REMEDIATION SYSTEM EVALUATION

FOR

ELMORE WASTE DISPOSAL SUPERFUND SITE
GREER, SOUTH CAROLINA

Report of the Remediation System Evaluation,
Site Visit Conducted at the Elmore Waste Disposal Site
19-20 September 2000

Final Report Submitted to Region 4
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NOTICE

Work described herein was performed by GeoTrans, Inc. (GeoTrans) and the United States Army Corps of Engineers (USACE) for the U.S. Environmental Protection Agency (U.S. EPA). Work conducted by GeoTrans, including preparation of this report, was performed under Dynamac Contract No. 68-C-99-256, Subcontract No. 91517. Mention of trade names or commercial products does not constitute endorsement or recommendation for use.

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EXECUTIVE SUMMARY

The Elmore Waste Disposal, Inc. Superfund site is located in Greer, South Carolina. The original Elmore Site occupies approximately half an acre between South Carolina Route 290 on the south, a CSX rail line on the north and is bounded on the west by property parcel 105 which contains an abandoned tavern, and a private residence on the east. An area of single family homes lies approximately 700 to 1100 feet to the north of the Elmore property, beyond the CSX rail line extending to Ward Creek which bounds the subdivision property on the north.

Contaminated waste oil and possibly other liquids were stored on site in a variety of containers. In June – August 1986, approximately 5,000 cubic yards of contaminated soil and 16,840 pounds of liquid were removed under the direction of the South Carolina Department of Health and Environmental Control. Ground water monitoring wells were installed and revealed contamination by volatile organic compounds (VOCs). The site was added to the NPL in March, 1989.

A ground water extraction and treatment facility was built to contain and remediate the contaminated ground water plume. The EPA RPM indicated the plant has been successfully operated for theeight months prior to the RSE team visit.

The RSE suggests several potential modifications to address effectiveness issues:

- Additional characterization is recommended to better define the plume.
- A formal capture zone analysis that incorporates additional hydrogeologic analysis is recommended.
- Indoor air sampling should be conducted at a few homes along Sunnyside Drive along Highland Avenue and Sunnyside Circle to determine indoor air impacts of VOCs.
- Surface water sampling should be conducted to determine impacts on the creek.

The RSE also suggest several potential modifications to reduce long-term costs:

- A reevaluation of the treatment criteria is warranted given the influent concentrations relative to the standards for discharge to the sewer system. This would obviate the need for operating the treatment plant with the exception of monitoring the influent concentrations. (Potential estimated savings of $600,000 over a 20-year period)
- Alternatively, obtaining a permit to discharge treated water into the creek. (Potential estimated savings of approximately $500,000 over a 20-year period)
- Elimination of the pesticide and SVOCs analyses for the effluent and electronic data transfer may save up to $2,000 annual (potential estimated savings of $40,000 over a 20-year period).

- Modifications to the GAC operations will double the lifetime of the GAC units and still allow the system to meet discharge criteria, and modifications to the service contract for the GAC units will facilitate site operations and prevent the necessity of purchasing three new units. (Potential estimated savings of $195,000 over a 20-year period)

Separate from the above recommendations, substantial cost savings (near $2,000,000) may result if aquifer goals are reconsidered and alternative technologies are used to replace the pump and treat system.

PREFACE

This report was prepared within the context of a demonstration project conducted by the United States Environmental Protection Agency's (USEPA) Technology Innovation Office (TIO). The objective of the overall project is to demonstrate the application of optimization techniques to Pump-and-Treat (P&T) systems at Superfund sites that are "Fund-lead" (i.e., financed by USEPA). The demonstration project was conducted in USEPA Regions 4 and 5.

The demonstration project has been carried out as a cooperative effort by the following organizations:

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The project team is grateful for the help provided by an EPA Project Liaison in each Region. Kay Wischkaemper in Region 4 and Dion Novak in Region 5 were vital to the successful interaction between the project team and the Regional Project Managers (RPM's) during the course of this project, and both actively participated in one Remediation System Evaluation (RSE) site visit conducted in their Region.

The data collection phase of this project included interviews with many RPM's in EPA Regions 4 and 5. The project could not have been successfully performed without the participation of these individuals.

Finally, for the sites where RSE's were preformed, additional participation and substantial support was provided by the RPM's (Ken Mallary and Ralph Howard in Region 4; Steve Padovani and Darryl Owens in Region 5), and their efforts are very much appreciated, as are the efforts of the State regulators and EPA contractors who also participated in the RSE site visits.

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1.0 INTRODUCTION

1.1 PURPOSE

The US Environmental Protection Agency's (USEPA) Technology Innovation Office (TIO) and the US Army Corps of Engineers (USACE) Hazardous, Toxic, and Radioactive Waste Center of Expertise (HTRW CX) are cooperating in the demonstration of the USACE Remediation System Evaluation process at Superfund sites. The demonstration of the RSE's is part of a larger effort by TIO to provide USEPA Regions with various means for optimization, including screening tools for identifying sites likely to benefit from optimization and computer modeling optimization tools for pump and treat systems, such as the MODMAN code.

The Elmore Waste Disposal Site was chosen based on initial screening of pump and treat systems managed by USEPA Region 4 and represented a site with relatively high operation cost and a long projected operating life. One or two sites in Regions 4 and 5 will be evaluated with RSE's in the first phase of this demonstration project. A report on the overall results from these demonstration sites will be prepared and will identify lessons learned, typical costs savings, and a process for screening sites in the USEPA regions for potential optimization savings.

The RSE process is meant to identify cost savings through changes in operation and technology, to evaluate performance and effectiveness (as required under the NCP and "five-year" review), assure clear and realistic remediation goals and exit strategy, and verify adequate maintenance of Government owned equipment. This report provides a brief background on the site and current operations, a summary of the observations made during a site visit, and recommendations for changes and additional studies. The cost impacts of the recommendations are also discussed.

1.2 TEAM COMPOSITION

The team conducting the RSE included:

Kathy Yager, HQ EPA TIO
Frank Bales, Chemical Engineer, USACE, Kansas City District
Dave Becker, Geologist, USACE HTRW CX
Bob Briggs, HSI GeoTrans (EPA TIO's contractor)
Lindsey K. Lien, Environmental Engineer, USACE HTRW CX
Peter Rich, HSI GeoTrans

1.3 DOCUMENTS REVIEWED

The following documents were reviewed as part of the RSE evaluation:

Author	Date	Title/Description
EPA	4/26/1993	ROD (and one ESD)
Bechtel	11/1995	Remedial Design Report
EPA	9/1998	Preliminary Closeout Report
Bechtel	4/1999	Interim Remedial Action Report
Bechtel	Q1/1999	Quarterly Monitoring Report, First Quarter 1999
Earth Tech	4/1999	Ground water Treatment System Design Report
Earth Tech/Bechtel	4/1999	Operation and Maintenance Manual
IT Group	6/1999	Individual Well Extraction Volumes for the Month of June, 1999
IT Group	7/2000	Ground water Extraction and Treatment System, Monthly Operations/Progress Report
Black and Veatch	7/15/2000	Annual Report and 2nd Quarter 2000 Monitoring Report

1.4 PERSONS CONTACTED

The following individuals were present during the site visit:

Ralph Howard, Remedial Project Manager, EPA Region 4
Ed Hicks, O & M Manager, Black and Veatch Special Projects Corporation
Alan Alewine, Site Operator, IT Group
Lucas Berresford, South Carolina Department of Health and Environmental Control
Greg Cassidy, South Carolina Department of Health and Environmental Control
Minda Johnson, South Carolina Department of Health and Environmental Control
Ed Bave, Regulatory Specialist, USACE HTRW CX
Mark Fisher, Industrial Hygienist, USACE HTRW CX
Jim Cheney, Chemist, USACE HTRW CX

1.5 SITE LOCATION, HISTORY, AND CHARACTERISTICS

1.5.1 LOCATION

The site is located in Greer, South Carolina near the intersection of State Highway 290 and Sunnyside Drive. The original Elmore Site occupies approximately half an acre between South Carolina Route 290 on the south, a CSX rail line on the north and is bounded on the west by property parcel 105 which contains an abandoned tavern, and a private residence on the east. An area of single family homes lies approximately 700 to 1100 feet to the north of the Elmore property, beyond the CSX rail line extending to Ward Creek which bounds the subdivision property on the north. The Elmore site is relatively flat between route 290 and the CSX rail line. The area slopes significantly to the north of CSX rail line to Ward Creek. The current site layout is shown on Figure 1.1.

1.5.2 POTENTIAL SOURCES

The Elmore Waste Disposal Site is known to have operated from 1975 to 1977; however, aerial photos reveal the presence of what was assumed to be a tanker truck receiving waste material taken as early as 1965. The company received and placed numerous drums containing various liquid and solid wastes. The drums were in various stages of decay. Contaminated waste oil and possibly other liquids were also stored on site in open topped tanks with an estimated volume of 5000 – 6000 gallons. In June – August 1986, approximately 5,000 cubic yards of contaminated soil and 16,840 pounds of liquid were removed under the direction of the South Carolina Department of Health and Environmental Control. Ground water monitoring wells were installed and revealed contamination by barium, cadmium, zinc, tetrachloroethene, trichloroethene, and 1,1,2-trichloroethane. The site was added to the NPL in March, 1989.

1.5.3 HYDROGEOLOGIC SETTING

Ground water occurs in residual soils and weathered and fractured biotite gneiss. Site soils are primarily silty clays and clayey silt and are from 0 - 30 feet thick. Saprolite extends from 15 to 30 feet below grade and bedrock weathered to various degrees is encountered to depths of over 150 feet. Dips of fractures and foliation are not known. Saprolite and weathered bedrock include slightly weathered but fractured quartz veins that may represent significant ground water flow paths. Ground water is encountered between 1 and over 25 feet below grade at elevations ranging from over 930 feet above mean sea level (msl) to less than 895 feet above msl. A spring was known to exist near the intersection of Sunnyside Drive and Sunnyside Circle and discharged small quantities of water. Regrading and the installation of a collection sump near the location of the spring have eliminated surface discharge. Ground water generally flows from south to north toward Ward's Creek at gradients of approximately 0.04 feet/foot. Previous pump tests have indicated that the hydraulic conductivities of the saprolite and weathered bedrock range from 2E-03 to 2E-04 cm/sec. Based on these hydraulic conductivities and gradient values and a site width of 600 feet and a saturated thickness of 60 feet, approximately 20 gallons per minute of ground water flow beneath the site in the contaminated zone. The degree to which ground water flow is focused in fractures is not clear and so the degree to which the pump test values represent the entire site is not known. As described below, extraction well flow rates are variable and suggest that the aquifer properties are significantly variable. Vertical gradients were generally upward throughout the site in early 2000, but previous work suggests that downward gradients may be observed in southern portion of the study area.

1.5.4 DESCRIPTION OF GROUND WATER PLUME

The ground water plume was defined through the Remedial Investigation, supplemental investigations by EPA and its contractors, the remedial design investigation, and remedy construction and monitoring. The plume, as determined in the second quarter of 2000, consists primarily of various organic compounds, including trichloroethene (TCE), perchloroethene (PCE), breakdown products of those solvents including 1,2 dichloroethene (cis 1,2 DCE) and vinyl chloride (VC), and benzene. Recent maximum levels of PCE and TCE exceed 4,000 ug/L, in several wells along the axis of the plume. Benzene is found in EW-01 on the west side of the upgradient portion of the plume and cis-1,2 DCE (maximum 570 ug/L) and VC (maximum 46 ug/L) are found in the same area and in areas directly downgradient. Although metals were originally thought to be elevated at the site, additional work demonstrated that the metals were not related to site activities. The plume extends approximately 1100 feet from the Elmore Site proper northward to Ward's Creek under the Sunnyside Circle subdivision and has a width of 400 -

800 feet wide. The width of the plume is somewhat poorly constrained to the east by monitoring well cluster 12 and the northward extent of the plume is only constrained by one shallow well, MW-02, north of Ward's Creek. Sampling of Ward's Creek both upstream and downstream of the projected extent of the plume suggests discharge of contamination from the ground water into surface water and 5 - 25 ug/L of TCE and approximately 5 ug/L of PCE has been measured at the downstream sampling station. The creek is estimated to have a base flow of 2.5 cubic feet/sec. This base flow was estimated by the RPM at the end of the RI, using a simple field method (flow-rate and stream cross-sectional area). However, it is only an estimate and represents only one measurement at one point in the seasonal/climate cycle. The spring near the intersection of Sunnyside Drive and Sunnyside Circle was contaminated with VOCs. The plume is primarily shallow near the northern edge of the Elmore Site proper but appears to deepen as it migrates to the north under the subdivision. The vertical extent of the plume near the creek is not clear.

2.0 SYSTEM DESCRIPTION

2.1 SYSTEM OVERVIEW

The remediation system consists of :

- 9 extraction wells
- 1 spring sump
- extraction pumps, double wall transfer piping to the treatment facility
- 525 gallon equalization tank
- a bag filter system, 2 - 100 filters in series
- 3-1000 pound granular activated carbon adsorbers 2 operated in series with one standby
- an NPDES composite sampler monitoring station
- discharge to the sanitary sewer
- remote operation and control system

The system was designed to treat a flow rate of 30 gpm from the nine extraction wells, and one spring sump. The actual flow discharged from the treatment facility generally averaged approximately 10 gpm during the second quarter of 2000. The maximum allowable discharge rate to the sanitary sewer system is 50,000 gallons per day or approximately 35 gallons per minute. Iron bacteria fouling has not been a problem in the extraction well network.

2.2 EXTRACTION SYSTEM

The extraction system includes nine wells, and a spring sump. The nine wells are 6-inch diameter stainless steel and have approximately 30 feet of screen (except wells EW-05I and EW-06I which have 60 feet and 40 feet), and a two-foot-long sump. Well depths are 48-50 feet for the shallow wells and 80-83 feet for the intermediate depth wells. Each well is supplied with a Grundfos submersible (5S or 10S) pump and pressure transducer. The well head is completed at grade inside a locked flush-mount vault. The connections to the extraction piping, flow-control ball-valve, flow meter, and sample port are all contained inside the vault. Power and control lines are run in below-grade conduits parallel to the collection piping.

2.3 TREATMENT SYSTEM

Ground water is extracted from a series of nine wells and a spring sump that discharged via HDPE polyethylene double walled piping to a 525-gallon equalization storage tank. Flow is then pumped via a float controlled 50 gpm centrifugal pump through bag filters and then to the three 1000 pound granular activated carbon units (two in series, with one in standby mode). The effluent is then discharged via a 3-inch gravity sewer to the Greer South Tyger Wastewater Plant via the sanitary sewer system. The treatment system was designed to treat at a continuous rate of 30 gpm with a peak capacity of up to 50 gpm. Maximum allowable discharge rate to the sanitary sewer is nearly 35 gpm.

3.0 SYSTEM OBJECTIVES, PERFORMANCE AND CLOSURE CRITERIA

3.1 CURRENT SYSTEM OBJECTIVES AND CLOSURE CRITERIA

The goal of the remedial action, as documented in the ROD dated April 26, 1993, is to both contain and remediate the ground water to specific goals. Ground water clean-up goals are based on either MCLs, proposed State MCLs, EPA action levels, or health-based remediation goals. Chemical-specific ground water cleanup goals include:

benzene	5 ug/l	methylene chloride	5 ug/l
beryllium	4 ug/l	nickel	100 ug/l
cadmium	5 ug/l	PCE	5 ug/l
carbon tetrachloride	5 ug/l	1,1,1-TCA	200 ug/l
chromium	100 ug/l	1,1,2-TCA	5 ug/l
cis-1,2-DCE	70 ug/l	TCE	5 ug/l
lead	15 ug/l	vanadium	200 ug/l
manganese	3,000 ug/l	vinyl chloride	2 ug/l.

Because no one uses ground water in the vicinity and indoor air quality sampling accomplished in 1994 indicated no measurable concentrations of site contaminants, there are no current human exposures, with the possible exception of direct contact with and ingestion of water from Ward's Creek. According to the EPA Region IV RPM Ralph Howard, the remedy is as stated in the ROD, but in the absence of people using well water, the remedy is intended to prevent discharge of contaminated water into the creek at levels that would present a human health or ecological risk. An ESD dated January, 1994 identified metals contamination as a product of the sampling process, and eliminated metals from consideration as site contaminants.

The plant is required to meet discharge standards for the publicly owned treatment works (POTW) set by the City of Greer. Currently, the primary standard is a limit of 2130 ug/l total VOCs. The plant must also monitor levels of pesticides in the effluent. Currently, influent concentrations are approximately 2300 ug/l total VOCs. Pesticides are not found in the influent or effluent.

3.2 TREATMENT PLANT OPERATION GOALS

The current contract for operations calls for the plant to operate 24 hours per day, seven days a week while treating water from all designated active extraction wells. The facility is visited weekly and is remotely monitored 24 hours per day, seven days a week with one individual on call to respond to trouble alarms at the facility. Extraction wells are operated in a manner that prevents frequent cycling of the wells. Pump on/off set points are selected to allow near continuous operation. The plant has been consistently meeting the primary effluent standard limit of 2130 ug /l total VOCs through the GAC system. The plant has consistently been removing VOCs to levels that would meet drinking water standards.

4.0 FINDINGS AND OBSERVATIONS FROM THE RSE SITE VISIT

4.1 FINDINGS

In general, the RSE team found the system to be well operated and maintained. The observations and recommendations given below are not intended to imply a deficiency in the work of either the designers or operators, but are offered as constructive suggestions in the best interest of the EPA and the public. These recommendations obviously have the benefit of the operational data unavailable to the original designers. The RSE team found the site operators and the remedial project manager very interested in improving the performance and cost effectiveness of the system. The site operators have been working very diligently to optimize the treatment plant and overcome unanticipated problems.

4.2 SUBSURFACE PERFORMANCE AND RESPONSE

4.2.1 WATER LEVELS

Water levels in monitoring wells outside of the extraction capture zones show little seasonal fluctuation and flow directions do not vary significantly. The available monitoring wells make determination of the composite cone of depression for the southern (shallow) line of wells difficult to determine. There is better evidence for a cone along the northern (intermediate depth) line of extraction wells. There is a strong vertical gradient near the northern line of wells. Maps of piezometric levels at the site have previously been constructed using the extraction well pump set point elevations but this approach should be avoided since the extraction well water levels do not reflect aquifer levels due to the well losses.

Water was observed in the ditch adjacent to Sunnyside Drive during the site visit. The source of this water is not clear, but a drainage pipe apparently originating from the southwest discharges to the ditch downstream of the driveway to the treatment plant.

4.2.2 CAPTURE ZONES

Based on the limited monitoring network, the determination of the capture zones for the two lines of extraction wells is difficult. There is uncertainty in the current extent of the plume east of EW-10S, and if there is a lack of capture along the shallow well line, it occurs in this area. Temporary well installation and sampling in 1997 east of the location of EW-10S suggested that the eastern edge of the plume was not much farther east of EW-10S. Without the operation of the sump (EW-09), there is also some concern about the capture of the western edge of the plume. The capture zone for the northern intermediate depth well line is also subject to uncertainty to the east but since the average flow rates for the northern line of wells is higher, especially in EW-02I and EW-04I, the capture zone seems to be broader in this area. Temporary shallow well sampling in 1997 east of the north line wells also suggested a nearby limit to the plume. Assuming a pre-pumping gradient of approximately 0.05 and hydraulic conductivity of 1E-3 cm/sec (a conservative number between the 2E-3 and 2E-4 cm/sec values determined from previous pump testing of EW-01S), the flow occurring within a 600-foot-wide and 50-foot thick plume is:

$$Q = kIA = 1E\text{-}3 \text{ cm/sec} * 0.05 \text{ cm/cm} * (600*50) \text{ sq ft} * (30.48 \text{ cm/ft})^2 * 1 \text{ L}/1000 \text{ cu cm} = 1.4 \text{ L/sec}$$

(note that 1.4 L/sec * 60 sec/min * 1 gallon/3.78 L = 22 gal/min)

This is approximately twice the average flow rate of the extraction system. The extraction system averaged under 11 gal/min in the 2nd quarter of 2000. This would indicate inadequate capture. If the hydraulic conductivities are lower, the pumping rate may be adequate, but significant heterogeneity is suggested by the production rates of the extraction wells. Certain wells including wells EW-05I and -06I, appear to have adequate capacity to pump more water than they are currently producing nearer the treatment plant's allowable 35 gal/min discharge rate to the POTW.

The hydraulic conductivities cited above were derived from a pump test of EW-01S. Water level responses in EW-06I due to pumping in adjacent wells EW-04I and EW-02I (when EW-06I was not pumped) were analyzed to estimate hydraulic conductivities at the intermediate depths. On 8/26/98, pumping occurred in EW-04I and EW-02I for almost 4 hours without pumping in EW-06I, after a prolonged shut down of the entire system. Using the hourly water level readings from EW-06 and the Jacob straight-line method, a transmissivity of between 0.006 and 0.008 sq ft/min were estimated. This compares well with the 0.0057 sq ft/min determined by Bechtel (1995) for MW-14I while pumping EW-01S, but approximately an order of magnitude lower than the transmissivity computed by Bechtel using the more appropriate pump test response data from MW-14S. This suggests that the hydraulic conductivities in the intermediate depths may be somewhat lower than the shallow depths, but there is a large uncertainty with these results. Again, if the hydraulic conductivities at the intermediate depths are lower than assumed in calculating the natural flow in the aquifer, the capture of the intermediate depth extraction wells would actually be better than indicated.

4.2.3 CONTAMINANT LEVELS

Contaminant levels in Ward's Creek have appeared to decline over time, as indicated by Figure 4-3 in the 2nd Quarter 2000 report (BVSPC, 2000). This would suggest that the system is affecting the plume in a way that reduces the discharge of contaminants to the creek. Based on the available concentration data for the monitoring and extraction wells since start-up, the extraction system appears to be reducing concentrations of TCE and to a lesser extent PCE in the southern shallow portion of the site. The northern intermediate depth system is significantly reducing concentrations in the deeper portion of the aquifer, but is not clearly impacting the intermediate depth aquifer. Concentrations of both TCE and PCE are increasing MW-01I and EW-06I and EW-04I on the eastern side of the northern line, and concentrations are decreasing somewhat or have no trend in EW-03I, EW-05I, and EW-02I. The higher concentrations on the east side of both the northern and southern extraction lines and the increasing trends in wells on the eastern side of the northern line of wells suggests that the line locations are centered west of the major axis of the plume. The slow rates of decline in wells with higher concentrations of PCE and TCE indicate that the time to achieve MCLs in the entire aquifer will be very great.

There is a concern that the plume may not completely discharge to Ward's Creek. The observed VOC concentrations in the surface water can be used to estimate the degree to which the plume is "captured" by the creek. It can be assumed that the mass of VOCs observed in the surface water of the creek is due entirely to contaminated ground water discharge. If so, the 9 gal/min ground water flow in the plume must discharge to the stream with an average concentration of 500-1000 ug/L of VOCs and be diluted by the 2.5 cubic ft/sec flow in the creek. A weighted average of the concentrations in the plume was computed at approximately 1000 ug/L total VOCs. Based on the similarity in the weighted average concentration in the ground water and the contaminant mass estimated to be discharging to the stream, it would appear that the plume may be largely discharging to the stream and not bypassing it.

4.2.4 NATURAL ATTENUATION POTENTIAL

Concentrations of PCE/TCE breakdown products such as cis 1,2 DCE and vinyl chloride are highest on the west side of the plume coincident with and downgradient of the area of benzene contamination in ground water and the small dump area previously removed just east of Sunnyside Drive. Ratios of TCE to PCE also suggest reduction of the PCE to TCE in the same area. The hydrocarbons were probably present in adequate quantities to drive the aquifer into reducing conditions which led to reductive dechlorination of the more chlorinated ethenes.

4.3 TREATMENT SYSTEM DOWN-TIME

The system does not have a contractual requirement for the plant to continuously treat water from all active extraction wells for some minimum time percentage. The system has been experiencing significant downtime due to unscheduled maintenance events. These include:

1) cleaning the scale from the wells and transducers;
2) frequent bag filter cleaning caused by high TSS present in the sump discharge;
3) repairing exterior cracks and coatings in carbon vessels associated with the lid flexure due to inadequate vacuum relief; and
4) a variety of control failures caused by power surges, lightning strikes and transducer malfunctions.

4.4 COMPONENTS OR PROCESSES THAT ACCOUNT FOR MAJORITY OF COSTS

Cost information was unavailable during the site visit, nor was it included in the information provided to the RSE Team. Additional research will be done to include this information in the final report. Total annual O & M costs for the project is approximately $180,000 per year which includes staffing and excludes analytical costs. These costs may not be indicative of long-term operational cost due to unforeseen maintenance problems described. Future costs may be 30-40% lower.

4.4.1 NON-UTILITY CONSUMABLES AND DISPOSAL

Consist primarily of GAC, with an estimated annual cost of approximately $12,000 based on the current VOC concentration and flow rate. Using data provided in the O&M manual regarding change out frequency, GAC expenditures would be expected to approach $15 – 20,000 annually.

4.4.2 LABOR

The staff consists of one part time operator. The operator conducts bi-weekly site visits to perform routine maintenance, or other visits as necessary. Note that some labor is expended in preparing a report documenting each site visit. These frequent reports may not be necessary once the system is operating as intended.

4.4.3 SAMPLING AND ANALYSIS

Sampling of approximately 8 monitoring wells and 9 extraction wells occurs quarterly. Certain monitoring wells outside the contaminant plume are sampled annually (MW-02, MW-13S and -13I, MW-12S and -12I). Quarterly sampling includes only volatile organics for the monitoring and extraction wells, and VOCs, semi-volatile organics, and pesticides/PCBs for the influent and effluent from the plant. Treatment plant influent/effluent biological oxygen demand, total suspended solids, chemical oxygen demand, copper, and lead concentrations and pH are determined monthly, as required by the POTW. Monthly effluent samples are analyzed by a local laboratory. The quarterly and semiannual analyses are performed by the EPA. According to the project staff, quarterly sampling requires 3 days labor by 2 persons. This labor cost is probably approximately $3,600. Analytical costs for the monthly effluent samples are approximately $14,000 per year.

4.4.4 TREATED WATER DISCHARGE

Currently, annual costs including power and discharge fees, for treated water disposal to the sanitary sewer line are approximately $20,000

4.5 RECURRING PROBLEMS OR ISSUES

4.5.1 WELLS

The extraction wells have generally performed acceptably. There is no well-defined program to identify well performance problems, but the operators do monitor the cycle times for the wells as an indicator of potential problems. Pumps are pulled and cleaned, if needed, approximately every 6 months. Pumps are activated based on water levels and pump switch set points are set based on achieving a minimum cycle time for the pump rather than achieving a minimum flow rate from each well. The pressure transducers have had problems with encrustation and cleaning or replacement of the transducers is periodically required. Well vaults and monitoring wells appear to be secure and in good shape. The control system had been a cause of system downtime, though the operators have been diligent in correcting this problem. The control system still periodically shows a low-flow alarm for well EW-03. The spring sump has consistently been a source of suspended solids in the treatment plant and the yield from the sump has been low. The sump was not producing water at the time of the site visit and had produced less than 400 gallons in the 2nd quarter 2000.

4.5.2 CARBON UNITS

Based on the intermittent nature of plant operations, and the long shake down period, it is difficult to establish if carbon run times have been as long as anticipated in the O&M manual (dated 4/19/99). Problems with particulate matter from EW09, and repairs to the units make an evaluation of the effectiveness difficult. The 2nd Quarter 2000 report (BVSPC, 2000) indicates 2 of the carbon units were changed out following breakthrough in the first carbon unit. The second unit still had significant treatment capacity remaining, and given the discharge levels to the sanitary sewer are very close to the plant influent concentration, the GAC units should not be changed out until completely exhausted.

4.5.3 TRANSFER PUMP

During the site visit, the transfer pump was making noise, most likely caused by a bearing near failure..

4.5.4 PIPING

The piping within the plant is minimal without obvious problems except the vacuum/siphoning problem related to the GAC units, which has been corrected.

4.5.5 BAG FILTERS

The bag filters are functioning properly since the EW-09 (sump) has been taken off line. The high particulate loading from EW-09 required bag change outs every few days. Since EW-09 has been off line, the bag life has increased to approximately 2 weeks. It should be noted that EPA still has concerns about not capturing the water in the area around EW-09.

4.5.6 SLUDGE HANDLING AND TREATMENT

Very little sludge is generated at the site. Backwash from carbon filters and sediment removed from bag filters is placed in a container, allowed to settle and excess water decanted back to the treatment train. So little sludge has been generated that disposal has not been necessary.

4.6 REGULATORY COMPLIANCE

There are no known exceedances of wastewater pretreatment criteria. The plant influent concentrations are just above the POTW acceptance standards.

4.7 TREATMENT PROCESS EXCURSIONS AND UPSETS, ACCIDENTAL CONTAMINANT/REAGENT RELEASES

4.7.1 CARBON VESSEL LEAKS IN THE PLANT

Exterior cracks formed in the vessels due to the lids flexing caused by a vacuum formed in the vessels after the transfer pump shuts off. This problem was diagnosed and repaired by the O&M staff.

4.7.2 CONTROL MALFUNCTIONS

As alluded to throughout the report, numerous controller problems occurred in the plant which resulted in shut downs. Control system problems resulted in 6 wells being shut down from October, 1999 to early February, 2000 while the problem was diagnosed and corrected. The Hi-level alarm in the 300 gallon equalization tank would stick intermittently during high inflow periods, and was replaced along with the equalization tank. A 525 gallon tank was installed to provide greater operational flexibility should multiple wells come on concurrently, or a large volume of water enter the tank over a short period of time.

4.8 Safety Record

The plant appears to have had an excellent safety record.

5.0 EFFECTIVENESS OF THE SYSTEM TO PROTECT HUMAN HEALTH AND THE ENVIRONMENT

5.1 GROUND WATER

The system appears to be achieving its containment goals based on the available data, though there is uncertainty on the extent of the plume to the east and the fate of the plume near Ward's Creek. Of particular interest is the vertical extent of the plume at the creek. It is assumed that the ground water, and therefore the plume, ascends toward the creek bed such that the plume discharges to the stream. If the weathered bedrock and saprolite structure allow the plume to migrate at depth below the stream, the plume may not be adequately contained to prevent exposures. If ground water levels rise due to increased precipitation and the sump (EW-09) remains inactive, there may be some risk of exposure to contaminated seepage near the sump and damage to the landscaping placed there. Furthermore, the nature of the ground water contamination on the actual Elmore property has not been characterized for some significant period of time.

5.2 SURFACE WATER

There may be current ecological and human exposure to surface water contaminated with chlorinated organics in Ward's Creek. The chlorinated organic concentrations are unlikely to be significant in the aquatic environment and do not exceed freshwater screening levels. The downstream sampling station in the creek is probably 400 feet downstream of the point of intersection between the major axis of the plume and the stream and may represent concentrations after substantial aeration of the surface water. The concentrations of contaminants are likely to be a maximum where the highest concentrations discharge to the stream bed. In addition, the concentrations of contaminants in the ditch along Sunnyside Drive have not recently been quantified.

5.3 AIR

Though there has been sampling of indoor air quality at a selected house or two, the persistent presence of vinyl chloride in the western portion of the plume may still be cause for concern. The clay-rich soil should inhibit vapor migration into the home.

6.0 RECOMMENDATIONS

6.1 RECOMMENDED STUDIES TO IMPROVE EFFECTIVENESS

6.1.1 PLUME DEFINITION

As recommended by the current operators, additional information east of the extraction lines and west of Mason Street would be very useful, as would additional multi-depth monitoring points near Ward's Creek (on both sides of the stream). At least one additional cluster of two monitoring wells is needed east of Sunnyside Circle west of Mason Street. These wells should cost approximately $15,000 to install and sample. An additional cluster of two monitoring wells (one shallow and one intermediate depth) is needed along but south of Ward's Creek midway between MW-02 and the downstream surface water sampling station. An additional intermediate depth well should be installed adjacent to MW-02. These three wells would cost approximately $21,000 to install and sample. Re-sampling of selected monitoring wells on the Elmore property is strongly recommended prior to any well decommissioning as part of site redevelopment. This additional data would greatly assist in assessing the impact on the plume from the past source removal. This re-sampling would cost approximately $1,000.

6.1.2 CAPTURE ZONE ANALYSIS

Once additional monitoring wells have been completed, a formal capture zone analysis should be performed on the basis of measured water levels, plus additional hydrogeologic analysis (i.e., analytical tools and/or a simple ground water flow model). The goal is to better understand the capture zone dynamics at the site and evaluate the adequacy of the current capture zone. It is recommended that this analysis also include simple response (pump) tests for a couple of representative extraction wells, including EW-05I, and/or EW-06I. The tests should be conducted following a system shutdown (done for other reasons such as maintenance) and the recovery of ground water levels to a "static" condition. The test should just consist of the restarting of the pump (at a maximum sustainable rate) and the simultaneous monitoring of the draw down response, on a logarithmically increasing interval, in nearby monitoring and extraction wells over the course of 1-2 days. Based on the draw down response, the transmissivity and storage coefficient should be confirmed for the location. These results can be used to predict the aquifer response and capture zone for the entire system compared to the existing plume. These tests could be done with existing treatment plant personnel at a cost of approximately $800 per well (8 hrs * $45/hour * 2 persons + $80/day rental of recorder/transducers). Data analysis would need to be done by a hydrogeologist or engineer at an estimated cost of approximately $2,000 (32 hours * $60/hour). Total cost of the pump tests would therefore be approximately $5000. Costs of the additional hydrogeologic analysis (i.e., analytical solutions, simple ground water modeling) to evaluate system-wide capture zones would cost approximately an additional $10,000. The additional information on the site hydraulic conductivities provided by the simple pumping tests will be invaluable in determining what flow rates are necessary to capture the contaminants most efficiently. The costs for the pump tests are extremely small compared to annual costs for operations. A numerical ground water model could be used very effectively to determine the optimal pumping configuration and to perform "what-if" analyses, especially if one were to consider alternatives such as a permeable reaction wall. The use of an optimization tool for flow models such as MODMAN would be potentially valuable. Additional information on the use of MODMAN for optimization of pump-and-treat systems used for containment of plumes is available at http://www.frtr.gov/optimization/.

6.1.3 INDOOR AIR IMPACTS

Time-averaged indoor air sampling for VOCs, especially vinyl chloride, could be considered during times of declining barometric pressure for a few homes just east of Sunnyside Drive along Highland Avenue and Sunnyside Circle. Some modeling of the vapor migration, such as the method of Johnson and Ettinger (1991) should be considered using the indoor air sampling results as a calibration point to project indoor vapor concentrations under other conditions. Sampling may cost $5,000 and the modeling analysis may cost an additional $5,000.

6.1.4 SURFACE WATER SAMPLING

A sampling station in the creek due north of wells EW-06I and -4I should be established and sampled at least once to determine the true range of impacts to the stream. Diffusion samplers set on or in the creek bed may be a very cost effective means to achieve a representative chlorinated organic sample. Finally, in order to assure that there are no unquantified risks due to surface water exposure, some sampling of the ditch along Sunnyside Drive for VOCs should be done downstream of the culvert under the back entrance to the treatment plant. Costs for these samples should be less than $1500.

6.2 RECOMMENDED CHANGES TO REDUCE COSTS

6.2.1 RE-EVALUATION OF TREATMENT CRITERIA

Given the influent concentrations relative to the standards for discharge to the sewer system, it may be beneficial to seek a slight increase in the discharge standard. The subject should be raised with the City of Greer. This would obviate the need for operating the treatment plant, though not for monitoring influent concentrations. In fact, sampling frequency may need to increase since the influent may still be quite close to a revised standard. The treatment equipment would need to be retained in case concentrations increase. The net savings may be approximately $30,000. As an alternative, the project team could seek the equivalent of a NPDES permit for discharge of the treated water to Ward's Creek or a tributary, such as the ditch along Sunnyside Drive. Such a permit would require substantial administrative effort to meet the substantive requirements, but since this would be an on-site action, the actual permit would not be required. The effluent water is not high in most metals, SVOCs, total dissolved solids, total suspended solids, or pesticides and pH is not extreme. If requirements could be met with the existing treatment plant, annual savings could be $25,000. It should be noted that the RPM recalls that this option was considered in 1997 and dropped (concerns included iron concentrations and the potential need for a treatment system), but agrees that a re-look of this option seems treasonable.

6.2.2 REDUCTION IN MONITORING AND REPORTING REQUIREMENTS

The RSE team concurs with the recommendation of the remedial project manager to eliminate the analysis of effluent for pesticides, SVOCs, and total suspended solids. This will require coordination with the City of Greer. Cost savings are probably less than $2,000/year. The current monitoring program for monitoring and extraction wells appears to be appropriate. Suggest that the operator use electronic data transfer and posting of monitoring results and inspection reports on the Internet to replace current weekly and monthly reports. Any daily reports should be terminated once routine operations are achieved. Cost savings for this have not been quantified.

6.2.3 MODIFY GAC OPERATIONS

Currently, the operating contractors replace the GAC in two of the three contactors upon breakthrough in the lead contactor. The two operating contractors should be allowed to reach complete breakthrough prior to requiring media replacement. This will double the life of the carbon while still allowing the facility to meet its discharge criteria which is very near the plant influent concentration. If the lag contactor should reach full exhaustion (effluent concentration equals or exceeds the influent concentration) the third (standby) vessel should be brought on line to treat the flow until the spent carbon can be replaced. This revision in operations will likely save $5,000 to $10,000 annually. In addition, the use of a service contract should be evaluated to eliminate the need for the operator to handle and dispose of the spent GAC. The service contract should include transportation of replacement vessels including GAC, and removal, regeneration and transportation of the spent GAC and vessels to the service supplier. Annual cost for renting 3-1000 pound contractors is approximately $7,200 plus GAC at about $2/pound in small quantities, including delivery. This option may not save money due to the infrequency of the deliveries, but would simplify facility operations a great deal, and expedite the carbon change out process with no mess, which is desirable in this location. If a service contract is not pursued, then 3 new contractors should be purchased to replace the existing units. Estimated cost of the new vessels is about $25,000.

6.2.4 NATURAL ATTENUATION

Based on the lack of current human exposure to the ground water contaminants, and the potential for only limited human and ecological at Ward's Creek, it may be possible to eliminate the operation of the extraction system entirely and still not present an unacceptable risk. As discussed in section 4.2.4, there appears to be some evidence of reductive dechlorination occurring at the site. Additional modeling of the contaminant transport would be necessary. The additional study of the ground water/surface water interaction would likely need to be revisited to re-evaluate the exposure scenarios. Institutional controls to prevent use of ground water and to reduce exposure to surface water would be vital. This measure may not be acceptable to either the state or public despite the potentially low risk. The time to clean up under natural conditions is likely to be very long, even though the near-surface sources have been removed. This suggestion is made to complete the presentation of options and is not strongly recommended. Potential savings are over $100,000 annually, or $2,000,000 over the life of the project.

6.3 MODIFICATIONS INTENDED FOR TECHNICAL IMPROVEMENT

6.3.1 CHANGES TO DATA EVALUATION PROTOCOLS

Recommend that the project team use the EPA data quality objective process or the USACE Technical Project Planning process (refer to USACE Engineer Manual EM 200-1-2, available at http://www.usace.army.mil/inet/usace-docs/eng-manuals/em200-1-2/toc.htm) to refine the strategy for monitoring performance at this site. Suggest those specific criteria for subsurface performance be developed. These criteria could include the achievement of a minimum pumping rate from each extraction line, achievement of a specific drawdown at monitoring wells (based on analytical or numerical models), reductions of concentrations in the creek or in specific monitoring wells, or maintenance of specific inward gradients (again potentially based on modeling results). The USACE

HTRW CX or EPA Ground Water Forum members can advise on this process. The entity with responsibility to assess the monitoring data should be clearly identified. A cost for the development of such a strategy is not easily quantified, but may range from $2,000 to $5,000 above the other costs described above.

6.3.2 GOALS FOR EXTRACTION FROM INDIVIDUAL WELLS

Rather than considering the cycle times for the well operation, a target extraction rate should be selected, based on the overall system goals and the well capacity, for each extraction well. In addition to this approach, the specific capacity of each extraction well should be monitored using the control system and tracked over time as an indication of well fouling or pump problems. The use of test kits, such as BART kits can help in early identification and treatment of biofouling problems. The operators are performing preventative maintenance on the well pumps and transducers and this good practice should continue. Refer to USACE Engineer Pamphlet 1110-1-27 (Jan 2000) for additional information on preventative maintenance. A copy can be accessed at:

http://www.usace.army.mil/inet/usace-docs/eng-pamphlets/ep1110-1-27/toc.htm.

6.4 MODIFICATIONS INTENDED TO GAIN SITE CLOSE-OUT

6.4.1 RECONSIDER CLOSURE CRITERIA

Given the level of effort that has been expended in removals of sources, the ground water quality improvements during two years of operations have been slow. The project team should consider the (un)likelihood of achieving MCLs in the aquifer in a reasonable time. Possibly, a re-evaluation of the ultimate goals for remediation of ground water is appropriate. As suggested by the RPM, the primary goal may really be to limit exposure at the creek. In that case, target ground water concentrations higher than MCLs may still be acceptable for achieving toxicity or carcinogenicity goals for exposure scenarios involving the creek. This would involve careful coordination with the State of South Carolina and probably a ROD amendment. Costs for this action have not been quantified. Cost savings may be significant by shortening the time that the extraction system would have to operate. The life span of the system would be shortened, but this would happen beyond a 20-year period used in this RSE for analysis of costs.

6.5. CHANGES IN CURRENT APPROACH TO SITE REMEDIATION REQUIRING REDESIGN

6.5.1 PERMEABLE REACTION BARRIER

The current use of pump and treat technology could be replaced by the use of a permeable reaction (iron filings) barrier (PRB) installed along the south side of Ward's Creek. Given the low natural ground water flow rate, the shallow depth to water near the creek, and the predominance of chlorinated organics as the contaminants currently of concern at this site, a PRB would be feasible at this site. Such a barrier would prevent discharge of the contaminants into the creek, assuming that the contaminant flow paths can be cut by the barrier. The relationship between the contaminant plume and the surface water must be clarified as recommended above. Assuming a 24-inch-thick PRB with a length of 600 feet and a 35-foot depth (lower 30 feet containing a mix of 2 parts iron to 1 part sand), an estimated cost would be approximately $1,000,000. This includes characterization ($8,000/100'), design ($50,000 lump sum), clearing ($1,000/100'), licensing ($12,000/100'), construction ($10,000/100'), materials (124,000/100'), and monitoring wells (6 wells @ $2,000/100'). In addition, a shorter (200') PRB intended to reduce the concentrations near the source (along Highland Avenue) is also recommended. The cost for this barrier would be approximately 1/3 of the cost for the PRB along the creek or $333,000. Based on a $160,000/year O&M cost for the current system, a payback time (based on avoided costs of operating the treatment plant) of less than 8 years is indicated. However, if O&M costs can be reduced, the payback period may be lengthened to over 10 years and the cost effectiveness may be in question. These costs for a PRB do not include contingencies that also may affect payback time. The lifespan for the iron is not known, but expected to be quite long. There would be significant disruption of the aesthetics near the creek and may make this alternative less desirable for the public. The secondary PRB near the source is recommended to reduce (but not eliminate) the concentrations in the plume and reduce the cost (thickness, iron content) of the wall near the creek and extend its life. If the secondary barrier near the source is not implemented, then the cost of the PRB near the creek would be higher and may require replacement sooner.

6.5.2 IN-SITU BIOREMEDIATION BARRIER

Accelerated anaerobic bioremediation could also be an alternative for containment of the chlorinated solvent plume. A bioremediation barrier would be installed at the same locations and depths as described for the permeable reactive barrier. The bioremediation would be facilitated by a "permeable organic barrier." The approach would use a similar construction approach but would include a mixture of sand and vegetable oil. Additional information is provided as an appendix.

Since a wall configuration for vegetable oil placement has not been constructed previously, the costs for this are not as well defined as some other alternatives. Vegetable oil field demonstrations have not been monitored for a long enough period to determine how frequently replenishment is required. Actual costs may differ from the estimate depending on the longevity of the oil in maintaining anaerobic conditions in the aquifer. Assume all characterization, construction, design, and monitoring well costs are the same as for the iron wall. Using the cost per pound for oil given above and assuming 20% of the volume of the wall is oil, the cost for materials for such a wall would be approximately $600,000 less than for iron filings. In addition, the licensing costs of approximately $100,000 would also be saved. Thus, the total cost may be approximately $600,000. A field demonstration would probably have to be performed prior to placement of any large-scale injection point barrier. The field demonstration would require placement of a small-scale barrier (about 50 feet long), and at least 9 months of ground water monitoring. Periodic replenishment of the oil would be required, but the oil could be injected into the sand backfill using direct push methods at a cost of perhaps $40,000 - 50,000/year.

7.0 SUMMARY

In general, the RSE team found the system to be well operated and maintained. The system effectiveness is subject to some questions, but generally appears to be working. It appears contaminants are continuing to travel towards Ward's Creek adjacent to the site, though at a reduced rate. A number of changes in the remedial approach or the operations of the system are suggested to possibly improve performance and reduce future operations and maintenance costs. These are summarized in the following Cost Summary Table.

The RSE team recognizes the difficulties in implementing changes to the permit under which the system operates and the costs for obtaining regulatory acceptance. If the changes to the treatment process and monitoring program could be proposed as a package to the State of South Carolina, then some time and cost efficiencies could be realized.

The strategy for implementing these recommendations should be:

1. Perform the additional characterization

2. Perform the capture zone analysis and optimization. The optimization of the extraction system should involve the evaluation of the feasibility of either the direct discharge of the extracted (untreated) water into the sanitary sewer or discharge of the treated water into the creek to determine the cost function for the optimization. The optimization goal would be to determine the least costly pumping scenario that still maintains capture of the system.

3. Eliminate the pesticide and SVOCs analyses, make changes to the data evaluation protocols, and set goals for extraction well production.

4. Reconsider aquifer goals and consider the alternative technologies to replace the pump and treat system. Since these recommendations would have many institutional and economic hurdles, the action on these should be made in parallel to the more realistic goals for improvement of the pump and treat system.

Table 7-1. Cost Summary Table

Recommendation	Reason	Additional Capital Costs ($)	Estimated Change in Annual Costs ($yr)	Estimated Change In Lifecycle Costs ($)*
6.1.2 Capture Zone Analysis	Effectiveness	$5,000	$0	$5,000
6.1.2 Ground water Modeling and Optimization	Effectiveness	$10,000	(Unknown - May be significant)	(Unknown - May be significant)
6.1.1 Plume delineation east of the current extraction lines, along Creek	Effectiveness	$36,000	$7,000	$176,000
6.1.3 Indoor air re-sampling	Effectiveness	$10,000	$0	$10,000
6.1.4 Surface water sampling	Effectiveness	$1,500	$1,500	$31,500
6.2.1 Discharge directly to sewer without treatment	Cost reduction	$0	($30,000)	($600,000)
6.2.1 Discharge treated water to Ward's Creek	Cost reduction	$7,500	($15,000)	($492,500)
6.2.2 Eliminate pesticide and SVOCs analyses	Cost reduction	$0	($2,500)	($50,000)
6.2.3 New GAC Vessels and Revise Change Out	Cost reduction	$25,000	($10,000)	($175,000)
6.2.3 GAC Service Contract	Cost reduction	$0	($1,000)	($20,000)
6.3.1 Changes to data evaluation protocols	Technical Improvement	$2,000-5,000	$0	$2,000-5,000
6.3.2 Goals for extraction well production	Technical Improvement	$0	(Unknown-May be significant)	(Unknown-May be significant)
6.4.1 Reconsider aquifer goals	Site Close-out	Unknown	(Unknown-May be significant in out years)	(Unknown-May be significant)
6.5.1 Permeable Reaction Barrier	Site Close-out	$1,330,000	($160,000)	($1,870,000)
6.5.2 In-situ bio barrier	Site Close-out	$600,000	($160,000)	($2,600,000)

*estimated change in life-cycle costs assumes 20 years, no discount rate. Costs in parenthesis imply a cost reduction.

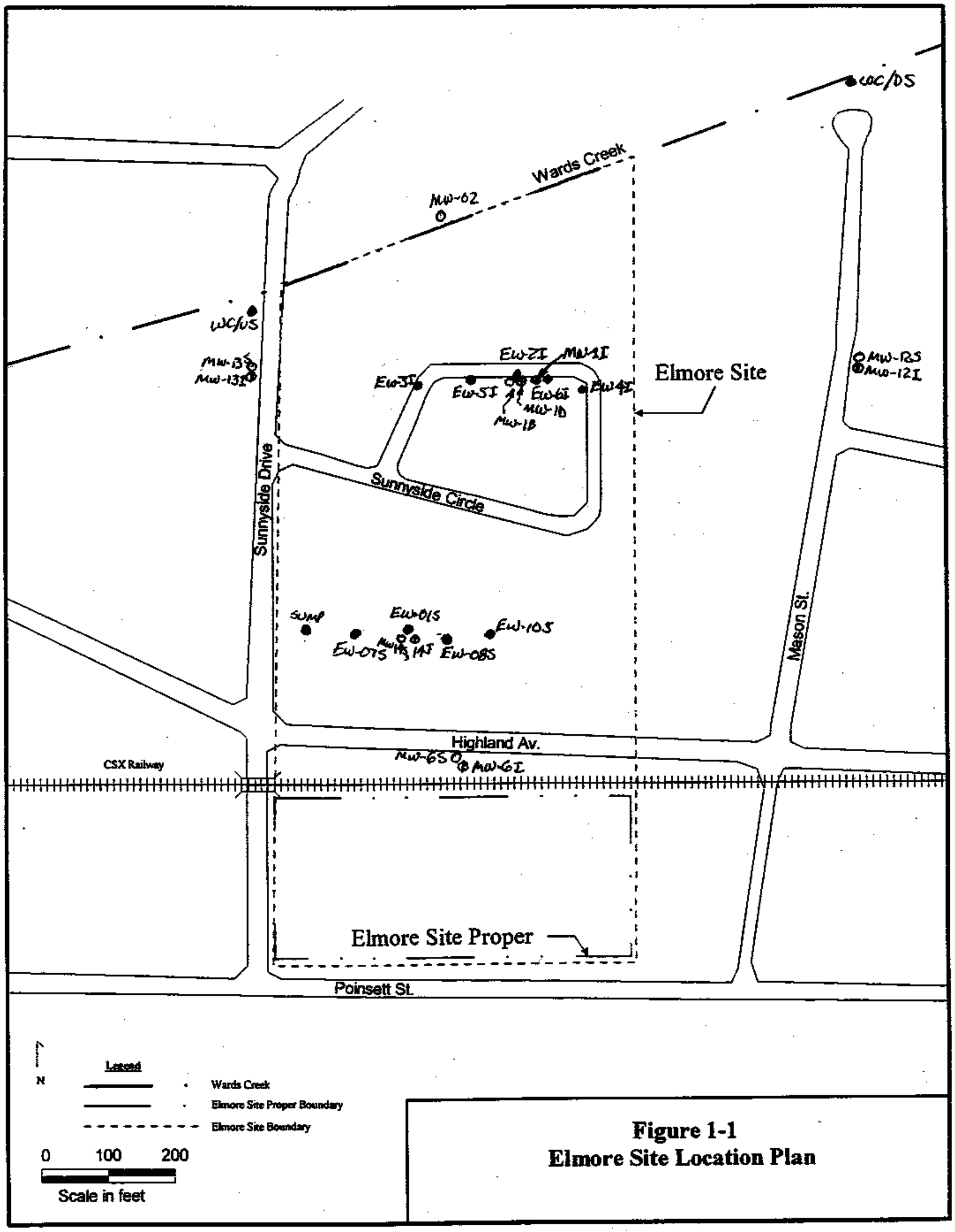
Appendix A - In-Situ Biological Treatment Using Vegetable Oil

Accelerated anaerobic bioremediation process rely on either native or introduced microorganisms to degrade chlorinated solvents such as PCE or TCE to innocuous end-products including ethene and ethane. An organic substrate (electron donor) must be added to the ground water to generate reducing conditions and provide the necessary carbon to support biodegradation of the chlorinated solvents. Organic substrates that have been used include soluble compounds such as benzoate, lactate, propionate, molasses, acetate, or methanol. As stated above, such processes have been inadvertently facilitated on site by the leakage of benzene and other hydrocarbons into the aquifer. Soluble substrates must be added periodically at either high batch dosages or continuously at low dosages to maintain anaerobic conditions. Ground water recirculation is generally necessary to distribute the dissolved organics throughout the contaminated site.

A second category of organic substrates includes relatively insoluble compounds such as the Hydrogen Release Compound (HRC) from Regenesis, and food grade oils. HRC is a polylactate ester that slowly releases lactate into the ground water. Soybean oil has been identified as a candidate oil product and an alternative to HRC for the following reasons: the specific gravity is just slightly less than water (0.93), so that it has a lesser propensity to move toward the surface of the water table than most other oils; it remains liquid even at very low temperatures (down to about -15 degrees C); and because it is extremely inexpensive (about 35 cents per pound). Slow-release substrates need to be added to ground water less frequently than soluble substrates, and may not require a ground water recirculation system. According to Regenesis, the HRC product should be replenished about every 6 to 12 months. Vegetable oil is expected to require less frequent replenishment than HRC, probably about every two years.

The Air Force Center for Environmental Excellence is conducting oil injection field trials of at three Air Force Bases. Injection of pure soybean oil and an emulsion of soybean oil and water are being tested. It is believed that substrate can be more widely and uniformly distributed via injection of an oil-water emulsion than through direct oil injection. Biological activity is expected to be heightened at the oil-water interface. Since the area of the oil-water interface will be much greater for an emulsion than for straight oil, it is expected that use of an oil-water emulsion will result in a more uniformly anaerobic zone.

Figure 1-1. Elmore Site Location Plan



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