Cost and Performance Summary Report
Electric Resistive Heating at the Former Woodbriar and Westwood Dry Cleaning Facility
Brookhill Azalea Shopping Center, Richmond, Virginia
May 2010

Executive Summary

The Former Woodbriar and Westwood Dry Cleaning Facility was located on the southern portion of the Brookhill Azalea Shopping Center at 114 Azalea Avenue in Richmond, Virginia. Small spills and releases of chlorinated volatile organic compounds (CVOC) occurred during the operation of the facility spanning from about 1965 through 1995. Analytical results from the initial Phase I and Phase II Environmental Site Assessments conducted in October 2003 and January 2004 respectively indicated the presence of CVOCs in groundwater. As a result, the site was recommended for, and accepted into, the Virginia Department of Environmental Quality (VDEQ) Voluntary Remediation Program (VRP) in June 2004. Additional sites assessments in 2005 and 2006 indicated the presence of tetrachloroethene (PCE), trichloroethene (TCE) and cis 1,2-dichloroethene (cis DCE) in the soil and groundwater that exceeded federal Maximum Contaminant Levels (MCLs). The dissolved CVOC plume began beneath the building footprint, the source area, and moved in the direction of the groundwater flow (south and southwest of the site).

Based on site assessment results, electrical resistance heating (ERH), an in situ thermal remediation technology, was selected to treat the source area and dissolved plume at the site. The ERH system was comprised of sixty-two electrode/vapor recovery wells located beneath and outside of the site. The system was designed to volatize CVOCs in the subsurface which would then be treated by a vapor treatment system installed on the site. ERH system progress was tracked by monitoring the energy application rate, temperature rates, and groundwater concentrations. The ERH system began operation on September 22, 2006, and was shut-off on December 12, 2007 when the target temperature for the site had been reached. After the ERH system was turned off, the vapor collection and treatment system ran for an additional two weeks to recover any soil vapors generated from the residual heat in the subsurface during system cool down. The vapor collection and treatment system was shut-off on December 28, 2007.

Additional soil and groundwater sampling and monitoring of the system were performed throughout the remediation process to track the progress of the remediation effort and allow ongoing adjustments to the system during its operation. The goals of the remedial action plan were to reduce baseline concentrations of PCE and other CVOC concentrations by 99.92% and achieve VRP Tier II standards which are consistent with unrestricted site use. The remedial actions performed at the site achieved significant mass removal of the contaminants of concern in approximately 1 year. Dissolved phase PCE concentrations detected in the source area were reduced by approximately 99% and the VRP Tier II screening levels for selected compounds were attained in several on-site monitoring wells. However, CVOC concentrations in several soil and groundwater samples remained above the VRP Tier II goals after ERH cleanup activities were complete based on sampling in June 2008. As a result, the goal of unrestricted site use

has not yet been obtained. The potential risks posed by these residual contaminants will be mitigated through institutional controls (ICs) placed at the site, including a deed restriction that limits the use of groundwater and a soil management plan. Based on the post-treatment results and the implementation of ICs, the site was recommended for closure under the VRP and for issuance of a Certificate of Satisfactory Completion of Remediation.

Summary Information

The Former Woodbriar and Westwood Dry Cleaning Facility (site) was located on the southern portion of the Brookhill Azalea Shopping Center at 114 Azalea Avenue in Richmond, Virginia. The dry cleaner operated from about 1965 through 1995, but the exact operation dates are not well documented. Small spills and releases of chlorinated volatile organic compounds (CVOC) compounds occurred during the general operation of the dry cleaning facility. At the time of the first site investigation in 2003, the site was used commercially as a shoe store; however; the building space became vacant as remediation efforts progressed. Mixed commercial and residential areas exist directly around the site. The current site owner, Mighty Oak, LLC, acquired the site after the dry cleaning facility closed and seeks to restore the site for unrestricted use (AECOM 2009).

In October 2003, Dominion Due Diligence group completed a Phase I Environmental Site Assessment (ESA) at the site and in January 2004 AECOM Environment (AECOM, formerly ENSR) performed a limited Phase II investigation that included sampling of soils and groundwater (from temporary well locations). The analytical results indicated that CVOCs in soil did not exceed EPA Region 3 cleanup values. However, various CVOCs were detected in groundwater samples exceeding Federal Maximum Contaminant Levels (MCLs). As a result, the site was recommended for, and accepted into, the Virginia Department of Environmental Quality (VDEQ) Voluntary Remediation Program (VRP). In September 2004, AECOM installed 6 monitoring wells (MW-1 through MW-6) at the site to further investigate the extent of groundwater contamination. Groundwater sampling and analysis activities confirmed and delineated the extent of groundwater contamination. In response, the VDEQ recommended a site-specific risk assessment to determine the need for possible remedial action. The VDEQ VRP uses a tiered screening approach to compare the contaminants of concern to risk-based standards (risk assessment). Based on the site owner's goal to restore the site for unrestricted use, Tier II screening levels (consistent with Federal MCLs) and a residential exposure scenario were used in the soil and groundwater risk assessments. These Tier II screening levels for both soil and groundwater are provided in Table 1. In addition, VDEQ suggested a human health risk assessment (HHRA) and ecological risk assessment to evaluate any remaining potential risks present at the site to potential future residents and commercial workers associated with the inhalation of volatiles in the indoor air. (AECOM 2009).

AECOM performed additional site characterization efforts in August 2005 and April 2006 to further delineate the source beneath the building at the site and evaluate feasible remedial options to address the contamination. Nine direct push soil borings (ENSR-1 to

ENSR-9) were installed at locations on and adjacent to the site in August 2005. The borings were installed at depths ranging from 24 to 25 feet below ground surface (bgs), with one deep soil boring (ENSR-4) installed at a depth of 30 to 40 feet bgs. Soil analytical results from five locations (ENSR-1, ENSR-2, ENSR-7, ENSR-8, and ENSR-9) within the building footprint indicated the presence of tetrachloroethene (PCE), trichloroethene (TCE) and cis 1,2-dichloroethene (cis DCE) in the soil underneath the building. The highest concentrations of PCE and TCE were detected at boring ENSR-2 exceeding their respective VRP Tier II screening standards. Potential vapor intrusion issues were investigated by collecting four soil gas samples from on-site and off-site locations at approximately six feet bgs. All of the soil gas samples exhibited detectable concentrations of PCE, TCE, cis-DCE, and trans-DCE. Similar to the soil and groundwater results, the highest concentrations were observed next to soil boring/well ENSR-2. Figure 1 shows the soil and soil gas collection locations and the CVOC concentrations detected in soil (AECOM 2009).

To support additional groundwater sampling as part of the 2005 site investigation, selected temporary soil boreholes were converted into monitoring wells and installed to a depth of approximately 25 feet bgs. A deep monitoring well/soil boring (ENSR-4) was installed at a depth of 38 to 40 feet bgs to investigate the potential presence and migration of non-aqueous phase liquid (NAPL). Impacts to the groundwater were observed in the immediate vicinity of ENSR-2 and in the direction of groundwater flow (with both on-site and off-site impacts). Compounds detected in groundwater at the site included PCE, TCE, cis DCE, 1,2-dichlorethene (trans-DCE), 1-4-dichlorobenzene (DCB), benzene, methyl-tert-butyl-ether (MTBE), and vinyl chloride (VC). Several of the groundwater monitoring wells contained CVOCs that exceeded the VDEQ Tier II screening standards. The highest concentration of CVOCs was detected in monitoring well ENSR-2 located next to the floor drain beneath the dry cleaning building; this was consistent with the soil analytical results. Although deep monitoring well ENSR-4 contained CVOCs above the Tier II screening standards for groundwater, there was no indication of dense NAPL (DNAPL) at this location. Figure 2 shows the groundwater monitoring well locations and detected CVOC concentrations (AECOM 2009).

Based on elevated soil and groundwater contaminant concentrations, the presence of odor, and high photoionization detector (PID) measurements from borings within the building, the site investigation identified a presumed source area adjacent to a floor drain located beneath the former dry cleaning facility. The site investigation indicated that impacts outside the building area are associated with a dissolved CVOC plume moving in the direction of the groundwater flow (south and southwest of the site). Soil and groundwater impacted with contaminants appeared to be concentrated primarily underneath the building footprint and were likely associated with releases into the upper vadose zone that migrated downward to the groundwater. The CVOC concentrations were determined to present an unacceptable risk for unrestricted use of the site (TRS 2006). In addition to CVOCs, groundwater samples also showed the presence of petroleum-related compounds which likely were released from a former off-site retail gasoline station located upgradient from the dry cleaning site. However, records indicate that response actions were completed at the gasoline station site and the site was given a

no further action determination. As a result, these gasoline-related compounds were not specifically addressed as part of the remedial action for this site (AECOM 2009).

Based on site characterization results, electrical resistance heating (ERH), an in situ thermal remediation technology, was selected to treat the source area and dissolved plume at the site to achieve the goal of unrestricted site use. This technology was selected based on its ability to rapidly remove the contamination mass that was leaching into the groundwater and also remove contaminants already dissolved in the groundwater. In addition, the residual heat from the process enables increased biological activity and natural attenuation processes that continue to remove CVOCs in the groundwater (AECOM 2009). The ERH system began operation on September 22, 2006, and was shut-off on December 12, 2007. The effectiveness of the ERH system was evaluated by monitoring the reduction of PCE, TCE, cis-DCE, and VC concentrations in site soil and groundwater. The ERH system comprised of an electrode/vapor recovery wells located across the site that would volatize CVOCs in the subsurface which would then be treated by a vapor treatment system installed on the site. Additional soil and groundwater sampling and monitoring of the system were performed throughout the remediation process to track the progress of the remediation effort and allow ongoing adjustments to the system during its operation. PID measurements of the discharge from the vapor treatment stream were obtained during operation of the ERH system to evaluate trends in VOC removal and monitor air quality during the installation of the electrodes. After the ERH system was turned off, the vapor collection and treatment system ran for an additional two weeks to recover any soil vapors generated from the residual heat in the subsurface during system cool down (AECOM 2009).

The remedial actions performed at the site achieved significant mass removal of the contaminants of concern in a time frame of approximately 1 year. Dissolved phase PCE concentrations detected in the source area were reduced by approximately 99% and the VRP Tier II screening levels for selected compounds were attained in several on-site monitoring wells. However, CVOC concentrations in several soil and groundwater samples remained above the screening levels after ERH cleanup activities were complete. As a result, the goal of unrestricted site use has not yet been obtained. The potential risks posed by these residual contaminants will be mitigated through institutional controls (ICs) placed at the site, including deed restriction that limit the use of groundwater and that require adherence to a specific soil management plan. Based on the post-treatment results and the implementation of ICs, the site was recommended for closure under the VRP and for issuance of a Certificate of Satisfactory Completion of Remediation. The Certificate will document the IC that groundwater beneath the site will not be used for any purpose other than environmental monitoring and testing (AECOM 2009).

Cleanup Authority	VDEQ Voluntary Remediation Program (VRP)
ID Number	VRP00389
Type of Action	Remedial (VRP)
Lead	AECOM (under contract to site owner)
Oversight	Virginia Department of Environmental Quality (VDEQ)

Figure 1: Soil Boring Locations and Detected CVOC Concentrations

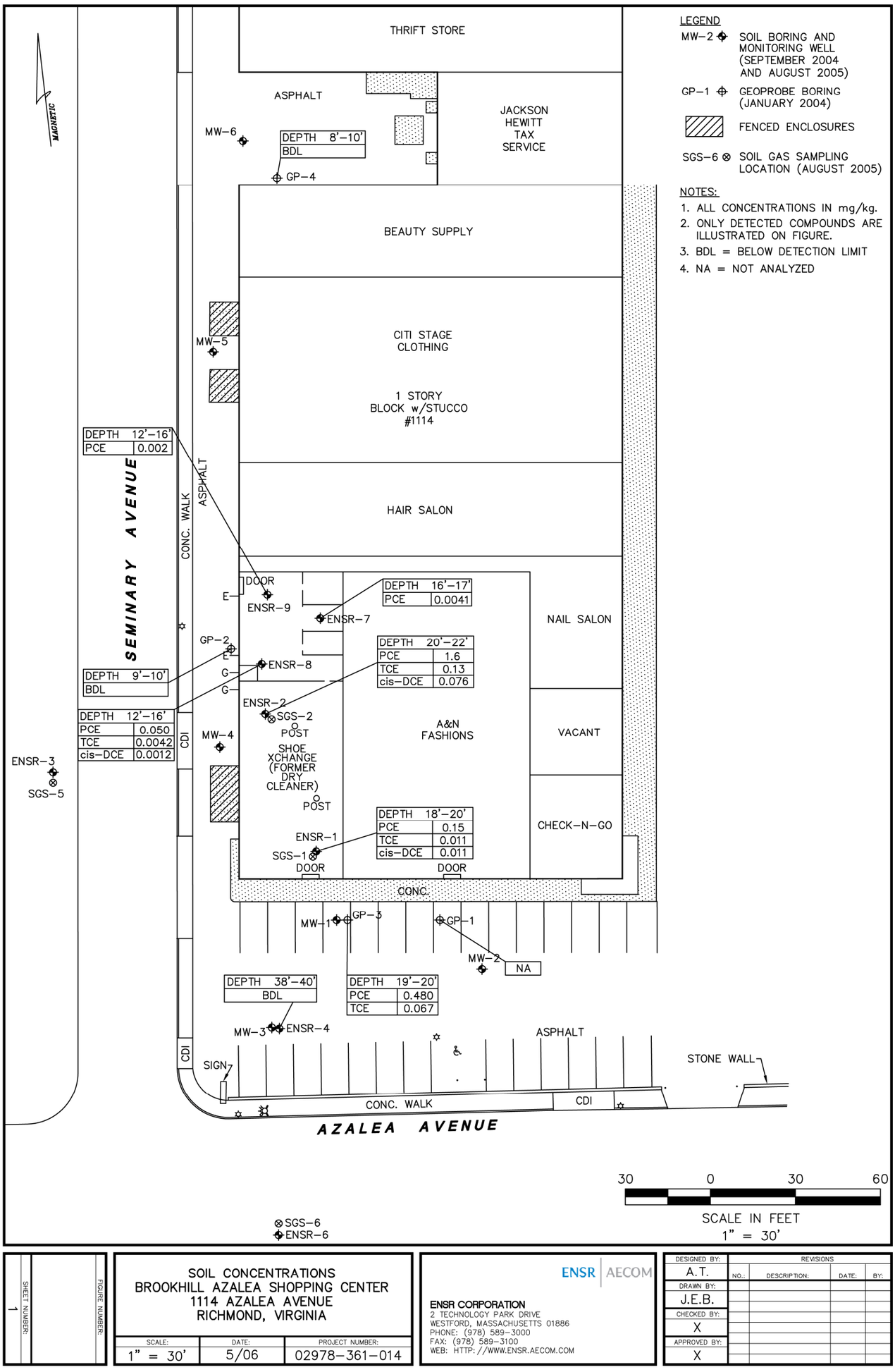
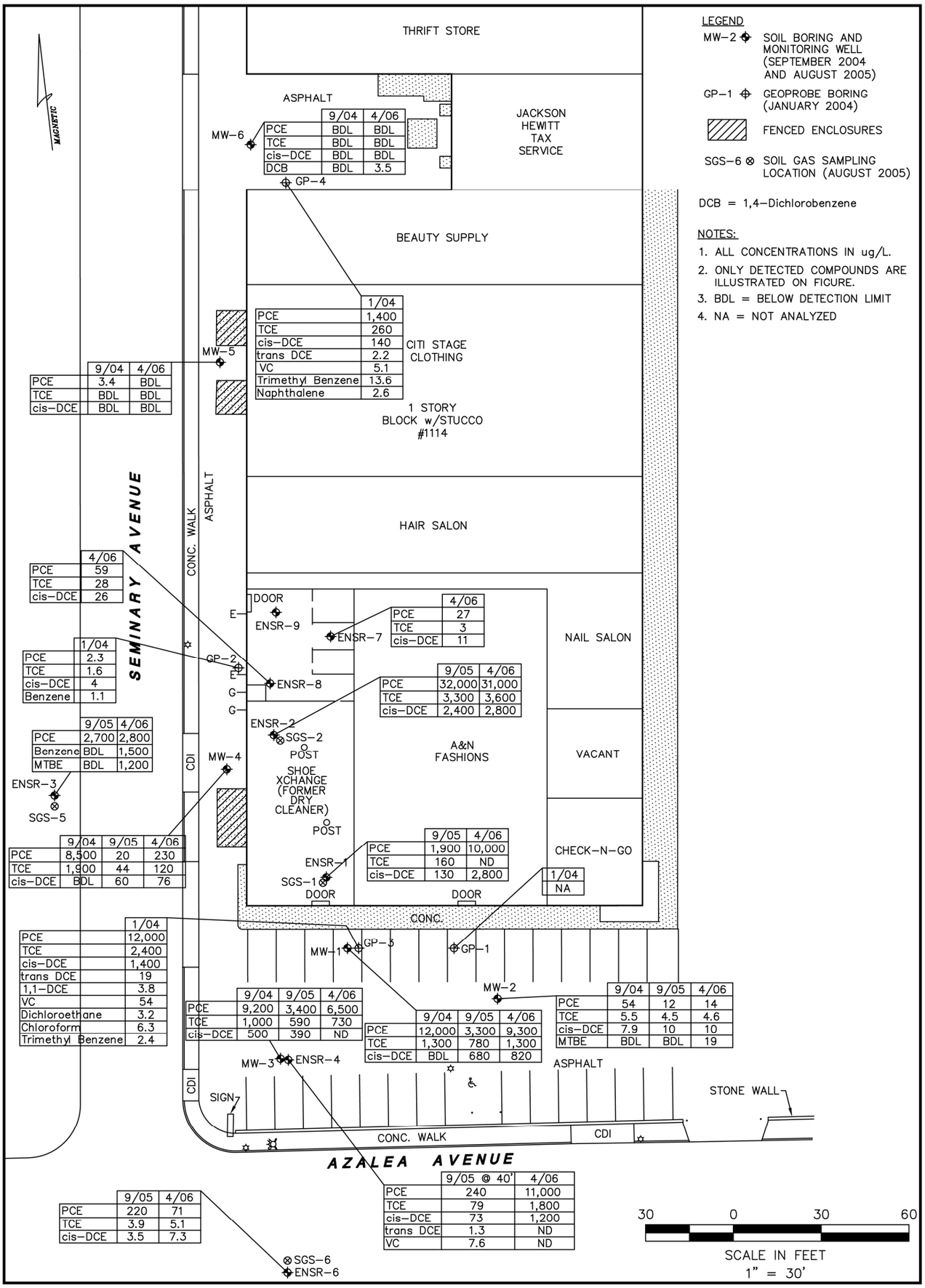


Figure 2: Groundwater Monitoring Well locations and Detected CVOC Concentrations



	9/04	4/06
PCE	BDL	BDL
TCE	BDL	BDL
cis–DCE	BDL	BDL
DCB	BDL	3.5

	1/04
PCE	1,400
TCE	260
cis–DCE	140
trans DCE	2.2
VC	5.1
Trimethyl Benzene	13.6
Naphthalene	2.6

	9/04	4/06
PCE	3.4	BDL
TCE	BDL	BDL
cis–DCE	BDL	BDL

	4/06
PCE	59
TCE	28
cis–DCE	26

	1/04
PCE	2.3
TCE	1.6
cis–DCE	4
Benzene	1.1

	9/05	4/06
PCE	2,700	2,800
Benzene	BDL	1,500
MTBE	BDL	1,200

	9/04	9/05	4/06
PCE	8,500	20	230
TCE	1,900	44	120
cis–DCE	BDL	60	76

	4/06
PCE	27
TCE	3
cis–DCE	11

	9/05	4/06
PCE	32,000	31,000
TCE	3,300	3,600
cis–DCE	2,400	2,800

	9/05	4/06
PCE	1,900	10,000
TCE	160	ND
cis–DCE	130	2,800

	1/04
	NA

	1/04
PCE	12,000
TCE	2,400
cis–DCE	1,400
trans DCE	19
1,1–DCE	3.8
VC	54
Dichloroethane	3.2
Chloroform	6.3
Trimethyl Benzene	2.4

	9/04	9/05	4/06
PCE	9,200	3,400	6,500
TCE	1,000	590	730
cis–DCE	500	390	ND

	9/04	9/05	4/06
PCE	12,000	3,300	9,300
TCE	1,300	780	1,300
cis–DCE	BDL	680	820

	9/04	9/05	4/06
PCE	54	12	14
TCE	5.5	4.5	4.6
cis–DCE	7.9	10	10
MTBE	BDL	BDL	19

	9/05	4/06
PCE	220	71
TCE	3.9	5.1
cis–DCE	3.5	7.3

	9/05 @ 40'	4/06
PCE	240	11,000
TCE	79	1,800
cis–DCE	73	1,200
trans DCE	1.3	ND
VC	7.6	ND

Time Line

October 2003	Phase I Environmental Site Assessment
January 2004	Phase II Environmental Site Assessment
August 2004	Site is entered into the VDEQ's VRP
September 2004	Monitoring well installation and additional site characterization.
August/September 2005	Site-specific risk assessment and further characterization efforts.
April 2006	Supplemental site characterization efforts to delineate the soil and groundwater contamination
May 25, 2006	Remedial Action Work Plan submitted to the VDEQ
June 19, 2006	Site preparation and mobilization activities begin.
June – September 2006	ERH treatment system installed.
September 22, 2006	ERH system operation initiated.
November 7 – 29, 2007	ERH system shut-off temporarily to address a sudden elevation in groundwater levels.
November 29, 2007	ERH system re-energized.
December 12, 2007	ERH system shut-off
December 28, 2007	Vapor collection and treatment system shut down.
December 28, 2007 – June 2008	Post-remediation groundwater and soil monitoring implemented.

Factors that Affected Cost or Performance

The majority soils in this area/zone are low-permeability silts and clays. This soil type is consistent with low hydraulic conductivity. The groundwater at the site was characterized as having a velocity of 3.5 feet per year (ft/yr) and a hydraulic conductivity in the range of 0.00004 to 0.00026 ft/min. The hydraulic conductivity of this zone would not likely allow the electrodes to remain wet throughout the remediation which would likely result in increased local electrical resistance and the uneven heating of the electrodes and soil. Therefore, a one-half inch diameter drip water hose was routed inside each borehole that contained an electrode during system installation. Recirculation provided by this drip hose was needed to control the heating of the electrodes.

In addition, the depth of the soil and the groundwater elevation beneath the site impacted the installation depth of the vapor recovery wells and soil and groundwater monitoring wells. Soils at the site were encountered beneath several inches of concrete under the building and consisted of sandy fill material grading into clay to a depth of 20 feet bgs. The average groundwater elevation at the site is 4 to 10 feet bgs. However, a three-month period of unusually heavy rains caused groundwater elevations to increase from 8 feet to 2 feet bgs at the site. This sudden elevation in water level submerged the vapor recovery wells. As a result, it became difficult to remove the vapors. In addition, excess water and silt were pulled into the treatment system components. This excess silt

and water required increased storage and disposal of condensate and more frequent maintenance of clogged equipment.

Matrix Characteristics

Parameter	Value
Soil Classification	Silty and sandy clay
Clay Content and/or Particle Size Distribution	Minor amounts of sandy fill material grading immediately into clay with varying amounts of silt and sand.
Depth/Thickness of Zone of Interest	0 to 30 feet bgs
Direction of Groundwater Flow	South to southwest
Groundwater Velocity	3.5 feet/year
Hydraulic Conductivity	0.00004 to 0.00026 feet/minute
pH:	4.7 to 5.5
Dissolved Oxygen	1.5 to 6.20 milligram/liter (mg/L)
Oxidation-Reduction Potential	1.5 to 7.5mg/L

Treatment Technology Description

ERH was identified as the most effective treatment technology alternative for dry cleaning source impacts at this site. This in-situ thermal treatment technology is aggressive and is capable of rapidly reducing contaminants to applicable remediation levels in low-permeable soils and groundwater (TRS 2006).

The ERH system uses in situ resistance heating and steam stripping treatment, in which electricity is supplied by a 3-phase electrical power source that is connected to the power control unit (PCU). Electricity is applied to the electrodes and current flows between them within the treatment area. Resistance to the electricity from underground soil causes the subsurface to heat to a temperature at or near the boiling point of water. A combination of contaminants and water will boil at a lower temperature than either the water or contaminant alone. Higher temperatures are required to create boiling conditions with increasing depth. When the subsurface is heated, the CVOCs in soil and groundwater volatize, creating in situ vapor and steam. The in situ vapor and steam are collected in vapor recovery wells using a vacuum to help recover the vapor and prevent steam from moving outside the treatment area. At the surface, CVOCs are separated from the steam by a condenser, and the resulting condensate water is recycled as condenser cooling water and as electrode drip water. The CVOC vapor in the air passing through the condenser is absorbed by Granulated Activated Carbon (GAC) units. For further information about this technology, visit the TRS Web site at http://www.thermalrs.com/ (AECOM 2009; TRS 2006; TRS 2009).

Design

The goal of the remediation technology was to heat the subsurface long enough to reduce baseline concentrations of PCE and other CVOC concentrations by 99.92%. The ERH

system was designed to maximize vapor recovery, minimize the duration of treatment, and maximize the capture and treatment of those vapors.(TRS 2006).

The ERH remediation treatment area consisted of 13,040 square feet (sq ft) at the southern end of the shopping center at the dry cleaning facility. This total area included the area under the building (4,349 sq. ft) and the area located under the parking lot adjacent to the building (8,691 sq. ft). The average remediation depth interval was from 6.7 to 30 feet bgs; however, electrical energy was applied over total depth intervals of approximately 4 to 31 feet bgs beneath the building and 10 to 31 feet bgs beneath the parking lot. The estimated target remediation volume was approximately 10,400 cubic yards (cy) (TRS 2006).

The system included a combination of sixty-two electrode/vapor recovery wells, of which 19 were installed inside the building and 43 were installed outside the building. Two different electrode designs were used, Full Electrodes and Deep Electrodes. Full Electrodes were used to heat the vadose and saturated zones at the site. Deep Electrodes were used to heat only the saturated zones. The vapor recovery wells were co-located with the electrodes to remove steam and CVOC vapors directly, without relying on vapor buoyancy. Spacing between each electrode and vapor recovery well was approximately 15-feet (center-to-center). The tight vapor recovery well spacing helped provide complete vapor capture to ensure that there was no migration of steam or vapors to the surface or outside the treatment area (TRS 2006).

The use of a large number of extraction points helped ensure that subsurface heterogeneity would not adversely affect vapor recovery. The total air extraction rate was estimated at approximately 440 standard cubic feet per minute (scfm) for the complete recovery of steam and heated soil vapors during remediation. These electrode/vapor recovery wells were installed in12-inch diameter boreholes to a maximum depth of 31 feet bgs. Well screens (0.040-inch slots) were installed at depths ranging from 6 to 10 feet bgs and surrounded by conductive backfill. In order to withstand the high temperatures caused by the resistive heating, the electrodes/vapor recovery wells were constructed of steel. The electrodes consisted of 50% steel shot and 50% graphite. Due to the low hydraulic conductivity of the saturated zone, the electrical resistance of the electrodes had a potential to increase, which would lead to uneven heating. To prevent this, a small amount of recirculation water was used to moisten soil adjacent to the electrodes. This was accomplished through one-half inch diameter drip water hose that was routed inside each borehole that contained an electrode (TRS 2006).

Site Preparation

Site preparation began on June 19, 2006. Two 550 gallon tanks were placed at the site to containerize groundwater and other decontamination fluid generated during installation of the treatment system components. In addition, a 25 CY container was installed at the site for storage/transport of the soils generated during installations of the electrode/vapor recovery wells. Polyvinyl chloride (PVC) monitoring wells already located at the site were replaced with stainless steel monitoring wells in order to withstand the higher

temperatures associated with the ERH system. New wells (ENSR-14 to ENSR-20) were installed within three to four feet of the former monitoring wells. (AECOM 2009)

Installation

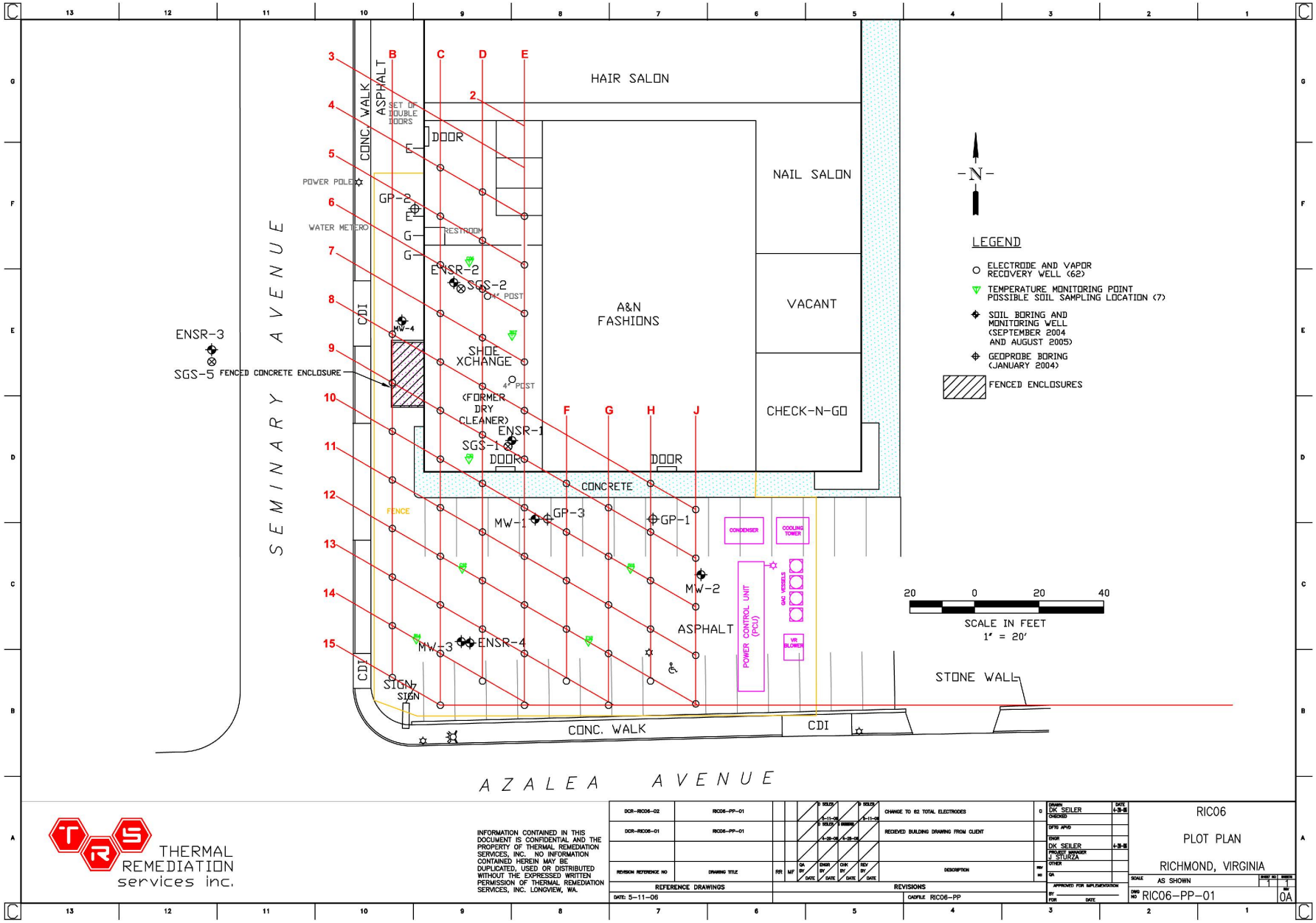
The ERH system was installed between June and September 2006 by Thermal Remediation Services, Inc. (TRS). This included installation of the electrical, piping, and plumbing fittings from the electrode and vapor recovery wells to the PCU, vacuum blower and the electrode drip tubing. The voltage was supplied by an electric utility adjacent to the site. The PCU had a maximum power output of 2,000 kilowatts (kW). The voltage was reduced to an appropriate level before electricity was delivered to the subsurface. Vapor recovery was performed using a 40-horsepower (hp) positive displacement blower, which is effective for applications using a high vacuum and relatively high flow. Above ground treatment equipment, which included the condenser/heat exchanger, fan/cooling tower, condensate storage tanks, and vapor-phase GAC vessels, were delivered and connected to their respective controls (TRS 2006). The GAC outlet was connected to the vacuum blower inlet and the vacuum blower outlet was connected to the atmosphere discharge stack. Four GAC vessels (each containing 1,000 pounds of GAC) were required to treat the collected vapors (AECOM 2009; TRS 2006).

In addition, seven temperature monitoring points (TMP) were placed at various locations in the electrode field to measure and track the subsurface temperature at multiple depths during ERH system operation. Each of the seven TMPs consisted of six thermocouples placed at five-foot depth intervals to a total depth of 30 feet bgs. The location of the electrodes and vapor recovery wells, TMPs, and monitoring wells are shown in Figure 3 (AECOM 2009).

Operation

Start-up and optimization of the ERH system spanned approximately two weeks. After all of the operating parameters attained ERH operational standards, the voltage was slowly increased (TRS 2006). The ERH system was monitored and operated remotely by AECOM and TRS from September 2006 to December 2007. In addition, weekly site visits were conducted for routine operation and maintenance of the system. During system operation, AECOM and TRS analyzed a variety of metrics daily, including: power application rates, total energy input to the subsurface, subsurface temperatures, condensate production rates, and VOC recovery data. Based on these data, adjustments to the system were made remotely, as needed. In addition, the daily system monitoring data were used to optimize the application of energy to the subsurface throughout the operation of the ERH system to achieve efficient subsurface temperature increases per unit of energy applied.

Figure 3: Location of Electrode/Vapor Recovery Wells and Temperature Monitoring Points



The ERH system was shut-off from November 7 to November 29 to address problems associated with a sudden increase in groundwater elevation resulting from heavy rains. During this period, 47 supplemental shallow vapor recovery wells were installed at a depth of 1 to 3 feet bgs to allow continued operation of the vapor recovery system. The system was re-enabled on November 29, 2007. To concentrate the electrical energy on locations where cleanup objectives had not been met, the ERH system was reduced from 62 wells to 28 on September 18, 2007. This reduction was guided by groundwater sampling data collected from on-site monitoring wells during the operation of the ERH system. Since the number of electrodes was decreased, the voltage could be increased from approximately 43 watts to approximately 61 watts per electrode. This increase in voltage allowed more rapid vaporization of residual contaminant mass within the targeted area. The ERH system was shut-off on December 12, 2007 when the design energy input for the site had been reached and there were no further significant changes in groundwater concentrations. The vapor collection and treatment system ran for an additional two weeks to ensure that no residual soil vapors escaped the treatment area during system cool down (AECOM 2009).

Sampling and performance monitoring were conducted throughout the operation of the ERH system to track remediation progress, to support operational decisions, and to manage waste streams. Sampling and monitoring were performed during district timeframes: pre-heating baseline sampling, sampling and monitoring during operation, and post-heating sampling (TRS 2006). Groundwater and vapor samples were collected at scheduled intervals during the remediation process. Groundwater samples were collected and analyzed for CVOCs at locations within the facility including near the contaminant source area where the highest CVOC concentrations were detected. Groundwater samples were also taken downgradient of the source area based on groundwater flow direction at the site. PID measurements of the vapor discharge from the vapor treatment stream were obtained to evaluate trends in CVOC removal from the subsurface. These samples were evaluated using real time PID measurements of the vapor discharge. Additionally, samples of the influent and effluent vapor phase carbon treatment units were collected weekly using SUMMA canisters. Vapor phase concentrations being removed from the subsurface were tracked throughout the entire remediation process to demonstrate compliance with vapor discharge permitting, monitor performance of the vapor treatment system, determine GAC change-out frequency, and to calculate the rate of CVOC recovery and the total mass of CVOCs removed during the ERH process. In addition, soil monitoring was conducted during the installation of the electrodes and vapor recovery wells to evaluate the soil CVOC concentration and the mass of CVOCs in the treatment area (AECOM 2009).

Operating Parameters (AECOM 2009; TRS 2006)

Parameter	Value
Number of electrode/vapor recovery wells	62
Depth of vapor recovery wells	31 feet bgs
Electrode material composition	50% steel shot and 50% graphite.
Diameter of borehole	12 inches

Total applied energy	4,200,000 kWh
Daily energy application rate	398 kW
Average subsurface temperature increase rate	4˚ C per day
Vapor and Air Extraction Rate	440 standard cubic feet per minute
Groundwater removal rate	6.3 gallons per minute

Performance Information

ERH Operational Data

The total applied energy for the ERH system was approximately 4,200,000 kilowatt-hours (kWh). The average daily application rate was 398 kW. The peak daily rate (1,379 kW) occurred during the first week of operation. The rate of energy application was reduced after groundwater temperatures reached the boiling point.

At the start of ERH system operation in September 2006, the average subsurface temperature was approximately 23˚ C. During ERH system operation, the average subsurface temperature increased at a rate of 4˚ C per day. Figure 4 shows the subsurface temperature increase at the TMPs throughout the operation of the ERH system. The heating rate slowed as the thermocouples installed at the site indicated that the boiling temperature was achieved at subsurface locations throughout the treatment area. Subsurface temperature measurements indicated that the highest temperatures occurred in thermocouples located at 20 and 25 feet bgs. The maximum average daily temperature of 102˚ C was reached on July 6, 2007. The average subsurface temperature on the last day of ERH system, December 12, 2007, was 87˚ C. Figure 5 shows the average subsurface temperatures over the entire treatment area with depth at selected weeks during the remediation (AECOM 2009; TRS 2006). Define and use

PID measurements of the vapor discharge indicated that vapor concentrations increased from 0 (September 2006) to 4 ppmv (March 2007). Prior to ERH system shut-down in 2007, the concentration of CVOCs dropped to 0.12 ppmv. The total mass of contamination removed from the subsurface by the ERH system was 102.3 pounds based on the concentration of CVOC vapors recovered during ERH operation and recorded airflow measurements (AECOM 2009). Figure 6 shows the influent concentrations and cumulative mass removal during the treatment process.

Post-Remediation Performance Data

After shut-down of the ERH system on December 12, 2007, groundwater, subsurface soil, and subsurface soil gas were monitored. The analytical results were evaluated to determine the reduction in CVOCs. The analytical results were also used in a post-remediation HHRA and ecological risk assessment to evaluate the remaining risk potential to future residents and commercial workers associated with the inhalation of volatiles in the indoor air at the site. The project remedial goals used for the Azalea site were the Tier II standards which are consistent with unrestricted site use. These remediation levels are presented in Table 1 (AECOM 2009).

Figure 4: Subsurface Temperature Increases at TMPs vs. Time

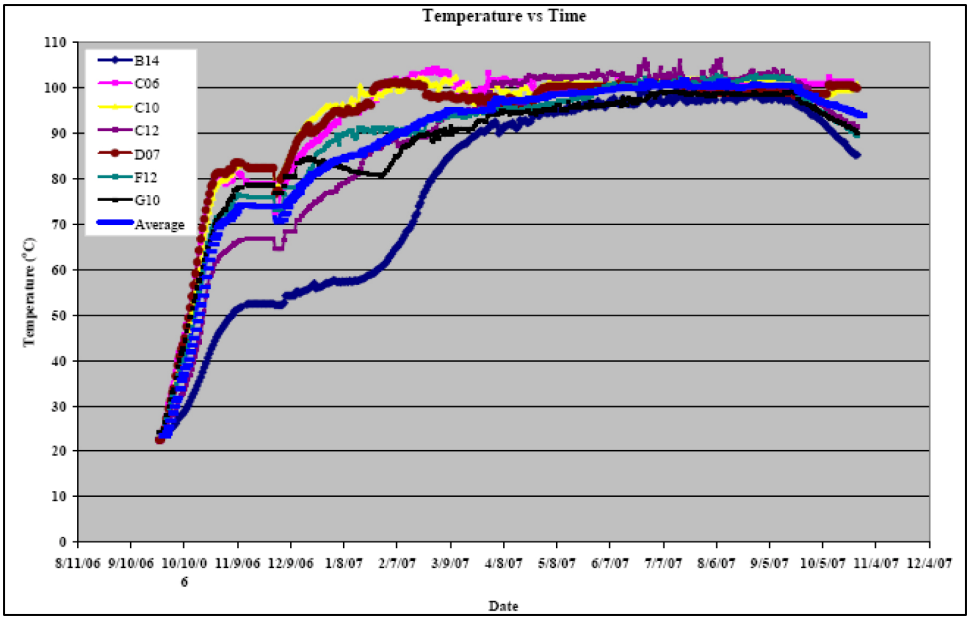


Figure 5: Average Subsurface Temperatures at TMPs with Depth during Selected Weeks of the Remediation Process

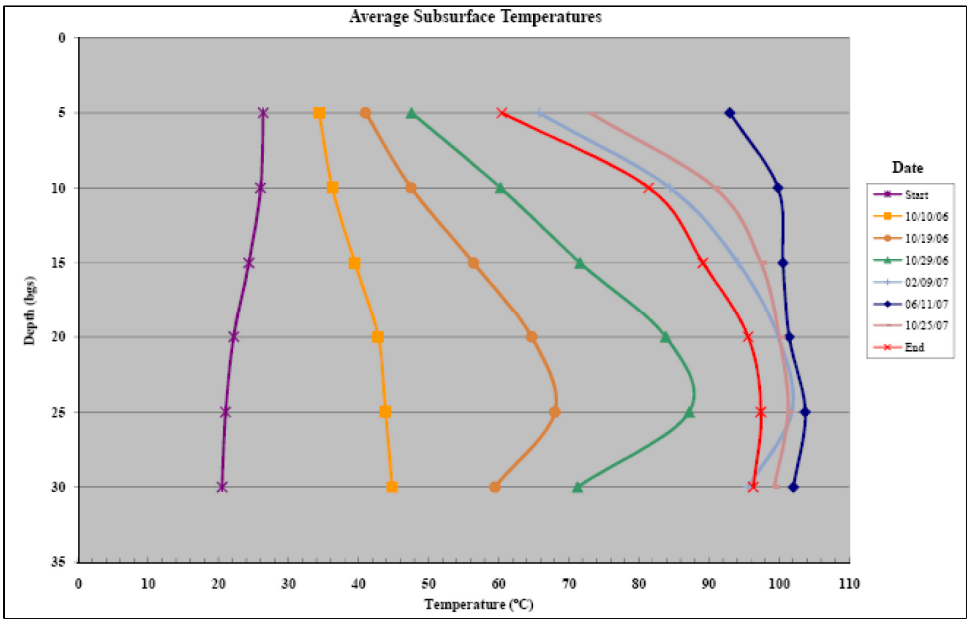


Figure 6: Cumulative CVOC Mass Removed

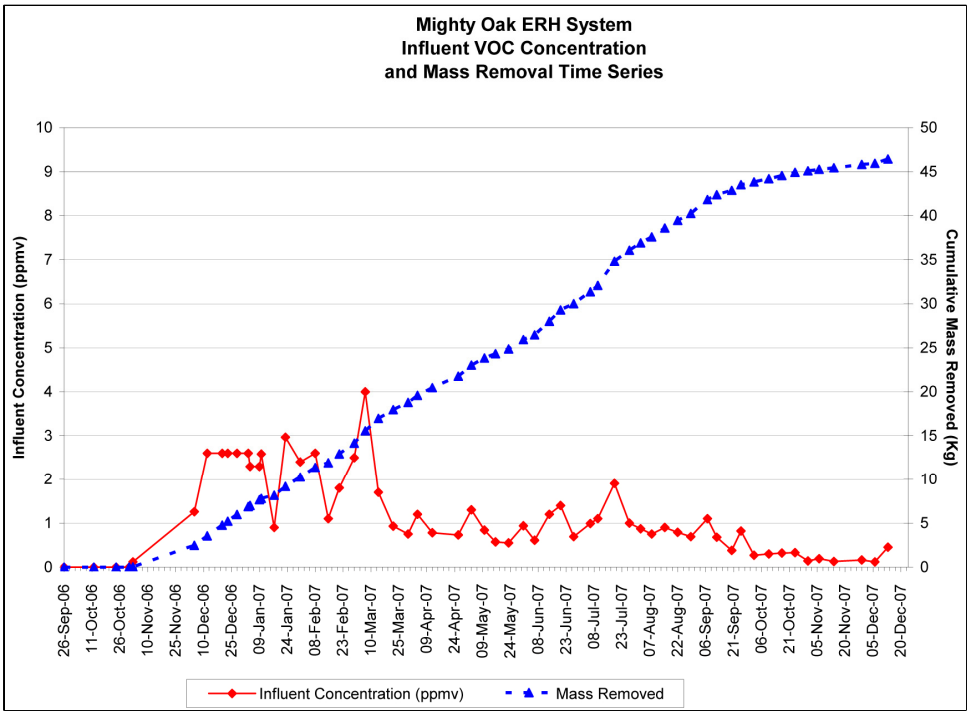


Table 1: VRP Tier II Screening Levels (AECOM 2006)		
Compound	**Groundwater standard (µg/L)**	**Soil standard (ug/Kg)**
PCE	5	378
TCE	5	43.7
Cis 1,2-DCE	70	483
Trans 1,2-DCE	100	995
Vinyl chloride	2	15.8

Groundwater Monitoring

Groundwater monitoring was conducted several months after shut-down of the ERH treatment system in March and June 2008 to evaluate the presence of CVOCs in the groundwater. Table 2 compares the analytical results from the 2004 site investigation and the post-heating monitoring event in June 2008. The groundwater monitoring consisted of low-flow sample collection from monitoring wells ENSR-3, ENSR-6, and ENSR-14 to ENSR-20. Figure 7 depicts the sampling locations and analytical results for these monitoring wells. The analytical results showed significant decreases in CVOC concentrations in a relatively short-time frame. In comparison to sampling results obtained in the 2004 site investigation, the majority of the contaminants of concern were below the VRP Tier II groundwater cleanup levels. The average reduction of PCE concentration in groundwater wells located within the ERH system area was 98.8%. The largest decreases in concentrations were observed in wells near the source area (ENSR-18, formerly ENSR-2) within the building. The average reduction of PCE concentrations in wells located within the source area was 99.4%. At ENSR-18, PCE concentrations were reduced from 32,000 µg/L (September 2004) to 200 µg/L (June 2008). PCE concentrations within the building ranged from 3.7 (ENSR-20) to 200 µg/L (ENSR-18) for samples collected on June 2008. Less significant decreases of PCE were observed in the monitoring wells located outside of the building but still within the ERH system area. PCE concentrations from samples collected outside of the building in June 2008 ranged from 3.0 µg/L at ENSR-15 to 2,600 µg/L at ENSR-3. TCE concentrations within the building ranged from below detection limits (bdl) at ENSR- 20 to 32 µg/L (ENSR-18). The highest TCE concentration (98 µg/L) after treatment was detected at ENSR-16 located outside of the treatment zone. Cis- 1,2 DCE concentrations ranged from 2.1 µg/L (ENSR-20) within the building to 300 µg/L (ENSR-16) outside of the building. For wells located at the periphery of the ERH treatment zone, CVOC concentrations decreased during the first six months of treatment but the rate of this decrease slowed during the remaining operation of the ERH system (AECOM 2009).

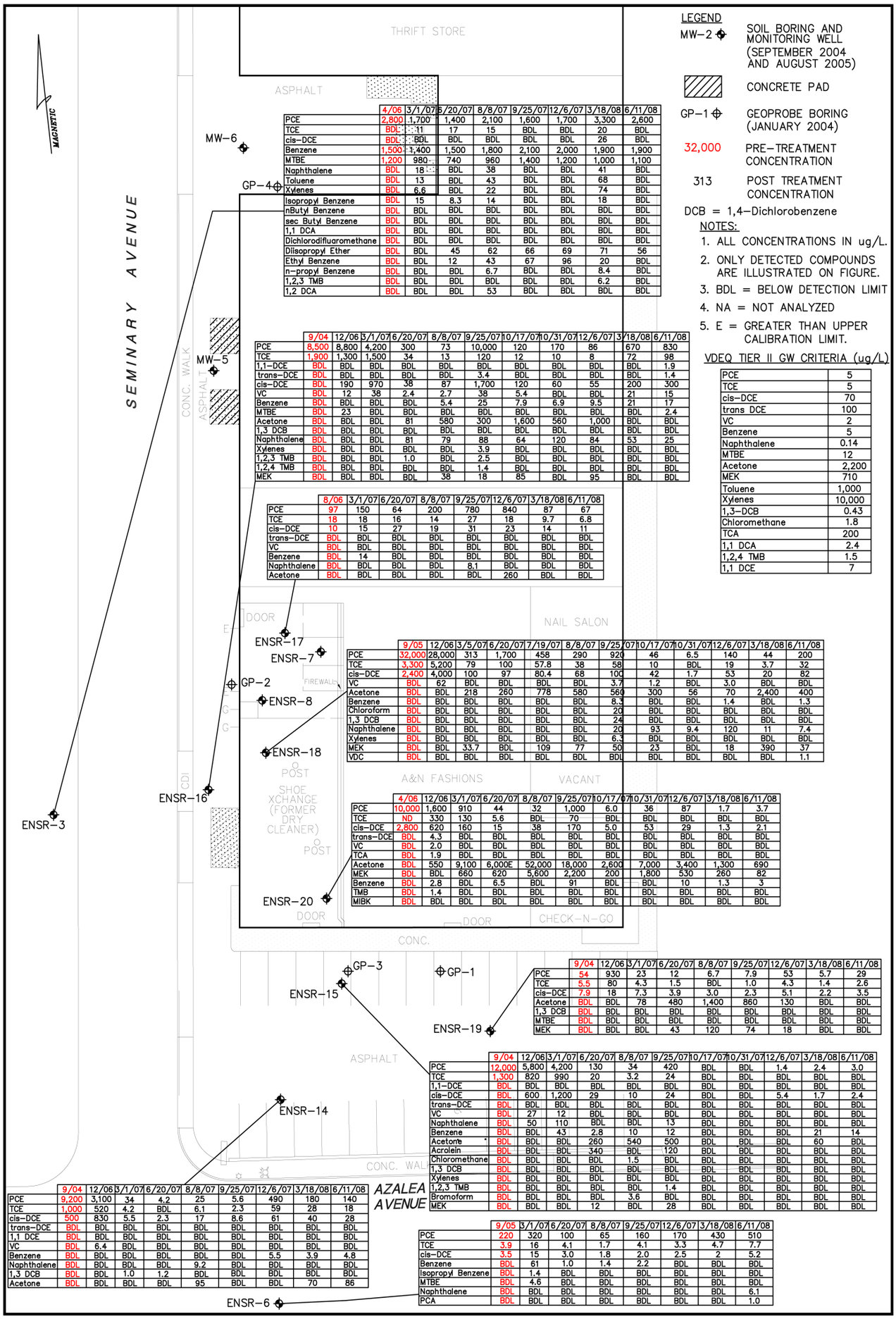
The results from the March 2008 sampling event indicated a significant increase in chlorides compared to background concentrations at down-gradient well ENSR-14 and off-site well ENSR-6. In addition, the concentration of ethene increased in well ENSR-18 near the source area. These increases in chlorides and ethenes indicated degradation of CVOCS. Based on these results, AECOM determined that CVOC concentrations within and adjacent to the treatment area will continue to decrease due to attenuation processes such as biodegradation which may occur after ERH treatment (AECOM 2009).

The post-remediation groundwater analytical results indicated that PCE, TCE, cis-DCE, and VC concentrations still exceed the VDEQ Tier II groundwater screening values for unrestricted use at several locations at the site. Therefore, groundwater use restrictions will be added to the deed to mitigate the potential risks posed by the remaining contamination (AECOM 2009).

Table 2: Groundwater Monitoring Well Analytical Results (AECOM 2009)			
Location	**Compound**	**2004 Sampling Results (µg/L)**	**June 2008 Sampling Results (µg/L)**
ENSR-3	**PCE**	1,700	2,600
	TCE	BDL	BDL
	cis- 1,2 DCE	BDL	BDL
	VC	No Results	No Results
	Benzene	2,000	1,900
ENSR-6	**PCE**	220	510
	TCE	3.9	7.7
	cis- 1,2 DCE	4	5.2
	VC	No Results	No Results
	Benzene	BDL	BDL
ENSR-14	**PCE**	9,200	140
	TCE	1,000	18
	cis- 1,2 DCE	500	28
	VC	BDL	BDL
	Benzene	BDL	4.8
ENSR-15	**PCE**	12,000	3
	TCE	1,300	BDL
	cis- 1,2 DCE	BDL	2.4
	VC	BDL	BDL
	Benzene	BDL	14
ENSR-16	**PCE**	8,500	830
	TCE	1,900	98
	cis- 1,2 DCE	BDL	300
	VC	BDL	15
	Benzene	BDL	17
ENSR-17	**PCE**	97	67
	TCE	18	6.8
	cis- 1,2 DCE	10	11
	VC	BDL	BDL
	Benzene	BDL	BDL
ENSR-18	**PCE**	32,000	200
	TCE	3,300	32
	cis- 1,2 DCE	2,400	82
	VC	BDL	BDL
	Benzene	BDL	1.3
ENSR-19	**PCE**	54	29
	TCE	6	3
	cis- 1,2 DCE	8	3.5
	VC	No Results	No Results
	Benzene	No Results	No Results
ENSR-20	**PCE**	10,000	3.7
	TCE	BDL	BDL
	cis- 1,2 DCE	2,800	2.1
	VC	BDL	BDL
	Benzene	BDL	3

Notes: BDL indicates below detection limit. µg/L indicates micrograms per liter.

Figure 7: Post-Treatment Groundwater Concentrations



	4/06	3/1/07	6/20/07	8/8/07	9/25/07	12/6/07	3/18/08	6/11/08
PCE	2,800	1,700	1,400	2,100	1,600	1,700	3,300	2,600
TCE	BDL	11	17	15	BDL	BDL	20	BDL
cis-DCE	BDL	BDL	BDL	BDL	BDL	BDL	26	BDL
Benzene	1,500	1,400	1,500	1,800	2,100	2,000	1,900	1,900
MTBE	1,200	980	740	960	1,400	1,200	1,000	1,100
Naphthalene	BDL	18	BDL	38	BDL	BDL	41	BDL
Toluene	BDL	13	BDL	43	BDL	BDL	68	BDL
Xylenes	BDL	6.6	BDL	22	BDL	BDL	74	BDL
Isopropyl Benzene	BDL	15	8.3	14	BDL	BDL	18	BDL
nButyl Benzene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
sec Butyl Benzene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
1,1 DCA	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Dichlorodifluoromethane	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Diisopropyl Ether	BDL	BDL	45	62	66	69	71	56
Ethyl Benzene	BDL	BDL	12	43	67	96	20	BDL
n-propyl Benzene	BDL	BDL	BDL	6.7	BDL	BDL	8.4	BDL
1,2,3 TMB	BDL	BDL	BDL	BDL	BDL	BDL	6.2	BDL
1,2 DCA	BDL	BDL	BDL	53	BDL	BDL	BDL	BDL

	9/04	12/06	3/1/07	6/20/07	8/8/07	9/25/07	10/17/07	10/31/07	12/6/07	3/18/08	6/11/08
PCE	8,500	8,800	4,200	300	73	10,000	120	170	86	670	830
TCE	1,900	1,300	1,500	34	13	120	12	10	8	72	98
1,1-DCE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.9
trans-DCE	BDL	BDL	BDL	BDL	BDL	3.4	BDL	BDL	BDL	BDL	1.4
cis-DCE	BDL	190	970	38	87	1,700	120	60	55	200	300
VC	BDL	12	38	2.4	2.7	38	5.4	BDL	BDL	21	15
Benzene	BDL	BDL	BDL	BDL	5.4	25	7.9	6.9	9.5	21	17
MTBE	BDL	23	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.4
Acetone	BDL	BDL	BDL	81	580	300	1,600	560	1,000	BDL	BDL
1,3 DCB	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Naphthalene	BDL	BDL	BDL	81	79	88	64	120	84	53	25
Xylenes	BDL	BDL	BDL	BDL	BDL	3.9	BDL	BDL	BDL	BDL	BDL
1,2,3 TMB	BDL	BDL	BDL	1.0	BDL	2.5	BDL	BDL	BDL	BDL	BDL
1,2,4 TMB	BDL	BDL	BDL	BDL	BDL	1.4	BDL	BDL	BDL	BDL	BDL
MEK	BDL	BDL	BDL	BDL	38	18	85	BDL	95	BDL	BDL

	8/06	3/1/07	6/20/07	8/8/07	9/25/07	12/6/07	3/18/08	6/11/08
PCE	97	150	64	200	780	840	87	67
TCE	18	18	16	14	27	18	9.7	6.8
cis-DCE	10	15	27	19	31	23	14	11
trans-DCE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
VC	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Benzene	BDL	14	BDL	BDL	BDL	BDL	BDL	BDL
Naphthalene	BDL	BDL	BDL	BDL	8.1	BDL	BDL	BDL
Acetone	BDL	BDL	BDL	BDL	BDL	260	BDL	BDL

	9/05	12/06	3/5/07	6/20/07	7/19/07	8/8/07	9/25/07	10/17/07	10/31/07	12/6/07	3/18/08	6/11/08
PCE	32,000	28,000	313	1,700	458	290	920	46	6.5	140	44	200
TCE	3,300	5,200	79	100	57.8	38	58	10	BDL	19	3.7	32
cis-DCE	2,400	4,000	100	97	80.4	68	100	42	1.7	53	20	82
VC	BDL	62	BDL	BDL	BDL	BDL	3.7	1.2	BDL	3.0	BDL	BDL
Acetone	BDL	BDL	218	260	778	580	560	300	56	70	2,400	400
Benzene	BDL	BDL	BDL	BDL	BDL	BDL	8.3	BDL	BDL	1.4	BDL	1.3
Chloroform	BDL	BDL	BDL	BDL	BDL	BDL	20	BDL	BDL	BDL	BDL	BDL
1,3 DCB	BDL	BDL	BDL	BDL	BDL	BDL	24	BDL	BDL	BDL	BDL	BDL
Naphthalene	BDL	BDL	BDL	BDL	BDL	BDL	20	93	9.4	120	11	7.4
Xylenes	BDL	BDL	BDL	BDL	BDL	BDL	6.3	BDL	BDL	BDL	BDL	BDL
MEK	BDL	BDL	33.7	BDL	109	77	50	23	BDL	18	390	37
VDC	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.1

	4/06	12/06	3/1/07	6/20/07	8/8/07	9/25/07	10/17/07	10/31/07	12/6/07	3/18/08	6/11/08
PCE	10,000	1,600	910	44	32	1,000	6.0	36	87	1.7	3.7
TCE	ND	330	130	5.6	BDL	70	BDL	BDL	BDL	BDL	BDL
cis-DCE	2,800	620	160	15	38	170	5.0	53	29	1.3	2.1
trans-DCE	BDL	4.3	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
VC	BDL	2.0	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
TCA	BDL	1.9	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Acetone	BDL	550	9,100	6,000E	52,000	18,000	2,600	7,000	3,400	1,300	690
MEK	BDL	BDL	660	620	5,600	2,200	200	1,800	530	260	82
Benzene	BDL	2.8	BDL	6.5	BDL	91	BDL	BDL	10	1.3	3
TMB	BDL	1.4	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MIBK	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL

	9/04	12/06	3/1/07	6/20/07	8/8/07	9/25/07	12/6/07	3/18/08	6/11/08
PCE	54	930	23	12	6.7	7.9	53	5.7	29
TCE	5.5	80	4.3	1.5	BDL	1.0	4.3	1.4	2.6
cis-DCE	7.9	18	7.3	3.9	3.0	2.3	5.1	2.2	3.5
Acetone	BDL	BDL	78	480	1,400	860	130	BDL	BDL
1,3 DCB	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MTBE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
MEK	BDL	BDL	BDL	43	120	74	18	BDL	BDL

	9/04	12/06	3/1/07	6/20/07	8/8/07	9/25/07	10/17/07	10/31/07	12/6/07	3/18/08	6/11/08
PCE	12,000	5,800	4,200	130	34	420	BDL	BDL	1.4	2.4	3.0
TCE	1,300	820	990	20	3.2	24	BDL	BDL	BDL	BDL	BDL
1,1-DCE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
cis-DCE	BDL	600	1,200	29	10	24	BDL	BDL	5.4	1.7	2.4
trans-DCE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
VC	BDL	27	12	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Naphthalene	BDL	50	110	BDL	BDL	13	BDL	BDL	BDL	BDL	BDL
Benzene	BDL	BDL	43	2.8	10	12	BDL	BDL	BDL	21	14
Acetone	BDL	BDL	BDL	260	540	500	BDL	BDL	BDL	60	BDL
Acrolein	BDL	BDL	BDL	340	BDL	120	BDL	BDL	BDL	BDL	BDL
Chloromethane	BDL	BDL	BDL	BDL	1.5	BDL	BDL	BDL	BDL	BDL	BDL
1,3 DCB	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Xylenes	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
1,2,3 TMB	BDL	BDL	BDL	BDL	BDL	1.4	BDL	BDL	BDL	BDL	BDL
Bromoform	BDL	BDL	BDL	BDL	3.6	BDL	BDL	BDL	BDL	BDL	BDL
MEK	BDL	BDL	BDL	12	BDL	28	BDL	BDL	BDL	BDL	BDL

	9/04	12/06	3/1/07	6/20/07	8/8/07	9/25/07	12/6/07	3/18/08	6/11/08
PCE	9,200	3,100	34	4.2	25	5.6	490	180	140
TCE	1,000	520	4.2	BDL	6.1	2.3	59	28	18
cis-DCE	500	830	5.5	2.3	17	8.6	61	40	28
trans-DCE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
1,1 DCE	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL
VC	BDL	6.4	BDL	BDL	BDL	BDL	BDL	BDL	BDL
Benzene	BDL	BDL	BDL	BDL	BDL	5.5	3.9	4.8	
Naphthalene	BDL	BDL	BDL	BDL	9.2	BDL	BDL	BDL	BDL
1,3 DCB	BDL	BDL	1.0	1.2	BDL	BDL	BDL	BDL	BDL
Acetone	BDL	BDL	BDL	BDL	95	BDL	BDL	70	86

	9/05	3/1/07	6/20/07	8/8/07	9/25/07	12/6/07	3/18/08	6/11/08
PCE	220	320	100	65	160	170	430	510
TCE	3.9	16	4.1	1.7	4.1	3.3	4.7	7.7
cis-DCE	3.5	15	3.0	1.8	2.0	2.5	2	5.2
Benzene	BDL	61	1.0	1.4	2.2	BDL	BDL	BDL
Isopropyl Benzene	BDL	1.4	BDL	BDL	BDL	BDL	BDL	BDL
MTBE	BDL	4.6	BDL	BDL	BDL	BDL	BDL	BDL
Naphthalene	BDL	BDL	BDL	BDL	BDL	BDL	BDL	6.1
PCA	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.0

SHEET NUMBER: 1

FIGURE NUMBER:

POST-TREATMENT
GROUNDWATER CONCENTRATIONS
BROOKHILL AZALEA SHOPPING CENTER
1114 AZALEA AVENUE
RICHMOND, VIRGINIA

SCALE:	DATE:	PROJECT NUMBER:
1"=30'	1/09	02978-361-014

AECOM

AECOM Environment
2 TECHNOLOGY PARK DRIVE
WESTFORD, MASSACHUSETTS 01886
PHONE: (978) 589-3000
FAX: (978) 589-3100
www.aecom.com

DESIGNED BY: R.F.
DRAWN BY: K.P.B.
CHECKED BY: A.T.
APPROVED BY: A.T.

REVISIONS

NO.:	DESCRIPTION:	DATE:	BY:

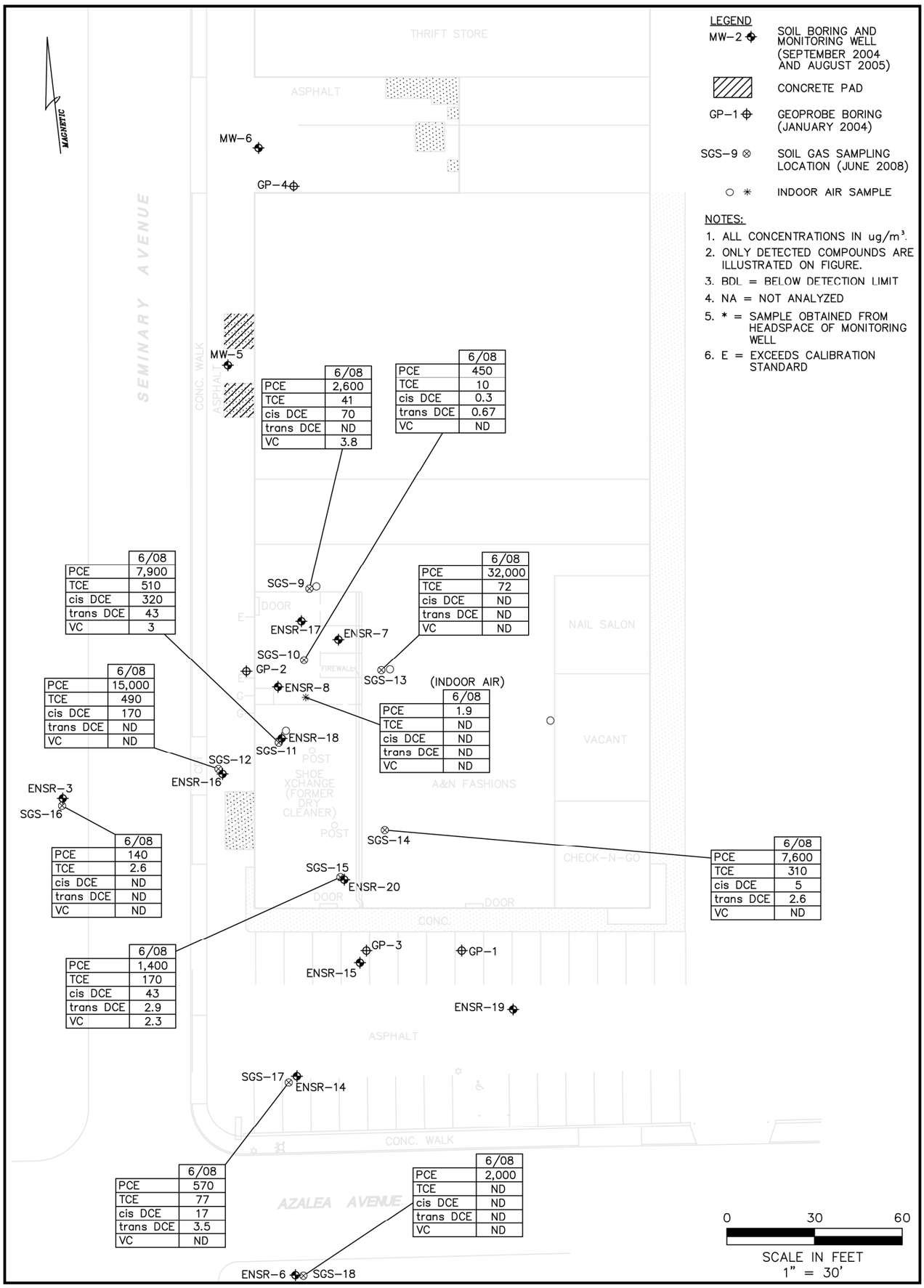
Soil Sampling
Based on sampling results, no soils exceeded the Tier III levels and no impacted vadose soils were detected off-site. Based on these results, no residential restrictions are planned for this site for soil exposure. However, residual CVOC concentrations in saturated soils remain in parts of the site that may exceed certain VRP screening levels for construction workers. These elevated soil concentrations, which exceeded VRP Tier II levels, were located in the source area beneath a four-inch thick concrete floor in the building and, as a result, were not easily accessible. In addition, these elevated soil concentrations were located within the saturated zone at the site and were subjected to the longest treatment duration of the ERH treatment zone. Therefore, it was determined that the potential exposure pathway to soil was incomplete. However, a soil management plan was recommended to protect construction workers from inadvertent contact during future subsurface site activities (AECOM 2009).

Note: Drilling through the slab is a fairly prevalent practice at in situ thermal project where sub-slab contamination must be addressed.

Soil Gas Monitoring
Soil gas sampling (SGS) points were installed at locations beneath the concrete slab in the former dry cleaning building and the adjacent building within the shopping center. SGS points were also installed at 5 locations outside of the dry cleaning building (off-site). Figure 8 shows the post-remediation soil gas and indoor air monitoring results obtained in June 2008. The sub-slab concentrations near the source area (SG-2/SGS-11) decreased significantly for all detected compounds. However, the results of the sub-slab samples (beneath the building) and soil gas samples from outside the building indicated that CVOC vapors were still present in the subsurface. Since the temperatures of the subsurface and groundwater were still elevated when the soil gas samples were collected, it is likely that the results were a little higher than will be observed after the subsurface has had time to cool down. PCE concentrations across the total treatment area ranged from 1.9 µg/L at ENSR-8 to 32,000 µg/L at Soil Gas Sampling (SGS) Location 13. TCE concentrations ranged from 510 µg/L (SGS-11) near the source area to undetected (SGS-18) outside of the building (AECOM 2009).

A HHRA of remaining vapor concentrations indicated that the cumulative cancer risks and hazard indices at the several sub-slab gas points were above risk targets for potential on-site future residents and commercial/industrial workers via an inhalation exposure pathway. However, indoor air concentrations presented below indicate that the site building slab is effective in mitigating vapor intrusion. There is a requirement for vapor mitigation if the building use changes to residential use or the building is replaced. Cumulative cancer risks and hazard indices indicated by soil gas samples collected off-site were below acceptable risk targets for potential on-site residents or commercial/industrial workers. Residual impacts to the groundwater located off-site will attenuate further through biodegradation. As a result, it was concluded that a vapor intrusion pathway does not exist off-site and no off-site use limitations are necessary (AECOM 2009).

Figure 8: Post-Treatment Soil Gas and Indoor Air Concentrations



Performance Data Quality

No exceptions or issues with data quality were noted in the references reviewed for this report.

Cost Information

No cost information was available from the technology vendor.

Observations and Lessons Learned

Some observations and lessons learned from the implementation of the remedy include:

- The sudden increase in groundwater levels resulting from heavy rains in the area submerged the vapor recovery well screens which made it difficult to remove vapors and required more frequent maintenance of the system to address excess water and silt in the treatment system. The excess water produced from the system was managed through an aboveground storage tank and the installation of water level control components within the condenser water recycle loop. These additions helped increase the surge volume handling capacity of the vapor recovery system.
- The installation of 47 supplemental vapor recovery wells during the temporary shut-off of the ERH system permitted the continued operation of the vapor recovery system despite the high groundwater levels.
- Residual CVOC concentrations remain in certain parts of the site that exceed VRP Tier II screening levels for both soil and groundwater. As a result, it was recommended that a soil and groundwater management plan be used if any future construction activities require accessing deep soils and/or groundwater in the area.
- Residual CVOCs present in the groundwater within and adjacent to the treatment area are expected to decrease over time through attenuation processes, including biodegradation (which typically occurs subsequent to the ERH treatment due to the effects of heat).
- An IC consisting of deed restrictions for groundwater restriction will address potential risks from the remaining CVOCs in groundwater.
- Soil gas and indoor air samples indicated that the building slab appears to more protective in mitigating vapor intrusion associated with remaining CVOCs in soil and groundwater than original predictions. Based on a risk evaluation using indoor air sampling at locations of maximum soil gas concentrations, no current restrictions are required for the vapor intrusion pathway. However, there is a requirement for vapor mitigation if the building use changes to residential use or the building is replaced (AECOM 2009).
- The project goal of significant mass removal in a time frame of approximately 1 year was achieved. Concentrations of dissolved phase PCE in the source areas were successfully reduced by about 99%.
- The soil gas samples collected off site indicated that the cumulative cancer risks and hazard indices are below the target range for off-site residents and

commercial/industrial workers. This indicates a potential vapor intrusion risk above target levels to off-site receptors does not exist.

- Based on the groundwater and soil results and risk assessment, the site was recommended for closeout under the VRP and issuance of a Certificate of Satisfactory Completion of Remediation detailing the ICs required at the site.

Contact Information

David Fleming
Thermal Remediation Services, Inc. (TRS)
7421-A Warren SE
Snoqualmie, WA 98065
Telephone: 425-396-4266
Fax: 425-396-5266

Art Taddeo
Senior Project Manager
AECOM
Technology Park Drive
Westford, Massachusetts 01886
Email: arthur.taddeo@aecom.com

Jerry Grimes
Virginia Department of Environmental Quality
Office of Remediation Programs 629 E Main St
Richmond, VA 23219
Telephone: 804-698-4207
Email: gjgrimes@deq.virginia.gov

Meade Anderson
Voluntary Remediation Project Officer
Virginia Dept. of Environmental Quality
629 E Main St
Richmond, VA 23219
Telephone: 804-698-4179
Fax: 804-698-4383
E-mail: jmanderson@deq.virginia.gov

References

The following references were used in preparation of this report:

1. AECOM, Inc. 2009. Draft Final Voluntary Remediation Report. Former Woodbriar and Westwood Dry Cleaning Facility, 114 Azalea Avenue (VRP00389). Richmond, Virginia. Prepared for: Mighty Oak, LLC.

2. AECOM, Inc. 2006. Remedial Action Workplan. Former Woodbriar and Westwood Dry Cleaning Facility, 114 Azalea Avenue (VRP00389). Prepared for: Virginia Voluntary Remediation Program.

3. Thermal Remediation Services, Inc. (TRS). 2009. TRS Electrical Resistance Heating Data Sheet. Retrieved from http://www.thermalrs.com/files/TRS_ERH_Sales_Sheet_022409.pdf on November 16, 2009.

4. TRS. 2006. Remedial Design and Work Plan- Electrical Resistance Heating Remediation. Former Woodbriar and Westwood Dry Cleaning Facility, 114 Azalea Avenue (VRP00389). Richmond, Virginia.