# SUMMARY OF PILOT OPERATION THERMALLY-ENHANCED SOIL VAPOR EXTRACTION AND FREE PRODUCT RECOVERY

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Abstract: Approximately 32,000,000 gallons of liquid waste were disposed at the former Chemical Waste Disposal Area, at NAS North Island. In 1997, a soil vapor extraction (SVE) system was installed to address vadose-zone volatile organic compounds (VOCs). The system operated for 26 months and removed approximately 80,000 pounds of mixed VOCs. In 1998, free product with commingled TCE was found underlying the site. In August 1999, a pilot-scale thermal enhancement was added to the existing SVE wellfield to address the free product, including 4 steam injection wells and 10 SVE/product-recovery wells. The pilot wellfield covered approximately one acre with approximately 50 feet of exposed vertical SVE well screen. The original SVE wellfield covered approximately 10 acres, with approximately 1,000 linear feet of exposed horizontal SVE well screen.

The pilot system operated for 9 months. Lessons-learned during the pilot led to operational changes and full-scale design parameters. The pilot operation removed approximately 28,600 pounds of fuel hydrocarbons and VOCs. This is compared to approximately 25,000 pounds removed by the original SVE system during its first 9 months of operation. The steam enhancement increased the mass removal rate of the SVE system by over 2400 percent based on pounds-per-month-per-foot of well screen.

## Introduction and Background

The former Chemical Waste Disposal Area at Naval Air Station North Island (the site) was used for liquid chemical waste disposal from the late 1940s through the mid-1970s. The estimated volume of liquid chemical disposed at the site is approximately 32,000,000 gallons. In 1996, OHM (presently IT Corporation) installed a soil vapor extraction (SVE) system at the site as an interim soil remediation measure. The objective of the work was to reduce the mass of volatile organic compounds (VOCs), primarily trichloroethene (TCE), in the vadose zone soil. The system operated from March 1997 through May 1999, and removed approximately 80,000 pounds of mixed VOCs from the soil during 26 months of operation. In some areas of the site TCE in extracted soil vapor was reduced to asymptotic concentrations. However, there were several areas that continued to produce elevated concentrations of TCE in the extracted soil vapor.

Additional soil and groundwater investigations were conducted in late 1998 using an innovative sampling technology known as the Site Characterization and Analysis Penetrometer System (SCAPS), and a method known as LASER Induced Fluorescence (LIF). This investigative work identified a volume of free product underlying the site. The free product consisted of weathered fuel hydrocarbons that contained a significant weight fraction of chlorinated solvents. The chlorinated solvents consisted primarily of TCE, which was

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measured at approximately 20 percent by weight of the free product, which was determined to be the source of the continued elevated concentrations of TCE in the extracted soil vapor.

Expanded Scope and System Modifications

In April 1999, the Navy requested IT/OHM to address the newly found free product at the site. This work included evaluation and recommendation of proven, innovative, and cost-effective technologies to enhance the existing system and remove free product underlying the site.

IT/OHM, the Navy, and the regulatory agencies determined that thermal enhancements to the existing SVE system would be the most technically appropriate and cost-effective approach. Steam-injection was determined to be implementable and available at minimal additional cost since steam was already available and in use at the project site. In August 1999, IT/OHM completed the system design and construction drawings for the thermally enhanced pilot system, and began modifications to the existing well field. Well field modifications included construction of two steam-injection wells (SIWs), ten dual-purpose free product recovery/vapor extraction wells (FP/VEWs), and ten temperature probes (TPs). Each TP consisted of five thermocouples installed at 4, 7, 9, 11, and 14 bgs. In September 1999, IT/OHM began operation of the pilot-scale thermal enhanced SVE system.

Pilot-Scale Operation

IT/OHM operated the pilot-scale system from September 1999 to May 2000. Product skimming was initiated first, followed by vapor extraction, and then steam injection. The existing vapor-phase carbon-adsorption treatment system was used to treat the extracted vapors. Steam was alternately injected continuously and intermittently by design, at various mass flow rates. It was noted within the first few days of intermittent steam injection that the injection capacity of the SIWs had reduced. An evaluation of the capacity loss was conducted, looking at four potential causes: construction defects, geochemical precipitation, biological fouling, and mechanical sorting of the aquifer matrix. The results of the evaluation eliminated construction defects in the well and biological fouling as potential causes. A limited Geochemical Modeling exercise using PHREEQ-C modeling software was conducted to evaluate several elements and potential fatal flaws, at various temperatures. The results of the modeling indicated that geochemical precipitation was not a significant concern for the site. The data indicated that mechanical sorting of the fine-grained materials in the aquifer was occurring, plausibly due to the “on/off” operation of steam injection, and that air entrainment may also contribute to the problem.

Following the capacity-loss investigation, four new FP/VEWs were installed. Operation of the expanded well field resumed and continued until May 5, 2000, at which time the entire pilot operation was successfully ended.

Pilot Scale Lessons Learned and Full-Scale Design Parameters

The data gathered during the thermally enhanced pilot operation was used as the basis for the full-scale design including the optimum SIW radius of influence, the optimum FP/VEW placement, the maximum expected vapor concentrations and temperatures, and the free product recovery rate. The lessons learned of primary import to the full-scale design are summarized below.

*Steam Radius of Influence (ROI):* Temperature data were used to identify two distances needed for the full-scale design and well field layout: the steam zone immediately surrounding the SIW, which is at steam temperature and the convective radius of influence (ROI). The steam-zone ROI was measured at approximately 15 feet, and the convective ROI at about 30 feet. The conductive ROI was also identified at approximately 40 feet.

*Specific Capacity Loss*: The loss of specific capacity was due primarily to intermittent steam injection that caused mechanical sorting of fine-grained material, and permeability impacts from air entrainment.

*Free Product Mobilization:* Free product was displaced from within the steam-zone around the SIWs, mobilizing it toward the recovery wells. The optimum distance for product recovery from wells was determined to be approximately 30 feet.

*TCE Mobilization*: TCE concentrations increased in both free product and groundwater as a result of steam injection. The increase in free product was attributed to *in situ* condensation of vaporized TCE as it moved away from the SIWs toward the recovery wells via SVE. This concentration increase indicates that product removal is a critical portion of the overall mass removal objective.

*Effectiveness*: Approximately 14,600 pounds of VOCs were removed in the vapor phase, and approximately 14,000 pounds of jet fuel were removed in the liquid phase during the 9-month pilot operation. Thermally-enhanced vapor extraction occurred through approximately 50 feet of exposed vertical SVE well screen. This compares to approximately 25,000 pounds of vapor-phase VOCs removed during the first 9 months of the original SVE operation, using approximately 1,000 linear feet of exposed horizontal SVE well screen. Comparing these data on a pound-per-month-per-foot of well screen, show that the thermal enhancement and free product recovery system increased the overall mass removal rate of the SVE system by over 2400 percent. The removal rate of the vapor extraction portion alone was increased by over 1200 percent.

Full-Scale Design/Implementation

Based on the pilot-scale operational data, a full-scale thermal enhanced SVE and free product recovery system will be installed at the site consisting of 34 SIWs, 58 FP/VEWs, 12 vapor-extraction wells (VEWs), 20 piezometers, and 29 temperature probes. The full-scale system is expected to be operational in fall 2001.