USE OF ELECTRICAL RESISTIVE HEATING FOR THE REMEDIATION OF CVOC AND PETROLEUM IMPACTS IN SOIL AND GROUNDWATER

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Introduction

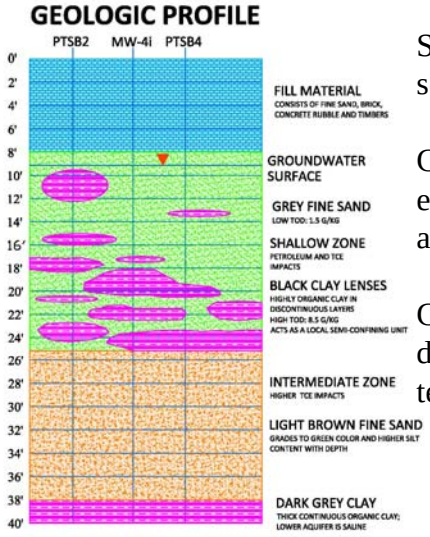
- Site is a former industrial property located in New York City, New York.
- Property is slightly larger than 1 acre .
- Former Site operations included a garage.
- TRC was retained in 2008 to assess remedial alternatives and advance to site closure.
- Multiple alternatives were screened to address soil and ground water impacts.
- Electrical Resistive Heating (ERH) was ultimately selected and implemented over a 9 month operational period.

Site Impacts

- Site was impacted with petroleum products, TCE and daughter products in the soil and groundwater.
  - Max TCE soil concentration was >10,000 mg/kg
  - Max TCE groundwater concentration >400,000 µg/L
- Petroleum impacts had been mostly removed in an earlier remedial excavation; however a 2 foot layer of residual product remained near the water table, which periodically manifested greater than 1 foot of free product in on-site monitoring wells.
- Product samples indicated moderately to highly weathered hydraulic and fuel oils.

TRC 3

Site Geology



Shallow and intermediate zones separated by organic clay lenses

Clay layer was identified in every boring; however thickness and depth were not consistent.

Complex geology impacted delineation and remedial technology selection.

TRC 4

Treatment Area Description

- The treatment area covered approximately 11,000 square feet (~1/4 acre).
- Targeted treatment depths varied between 25 and 40 feet below grade.
  - Shallow treatment was intended to address area impacted only with petroleum hydrocarbons.
  - Intermediate treatment area to address chlorinated solvent impacts.
- Total treatment volume of approximately 13,750 cubic yards.
- Treatment groundwater volume of 830,000 gallons.
- Anticipated contaminant mass of ~1,500 lbs (TCE) based on soil and ground water concentrations.

Remedial Alternative Selection

- NYSDEC directed the client to address both petroleum and CVOC impacts rapidly and effectively.
- Multiple alternatives were examined including:
  - Product recovery
  - ISCO and EISB, coupled with ground water recovery
  - Excavation
  - Thermal treatment
- Thermal treatment was selected for rapid remediation and the ability to address both contaminants simultaneously.
- Costs and potential time frames for alternatives are presented on next slide.

Remedial Alternative Selection

SUMMARY OF PROPOSED ALTERNATIVES

ALTERNTIVE	COST	APPROXIMATE DURATION	ALTERNTIVE	COST	APPROXIMATE DURATION
A1: SHALLOW EXCAVATION - INTERMEDIATE ZONE BIO-REMEDIATION Assumptions: - Excavate approximately 100' x 100' area to 15 feet below grade. - Impacted soil assumed to be between 5 and 15' below grade - Impacted soil to be disposed of off-site - 400 linear feet of sheet piping installed - In-Situ Biological Treatment over an area of approximately 65 x 40' - Bio treatment zone from 15 to 40' below grade - Assumes 2 rounds of bio treatment	$ 2,400,000	Excavation duration is approximately 6 weeks Bio duration is anticipated to be between 6 months and 1 year	***A2: THERMAL TREATMENT - SHALLOW ONLY INTERMEDIATE ZONE BIO-REMEDIATION*** Assumptions: - Thermal remediation will be conducted in an approximately 100' x 100' area - Treatment will be conducted from 6.5' to 25' below grade - Heating and extraction electrodes will be spaced through the treatment area - Piping and electrical wiring will be placed above grade - In-Situ Biological Treatment over an area of approximately 65 x 40' - Bio treatment zone from 15 to 40' below grade - Assumes 2 rounds of bio treatment	$ 2,500,000	Thermal treatment duration is anticipated to be between 6 months and one year Bio treatment duration is anticipated to be between 6 months and one year
A3: SHALLOW ZONE PRODUCT EXTRACTION - INTERMEDIATE ZONE BIO-REMEDIATION Assumptions: - Product extraction will be conducted through a well network - Extraction piping will be installed above grade - Extracted ground water will be treated and discharged to sewer to surface - Water discharge will require permits - Recovered product will be separated and containerized for off site disposal - Will likely leave some residual immobile product in place - Pumping duration is estimated and may require more time - In-Situ Biological Treatment over an area of approximately 65 x 40' - Bio treatment zone from 15 to 40' below grade - Assumes 2 rounds of bio treatment	$ 1,700,000	Product extraction duration is anticipated to range between two to four months Bio treatment duration is anticipated to be between 6 months and one year	***A4: THERMAL TREATMENT - SHALLOW AND INTERMEDIATE ZONES*** Assumptions: - Thermal remediation will be conducted in an approximately 100' x 100' area - Treatment will be conducted from 6.5' to 40' below grade - Heating and extraction electrodes will be spaced through the treatment area - Piping and electrical wiring will be placed above grade	$ 2,300,000	Thermal treatment duration is anticipated to be between 6 months and one year

Alternative A4 was selected to conduct the remediation. The application of Thermal Remediation was deemed to be the most likely technology for successful site closure in a short duration. The final remediation costs were very close the proposed cost estimate.

Remedial Goals

- Remedial Goals for the project were established with NYSDEC prior to final design and implementation.
- TCE cleanup goals were established for soil and groundwater:
  - Reduce groundwater concentrations to below 400 μg/L to allow for continued bioremediation of TCE and daughter compounds after ISTT operations completed.
  - Reduce soil impacts to prevent continued impacts to groundwater.
- Petroleum treatment goals included the removal of the volatile and mobile constituents to mitigate future vapor intrusion concerns and to remove any observed petroleum products in wells at the Site.

Technology Selection and Contracting

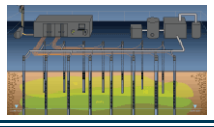
- In-situ thermal treatment (ISTT) was selected for the remediation program.
- The TRS Group was selected as the technology provider/contractor to implement an Electrical Resistive Heating (ERH) program.
- TRC, TRS and the client entered into a 3 way contract
  - TRC did not contract directly with TRS, however each parties' responsibilities overlapped and directly interacted with each other, resulting in the need for the three party contract.
  - TRS provided a fixed priced contract with performance goals.
  - Three party contract resulted in overall cost savings for client by reducing multiple markups.

TRC Results you can rely on

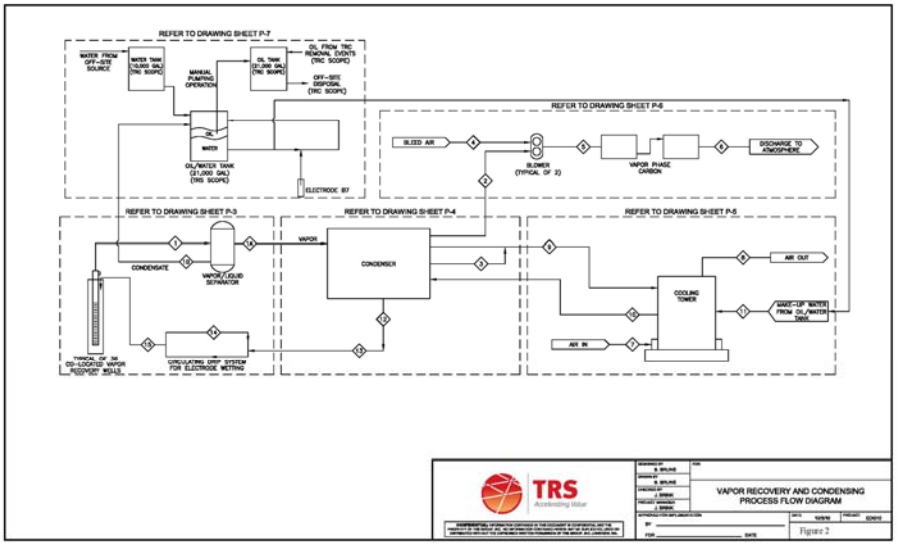
TRS Accelerating Value

ERH Description

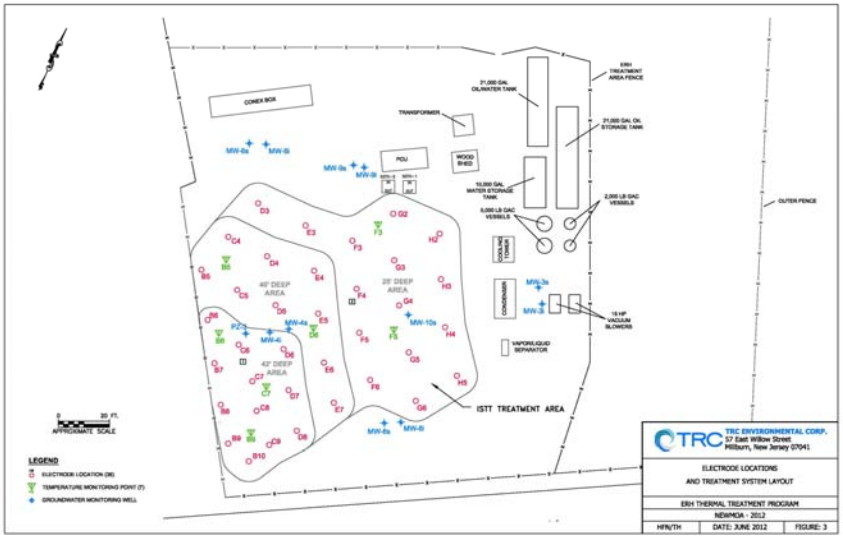
- The ERH process heats the soil and ground water by passing an electric current through the ground
- Electrodes are arrayed in a triangle, with each point receiving one phase of a three phase current (formerly known as Six Phase Soil Heating)
- The soil matrix's resistance to the current produces the heat
- The heat volatilizes a portion of the ground water creating steam and evaporating/volatilizing the contaminants
- Steam is created in-situ, not injected
- The buoyancy of the steam causes it to rise through the groundwater where it is recovered at a vapor recovery point
- Permeability of the soil does not greatly impact heating or steam recovery, however a continuous impermeable layer will complicate vapor recovery



Process Flow Diagram



Site Plan With ISTT Layout

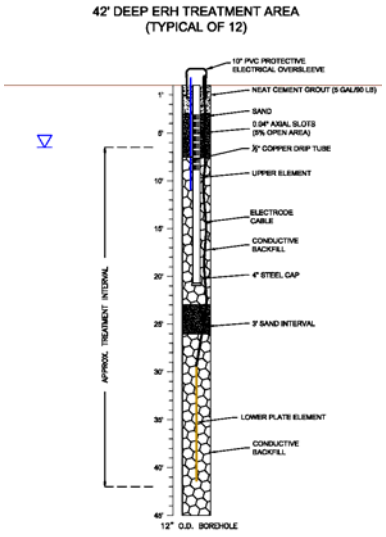


Site Views

Below: Electrode field in the snow

Above: Electrical Control Equipment and Power Supply

Electrode Construction Details



Electrodes drilled to depths of 27, 40 and 42 feet below grade.

A 4” Steel pipe, slotted from 3 to 9 feet was served as the vapor recovery point and top electrode.

A 12’ copper plate served at the lower electrode.

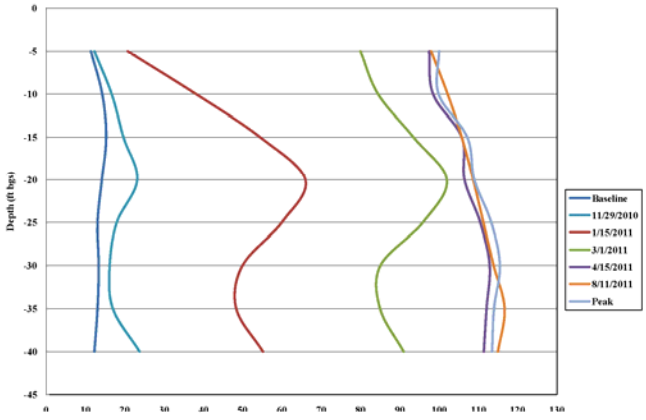
Electrode installation occurred over 5 weeks (36 electrodes)

Electrode Photos

Above: Conductive Backfill Material (Graphite)
Right: Electrode before connections and capping

Getting Hot – Increasing Temperatures

Subsurface Temperatures v. Time and Depth



Temperature Profile at TMP C7

Vapor Control

- Extracted vapors were treated using an array of GAC vessels.
- Approximately 30,000 lbs of spent, non-hazardous GAC were consumed during the project.
  - Alternate contaminant control technologies could have been used, including the C3 technology and oxidation.
  - The use of an oxidation technology would have required pH neutralization due to the presence of chlorine in contaminant.
- Influent and effluent air samples were collected to assess contaminant removal and emission control.
- Ambient air monitoring program was implemented during active ISTT operation to assess potential impacts on local air quality.
- Additional site ambient air surveys were conducted using a sensitive PID (PPB RAE), to identify any sources of air quality impacts on a live basis.

Vapor Control - GAC

Early Morning GAC Vessel Delivery

Insulated GAC Vessels
(2x 5,000 lb vessels and 2x 2,000 lb vessels)

Hot Water/Product Safety

•Product gauging was conducted periodically through the system operation.
•Gauging operation required lock-out/tag-out of electricity to the field, and manual gauging for product.
•All hot work required extra PPE.

•Incorporation of a full length heavy rain coat, heat resistant gloves and hard hat with face shield were required during all "hot" work.
•Ice Baths were incorporated in soil and groundwater sampling programs.

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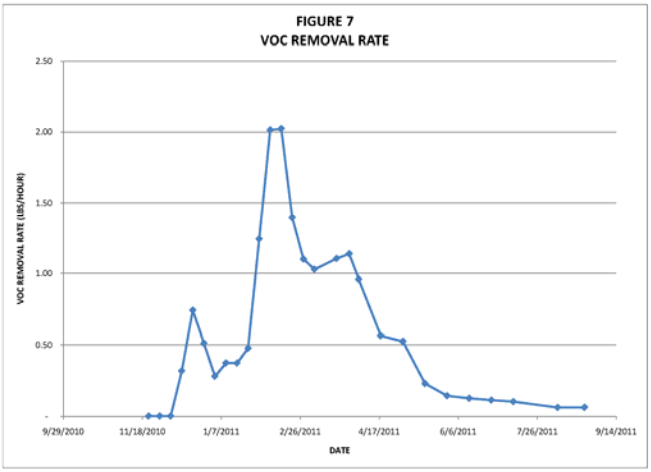
Contaminant Removal Rates

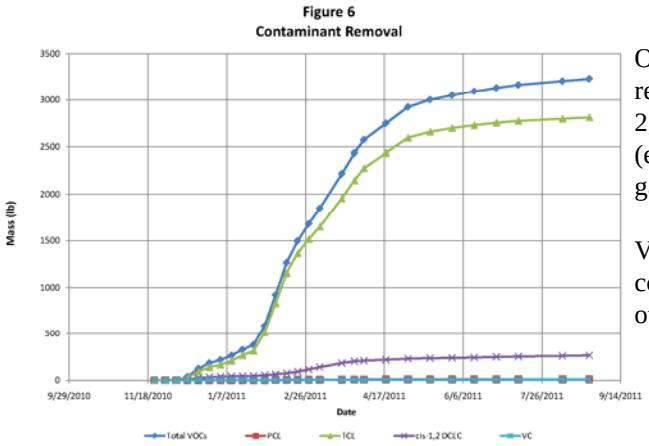


Removal rates peaked at over 2.0 lbs/hour in February

283 Days of operation, average flow rate of 390 CFM

TRC 20

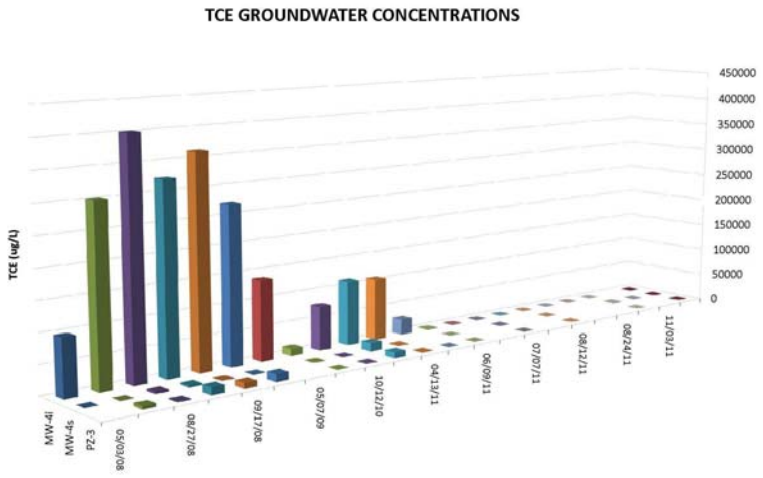
Cumulative Mass Removal



Over 3,200 lbs of VOCs removed from the site; 2,800 lbs of TCE (equivalent to ~230 gallons of pure product)

VOC groundwater concentrations reduced over 99.99%

Success!



Petroleum Remediation

- No separate phase product recovered or observed during treatment duration.
- BTEX compounds were removed during operation, however relatively low concentrations were often masked by high TCE and cis-1,2 DCE concentrations in influent air samples.
- Treatment program was able to demonstrate that remaining petroleum product was sufficiently stripped of volatile components, and rendered immobile.
- Post treatment soil samples did not show concentrations of BTEX compounds exceeding RSCO standards.
- Active product recovery event did not accumulate any free phase petroleum.

Continued Biodegradation

- Post treatment sampling (90 days after heating stopped) indicated population of TCE degrading bacteria were still present in the on-site groundwater.
- ISTT did decrease microbial population, but did not sterilize the groundwater.
- Remaining dechlorinating bacteria are in an ideal geochemical environment for continued reductive dechlorination.
  - Groundwater OPR is strongly negative.
  - Dissolved oxygen concentrations remained depressed after heating stopped.
- Removal of source area should expedite bioremediation of residual dissolved CVOC impacts.

Lessons Learned

- Get permits early – air permitting was a critical path item
- Prepare for water management
  - Storage or discharge options need to be worked out prior to startup.
  - Shallow groundwater and humid recovered vapors can lead to high water production rates.
- Prolonged peak contaminant recovery during thermal treatment may require alternate vapor treatment technologies.
- Site security requirements are necessary during the entire project implementation.
- Groundwater temperatures remain elevated for long duration after completion.

Project Team

Special Thanks to the Project Team

- TRC Team:
  - Nidal Rabah, PhD, PE, LSRP
  - Yasemin Kunukcu, PhD
  - Brian Ross
  - Audra Safter-Myers
  - Kevin Lau
- TRS Team:
  - Jeffery Brink, PG
  - Chris Blundy
  - Bradley Morris
  - Jacob Seaman

Thank You

- Take Away Points:
  - ERH/ISTT is a viable option, but at higher costs.
  - Health and Safety are paramount in ISTT programs
  - ISTT allowed for rapid remediation, with quantifiable results in meeting remedial cleanup goals
  - 9 months of active operation removed over 3,200 lbs of VOCs
  - Total project costs of approximately $2.3MM, but placed the project well on the path to closure.
- Questions?