CHLORINATED SOLVENT SOURCE CONTROL ON A LIMITED BUDGET

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ABSTRACT: Past operations of the former Spin 'N Span Cleaners and Laundry facility located in downtown Memphis, TN appear to be the source of perchloroethene (PCE) and daughter products found in the site soil and groundwater. As a result of a site investigation, it was estimated that there is 7.9 kg of PCE and 0.04 kg of TCE in the subsurface. A Remedial Alternatives Study in September 2003 indicated that anaerobic bioremediation would the most cost effective treatment technology for this site.

Based on the SRS™ application design model, 12,500 pounds of Slow Release Substrate (SRS™) were injected at 60 locations in November, 2005 and February, 2006. Based on the diminishing chlorinated compounds and sulfate concentrations, the injection of SRS™ substrate enhanced in-situ bioremediation at this site. PCE concentrations in groundwater within the source area injected with SRS™ decreased by 96% and 99% within the first eleven months.

INTRODUCTION: Past operations of the former Spin 'N Span Cleaners and Laundry facility located in downtown Memphis, TN appear to be the source of PCE and daughter products including trichloroethene (TCE), cis-1,2-dichloroethene (cis-1,2-DCE), and vinyl chloride (VC) found in the site soil and groundwater. The facility operated as a drycleaner from 1963 through 2001 with PCE being used until 1996. The building has since been demolished and the property converted to a parking lot.

Chlorinated solvent contamination in the soil and groundwater was found during a Phase II Environmental Site Assessment in 1996. The site was accepted into the Tennessee Drycleaner Environmental Response Program in 1998. As a result of its site investigation, Ensafe, Inc. of Memphis, TN, estimated there was 7.9 kg of PCE and 0.04 kg of TCE in the subsurface. The shallow, unsaturated soils (0 to 5 ft) were excavated after building demolition.

Regional Geology: The Memphis area and the site are located on the boundary between the Mississippi Alluvial Plain and the Gulf Coast Plain physiographic subdivisions in the Mississippi Embayment. The Mississippi Embayment is a 200-mile (124 km) wide trough that gently plunges southward along it's axis (the Mississippi River); the embayment trough is filled with a wedge of several thousand feet thickness of Quaternary, Tertiary and Cretaceous (0 to 140 million years aged) unconsolidated sediments. Typically sediments are primarily sand, gravel, silt, clay, lignite and mixtures of those constituents. In ascending order the sequence consists of the Wilcox Group, Claiborne Group, Terrance Deposits and surficial loess deposits. The Tertiary materials contain permeable zones that produce ground water under confined conditions.

The lower Wilcox Group is made up of the Old Breastworks Formation (approximately 250 feet – 76 m of clay, silt, sand and lignite), overlying the Old Breastworks Formation is the Fort Pillow (1400-foot) Sand Unit. The upper Wilcox Group comprises the Flour Island Formation and consists of silty clay and sandy silt.

The lowermost Claiborne Group formation is the Memphis Sand; this unit is a massive sand that includes subordinate silt and clay lenses and ranging from 500 to 900 feet (152 to 274 m) thick. Overlying the Memphis Sand are the Jackson, Cockfield and Cook Mountain Formations. The Jackson (Jackson Clay) Formation is a fine sand or sandy clay whose thickness ranges from 0 to 50 feet (15 m). The Cockfield Formation in Memphis is limited to erosional remnants of inter-fingered fine sands, silts, clays and lignite lenses. The Cockfield thickness ranges from 0 to 250 feet (76 m). The uppermost Claiborne Group is the Cook Mountain Formation; a from 30 to 150 feet (9.1 to 45.7 m) thick clay confining unit that locally may contain fine sand. A few domestic wells in the Memphis area are screened in the discontinuous and interconnected Cockfield sands. Most of the drinking water used in Memphis is pumped from the confined Memphis Sand Aquifer. Beneath the Memphis Sand is another confined aquifer, the Fort Pillow Sand, which is not widely used for drinking water in this area.

Site Geology: At this facility only loess and alluvial/fluvial materials were penetrated during site characterization and remediation activity. Site borings penetrated a maximum depth of 76.5 feet (23.3 m) below surface grade. Figure 1 shows the site geological cross section. Field observations suggest that site grading has disturbed up to five feet (1.5 m) of surficial material. The lithology encountered includes approximately 0.5 feet (0.15 m) of gravel fill and organic material. The fill overlies a silt and clayey silt loess that ranges from approximately 13 to 25 feet thick (4.0 to 7.6 m) and which is present across the site. Depending on season, softer intervals were encountered in the loess at depths ranging from between 5 and 15 feet (1.5 to 4.6 m) and 12 and 21 feet (3.7 to 6.4 m). These soft areas may represent more transmissive soil intervals that are aiding contaminant distribution from the source zone. Underlying the loess is a homogenous approximately 40 to 45 foot (12.2 to 13.7 m) thick sequence of sand and sandy silts/clays that is present across the site. This alluvial/fluvial deposit also contained a clayey sand sequence which varied in thickness from 2 to 13 feet (0.6 to 4.0 m), and which was encountered at approximately the same elevation, from 21 to 24 feet (6.4 to 7.3 m). This interval coincides with the characterization data showing chlorinated solvent impacts over the 15 to 20 foot (4.6 to 6.1 m) depth interval. At depths ranging from 57 to 73 feet (17.4 to 22.3 m) bgs, a clay confining unit was encountered. This unit is found across the site.

Site ground water flow is to the south-southwest and the gradient is approximately 0.017 feet/foot. The ground water flow rate was calculated to be 1.78×10^{-1} feet/day (6.3×10^{-5} cm/sec). The seasonal high water table ranges from approximately 5 to 10 feet (1.5 to 3.0 m) depth.

PCE Contamination: The soil investigation results indicate high PCE concentrations over a much larger area than expected. PCE is expected to travel down through the soil from the source area, not spread laterally as seen at this site. The seasonal introduction of this water likely dissolved the PCE that had sorbed to soil in the source area and carried it throughout this zone, leaving residual contamination behind as the area dried during times of little rain. This action has created a horizontal transition zone that could act as a source to underlying soil and eventually to the surficial groundwater. Figure 2 shows the source area. It appears likely that, with time, the impacted area will increase in size. The rate of this increase will depend upon the amount of rainfall over a given period, and the ratio of asphalt/concrete/buildings to grassy area where infiltration occurs, which will be dependent, in part, upon future site development.

Ensafe, Inc. completed a Remedial Alternatives Study in September 2003 which indicated that anaerobic bioremediation would the most cost effective treatment technology for this site. Table 1 summarizes Ensafe's initial cost projections for groundwater remediation.

Table 1. Initial Cost Projections for Groundwater Remediation

Technology	**Cost –Net Present Value**	**Time Required**
In-Situ Thermal Remediation	N/A	6 to 12 months
Groundwater pump & treat	N/A	30 years or more
Monitored Natural Attenuation	$178,000	30 years or more
In Situ Chemical Oxidation	$406,200	2 years
Enhanced in-situ anaerobic bioremediation	$320,500	2 years
Enhanced anaerobic-aerobic sequential biotreatment	N/A	3 to 10 years

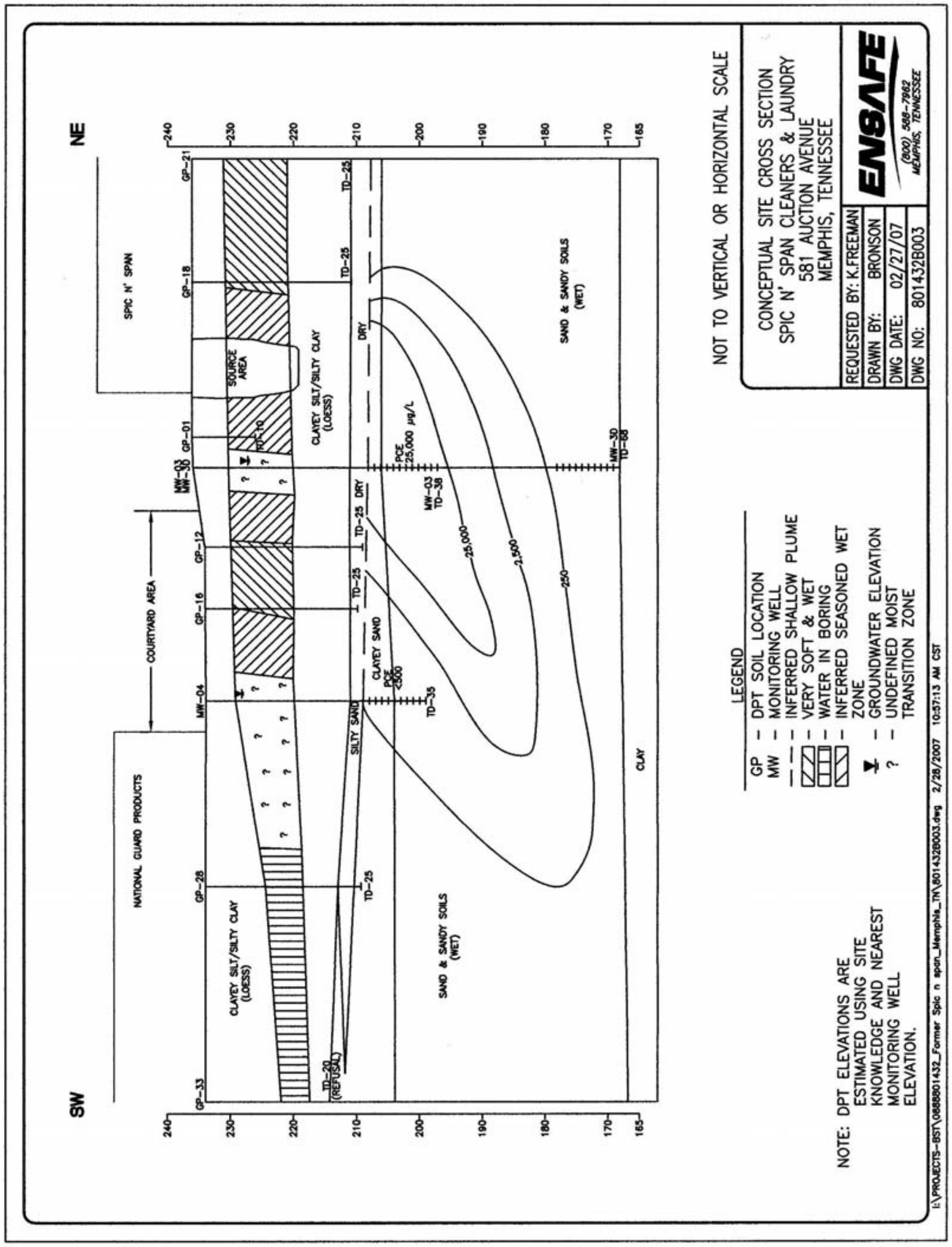

Figure 1. Site Conceptual Geological Cross-Section

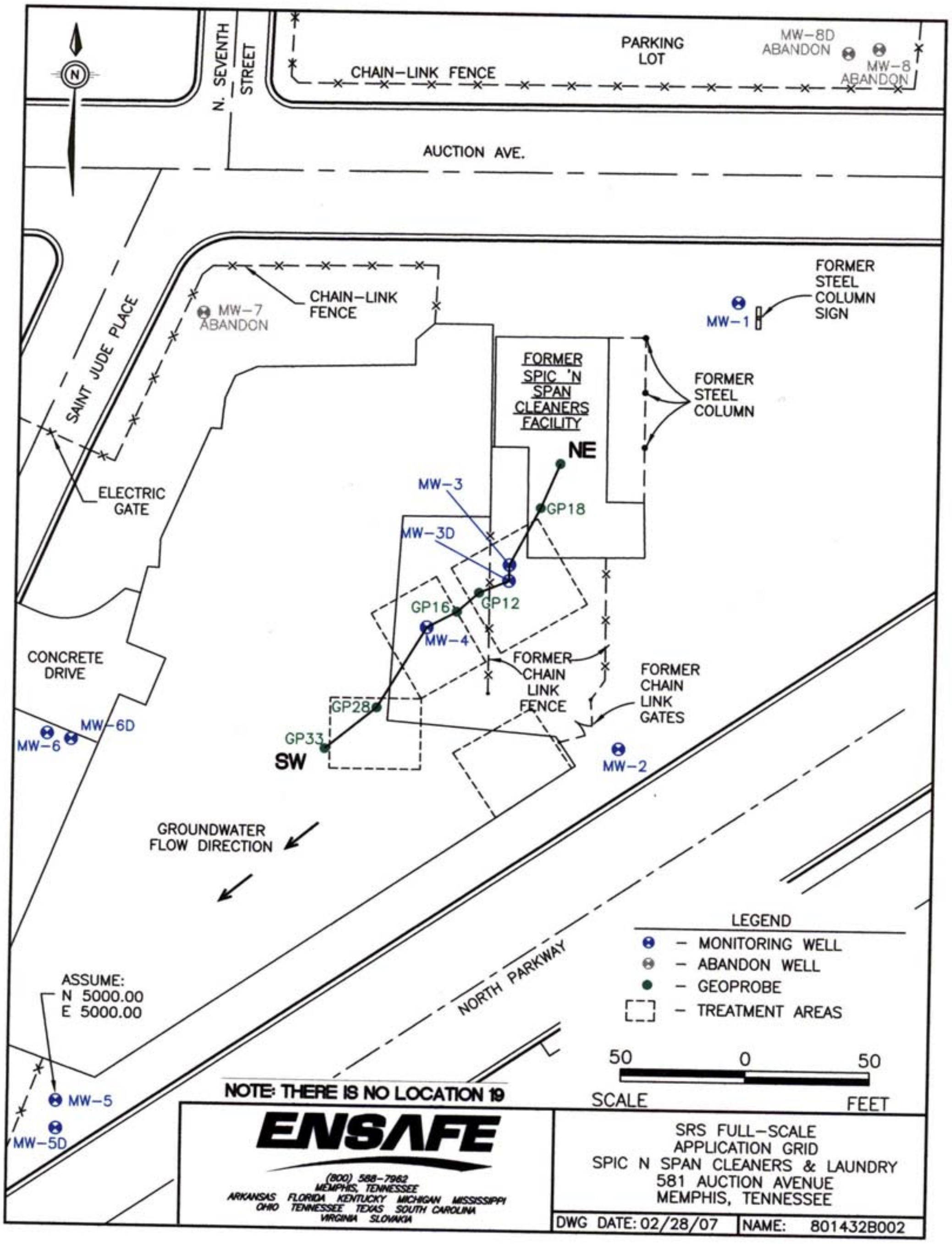

Figure 2. Site Map and SRS Injection Grid

MATERIALS AND METHODS: Tennesee's Dry Cleaner Environmental Response Program (DCERP) personnel reviewed commercially available hydrogen donor substrates and selected Terra Systems, Inc.'s Slow Release Substrate or SRS™ substrate package because of its lower cost and improved distribution pattern. SRS™ contains emulsified soybean oil and organic and inorganic nutrients. An application design was prepared by Ensafe, Inc. for three key areas of the contaminant plume. Limited funding and a large number of dry cleaner program sites dictates that investigation and remediation costs be held to a minimum. As a consequence, the SRS™ loading estimate was based on data from 3 monitor wells within the plume area.

Table 2 Basis For System Design

Parameter	Value
Groundwater seepage velocity	65.5 ft/yr (20 m/yr)
Porosity	0.20
Tetrachloroethene	10,840 µg/L
Trichloroethene	620 µg/L
cis-1,2-Dichloroethene	1,786 µg/L
Vinyl Chloride	116 µg/L
Dissolved Oxygen	0.7 mg/L
Sulfate	200 mg/L
Nitrate	4.0 mg/L

Based on the SRS™ application design model, 12,500 pounds (5,682 kg) of SRS™ concentrate substrate was injected at 60 locations in November 2005 and February 2006 by Tri State Services, Inc. The total depth of the injection was dependent on the treatment area, but was generally no more than 30 ft. (9.1 m) bgs. The SRS™ was diluted with activated carbon filtered water and injected through direct push rods driven by a Geoprobe® direct push machine with a GS-2000 grout pump. Chase water was injected after the SRS™ injection to move it away from the injection point. The injection volumes were based on the concentrations of the contaminants and the geology .

Table 3. Treatment Areas and Volumes of SRS™ and Dilution/Chase Water

Treatment Area	MW-3 Plume Core	MW-4 Non-Core	GP-28
Dimensions	40. x 40 ft (12.2 x 12.2 m)	40 x 30 ft. (12.2 x 9.1 m)	30 x 30 ft. (9.1 x 9.1 m)
Injection Points	27	24	9
Treatment Zone Thickness	28 ft. (8.5 m)	15 ft. (4.6 m)	10 ft. (3.0 m)
SRS™ Volume	993 gal (3,759 L)	283 gal (1,071 L)	162 gal (613 L)
Dilution & Chase Water Volume	2,886 gal (10,924 L)	644 gal (2,438 L)	624 gal (2,362 L)

The injection points were spaced approximately 9 ft. (2.7 m) apart in a grid pattern that covered each of the three areas.

To evaluate the effectiveness of the treatment system, groundwater samples are being collected from six monitor wells on a semi-annual basis. In addition to analyzing the groundwater for Volatile Organic Compounds (VOCs), the samples are being analyzed for sulfate, nitrate, total organic carbon (TOC), pH, dissolved oxygen, ORP, and specific conductivity.

RESULTS AND DISCUSSION: Injection of SRS™ substrate impacted two monitor wells within the injection grid area as evidenced by the increases in TOC, decreases in the sulfate levels. and reductions in the PCE concentrations within MW-03 and MW-04. As expected, upgradient monitor well MW-01 and side-gradient monitor well MW-02. were not impacted by the SRS™ injection as evidenced by low TOC concentrations (<2 mg/L) and high sulfate levels (>230 mg/L).

As indicated in the Figure 2, there are 3 monitor wells (MW-03, MW-03D, and MW-04) within the treatment area. The original design did not anticipate impacting monitor wells MW-01, MW-02, and MW-05.

Tables 4 through 7 illustrate the reductions in dissolved chlorinated concentrations (on a micromolar - µM basis so that one µM of PCE is equivalent to one µM of TCE, cis-1,2-DCE, and VC) and the changes in competing electron acceptors (sulfate and dissolved oxygen or D.O.) and TOC concentrations for wells MW-03, MW-03D, MW-04, and MW-5, respectively.

Table 4 MW-03 Results

Parameter	Units	April 2005	May 2006	Oct. 2006
PCE	µM	189.4	3.7	6.6
TCE	µM	11.2	0.49	0.52
cis-1,2-DCE	µM	20.1	7.3	4.0
VC	µM	2.6	46.7	2.5
Sulfate	mg/L	NA	ND	ND
TOC	mg/L	NA	1,500	2,990
D.O.	mg/L		0	
ORP	mV		-276	

Table 5 MW-03D Results

Parameter	Units	April 2005	May 2006	Oct. 2006
PCE	µM	NS		ND
TCE	µM	NS		ND
cis-1,2-DCE	µM	NS	0.024	0.015
VC	µM	NS		
Sulfate	mg/L	NS	61.5	57.9
TOC	mg/L	NS	1.24	ND
D.O.	mg/L		0	0.61
ORP	mV		-144	-214

Table 6 MW-04 Results

Parameter	Units	April 2005	May 2006	Oct. 2006
PCE	µM	6.8	0.13	0.070
TCE	µM	3.0	0.027	0.026
cis-1,2-DCE	µM	32.6	10.8	6.5
VC	µM	2.9	19.7	8.5
Sulfate	mg/L	NA	118	53.6
TOC	mg/L	NA	12.4	16.3
D.O.	mg/L		0.28	0.84
ORP	mV		-138	-399

Table 7 MW-05 Results

Parameter	Units	April 2005	May 2006	Oct. 2006
PCE	µM	0	0	0
TCE	µM	0.011	0.011	0.020
cis-1,2-DCE	µM	2.6	3.2	2.6
VC	µM	0.029	0	0.029
Sulfate	mg/L	NA	295	280
TOC	mg/L	NA	1.79	1.64
D.O.	mg/L		0	0.83
ORP	mV		14	-49

NA – Not Analyzed
NS – Not Sampled

CONCLUSIONS: Based on the diminishing chlorinated compounds and sulfate concentrations, the injection of SRS™ substrate enhanced in-situ anaerobic bioremediation at this site. PCE concentrations in groundwater within the source area injected with SRS™ decreased by 96% and 99% within the first eleven months. A significant regulatory concern is the increase in vinyl chloride. The vinyl chloride concentrations are expected to decrease.

Residual DNAPL does not appear to be present at this site. However, moving substrate into areas with dissolved constituents is proving to be a challenge because of the site geology. Continued semi-annual groundwater sampling events will monitor the chlorinated compound concentrations which will impact the decision of if, when and where to make additional substrate injections. To date, costs for the SRS™, injection, and post-injection monitoring have been $61,000.