# MGP Site Remediation Completed by In Situ Gas Thermal Remediation

GTR | Gas Thermal Remediation

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GEO | Environmental Remediation Company

# Outline of Presentation

(1) Introduction via Examples

- Case 1: MGP site remediation (**In-Situ**)
- Case 2: TPH-d/highly chlorinated contamination site remediation (**Ex-Situ**)

(2) Further Discussion

- Advantages of GTR
- Challenges of GTR

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# Example 1: Site Information


Looking East at Basque Hotel Restaurant (Urroz Property)

Looking East at Basque Hotel Restaurant Parking Lot

Looking East at Office Building (Ford Property)

Looking Southeast A&R Auto Sales Lot (Ford Property)

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# Example 1: Pilot Test Site

- **Area:** 400 $ft^2$ * 20 ft bgs
  - **Constituents and magnitude of impacts consistent with remaining portions of the site**
- **COCs:** MGP waste, Benzo(a)Pyrene or equivalent, Naphthalene, Chrysene, TPH, and other VOCs
- **Lithology:** Silty sand and clay, highly heterogeneous
- **Setting:** Dirt/Gravel Parking Lot
- **Utilities Used:** Natural Gas and temporary electrical connection

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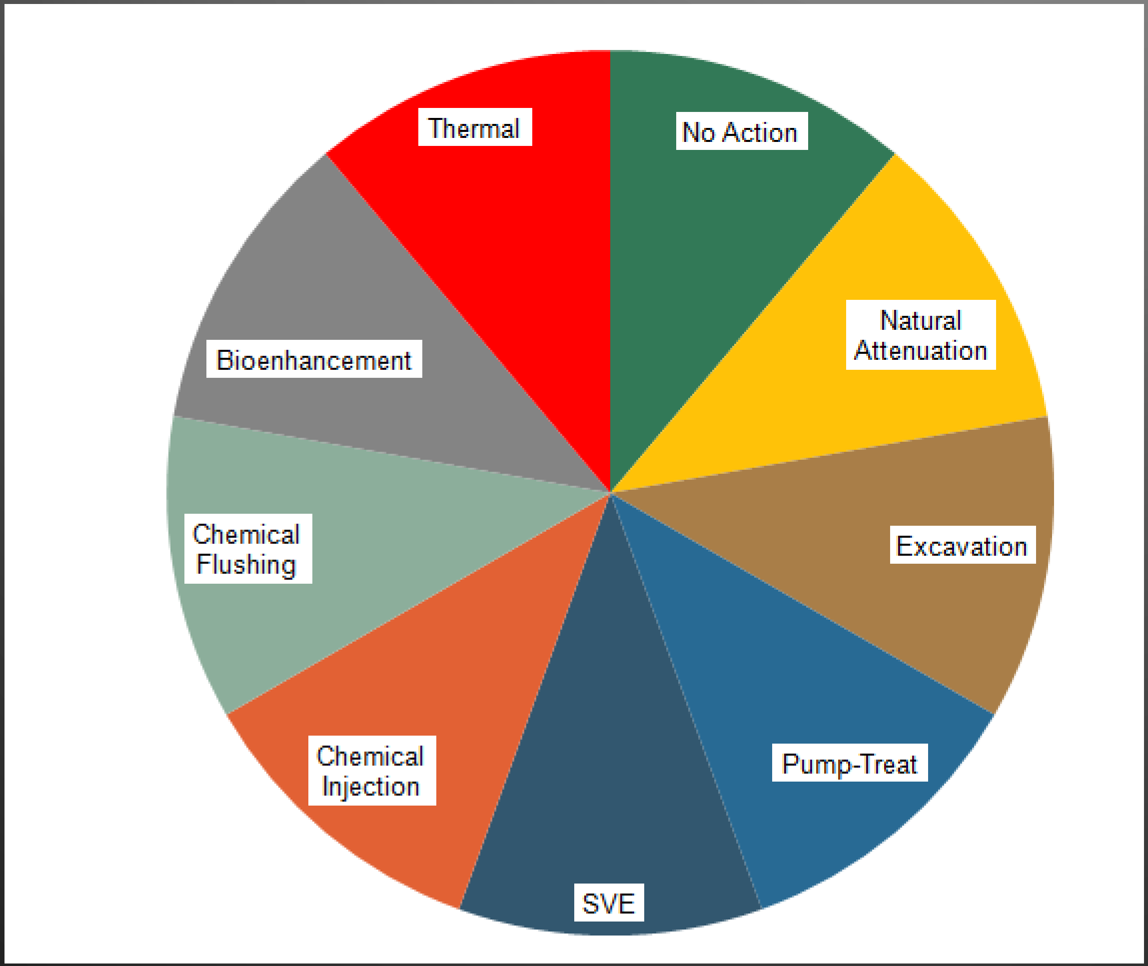
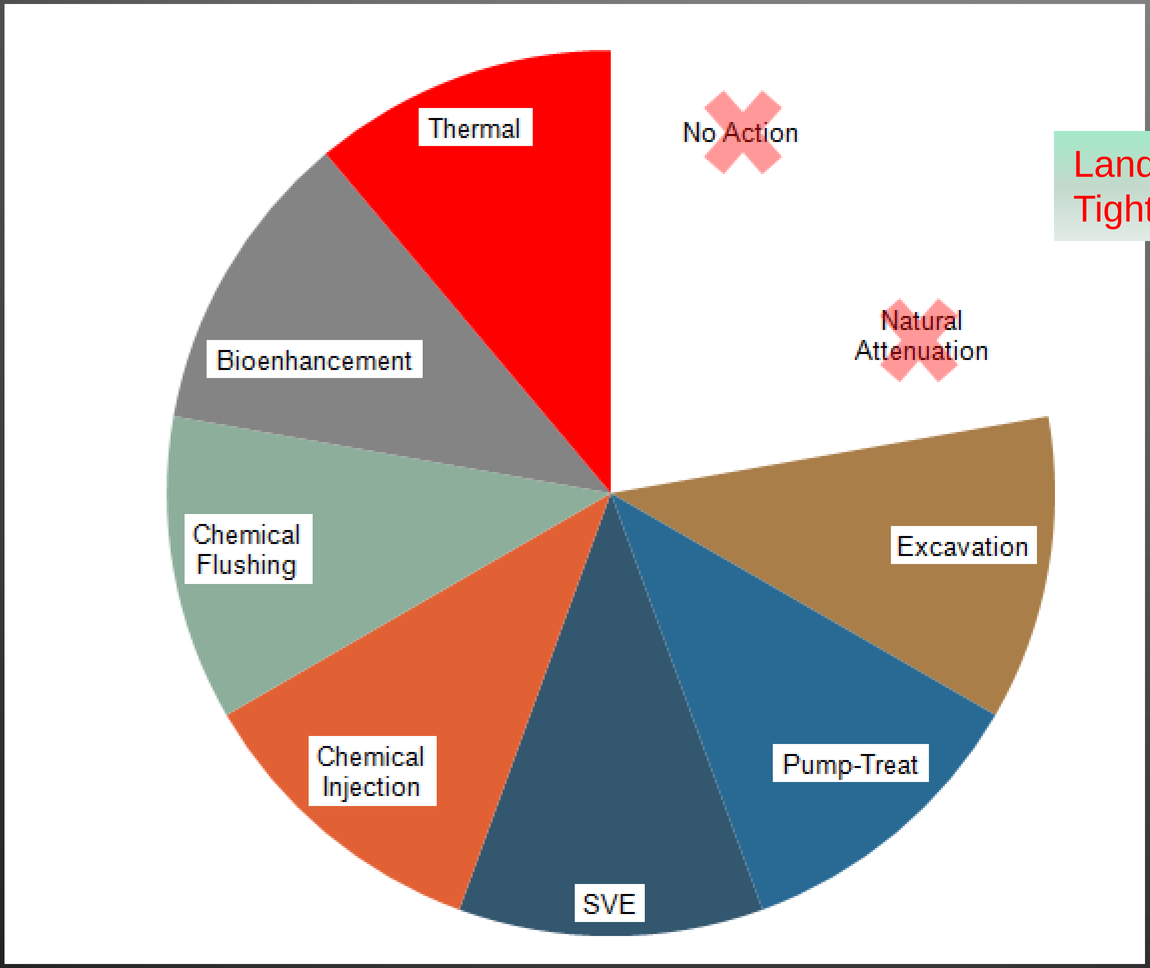
# Screening of Remediation Technologies



# Screening of Remediation Technologies




Land Development
Tight Schedule

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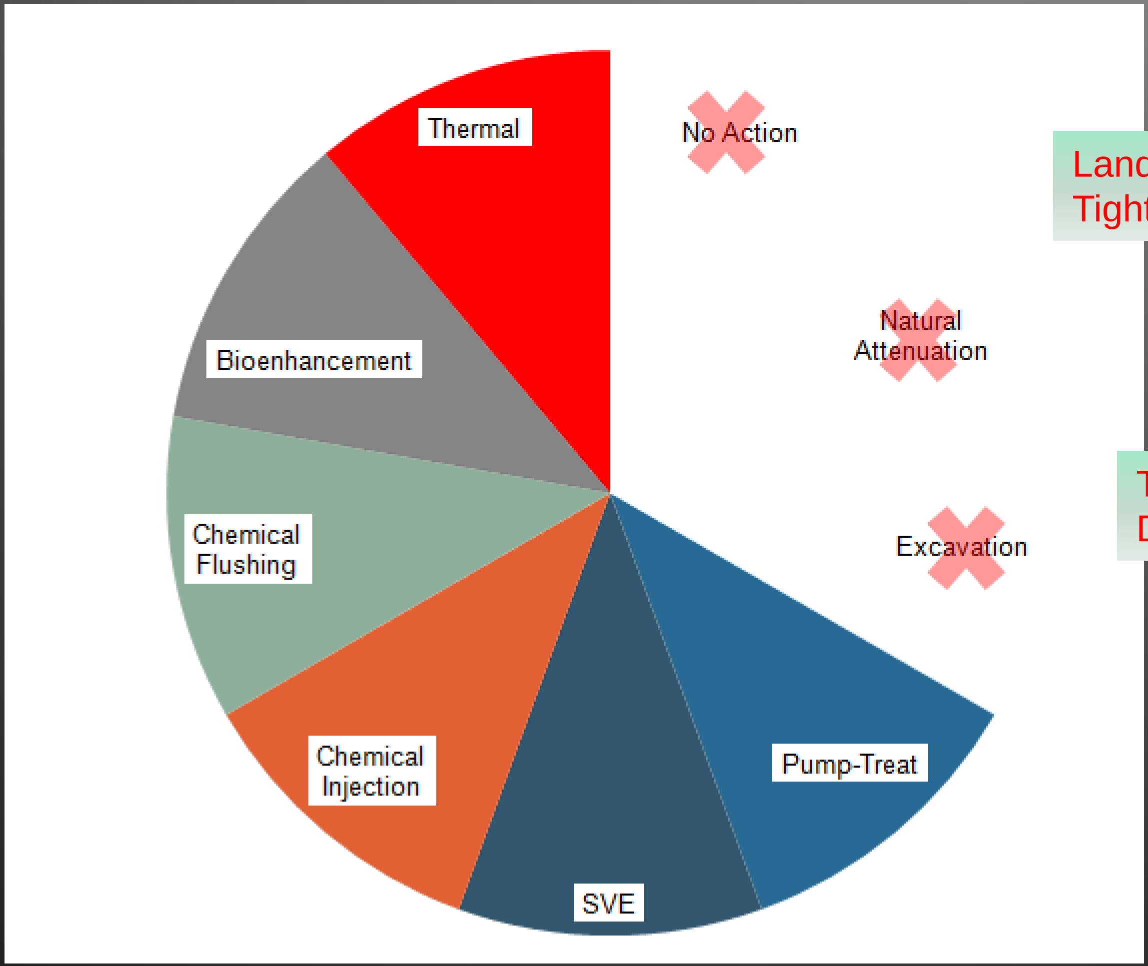
# Screening of Remediation Technologies




Land Development
Tight Schedule

Transportation /
Disposal fee

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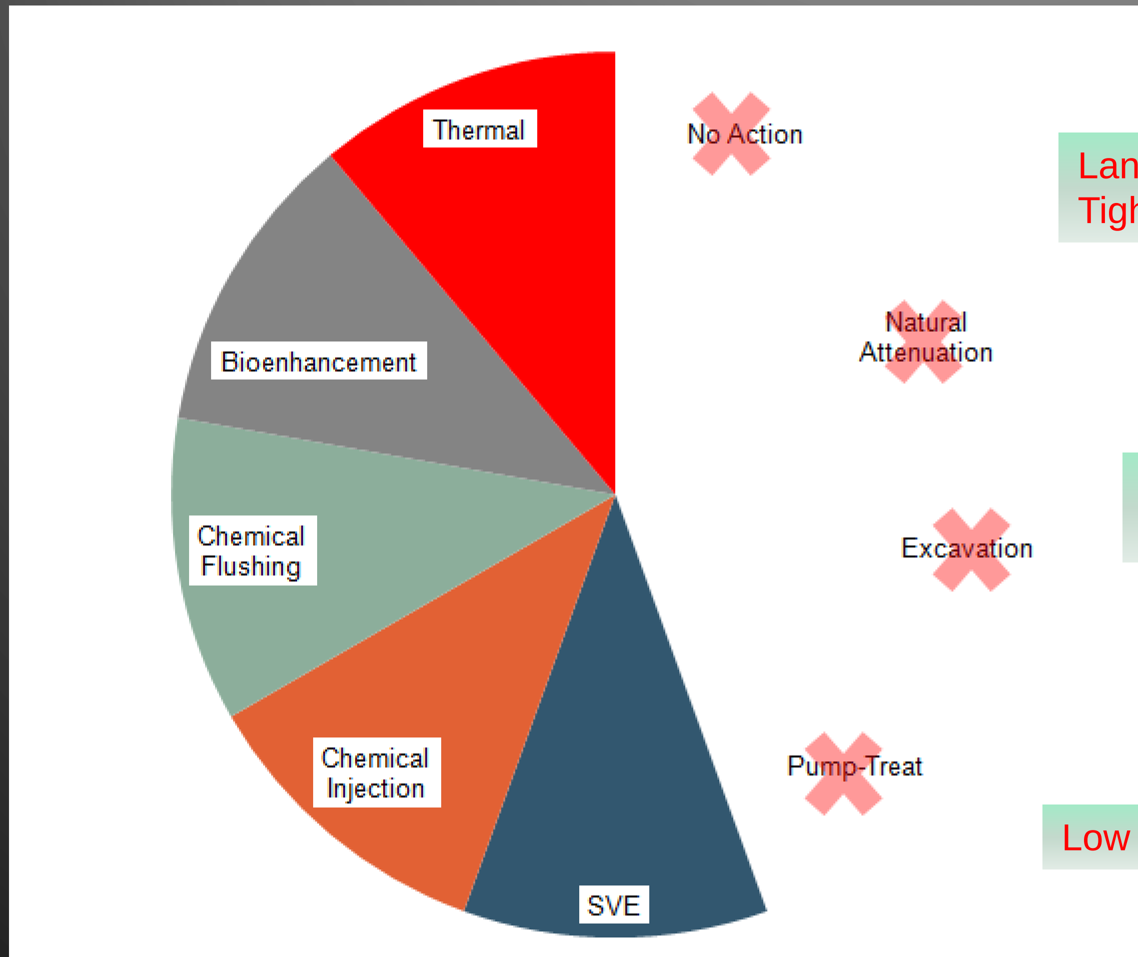
# Screening of Remediation Technologies




Land Development
Tight Schedule

Transportation /
Disposal fee

Low Solubility

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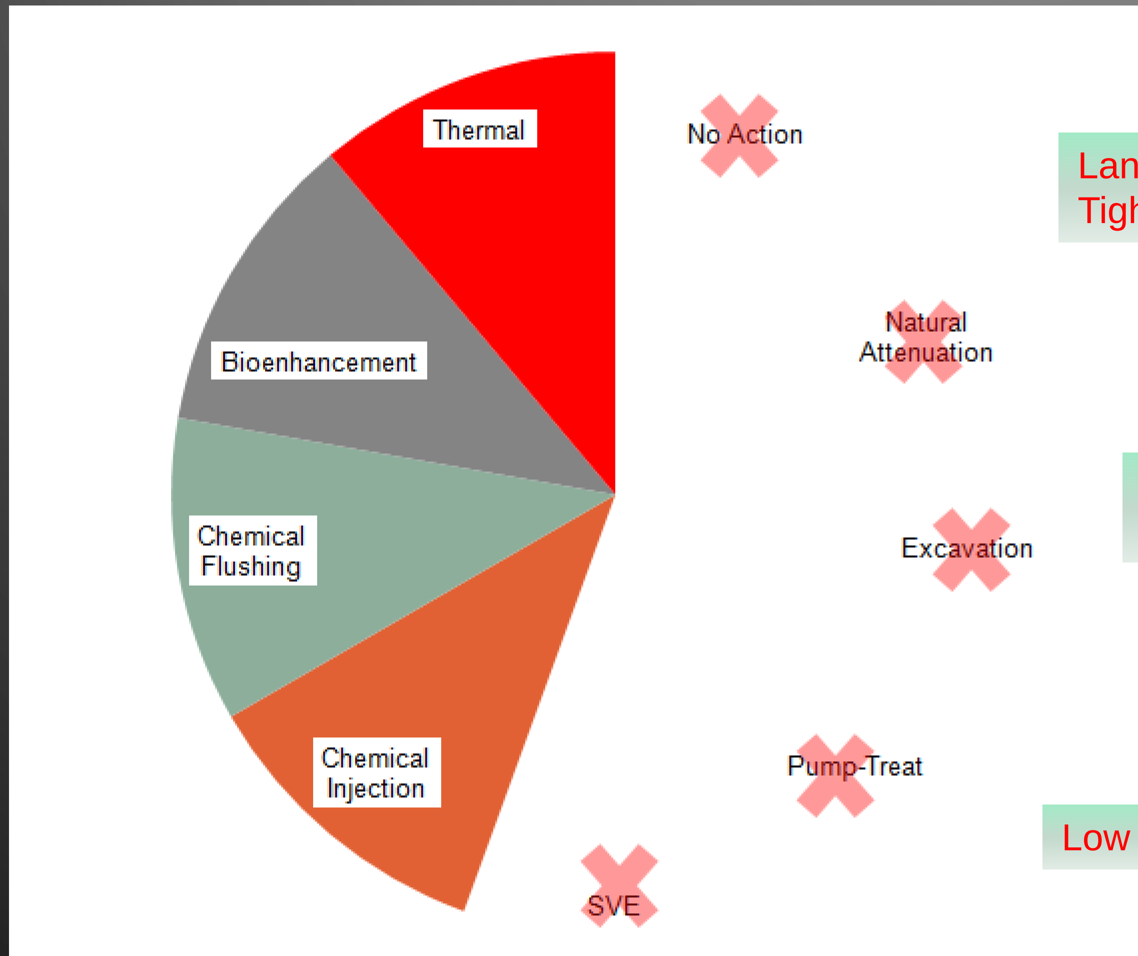
# Screening of Remediation Technologies



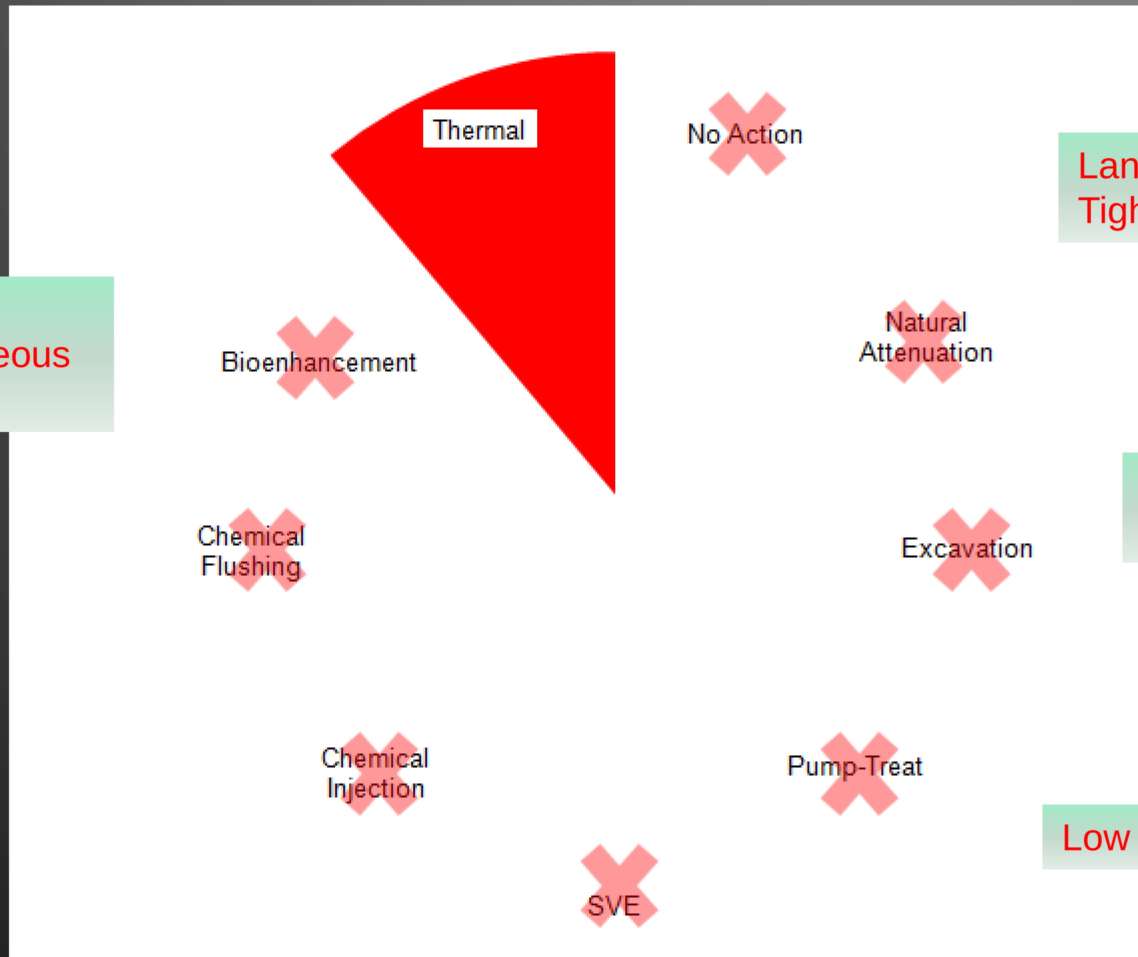

Land Development
Tight Schedule

Transportation /
Disposal fee

Low Solubility

Low Vapor Pressure

# Screening of Remediation Technologies




Low Permeability
Highly Heterogeneous lithology

Land Development
Tight Schedule

Transportation / Disposal fee

Low Solubility

Low Vapor Pressure

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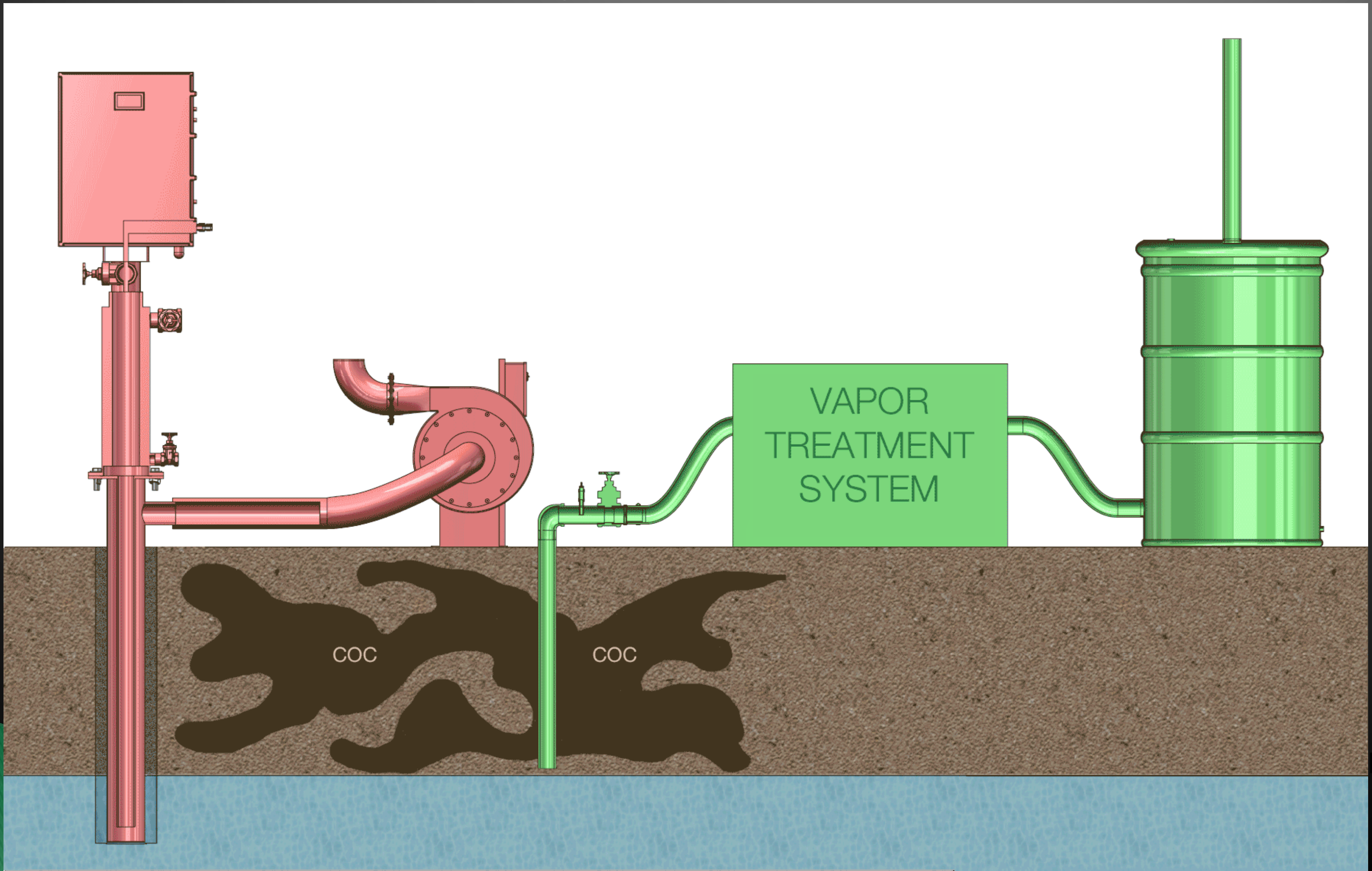
# What is GTR

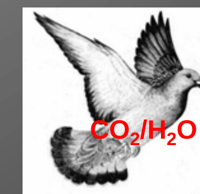
GTR= Gas Thermal Remediation

- Propane/Natural gas/Diesel as fuel to heat the thermal conduction heater wells.
- Soil and groundwater are heated indirectly through conduction. Treatment temperatures from **~100˚C** to **>400˚C.**
- Vaporized contaminants collected from extraction wells are routed to the appropriate vapor treatment module.
- Closed-loop in-situ thermal conduction heating system. No pollution emission into atmosphere.



# Health and Safety

- Combustion air and contaminant vapor are in different close loops.
- No hot air or any injection to the ground. Only energy to ground.
- No contaminant release into atmosphere.




The combustion air into the atmosphere only include $CO_2/H_2O$ (like home BBQ)


All vaporized contaminants are collected in vapor treatment system from extraction wells.



Only energy to the ground

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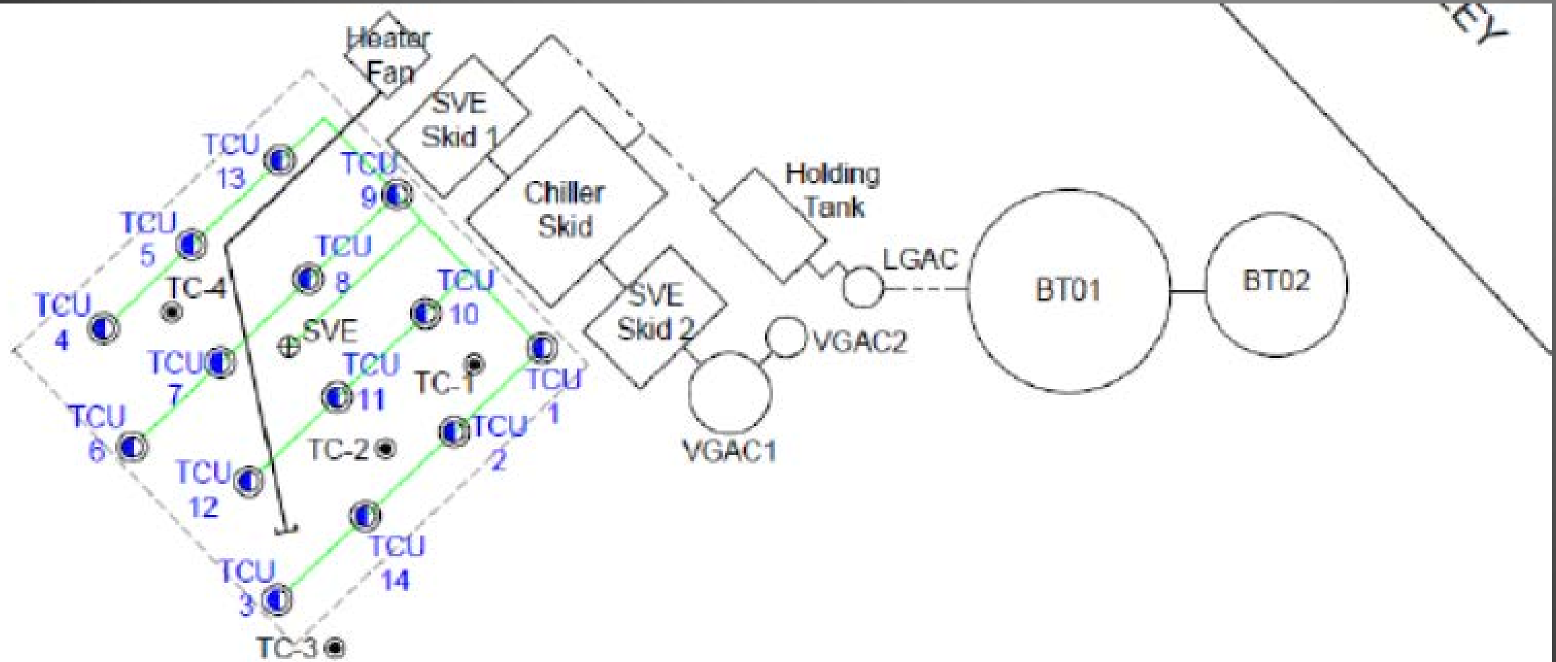


In Situ Heating + Vapor Extraction = In Situ GTR


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# Heating Equipment

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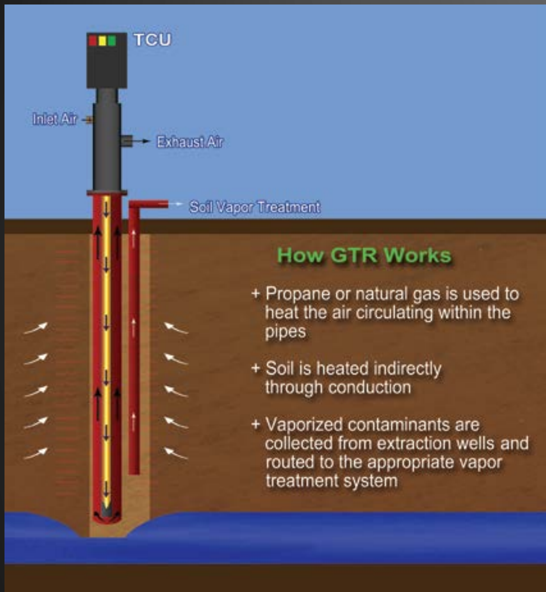
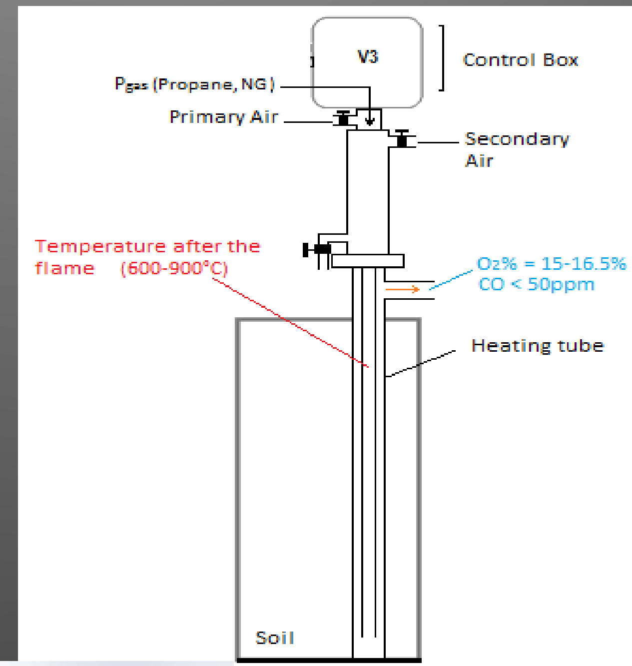
# Heater Wells (co-axial)

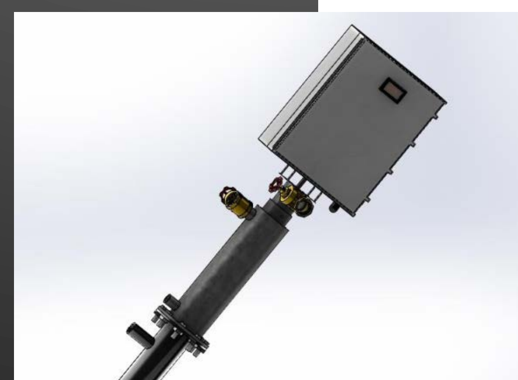



**TCU Inside**




Outer tube

Inner tube



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# Vapor Treatment System


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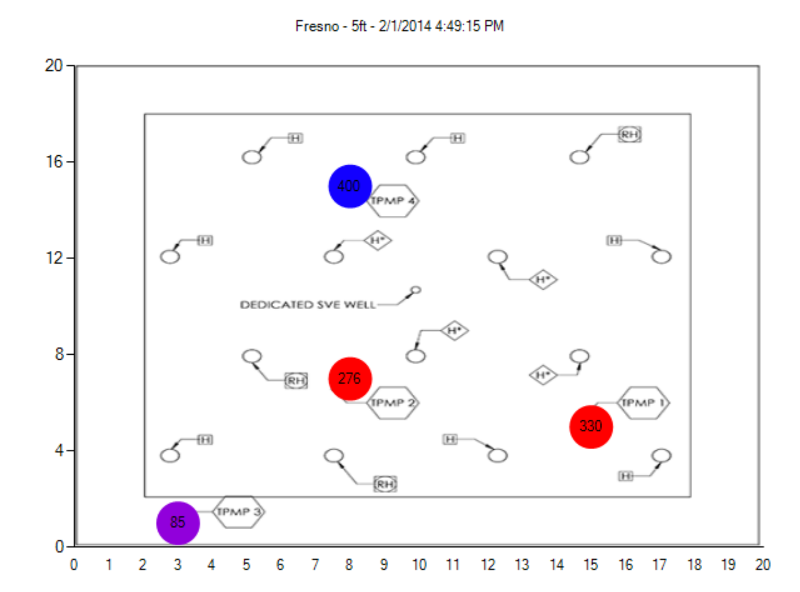
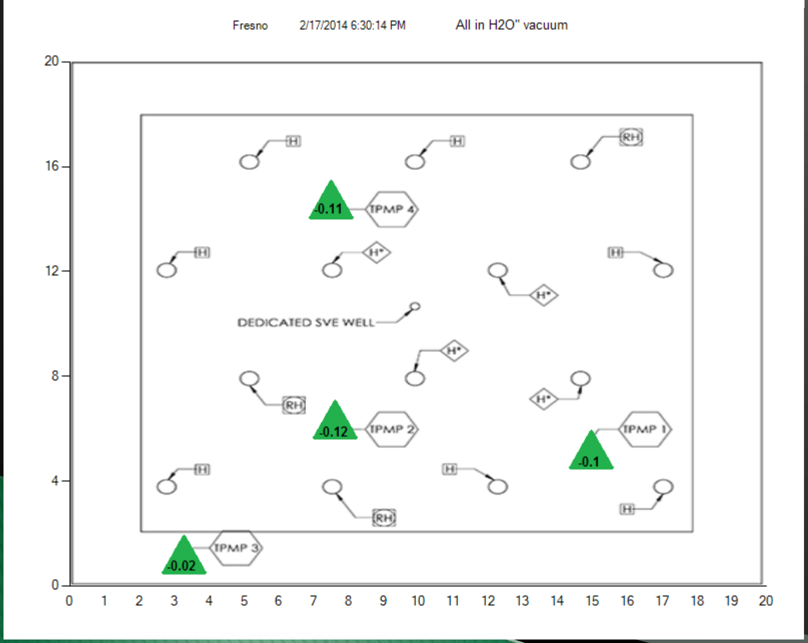
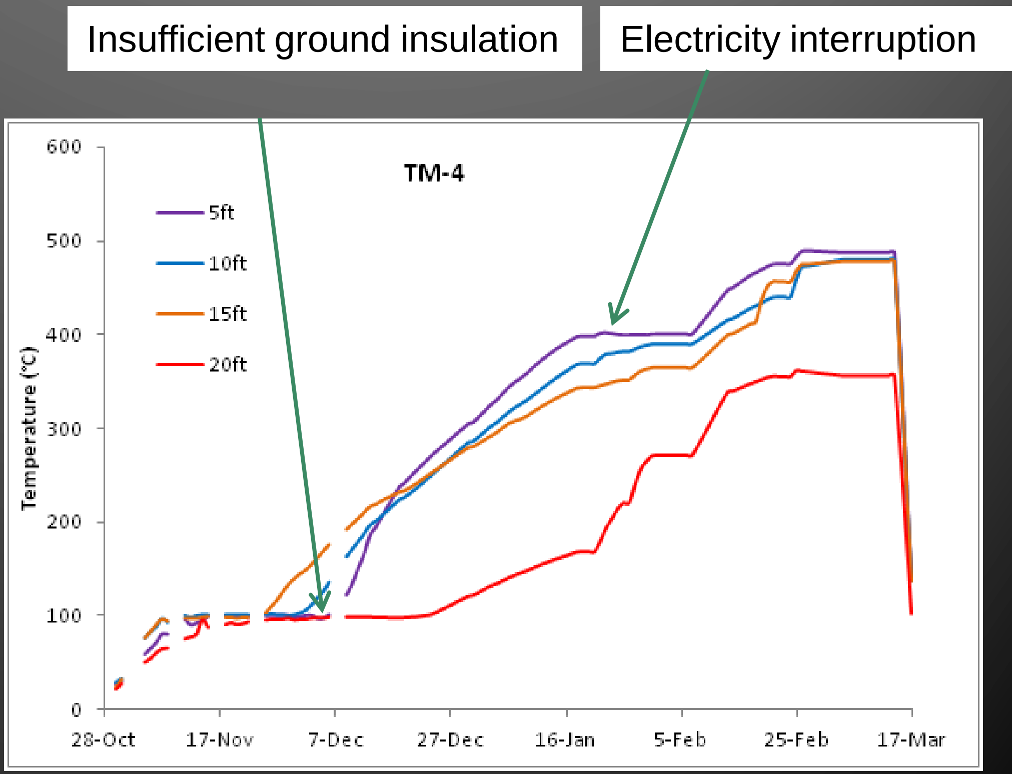
# Remote Monitoring System




Remote site monitoring data are available on GEO's website for both GEO and Client's engineers and managers.

Operation adjustment is conducted in time based on the monitoring results.

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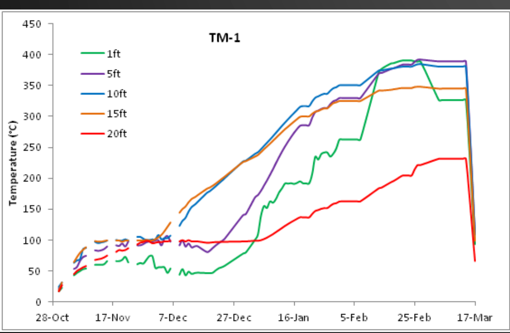
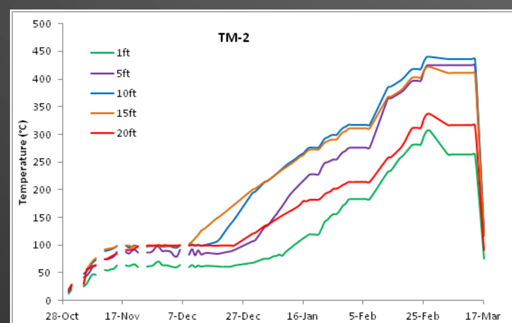
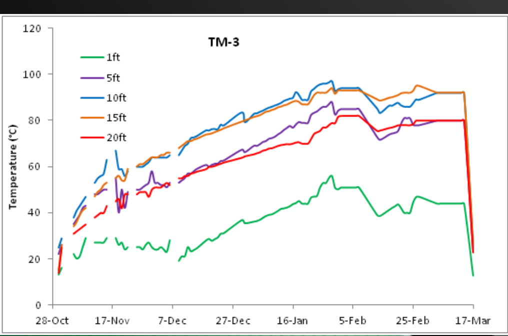
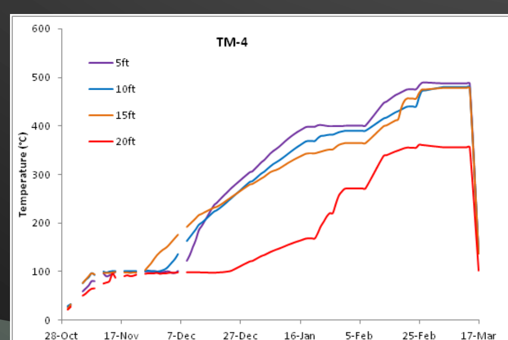
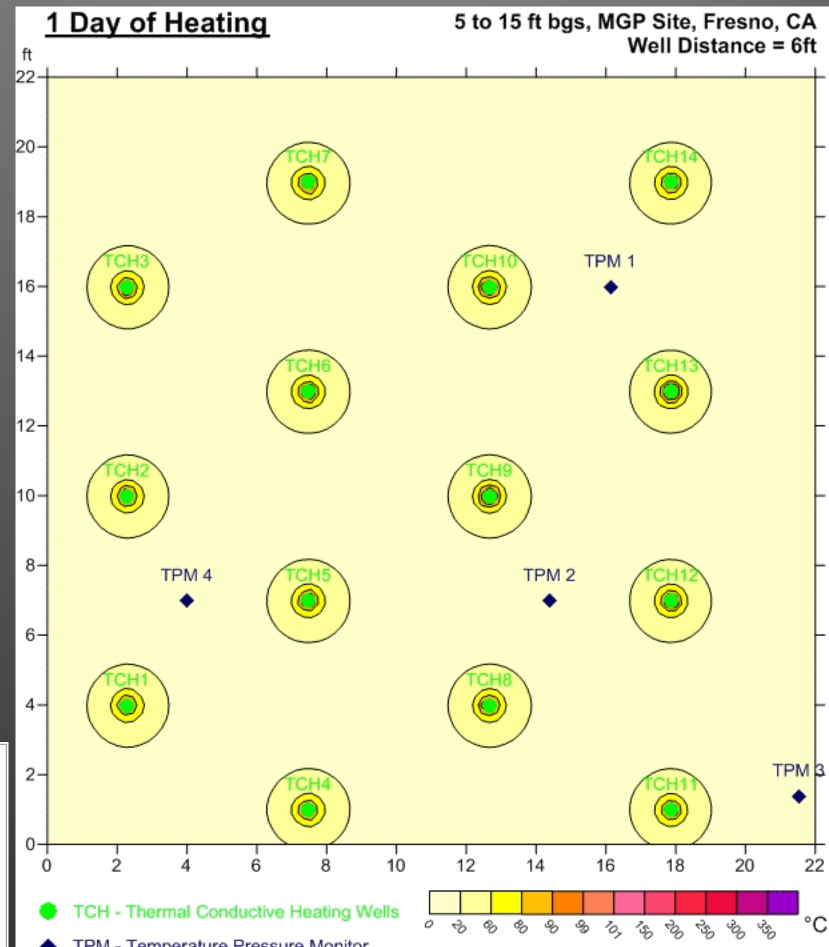
# Performance Evaluation Criteria: Temperature Evolution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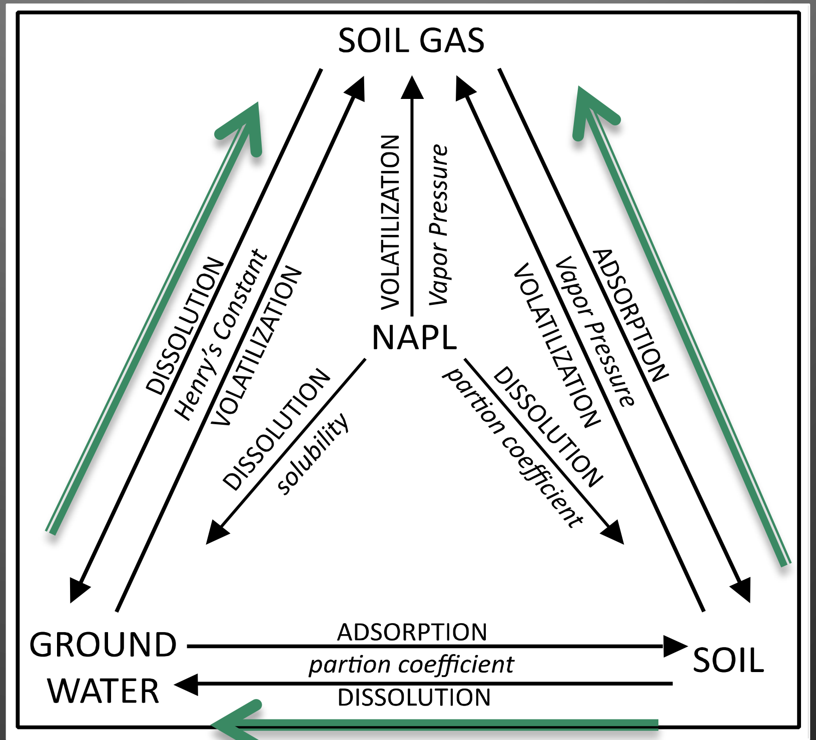
# What happens when Temperature increase

Vapor pressure ↑
Viscosity ↓
Desorption ↑
Diffusion ↑
Solubility ↑

Biodegradation ↑
Hydrolysis
Thermal Oxidation




Source: Modified from Huling, S.G., and J.W. Weaver 1991

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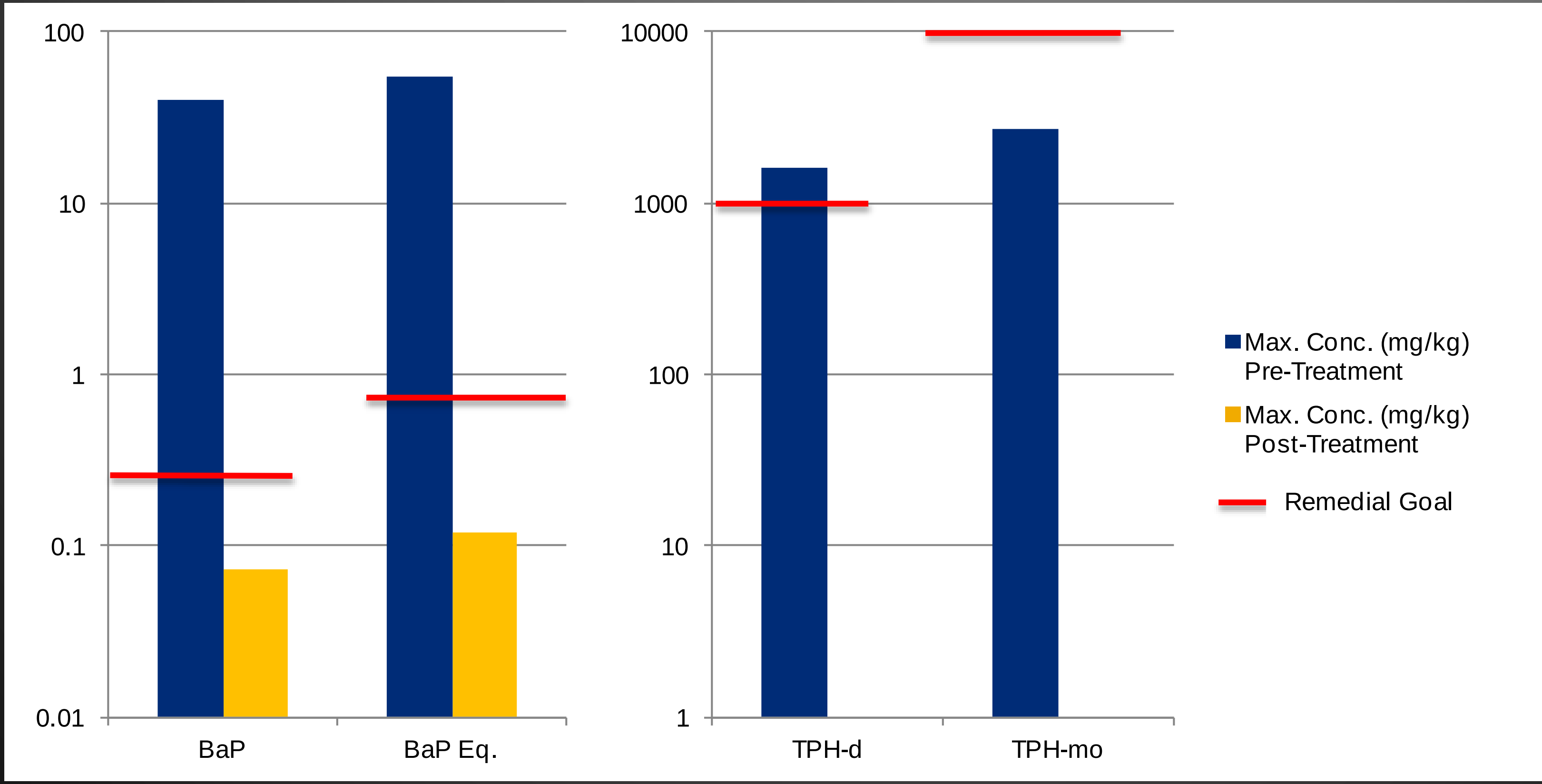
# Final Results

- Pre-treatment samples collected during infrastructure installation (9/2013)
- Post-treatment samples collected prior to system shutdown (3/2014)*




*VOC samples collected with Terracores and cooled immediately to eliminate the potential for VOC loss during sampling

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# System Usage and Mass Reduction

- **Input:**
  - Natural Gas: 1.78E+04 therms
  - Electricity: 6.39E+04 KWh
- **Output:**
  - Contaminant Reduction:
    - **TPH-d and TPH-mo: 100%**
    - **BaP equivalents: 99.7%**
  - Off-Gas Treated: 6.81E+06 cubic feet
  - Water Treated: 16,400 gallons
  - VGAC Utilized: 1,500 pounds

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# Conclusions

1. Meets DTSC's goals for more sustainable MGP remediation
2. GTR contained and captured all vapors
3. Schedule extended due to electrical interruption and higher soil moisture content
4. cost-effective vs. excavation for deep impacts
5. Provided specific kinetic information for full scale design
6. Limited risk to Client (guaranteed scope of work from GEO). Client costs would only be for mob/demob, energy, oversight and sampling/analysis, if unsuccessful
7. GTR is a sustainable and risk mitigating remedial approach

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# Challenges and lessons learned

1. Higher water content of soil than expected impacted heating schedule – recommend provide greater density of sampling for moisture content
2. Electrical interruption caused down time, and thereby impacted system heating capabilities (downed power line away from the site) – recommend providing backup generators
3. Longer heating duration increased heat lost to surface – installed thermal blankets. Recommend higher R value ‘air entrained’ material to improve overall thermal efficiencies

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# Example 2: Ex-Situ GTR

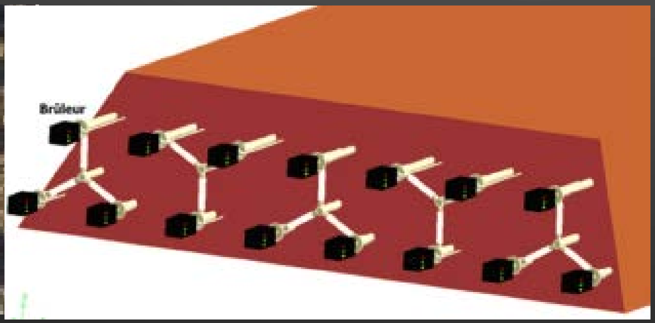
Central Valley California

GTR Gas Thermal Remediation

- Target Temperature: 200°C
- Thermal Treatment Duration: 39 days
- Treatment Goal: Reduction of more than 30,000 mg/kg to less than 100 mg/kg Diesel

# Ex-situ: PAHs site in France

- Contaminants : PAHs and Heavy Hydrocarbons > 50,000 mg/kg
- Geology: Clay, sand — Volume: 620 m3
- Treatment Time: 37 days — Target Temperature: 200°C
- Challenges: Treatment area surrounded by residences on three sides
- Heating Tubes: 15
- Return Tubes: 5
- Remedial Goal: < 50 mg/kg
- Remedial Result: Avg. Concentrations < 25 mg/kg
- Both Performance and Time Guarantees Achieved





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# No onsite electricity required

Small Generator

→ 25 – 60 kVa

→ Gas or Diesel

Project Site in Netherlands February 2012


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# Advantage 1: Versatility

Heat Transport Equation:

$$q''_x = -k(dT/dx)$$

Where:

$q''_x$ = heat energy flux in the x direction ($W \cdot m^{-2}$)
$k$ = thermal conductivity ($W \cdot m^{-1} \cdot K^{-1}$)
$dT/dx$ = temperature gradient in the x direction ($K \cdot m^{-1}$).

| Soil | Thermal Conductivity ($\lambda$) [W/m/K] | Hydraulic Conductivity (K) [cm/s] |
|---|---|---|
| Clay (dry) | 0.15-1.8 | $10^{-5}$-$10^{1}$ |
| Water saturated clay | 0.6-2.5 | |
| Sand | 0.15-0.77 | $10^{2}$-$10^{5}$ |
| Water saturated sand | 2-4 | |
| Gravel (dry) | 0.7 | $10^{4}$-$10^{7}$ |
| Water saturated gravel | 1.7-4 | |
| Fractured Bedrock | 1.4-4.0 | $10^{-7}$-$10^{7}$ |

Thermal Conductivity

$$\frac{Clay}{Sand} = \frac{1.3}{0.52} = 2.5$$

Hydraulic Conductivity

$$\frac{Sand}{Caly} = \frac{10^4}{10^{-4}} = 100{,}000{,}000$$

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ACE EE 2009
http://www.engineeringtoolbox.com/thermal-conductivity-d_429.html

# Advantage 1: Versatility

| Level of Heating & Contaminant | TTT (Target Treatment Temperatur, °C) | Heating Well Spacing (m) | Heating days to TTT | Desiccation of Zone? |
| --- | --- | --- | --- | --- |
| **1. VOCs:** (Benzene, DCE,ect) | <100 | 2.5-5.0 | 10-60 | No |
| **2. VOCs** (BTEX, TCE,PCE,gasoline, partial diesel, etc) | 100 | 1.8-3.0 | 21-90 | No |
| **3. SVOCs** (motol oil, MPG, PAHs, PCBs, dioxins,etc) | >100 | 1.5-2.2 | 80-150 | Yes |

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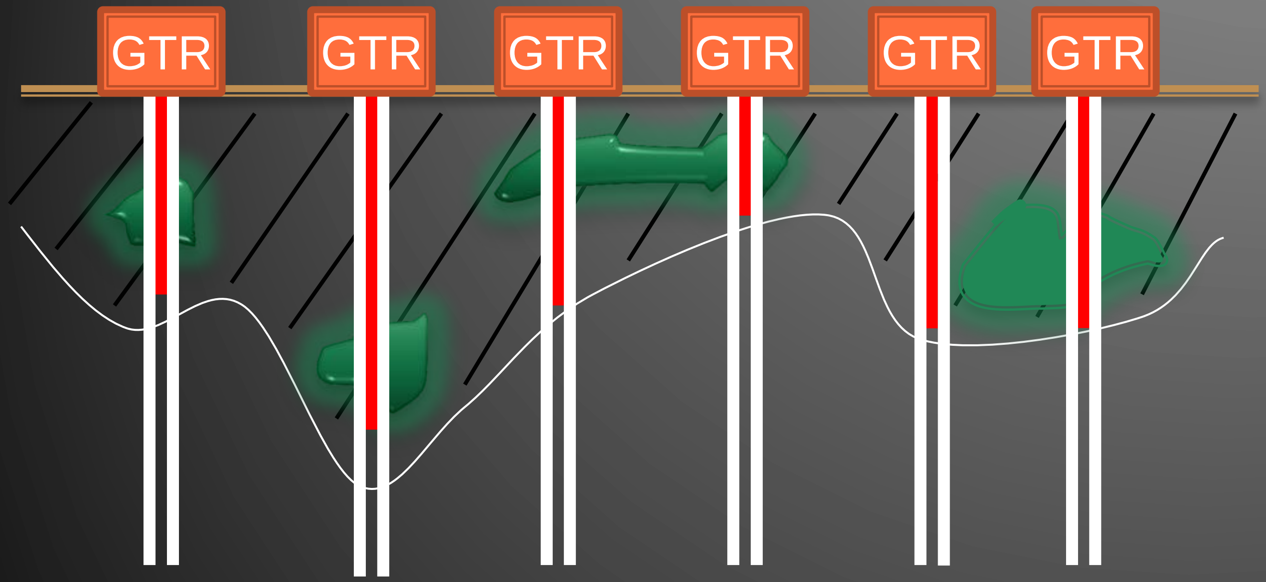
# Advantage 2: Flexibility




- **Faster (**Rapid mobilization, smaller footprint, & no electrical installation)
- **Scalable** (Can be applied to very small and very large projects)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# Advantage 2: individual burners

- Low energy consumption
  - 100 -150 kWh per ton of soil treated
  - Energy efficiency: >85%
- Safety
  - Totally enclosed design
  - Low power (40 kW)
- Easy to move (30 – 45 pounds)
  - Modular grid and zone pre-heating approaches
- Maximum control and flexibility
  - Length, number, orientation, timing, temperature
  - Each burner is independent and controlled via PLC
- Reliability
  - Easy replacement in the field = no heating downtime

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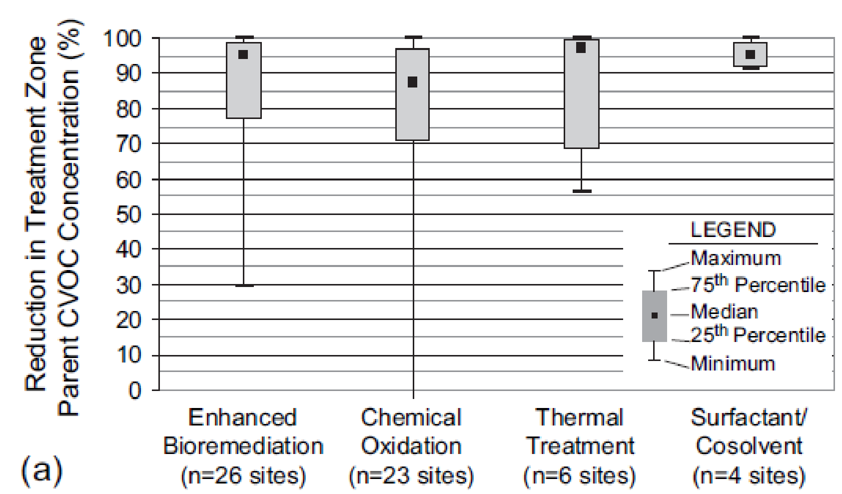
# Advantage 3: Performance Guarantee

- Fast (2 – 6 months)
- Highly predictable results
- No vapor emission, No unwanted mobilization
- Minimal Neighborhood impact

# Advantage 3: Performance Guarantee

**No Rebound** → **Less long term cost**

- Chemical injection or bioremediation may rebound post-remediation due to untreated contaminant mass in the less permeable soil bleeds back out and re-contaminates the more permeable zones



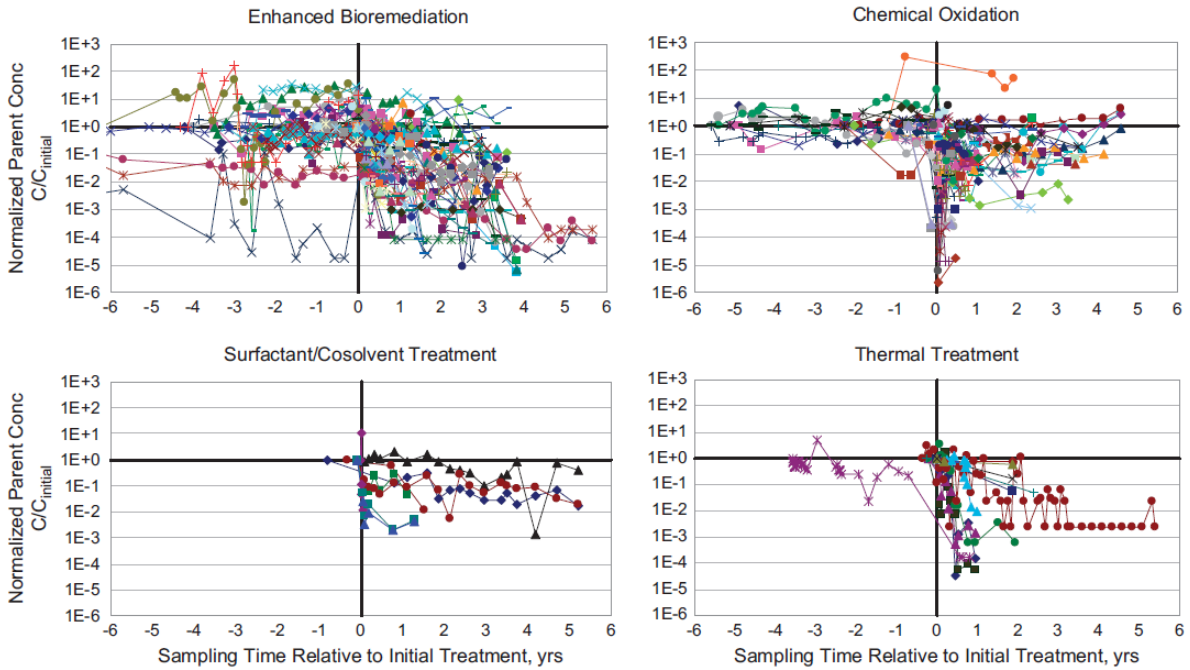




**Figure 1. Temporal concentration records for wells at source depletion sites. Concentration is normalized by the initial measured concentration. Sampling time is normalized by the time of the initial source depletion treatment.**

Ground Water Monitoring&Remediation

## Performance of DNAPL Source Depletion Technologies at 59 Chlorinated Solvent-Impacted Sites

*by Travis M. McGuire, James M. McDade, and Charles J. Newell*

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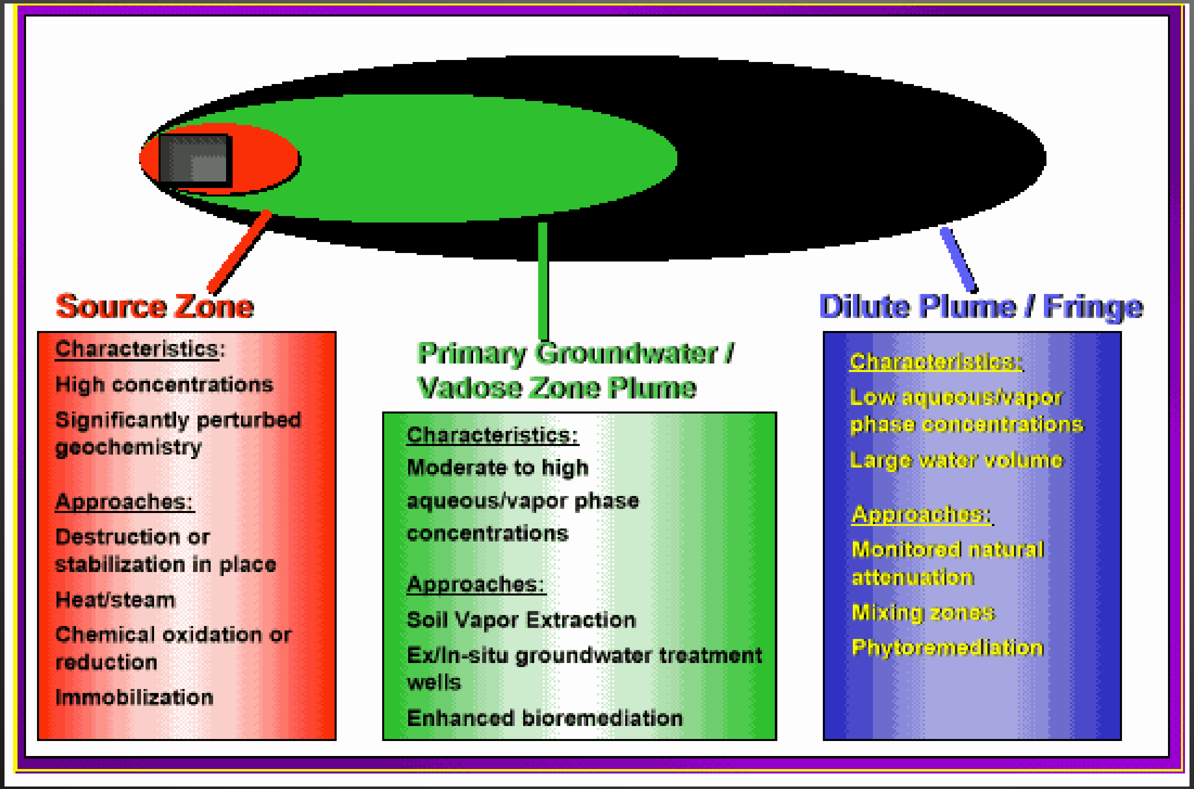
# Challenge 1: Remediation Goal

Economically applicable to source zone: NAPLs, high concentration soil.
Remediation goal is usually set as NAPLs removal and soil concentration reduction.

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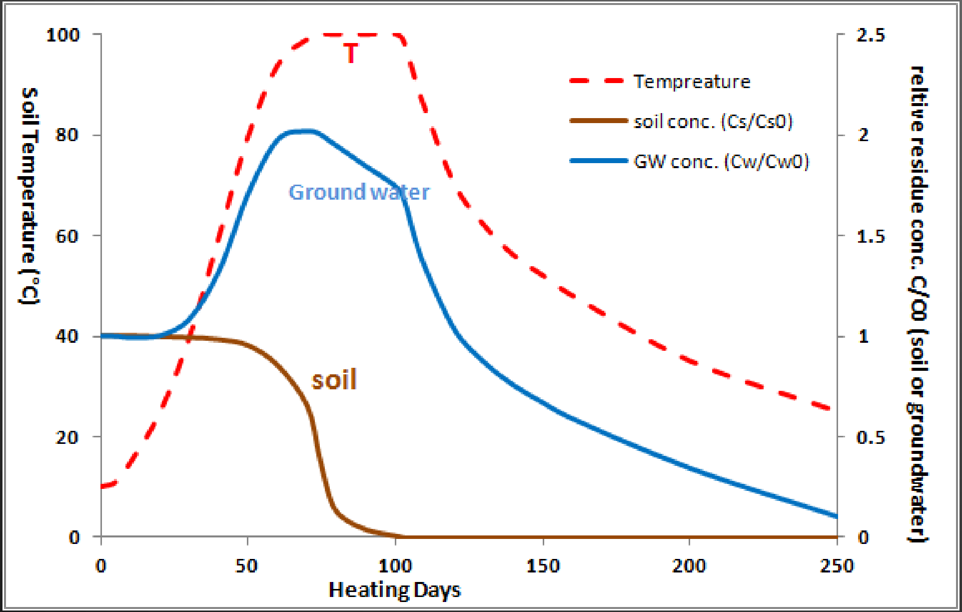
# Challenge 1: Groundwater Goal

It needs to be very careful if groundwater is selected as remediation goal:
(1) Sampling time selection
(2) Invasion from outside treatment zone

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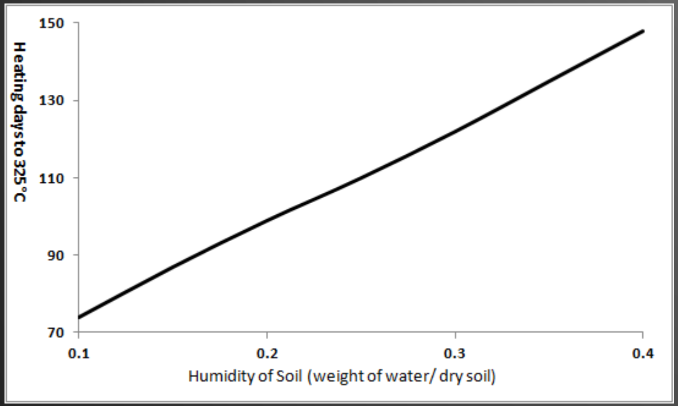
# Challenge 2: Site Condition

- Water is an important effect on thermal selection.

Humidity in Vadose zone




GW velocity at Saturated zone:

Dewatering needs to be designed if GW>1ft/day or 1E-3 cm/s

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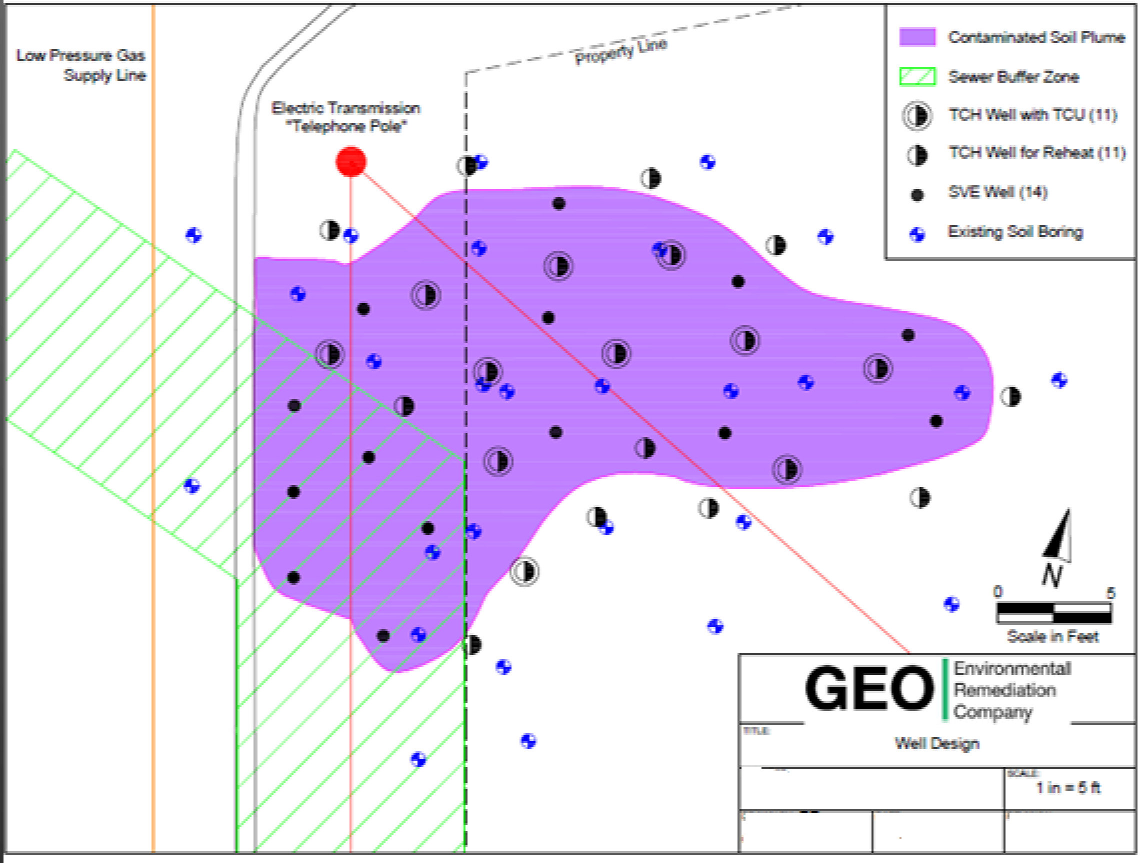
# Challenge 2: Site Condition

Underground utility lines
Drench
Monitoring wells with PVC tube

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# Challenge 3: Cost

| ISTD Project Estimates | | | | | |
|---|---|---|---|---|---|
| *Surface* | *Avg. Depth* | *Volume $m^3$* | *Pollutant* | *Difficulty?* | *Total Price* |
| 62 m² | 4 m | 248 | TPH | normal | $43,500 |
| 23 m² | 14 m | 322 | CVOCs + TPH | normal | $90,350 |
| 3551 m² | 9 m | 31959 | TPH | normal | $3,770,000 |
| 1263 m² | 9 m | 11367 | CVOCs + TPH | ATEX zone | $2,262,325 |
| 80 m² | 12 m | 960 | Creosote + TPH | LNAPL present | $277,550 |
| 125 m² | 7 m | 875 | CVOCs + TPH | incl. saturated | $237,250 |
| 60 m² | 5 m | 300 | CVOCs | normal | $57,200 |
| 45 m² | 6 m | 270 | SVOCs + PAHs | under building | $55,250 |
| 73 m² | 4 m | 292 | Mercury; SVOCs | under building | $189,150 |

**Prices are all inclusive (drilling, installation, energy/utilities, and operations).**

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# Challenge 3: Cost

Both remediation goal and site condition affect the cost. Other important factors include:

## Factor 1: COCs

| Level of Heating & Contaminant | TTT (Target Treatment Temperatur , °C) | Heating Well Spacing (m) | Heating days to TTT | Desiccation of Zone? | Costs (all inclusive) ($/m$^3$) |
|---|---|---|---|---|---|
| **1. VOCs:** (Benzene, DCE,ect) | <100 | 2.5-5.0 | 10-60 | No | 40-200 |
| **2. VOCs** (BTEX, TCE,PCE,gasoline, partial diesel, etc) | 100 | 1.8-3.0 | 21-90 | No | 60-300 |
| **3. SVOCs** (motol oil, MPG, PAHs, PCBs, dioxins,etc) | >100 | 1.5-2.2 | 80-150 | Yes | 150-900 |

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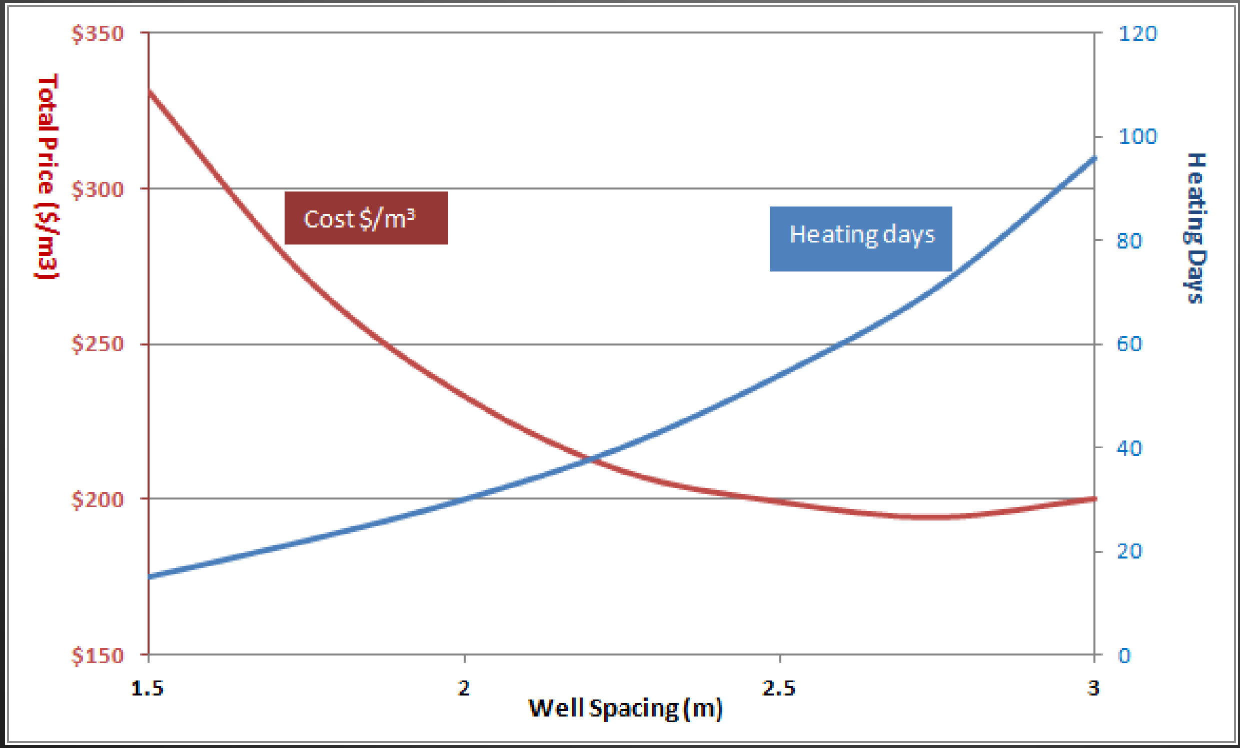
# Challenge 3: Cost

- Factor 2: Design of heating wells spacing

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# Summary

GTR© ISTCH System:

1. **Applicability:** soil temperatures < 70°C to > 325°C
2. **Speed:** Mobilize and commence GTR operations in Weeks
3. **Scalability: small pilots to acre size projects**
4. **Economics**: No waiting/paying for electrical utilities, transformers, switchgear, third party inspections.
5. **<u>Guarantees</u>** available

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# Questions?

http://www.georemco.com/

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