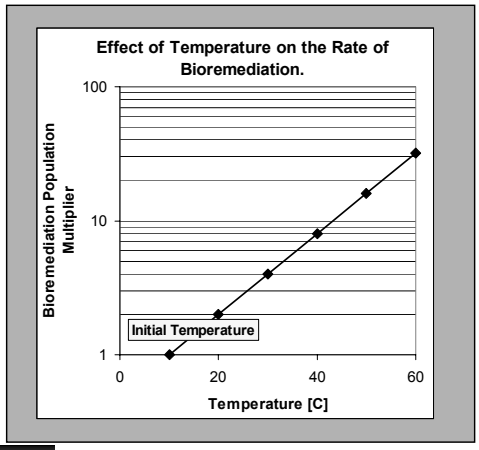
- **Vapourization**
- **Dynamic Vapour Stripping**
- **Accelerated Bioremediation**

Vapour Pressure-Temperature Relationship



Once the Benzene is volatilized it can be easily and rapidly recovered from the soil at multi-phase extraction wells.

Heat and Bioremediation



Once the soil is heated the rate of temperature decline is about ¼ °C per day resulting in a long duration of accelerated natural attenuation.

Source: "Analysis of Selected Enhancements for Soil Vapor Extraction", EPA Report EPA-542-R-97-007

Why Electrical Heating

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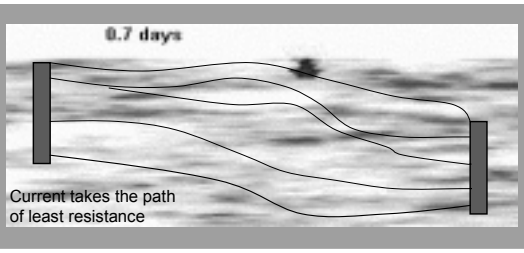
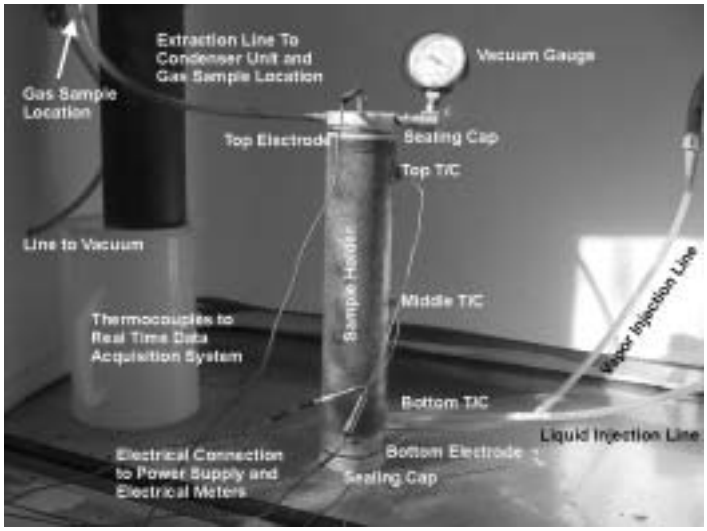
- ***C***urrent can be focused in the soils so little of the energy is wasted. The conduction path is the soil and is where energy dissipation occurs.
- ***G***etting heat into the formation is not limited by depth or the permeability of the soil and during heating permeability is created through a process of micro-fracturing (thermal expansion and high pore pressure release).
- ***S***afe and simply technology to operate and integrates seamlessly with other conventional in-situ remediation technologies such as SVE and bioremediation.
- ***F***or L-DNAPLS, the success of the remediation of the miscible NAPL does not depend on knowing the detailed distribution of the NAPL in-situ.



The energy cost to electrically heat a m^3 of contaminated soil is about the same as the cost of fuel used by a truck to haul it away.

Bench Scale Investigation



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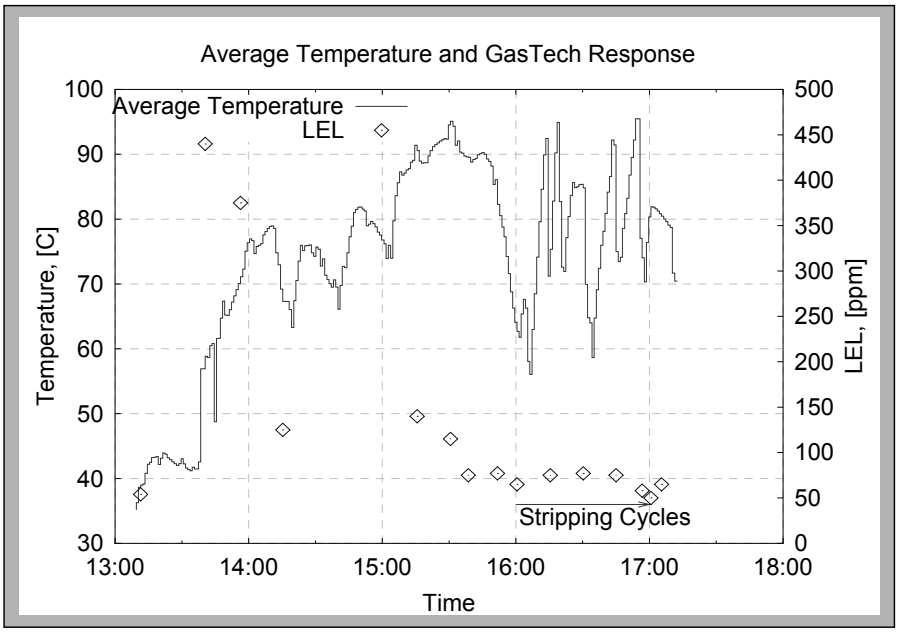
Average Temperature and GasTech Response
Average Temperature
LEL
Stripping Cycles
Temperature, [C]
LEL, [ppm]
Time
100
90
80
70
60
50
40
30
500
450
400
350
300
250
200
150
100
50
0
13:00
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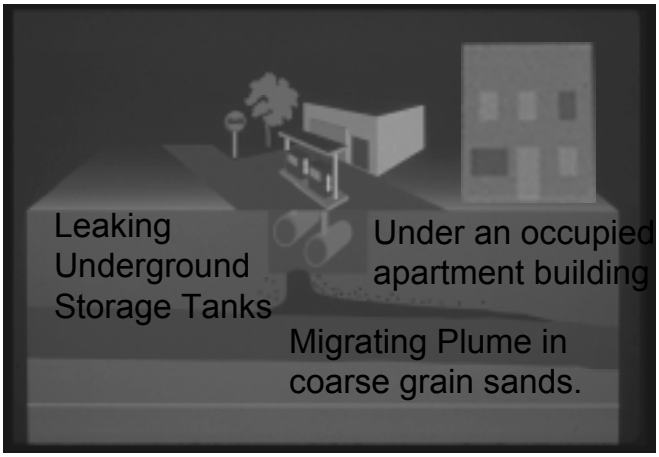
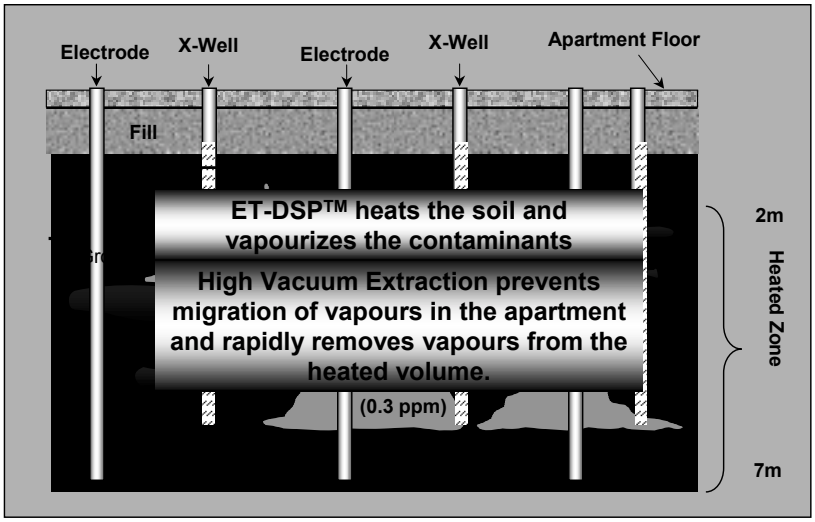
The Problem

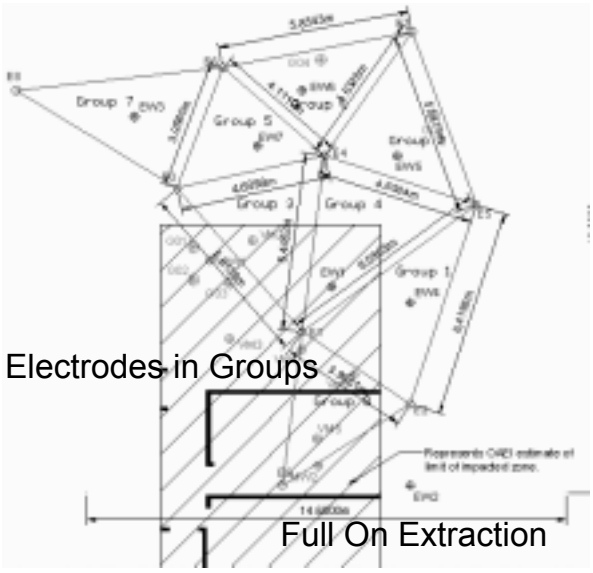


Cleanup criteria is 0.30 ppm benzene

Concept of the Solution:
ET-DSP™ with High Vacuum Extraction



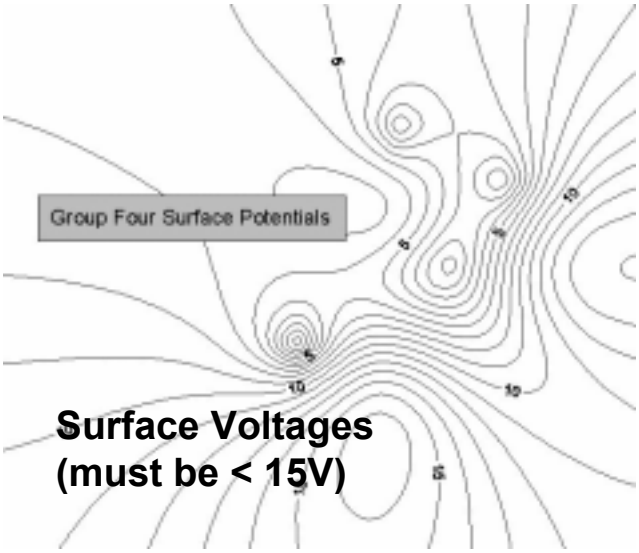
Implementation of the Solution



Electrodes in Groups

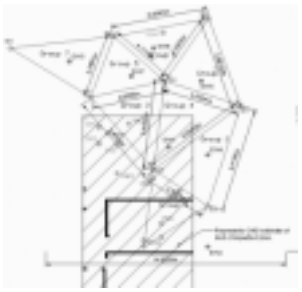
Full On Extraction

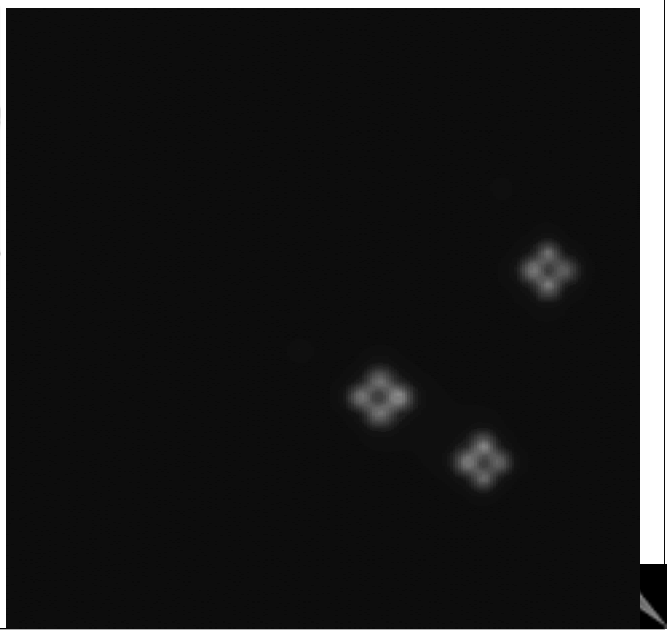
Modeling of the Solution: The Grounding



Surface Voltages (must be < 15V)

Modeling of the Solution: The Process





Drilling Electrodes and Extraction Wells

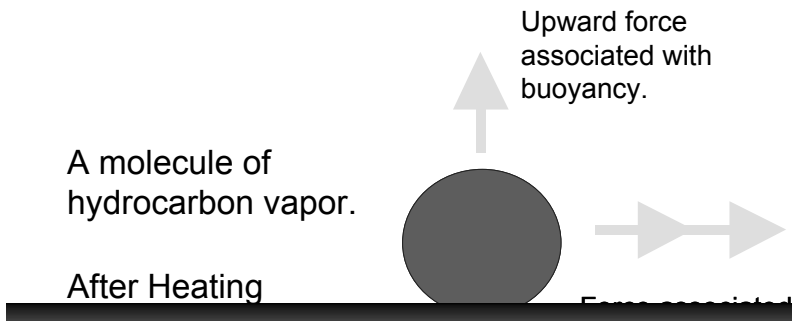
- In the apartment.
- In tight spaces.
- On the front lawn.

In the Apartment

In Tight Spaces

And … on the Front Lawn

Why High Vacuum Extraction (HVE).



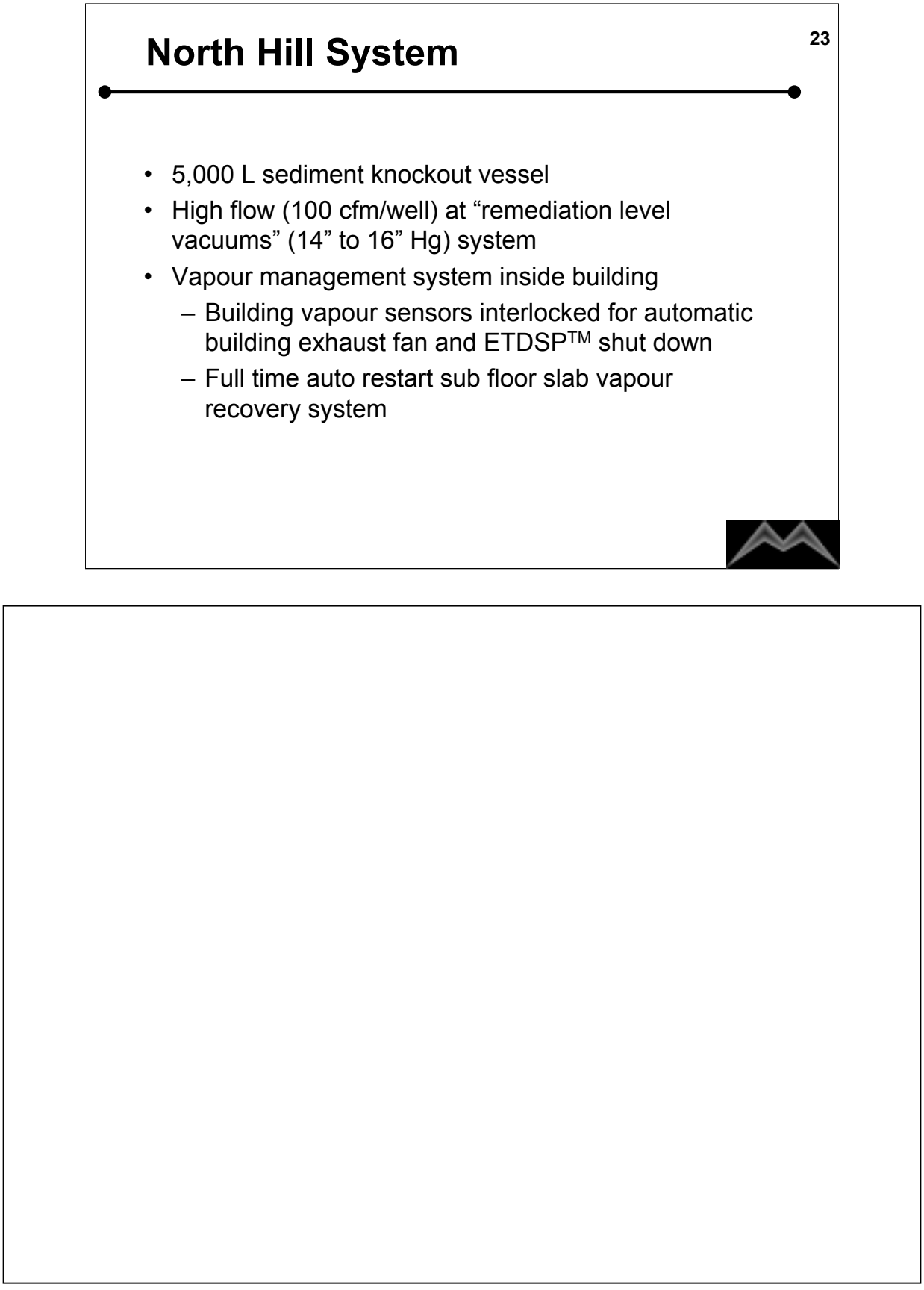
The radius of capture is usually much less than the radius of influence and therefore extraction wells are placed closer together and a HVE System is used to prevent vertical migration of the vapors and redistribution of contaminants.

Multi-Phase Extraction System

1. Well designed based on site-specific characteristics determined during pilot testing activities
2. Sized to handle 10 to 25% more air flow at the desired vacuums than initially calculated
3. Critical to be equipped with a suitably sized silt knockout system with clogging resistant liquid transfer piping
4. Quite running and low overall maintenance
5. Sediment friendly water treatment system

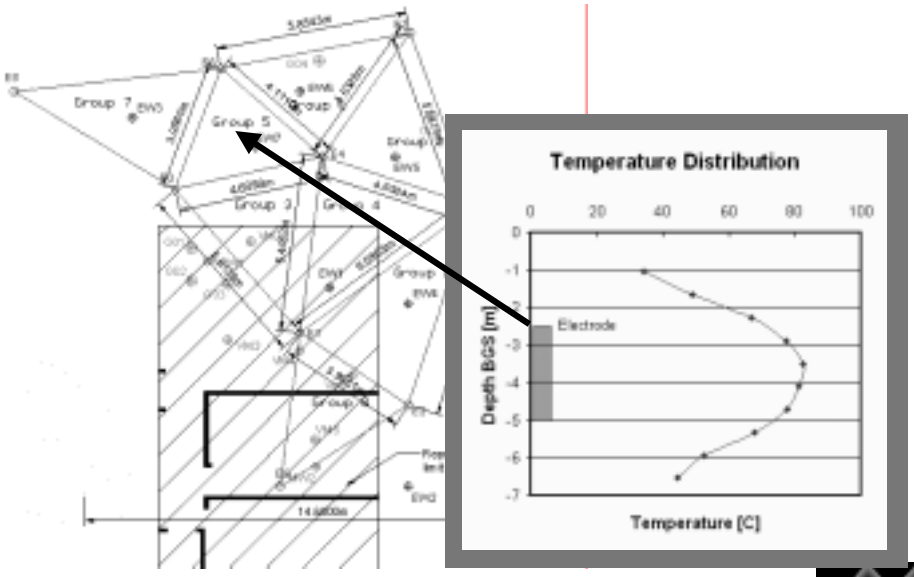
North Hill System

- 5,000 L sediment knockout vessel
- High flow (100 cfm/well) at “remediation level vacuums” (14” to 16” Hg) system
- Vapour management system inside building
  - Building vapour sensors interlocked for automatic building exhaust fan and ETDSP™ shut down
  - Full time auto restart sub floor slab vapour recovery system

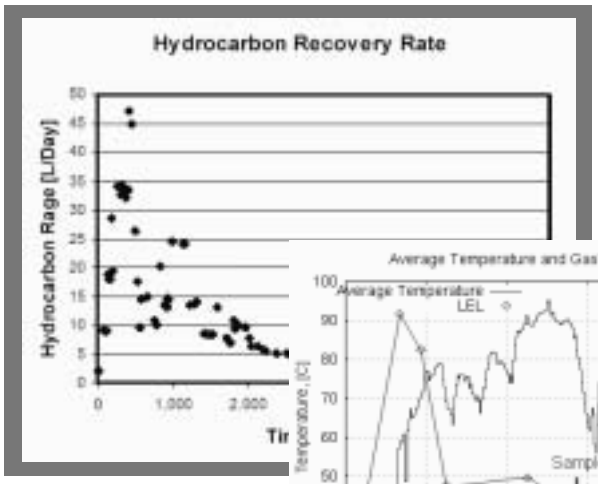


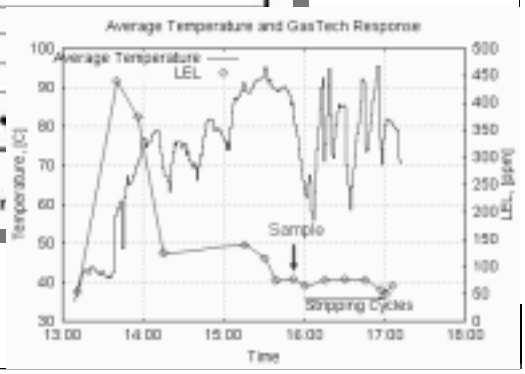
High Vacuum Extraction System

Results: Temperature Distribution

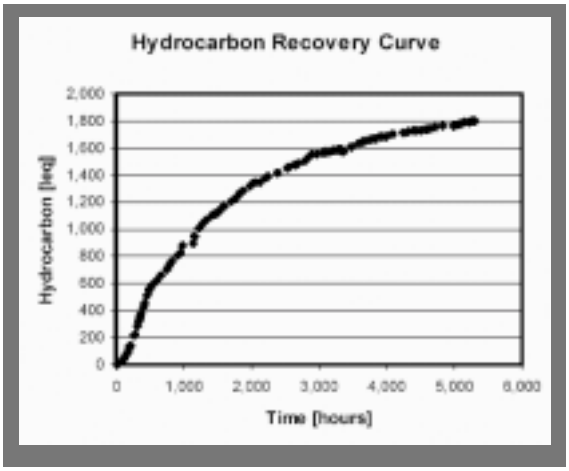


Results: Hydrocarbon Recovery Rate





Results: Hydrocarbon Recovery Curve



Results

- Non-detect on all samples
- All In Costs: $US 55.45 per yd^3
- ET-DSP™ and Power Costs: $US 18.09 per yd^3

Thanks to Shell for permission to give this presentation and Sequoia Environmental for assistance with this paper.