

**Cost and Performance Summary Report**  
**Soil Vapor Extraction and In Situ Chemical Oxidation at Swift Cleaners, Jacksonville,**  
**Florida**  
**June 2007**

**Summary Information [1, 4, and 12]**

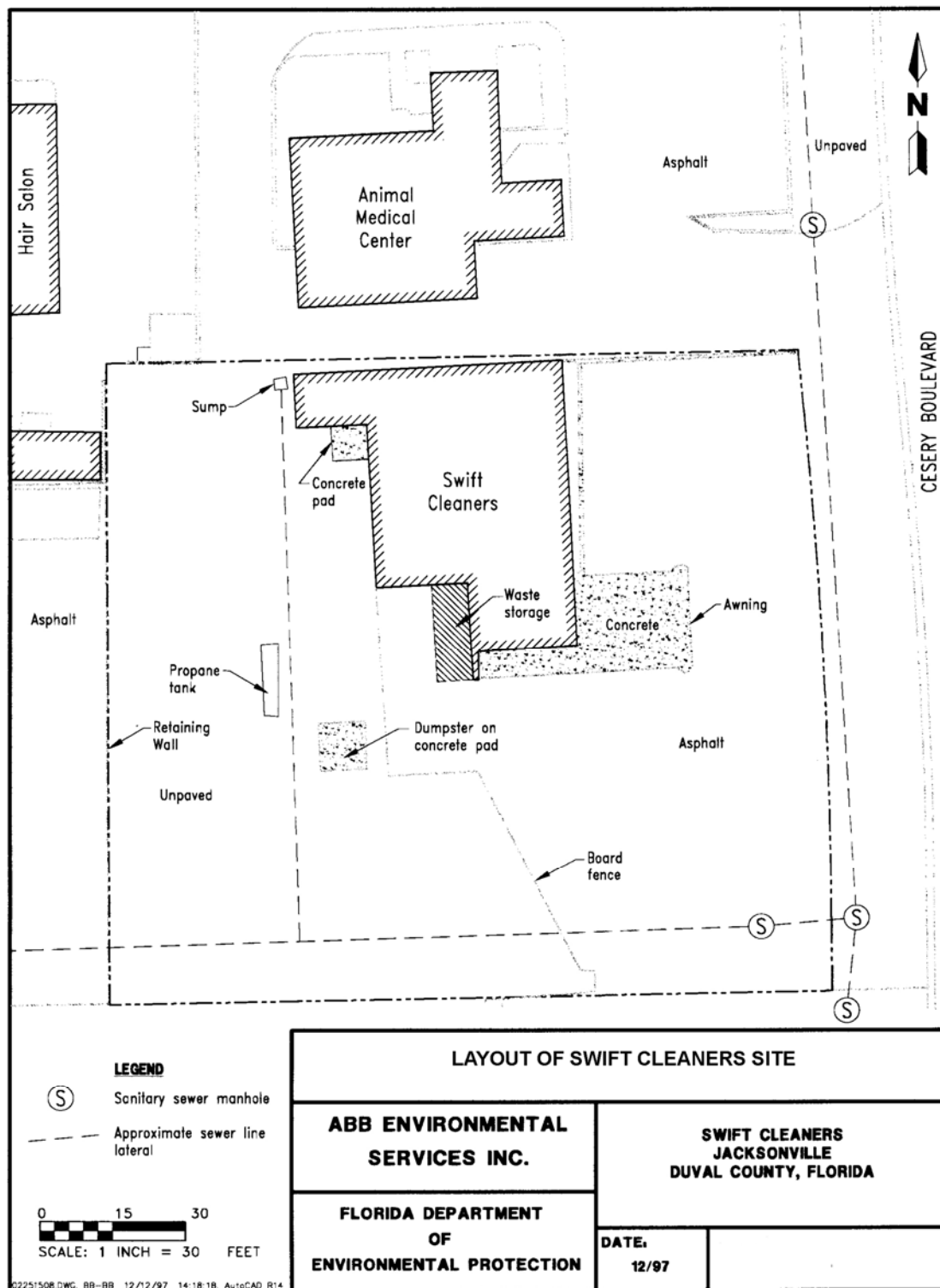
Swift Cleaners in Jacksonville, Florida, is an active dry cleaning facility that has been in operation since 1971. The facility uses tetrachloroethene (PCE) as a dry cleaning solvent. The site is located in a commercial and residential setting; the nearest water supply well is located about a quarter mile south-southwest of the site. No other active dry cleaning facilities are in the vicinity, although a dry cleaning business was formerly located east of the facility. An active gasoline service station is located at the northeastern corner of the site. Three source areas of contamination were identified at the facility. These areas include (1) the area outside the service door of the facility where spent filters were stored in the past, (2) the soils beneath the building floor slab near the dry cleaning machine, and (3) a former leak in a sanitary sewer line. Figure 1 provides a layout of the Swift Cleaners site.

An environmental assessment was conducted in 1997 to delineate the extent of contamination. Soil was assessed using soil gas surveys as well as soil borings and direct-push sampling techniques. The results of the soil gas survey revealed PCE contamination on the west side of the Swift Cleaners building, with the highest concentrations at the northwestern corner. The soil samples were analyzed for volatile organic compounds (VOCs), and the probable source area of the PCE plume was identified nearly 55 feet (ft) west of the Swift Cleaners building. The main source of waste at the site was found to be inappropriately discarded spent filters that contained PCE. The maximum PCE concentration in the source area was approximately 40 milligrams per kilogram (mg/kg), with the highest concentration at approximately 1 foot below ground surface (bgs).

A ground water assessment was conducted in three phases using direct-push sampling. Ground water samples were collected from three sampling depths ranging from 20 to 22 ft bgs, 30 to 32 ft bgs, and 40 to 45 ft bgs, and were analyzed for VOCs. Based on analytical results, ground water contamination at the site consisted almost entirely of PCE. PCE was detected to a depth of 43 ft bgs 240 ft from the southwestern corner of the Swift Cleaners building. The PCE plume appeared to have migrated vertically and laterally westward to a maximum depth of approximately 60 ft bgs in the area downgradient from the source. The highest concentration of PCE in ground water was 10,000 micrograms per liter ( $\mu\text{g/L}$ ), at a depth of 40 to 45 ft bgs. This result indicated the presence of PCE as dense nonaqueous phase liquid (DNAPL), with the source zone located behind the Swift Cleaners building. The downgradient edge of the plume could not be delineated because of off-site access issues.

High concentrations of PCE were also detected in ground water samples obtained from sampling locations north of the site. Since the flow of ground water at the site was to the west-southwest, it appeared that a possible second source of PCE contamination may be present to the north.

**Figure 1: Layout of the Swift Cleaners Site [1]**

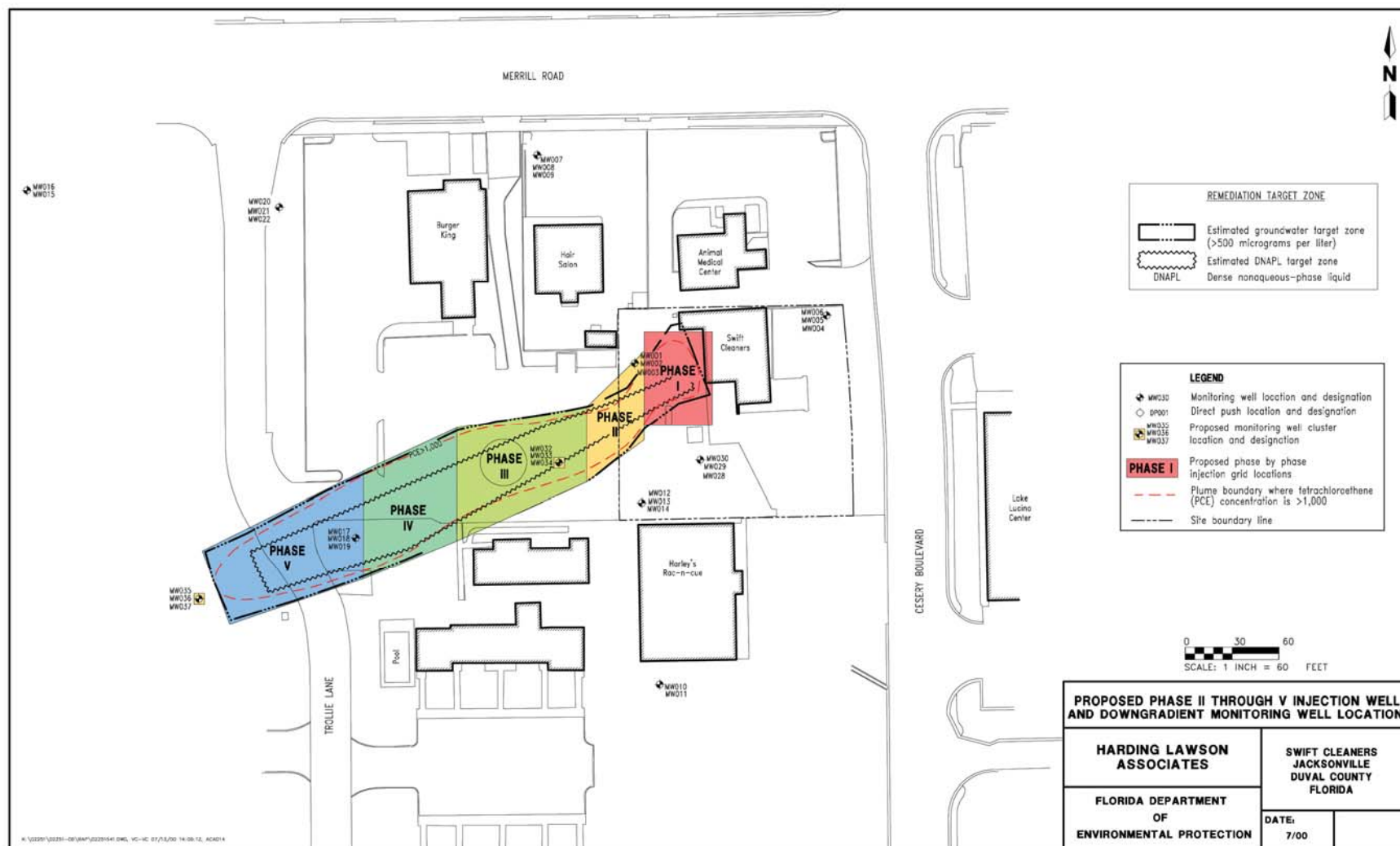


The former dry cleaning site, as well as the active gasoline service station, were thought to be possible second sources.

The remedial action plan (RAP) developed for the site included in situ chemical oxidation using Fenton's reagent to treat ground water and DNAPL contamination and soil vapor extraction (SVE) to treat the soil. A pilot test was conducted in 1999 to evaluate the viability of chemical oxidation at the site. Based on the results, a multiphase approach was developed for the full-scale application (Phase I to Phase V). Figure 2 illustrates the various proposed phases for chemical oxidation injection and the remediation target zone. Phase I of the full-scale application was implemented from May 2001 to April 2002. The Phase I treatment area consisted of two sub-areas, IA and IB. Area IA was the location of the original pilot test, and Area IB was downgradient from IA. At the end of each injection event, ground water samples were collected and analyzed for contaminant concentrations as well as parameters such as pH, ferrous iron, and sulfate. After Phase I had been implemented, however, the Florida Department of Environmental Protection (FDEP) concluded that implementation of Phases II to V would not be cost effective and is currently evaluating various options for treatment of the downgradient PCE plume. Treatment options include enhanced biodegradation with reductive dechlorination, thermal treatment, and excavation of the contaminated soil in the source area. As of March 2007, full-scale application (SVE) of the remedial action was still under way at the site, and approximately 22,500 cubic ft (ft<sup>3</sup>) of soil and 37,500 ft<sup>3</sup> of ground water had been treated.

Florida Department of Environmental Protection (FDEP) Facility ID:		169501352
Type of Action:	Remedial	
Lead:	Bureau of Waste Cleanup (as part of FDEP's Dry Cleaning Solvent Cleanup Program)	
Oversight:	FDEP	

Figure 2: Proposed Phases for Chemical Oxidation Injection and Remediation Target Zone [4]



## Timeline [2, 3, 4, 8, and 12]

Dates	Activities
<b>Soil Vapor Extraction</b>	
March 6 to May 9, 2001	SVE system installed and beginning of system operation
April 2002 to Present	SVE system operations and maintenance (O&M) continue
<b>In Situ Chemical Oxidation</b>	
September to November 1999	Pilot test
March 13 to 15, 2001	Collected baseline samples from monitoring wells and injection wells
May 21 to 25, 2001	Phase I-first injection in Area IA and Area IB
June 18 to 21, 2001	Phase I-second injection in Area IA and Area IB
August 2001 to April 2002	Conducted year 1 quarterly ground water sampling
March 26 and 27, 2002	Redeveloped select monitoring wells and completed injection for select wells in Areas IA and IB
April 2002	Phase I-completed third injection at Areas IA and IB
August 2002, November 2002, February 2003	Conducted year 2 quarterly ground water sampling
September 2004 and May 2006	Conducted annual ground water monitoring

## Factors That Affected Technology Cost or Performance [1, 2, 4, and 12]

Listed below are the key matrix characteristics relevant to SVE and chemical oxidation and the values measured for each during site characterization.

### Matrix Characteristics

Parameter	Value
<b>Soil Vapor Extraction</b>	
Soil Classification	<ul style="list-style-type: none"><li>• Ground surface to 45 ft bgs: silty, very fine to fine-grained sands at the surface</li><li>• From 45 to 65 ft bgs: clayey, very fine-grained sand with clayey sand lenses</li><li>• From 65 to 80 ft bgs: limestone interbedded with clay</li></ul>
Clay Content and Particle Size Distribution	<ul style="list-style-type: none"><li>• Intermediate zone: silty sands with laterally discontinuous zones of cemented organic material overlying grayish-green clayey sands</li><li>• Deep zone: grayish-green clayey sand overlies limestone rock aquifer</li></ul>
Air Permeability	Based on hydraulic conductivity
Soil Permeability	$4.4 \times 10^{-8}$ square centimeters ( $\text{cm}^2$ )

Parameter	Value
Porosity	20 percent
Depth bgs or Thickness of Zone of Interest	Ground water at 60 ft bgs
Total Organic Carbon	Maximum detected value 105 milligrams per liter (mg/L) at a depth of 43 ft bgs
Presence of NAPLs	PCE DNAPL present
<b>In Situ Chemical Oxidation</b>	
Soil Classification	<ul style="list-style-type: none"> <li>• Silty, very fine to fine-grained sands from ground surface up to 45 ft bgs</li> <li>• Clayey, very fine-grained sand with clayey sand lenses from 45 to 65 ft bgs; and</li> <li>• Limestone interbedded with clay from 65 to 80 ft bgs</li> </ul>
Clay Content and Particle Size Distribution	<p>Intermediate zone: silty sands with laterally discontinuous zones of cemented organic material overlying grayish-green clayey sands.</p> <p>Deep zone: grayish-green clayey sand overlies limestone rock aquifer</p>
Hydraulic Conductivity	<p>Shallow zone: 12.29 ft/day</p> <p>Intermediate zone: 15.10 ft/day</p> <p>Deep zone: 11.52 ft/day</p> <p>Rock aquifer: 10.48 ft/day</p>
pH	5.5 to 6.5
Depth to Ground Water	3 to 14 ft bgs
Deepest Significant Ground Water Contamination	50 ft bgs
Plume Size	300 by 1,000 square ft

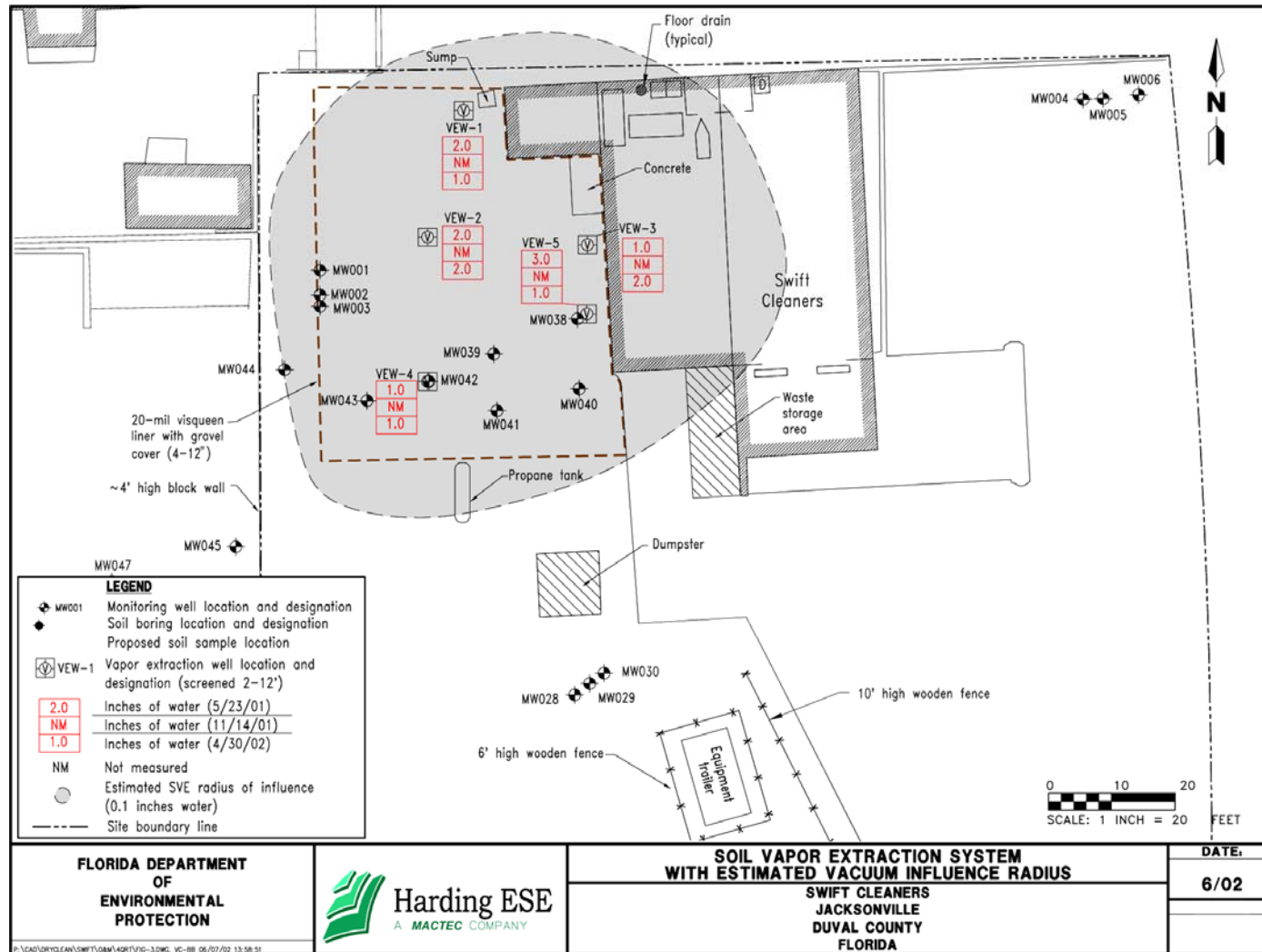
## Description of Treatment Technology [4, 8, and 12]

### SVE

The SVE system was started in May 2001 and consisted of five 12-foot vapor extraction wells (VEW). The design radius of influence is 15 ft with a design flow rate of 27 cubic ft per minute (cfm). Additional VEWs are being considered for the SVE system.

Figure 3 shows the SVE system and the location of the VEWs, including the estimated radius of vacuum influence.

Figure 3: SVE System and Estimated Vacuum Influence Radius [8]



## Chemical Oxidation

### Pilot Test

A pilot test of chemical oxidation was conducted from September to November 1999 in the source area at the upgradient edge of the ground water plume at the site. The test area covered approximately 2,500 square ft (ft<sup>2</sup>) and consisted of three injections of Fenton's chemistry-based Oxy-Cat™. The reagent was injected using six injection well clusters with two wells each (IW001-012). Figure 4 provides a map of the injection wells at the Swift Cleaners site. The wells were screened at depths of 30 to 40 ft bgs and 40 to 45 ft bgs, and the average radius of influence was 7.5 ft. The concentration of hydrogen peroxide used for the first injection was 25 percent; this concentration was then reduced to 12.5 percent for subsequent injections. The injection rate was 7 gallons per minute (gpm) for the initial injection and was reduced to 3.5 gpm for the second and third injections. The pilot test required between 200 to 400 gallons of the ferrous iron catalyst and between 300 to 800 gallons of hydrogen peroxide. Ground water samples were collected in three episodes from 10 locations within the application area, the downgradient area, and from peripheral locations (for evaluation of control). Nine existing permanent monitoring wells were used for ground water sampling. These included MW001 through MW006 and MW028 through MW030. Monitoring well cluster MW004 through MW006 provided information about background contaminant levels, while clusters MW001 through MW003 and MW028 through MW030 were used to evaluate the extent of the injection and detected any contaminant migration. The six injection well clusters were also sampled.

### Pilot Test Results

Results of the pilot test indicated that PCE concentrations decreased in some areas but increased significantly in others. The increase in PCE concentration is attributed to desorption of the contaminant mass in these areas as a result of the application of the chemical oxidation technology. After the third injection event, sampling results showed that the mass of PCE had reduced significantly in the 30- to 40-foot bgs interval zone but fluctuated dramatically in the 40- to 45-foot bgs zone. The fluctuating concentrations of PCE were attributed to a series of desorption, solubilization, and destruction events. The pilot test demonstrated that the intermediate and deep areas with higher concentrations of PCE would require a larger volume of the chemical oxidation reagent to reduce PCE levels to the ground water cleanup goals. It also showed that chemical oxidation using Fenton's chemistry was capable of remediating both the dissolved-phase and adsorbed-phase PCE at the site.

### Full Scale (Phase I)

Before the first injection event, baseline ground water samples were collected from selected monitoring and injection wells (MW001 through MW006, MW032 through MW043, IW003 through IW006, and IW009 through IW032). After each injection (Fenton's chemistry-based Oxy-Cat™) event, selected monitoring wells were resampled and analyzed for ground water parameters such as VOCs, iron, sulfate, total dissolved solids, pH, and temperature to evaluate the progress of ground water remediation.



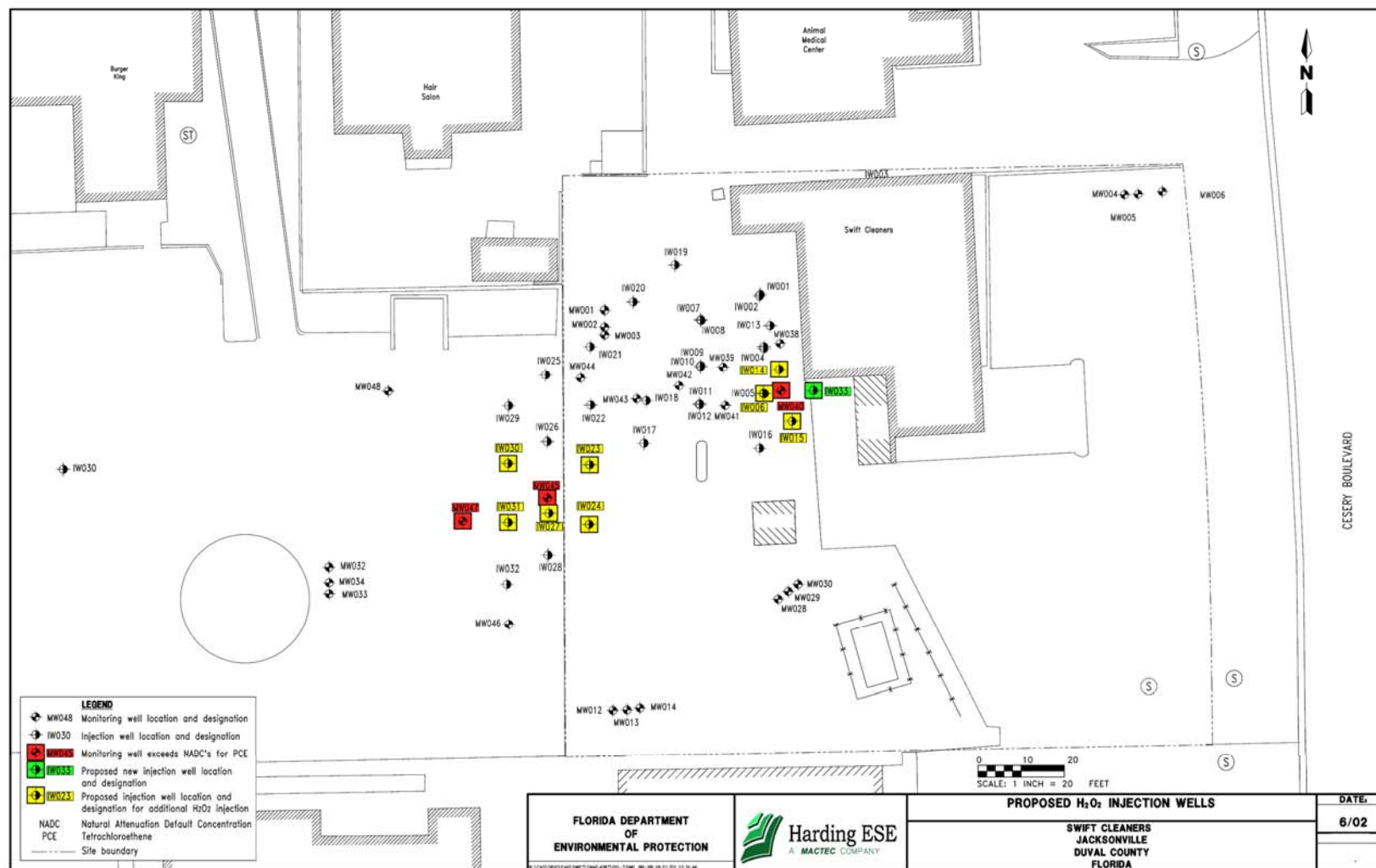
Phase I, which began in April 2001, focused on two areas: Area IA and Area IB. Area IA was the same as the 2,500 ft<sup>2</sup> pilot-test area, which contained a large portion of the contaminant mass. In addition to the five existing vapor extraction wells, seven new injection wells (IW013 through IW019) were installed in this area at depths ranging from 35 to 45 ft bgs. These new wells were installed in response to the pilot test that showed that PCE mass was higher in the target area than was previously anticipated and that a larger volume of reagent would be required to treat the contamination. Area IB was downgradient of Area IA and covered 2,000 ft<sup>2</sup>. Thirteen new injection wells were installed in this area.

The injection events for both Areas IA and IB each consisted of 20 pounds of carbon dioxide (CO<sub>2</sub>) injected in the deep zone and 40 pounds of CO<sub>2</sub> injected in the shallow zone to bring the pH up to the target range of 4 to 6. This event was followed by injection of approximately 400 gallons of 300 parts per million (ppm) iron sulfate catalyst and between 400 and 600 gallons of hydrogen peroxide (12.5 percent for the shallow zone and 25 percent for the deep zone). Both the catalyst and hydrogen peroxide were injected at a rate of 3.5 gpm. After the first injection event, interim ground water samples were collected from monitoring wells MW038 through MW048 and injection wells IW003 through IW006 and IW010 through IW032. Monitoring wells MW005, MW006, MW018, MW038, MW040 through MW048 and injection well IW022 were sampled after the second injection event.

A third injection was conducted in April 2002 based on the results of ground water samples collected after the first two full-scale injection events in Areas IA and IB. The third injection consisted of 11 select injection wells from Areas IA and IB; approximately 400 gallons of catalyst and 600 gallons of 15 percent hydrogen peroxide were used. Interim ground water samples were collected from monitoring wells MW029, MW038 through MW042, and MW044 through MW047 after the third injection event.

The RAP indicated that in the future Fenton's reagent (Phases II to V) would be injected to address the downgradient PCE plume. However, it was determined that implementation of Phases II to V would not be cost effective. As of March 2007, FDEP planned to assess soil and evaluate various options to treat the downgradient PCE plume. Treatment options include enhanced biodegradation with reductive dechlorination, thermal treatment, and excavation of the contaminated soil in the source area.

**Figure 4: Map of Injection Wells at Swift Cleaners Site [4 and 12]**



## Operating Parameters [12]

Listed below are the key operating parameters for SVE and in situ chemical oxidation using Fenton's Reagent and the values measured for each.

Parameter	Value
<b>Soil Vapor Extraction</b>	
Air Flow Rate	27 cfm
Operating Pressure/Vacuum	10 to 27 inches of H <sub>2</sub> O
<b>In Situ Chemical Oxidation</b>	
pH	5.5 to 6.5
Pumping Rate	3.5 gpm
Additives and Dosage	300 ppm of ferrous sulfate catalyst and 12.5 percent or 25 percent hydrogen peroxide
Injection Rate	3.5 gpm

## Performance Information [3, 4, and 12]

Cleanup target levels for soil at the site were based on leachability tests, while the cleanup levels for ground water were based on the primary standards (maximum contaminant levels (MCLs)). The goal was to use active remediation such as chemical oxidation to reduce the contaminant levels to the natural attenuation default source concentrations (NADSC) and then use monitored natural attenuation (MNA) to lower concentrations to below NADSCs to the primary standards (MCLs). Table 1 shows the cleanup target levels in ground water and soil at the Swift Cleaners site.

**Table 1: Cleanup Target Levels in Ground Water and Soil for Swift Cleaners [4 and 12]**

Chemicals of Concern	Ground Water Primary Standards (MCLs) (µg/L)	Natural Attenuation Default Source Concentrations (NADSCs) (µg/L)	Soil Cleanup Target Levels (mg/kg)
PCE	3	300	0.05
TCE	3	300	0.03
Cis-1,2-DCE	70	700	0.4
Trans-1,2-DCE	100	1,000	0.6
1,1-DCE	7	700	0.06
Vinyl chloride	1	100	0.007

Note: DCE – Dichloroethene  
MCL – Maximum Contaminant Level  
mg/kg – Milligrams per kilogram  
µg/L – Micrograms per liter  
TCE – Trichloroethene

## SVE

Table 2 provides a summary of PCE concentrations in VEWs from system startup in May 2001 to August 2006. Quarterly monitoring of the SVE system indicated that it continued to remove PCE from the soil target area. As of August 2006, the SVE system was operational and removing approximately 1 to 4 pounds per month and has removed a total of 140.7 pounds. Additional VEWs were being considered for the SVE system.

**Table 2: Concentration of PCE in Select Vapor Extraction Wells (3, 5, 6, 7, 8, 9, and 10)**

PCE Concentration (mg/m <sup>3</sup> ) in Vapor Extraction Wells (VEW)					
Sampling Date	VEW001	VEW002	VEW003	VEW004	VEW005
May 2001 (Initial)	5.119	2.118	4.458	9.288	1.896
August 2001	1.323	1.3	0.435	0.497	0.257
November 2001	0.104	0.19	0.07	0.071	0.057
February 2002	0.569	0.545	0.21	0.208	0.183
April 2002	1.807	0.47	0.809	0.662	0.268
August 2002	0.134	0.467	0.025	0.473	0.025
November 2002	2.247	2.346	0.602	0.248	0.073
February 2003	2.935	3.842	0.134	0.152	0.082
October 2003	1.5	1.3	BDL	BDL	BDL
April 2004	1.9	1.9	0.670	BDL	BDL
August 2004	1.8	2.2	0.530	BDL	BDL
August 2005	7.2	5.6	1.0	0.920	BDL
February 2006	5.5	BDL	1.0	1.100	BDL
August 2006	6.8	8.4	3.5	0.67	BDL

Note: BDL – Below Detection Limits  
mg/m<sup>3</sup> – Milligrams per cubic meter

## Chemical Oxidation

### Phase I (Full Scale)

Table 3 shows concentrations of PCE in samples from select Phase I monitoring wells from the start of the chemical oxidation treatment to the most recent monitoring event in May 2006. Monitoring well MW006 is located upgradient of the Phase I injection area. Monitoring wells MW040, MW034, MW045, and MW047 are located in the immediate downgradient area of the Phase I injection area. Monitoring wells MW018, MW036, MW037, and MW024 are located farther downgradient of the Phase I injection area. Samples collected from the source area in September 2001 after the first and second injections for Areas IA and IB showed that PCE concentrations were reduced to below 200 µg/L in most monitoring wells. This reduction indicated that the chemical oxidation injections were affecting the target areas. However, monitoring results from November 2001 revealed that concentrations of PCE in several wells in the source area had increased to levels at, or above, baseline concentrations. An example was seen in samples from well MW040, located within the suspected source area, where the PCE baseline concentration was 1,050 µg/L. Samples from this well exhibited a concentration of 21 µg/L in September 2001 and 1,420 µg/L in November 2001. A third injection was conducted in March 2002 at 11 selected wells in Areas IA and IB to address the areas where contaminant

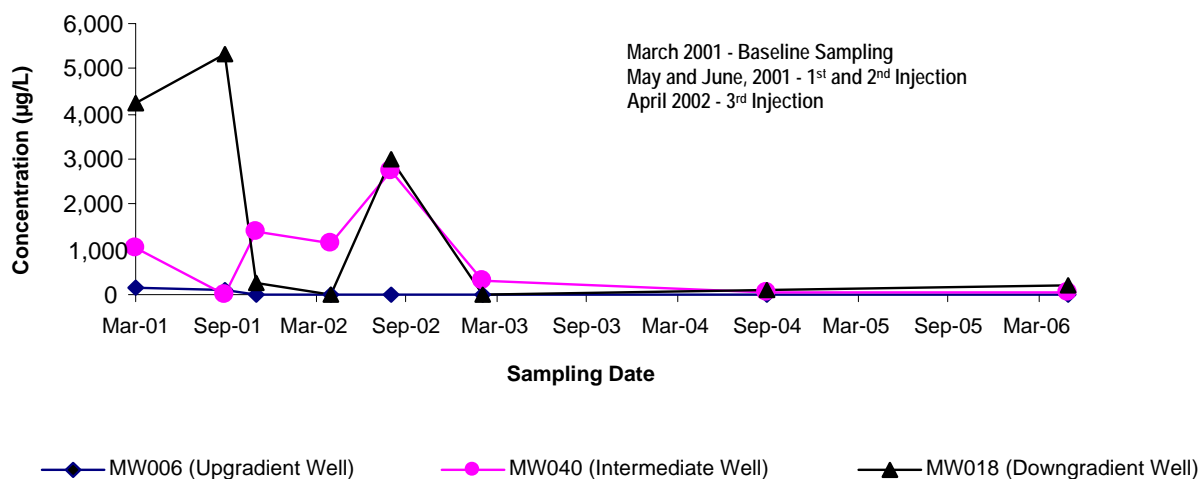
rebound was identified. Figure 5 illustrates the change in PCE concentration over time in select upgradient, intermediate, and downgradient wells.

**Table 3: Concentration of PCE in Select Monitoring Wells [2, 3, 5, 6, 7, 8, 9, 10, and 12]**

Monitoring Well (MW)	PCE Concentrations (µg/L)							
	March 2001 (Baseline Concentration)	September 2001	November 2001	April 2002	August 2002	February 2003	September 2004	May 2006
<b>Upgradient Well</b>								
MW006	145	105	6.1	NS	NS	NS	3.1	1.8
<b>Intermediate Wells</b>								
MW040	1,050	21	1,420	1,140	2,740	330	51	50
MW034	1,820	920	470	NS	600	645	160	120
MW045	1,200	165	265	1,240	550	515	57	45
MW047	960	70.5	215	510	1,020	835	190	40
<b>Downgradient Wells</b>								
MW018	4230	5,340	275	NS	2,980	NS	120	220
MW036	57.6	NS	NS	NS	NS	NS	350	110
MW037	150	NS	NS	NS	NS	NS	290	390
MW024	77	NS	NS	NS	NS	NS	NS	85

Note: NS – Not sampled

**Figure 5: PCE Concentration in Select Upgradient, Intermediate, and Downgradient Wells**



In 2004, a site investigation was conducted using membrane interface probe (MIP) technology. MIP technology is a means of identifying and delineating subsurface VOCs in soil and ground water. As the MIP is pushed into the soil, VOCs in the subsurface diffuse across the MIP's membrane and are absorbed into a vehicle gas, which is transported to the ground surface and then into a gas detector that measures the concentration of the VOCs. The MIP investigation revealed that downgradient concentrations of PCE still exceeded the NADSC value of 300 µg/L. Based on these results, a ground water monitoring program was developed for the site.

The results of the 2004 ground water monitoring indicated that elevated concentrations of PCE were present at certain locations on the site in the shallow, intermediate, and deep zones of the aquifer. The general trend, however, seemed to be an overall decrease in PCE concentrations in all three zones. However, increased concentrations of PCE in some downgradient wells appeared to indicate off-site migration of PCE within the deep zone of the surficial aquifer. PCE values were generally below the applicable NADSC values. Concentrations of trichloroethene (TCE) (0.17 to 660 µg/L) increased in all surficial aquifer zones. However, low concentrations of cis-1,2-dichloroethene (DCE) (0.090 to 190 µg/L), trans-1,2- DCE (0.12 to 6.3 µg/L), and vinyl chloride (0.25 µg/L) indicated that the contaminants were not being degraded beyond TCE. No ground water monitoring was conducted in 2005.

In May 2006, ground water samples were collected from monitoring wells and analyzed for selected VOCs, chloride, total iron, sulfate, total organic carbon, and total dissolved solids. The analytical results for PCE in samples from selected monitoring wells are presented in Table 2. In general, the 2006 analytical results for ground water indicated a decrease in concentrations of PCE and TCE in all three surficial aquifers. Cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride continued to be detected at low concentrations, indicating that the contaminants are not effectively degrading beyond TCE.

The levels of dissolved oxygen (DO), oxidation-reduction potential (ORP), total organic carbon, sulfide, and carbon dioxide measured in 2004 and 2006 indicate a reduction in their values since the last injection event in April 2002, suggesting that conditions were favorable for natural attenuation. However, high concentrations of sulfate, greater than 20 milligrams per liter (mg/L), were detected in the ground water samples (7.1 to 54 mg/L in 2004; 10 to 70 mg/L in 2006). A high sulfate concentration competitively inhibits reductive dechlorination, suggesting that natural attenuation might not occur through anaerobic biodegradation alone.

### **Performance Data Quality [1 and 2]**

No exceptions to established quality assurance/quality control (QA/QC) procedures were noted in the available references.

## Cost Information [12]

The following costs were incurred for implementation of SVE and chemical oxidation at the Swift Cleaners site.

Cost for characterization	\$164,000
Cost for design and implementation	\$110,000 (pilot test) \$118,000 (SVE construction) \$200,000 (in situ chemical oxidation – three injection events)
Operation and maintenance (O&M) costs	\$30,000 per year (soil) \$30,000 per year (ground water)

## Observations and Lessons Learned

The most recent (2006) ground water monitoring results indicate that elevated concentrations of PCE are still present at certain locations on the site in the shallow, intermediate, and deep zones of the aquifer. Still, the general trend appears to be an overall decrease in concentrations of PCE in all three zones. PCE values were generally below the applicable NADSC values.

Concentrations of TCE increased in all surficial aquifer zones. However, very low concentrations of cis-1,2-DCE, trans-1,2-DCE, and vinyl chloride indicated that contaminants are not being degraded beyond TCE. Samples from some downgradient wells showed increased PCE concentrations, which may be a result of off-site PCE migration within the deep zone of the surficial aquifer. As of March 2007, FDEP was planning to assess soil and evaluate various options to treat the downgradient PCE plume. Treatment options include enhanced biodegradation with reductive dechlorination, thermal treatment, and excavation of the contaminated soil in the source area.

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