DRAFT EVALUATION REPORT
PILOT SOIL VAPOR EXTRACTION AND TREATMENT
OPERABLE UNIT CARBON TETRACHLORIDE PLUME
FORMER FORT ORD, CALIFORNIA

TOTAL ENVIRONMENTAL RESTORATION CONTRACT
CONTRACT NO. DACW05-96-D-0011

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Table of Contents

List of Tables

List of Figures

List of Photographs

List of Appendices

List of Acronyms and Abbreviations

3D	three-dimensional
Army	U.S. Department of the Army
bgs	below ground surface
cfm	cubic feet per minute
CT	Carbon Tetrachloride
CTP	Carbon Tetrachloride Plume
EPA	U.S. Environmental Protection Agency
FWV	Field Work Variance
GAC	granular activated carbon
OU	Operable Unit
ppb	parts per billion
ppbv	parts per billion by volume
SAP	Sampling and Analysis Plan
SVE	Soil Vapor Extraction
VOC	volatile organic compound

1.0 Introduction

This report describes the operation of a pilot soil vapor extraction (SVE) and treatment system that was installed to remediate vadose zone soils in a suspected source area for the Operable Unit Carbon Tetrachloride Plume (OU CTP) at former Fort Ord, Marina, California. This report was prepared for the U.S. Department of the Army (Army) by Shaw Environmental, Inc. (Shaw) under the Total Environmental Restoration Contract II No. DACW05-96-D-0011.

The pilot SVE was implemented because analytical results from soil gas and groundwater samples collected in the vicinity of Lexington Court and Ready Court suggested that a source of carbon tetrachloride (CT) was present in the vadose zone soils in this area (Mactec, 2004). These previous investigations showed that soil gas concentrations were higher in proximity to the water table than at shallow depths. The suspected source area for the OU CTP is located in the northern portion of former Fort Ord, generally south of the city of Marina and north of Imjin Parkway (Figure 1-1). Figure 1-2 shows the estimated concentration of CT prior to the operation of the pilot SVE.

The objectives for the pilot SVE were established in the *Final Work Plan and Sampling and Analysis Plan, Pilot Soil Vapor Extraction and Treatment, Operable Unit Carbon Tetrachloride Plume, Former Fort Ord, Marina, California* (Work Plan/SAP), (Shaw 2004a). The Work Plan/SAP has been provided as Appendix A. All field work variances (FWV) associated with this plan are additionally provided in Appendix A. The Army directed Shaw to design a mitigation that would:

- Provide source control for the CT groundwater plume, and
- Reduce or minimize potential for vapor intrusion into the nearby housing area.

As described in this report, Shaw installed three new SVE wells and converted two existing monitoring wells to extraction wells. The extraction wells were tied in via pipeline to a vapor treatment system installed in an unused garage at Lexington Court. The treatment system used granulated activated carbon (GAC) to remove CT and other volatile organic compounds (VOCs) from the extracted soil vapor. Sixteen new nested monitoring probes, plus three existing shallow probes, were used to monitor system performance. This report documents that the pilot SVE has been successful in removing CT and other VOCs that were contained in the vadose zone to non-detectable or low estimated concentrations below the reporting limits in a majority of the probes measured.

Prior to operation of the pilot SVE, Shaw conducted indoor air sampling at a building in Lexington Court (Photograph 1-1). The results showed that the concentrations of VOCs present

in indoor air samples were within the range of background concentrations measured during ambient air monitoring activities conducted at various other locations at the former Fort Ord. These results suggested that even before the pilot SVE was operated the subsurface vapors from the

CT plume were not contributing to low-level VOC concentrations measured in indoor air. The potential for vapor emissions has been further reduced by operation of the pilot SVE. The indoor air sampling results are presented in the *Draft Final Report, March 2004 Indoor Air Sampling, Lexington Court, Former Fort Ord, California, Revision 0* (Shaw, 2004b).

2.0 Operations Summary

A chronology of the work conducted for the pilot SVE is presented in Table 2-1. Construction began on February 10, 2004. The pilot SVE was operated in two periods, from April 6 to June 14, 2004 (Phase I), and from September 9 to November 8, 2004 (Phase II).

Construction operations included the installation of three new pilot SVE wells and the conversion of two existing monitoring wells to extraction wells. The extraction wells were tied in via pipeline to the vapor treatment system installed in an unused garage at Lexington Court. Figure 2-1 shows the site layout, the location of the extraction wells, and the collection header system layout. The construction details for the extraction wells, wellheads, and vaults are shown in Figure 2-2. Twelve new nested monitoring probes and three existing shallow probes were used during Phase I to monitor system performance. Four additional monitoring probes were added prior to Phase II. Figure 2-1 shows the location of the monitoring probes. The construction and installation details for the monitoring probes are shown in Figure 2-3. Table 2-2 is a summary of completion depths of all wells and probes. Photographs 2-1 through 2-3 show construction of the wells, pipelines and vaults. Appendix B contains the well logs for installed wells.

The blower unit for the treatment system was located inside the garage at 6277 Lexington Court (Photograph 2-4). Soundproofing was added to reduce noise (Photograph 2-5). The treatment system used two 2000-pound GAC units to remove CT and other VOCs from the extracted soil vapor. These units were installed outside the garage within a security fence (Photograph 2-6).

System shakedown occurred in early April 2004. Phase I system operation started April 6, 2004. The system had some initial down time as adjustments were made to increase the operational efficiency. Sampling initially followed the schedule in the Work Plan/SAP (Shaw, 2004a). A significant reduction in the VOC concentrations was observed after initial results were received from the samples collected from the system, extraction wells, and probes. Based on this information, FWV TII-077 was implemented on May 18, 2004, in order to modify which probes and depths required sampling.

After a significant reduction in concentrations was observed in all sampling locations, which demonstrated the efficacy of the system, the pilot SVE was shut down on June 14, 2004. The monitoring data was evaluated to determine if additional operation was justified. While the system was shut down, four additional probes, approved by FWV TII-082, were installed to provide monitoring data to the north of the area originally evaluated. Also while the pilot SVE was shut down, three rounds of sampling were conducted in two probes to monitor for rebound.

Based on the monitoring data it was determined that the pilot SVE would be operated for an additional period. Phase II operation of the pilot SVE began on September 9, 2004, and concluded on November 8, 2004. A continued reduction of VOC concentrations in all sampling locations was observed during Phase II operations. The system was shut down on November 8, 2004, because influent CT concentrations had been reduced to an asymptotical low level [approximately 2 parts per billion (ppb)], and low concentrations were recorded in all the monitoring probes.

Following an informal data presentation to the regulatory agencies, the blower and GAC vessels were removed. The wells, pipelines and probes remain in place.

One final round of sampling occurred in May 2005 to confirm that there had been no significant changes in concentrations since the system was shutdown. No significant increases in VOC concentrations were observed.

3.0 Pilot Soil Vapor Extraction System Operation

As previously stated, the system began Phase I operations on April 6, 2004. Initially some adjustments had to be made to the system for optimal performance. In addition, throughout Phase I operations periodic maintenance was required on the generator that was used to power the pilot SVE, and the blower unit. The initial adjustments and maintenance reduced system performance only slightly. Phase I operations of the pilot SVE were shutdown on June 14, 2004.

Phase II operations began on September 9, 2004. Except for minor maintenance on the system, during Phase II the system operated at very close to 100 percent efficiency. Figure 3-1 presents the daily operating hours of the pilot SVE for both Phase I and II operations.

The following table provides an operating statistics summary for Phases I and II of the pilot SVE:

Phase I	System stopped 06/14/04
Total Available Hours Since Start (to 06/14/04 shutdown)	1704 (10.1 weeks)
Total Hours of Operation	1410.1 (8.4 weeks equivalent)
Percent Utilization (hours operated / Total available hours)	82.8%
Phase II	System stopped 11/08/04
Total Available Hours Since Start (09/09/04)	1464 (8.7 weeks)
Total Hours of Operation	1440.6 (8.6 weeks equivalent)
Percent Utilization (hours operated / Total available hours)	98.4%
Combined Phase I and II	
Total Available Hours for Operation Since Start (06/14/04)	3168 (18.8 weeks equivalent)*
Total hours of Operation (Phase I + Phase II)	2850.7 (17 weeks equivalent)
Percent Utilization (hours operated / Total available hours)	90%

**does not include shutdown between 6/14/04 and 9/9/04*

4.0 Pressure and Radius of Influence

Pressure measurements were taken at the extraction wells and monitoring probes following the schedule outlined in the work plan. Applied pressure and flow rate measurements were made on the extraction wells using a GEM-500™ Landfill Gas analyzer. More sensitive measurements of induced pressure at the probes were made using a Druck DPI 740, precision pressure indicator. Appendix C presents the completed field data forms for the measurements that were made of the system.

The measurements were made to confirm that the pilot SVE would meet the design objective for induced vacuum [0.1 in water column vacuum within the pre-pilot SVE 20 ppb CT contour]. Calculated flow rate at the system ranged from 680 to 790 cubic feet per minute (cfm). The average flow rate for both Phase I and II was approximately 760 cfm. The calculation used to determine flow rate is described in Section 7.0.

Figure 4-1 shows the measured vacuum contours in the deep probes (85 feet depth). Figure 4-2 shows the measured vacuum contours in the intermediate depth probes (60 feet). As can be seen from these figures, the design goal was generally achieved. The induced vacuums at the new probes (SGP-63, -64 and -65) installed to the north of the original probes were at or slightly below 0.1 in water column goal, indicating that the pilot SVE was less effective at these locations.

The effectiveness of the pilot SVE was confirmed by the results from monitoring probes presented in Section 5.0. Concentrations of VOCs were reduced to low levels in all the original probes installed in Phase I. Less reduction was observed in the probes installed in Phase II.

The flows of the extraction wells were maximized through Phase I operations, and most of Phase II operations. A summary of the measured flow rates is provided in Table 4-1. During October 2004, flow rates were reduced in extraction wells MW-BW-62-A, MW-BW-63-A, and MW-BW-70-A thus increasing the overall flows in MW-BW-68-A, and MW-BW-69-A. This was performed to focus the vapor extraction in areas that had higher remaining CT concentrations.

5.0 Volatile Organic Compound Analytical Results

Samples were collected from the treatment system [influent, between GAC beds (midstream), effluent], monitoring probes, and extraction wells. The chemicals of concern were four VOCs that had been detected in the soil gas and the underlying groundwater plume:

- Carbon Tetrachloride
- Chloroform
- Trichloroethene
- Tetrachloroethene

Samples were analyzed per the requirements of the Work Plan/SAP (presented in Appendix A). The samples were analyzed by U. S. Environmental Protection Agency (EPA) Method TO-15 (EPA, 1999a), which is a procedure for sampling and analysis of VOCs in gas. The VOCs are separated by gas chromatography and measured by a mass spectrometer or by multi-detector techniques. The method presents procedures for sampling into canisters to final pressures both above and below atmospheric pressure (respectively referred to as pressurized and sub-atmospheric pressure sampling). Analysis of samples was performed by Air Toxics Ltd., Folsom, California.

Data review was performed in accordance with the *Chemical Data Quality Management Plan, Former Fort Ord, California* (IT, 2001) and *Contract Laboratory Program National Functional Guidelines for Organic Data Review* (EPA, 1999b). All sample results from the sampling period were subjected to Level III data review, which comprises an evaluation of quality control summary results for sample holding times, initial and continuing calibrations, surrogates, laboratory duplicates, laboratory control samples, method blanks, and field duplicate samples.

A Level IV evaluation of the quality control summary forms as well as the raw data, to confirm sample quantitation and identification was performed on 11 percent (Phase I), 12 percent (Phase II), and 12 percent (Phase III additional sampling) of the VOCs by EPA Method TO-15. No results from either Phase I, II, or III required qualification based on the Level III/IV performed on the data. Data review was performed by Laboratory Data Consultants, Carlsbad, California.

5.1 Soil Vapor Extraction System Monitoring

Analytical results for Phase I and Phase II analysis of influent, midstream, and effluent results are presented in Table 5-1. Figure 5-1 shows the concentration of CT in the influent samples versus time. As can be seen from this plot, the concentration decays exponentially over time; the largest reductions were seen in the first weeks of operation. Figure 5-2 shows the concentration

of the other VOCs measured in the influent versus time. The data demonstrates that these concentrations also decreased as the pilot SVE was operated. Figure 5-3 presents a plot of the extraction well CT concentration versus the total cumulative operation time of the pilot SVE.

Results for all VOCs in the midstream and effluent samples collected during Phase I and Phase II operation were non-detectable indicating no breakthrough.

5.2 Monitoring Probe and Extraction Well Monitoring

Analytical results for Phase I, II, and III analysis of the monitoring probes and extraction wells are presented in Tables 5-2A and 5-2B. All monitoring probe and extraction well concentrations decreased over time. The decrease in concentrations observed in monitoring probes correlates to the location of the probe relative to the extraction wells. The closer a probe was to the location of an extraction well, the more induced vacuum was created, and consequently the greater amount of VOCs that were removed from that location.

After Phase I operations were terminated on June 14, 2004, three rounds of additional probe sampling occurred over a period of 3 months in the deep probes of SGP-55 and SGP-62 to evaluate for potential rebound that might occur after the pilot SVE was shut down. Figure 5-4 presents a plot of the data for these two deep probes. As can be seen from the plot, there was a small concentration increase in both probes after Phase I operation shutdown.

Figures 5-5, 5-6, and 5-7 present the concentration of CT that was measured in the deep, intermediate and shallow monitoring probes. Figure 5-8 presents the CT results for samples collected from the near-surface monitoring probes. Figures 5-9, 5-10, and 5-11 present results for chloroform, trichloroethene, and tetrachloroethene in the deep monitoring probes.

Figure 5-12 presents the results from sampling SGP-66 located near Preston Drive approximately 1,200 feet north of the center of the SVE area. This probe was installed at a location where the CT concentration in groundwater has been observed to be approximately one order of magnitude higher than in the SVE area. There were no detectable VOCs in SGP-66.

An additional round of sampling was conducted in May 2005 to confirm that there had been no significant changes in concentrations since the system was shutdown. Table 5-3 presents the CT concentrations for all probes sampled during this period. In addition, the CT concentration measured during the previous round of sampling is presented. This data demonstrates that only minor variations (slightly positive or negative) in concentrations have occurred, and there is no evidence of any significant rebound over a 6-month period after the system was shut down in November 2004.

6.0 Modeling of Volatile Organic Compound Results

In order to obtain a more complete visualization of the CT vapor impacted soil volume, analytical results obtained from the extraction wells and monitoring probes were modeled using three-dimensional (3D) visualization software (Environmental Visualization System, developed by C Tech Development Corporation). The 3D visualization modeling also provided additional estimates of the mass of CT present in the subsurface (Section 7.0). Table 6-1 summarizes CT mass estimates prior to and after Phase I operation of the pilot SVE. In modeling the pre-Phase I volume of impacted soil some control points were required with an assigned concentration of 1 parts per billion by volume (ppbv) to constrain the interpolation/extrapolation of the soil volume. These were strategically located around the impacted soil volume to present the 1-pbbv contour. Post-Phase I modeling did not require control points because concentrations had been reduced significantly so that the 1-ppbv contour was delineated by existing sampling points. Figures 6-1 through 6-3 present horizontal slices through deep [80 feet below ground surface (bgs)], intermediate (50 feet bgs), and shallow (20 feet bgs) zones of the CT impacted soil volume. Figure 6-4 presents 3D vertical cross sections by combining Figures 6-1 through 6-3.

Three-dimensional visualization modeling was also used to examine possible correlation between the underlying CT groundwater plume and the soil vapor. Using the 3D modeling software the location of the center of mass of the CT impacted soil volume was calculated for 10-foot depth intervals. Figure 6-5 presents the results of the center of mass location calculations for the soil volume impacted at concentrations exceeding 1 ppbv and 20 ppbv. The center of mass shifts north for deeper intervals (90-100 and 100-110 feet bgs) by about 50 and 30 feet for the soil volumes exceeding 1 ppbv and 20 ppbv, respectively. In both cases, the center of mass also shifts from east to west by approximately 30 feet with increasing depth. The observed shift in the center of mass is consistent with a hypothesis that the impacted soil vapor was a source for contamination that entered the groundwater and then moved down gradient towards the north.

7.0 Contaminant Mass Removed by Soil Vapor Extraction

The amount of CT removed by the pilot SVE was calculated from influent analytical results, flow rates, and operation times. Figure 7-1 presents a plot of influent CT concentration versus cumulative operating hours showing the exponential decay equation used to calculate mass. Flow rate (cfm) was determined by the measurement of temperature, barometric pressure, pipe diameter, and pitot tube pressure at the pilot SVE and was calculated following the manufacturers guidelines presented in *Bulletin No. 11, Air Velocities with the Dwyer Pitot Tube* (Dwyer, 1992). These guidelines are provided as Appendix D.

Measurements were made periodically for these parameters at the system, and interpolated between data points. Figure 7-2 presents the cumulative mass of CT removed versus cumulative operating hours (for Phases I and II operations). By this methodology, the calculated mass of CT removed by the pilot SVE is approximately 0.73 pounds.

As stated in the previous section, 3D computer modeling of the monitoring probe results was used to determine the mass of CT contained in the soil vapor prior to pilot SVE operation. This calculation was made for the volume enclosed by the 1 ppb CT contour. The mass calculated by this methodology was 0.31 pounds CT. It would be expected that this method would yield a lower mass since the model was artificially truncated to the north of the pilot SVE due to the limited number of data points in that area.

8.0 Conclusions

As evidenced by the reduction in VOCs in the influent, monitoring probes, and extraction wells, the pilot SVE was very effective in removing VOCs, specifically CT from the soil gas.

The objectives for the pilot SVE were stated in the Work Plan/SAP as follows:

> *Implement a pilot mitigation that will:*
>
> – *Provide source control for the CT groundwater plume, and*
> – *Alleviate the potential for vapor intrusion into the nearby housing area.*
>
> *At the end of 3 months the effectiveness of the mitigation will be evaluated. If the system is efficiently removing CT, operation will continue at the discretion of the Army until either: a) cleanup levels have been attained, or b) removal of CT is low and continued operation is not cost effective.*

Evaluation of the pilot SVE results shows that these objectives were met:

- Remaining concentration VOCs above the groundwater are low, and will be addressed in the CT Remedial Investigation/Feasibility Study.
- Shallow soil concentrations are very low and are not a significant source for vapor intrusion.

9.0 References

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