Cape Canaveral Air Force Station

Thermal—Zero Valent Iron

Site Name: Cape Canaveral Air Force Station
Site Location: Cape Canaveral, Florida
Technology Used:

- Thermal (Steam and Hot Air)
- Zero Valent Iron (ZVI)
- Soil Mixing

Regulatory Program: Florida Department of Environmental Protection RCRA Program
Remediation Scale: Full
Project Duration: March 2004 to June 2007

Site Information: A combination of technologies has been used to treat four source areas at Cape Canaveral Air Force Station. The steam and iron-enhanced soil mixing was initiated in 2004 at the first two source areas at Space Launch Complex 15 (SLC-15), which was used for conducting test flights of Titan missiles between 1959 and 1964. The abandoned launch complex was later used for various storage, waste treatment, and waste management activities. After successful implementation at SLC-15, the technology was then deployed at the Security Police Confidence Course (SPCC) and Facility 1381 in 2006. SPCC was a training course for security police that was the former site of rocket propellant and chemical storage, rocket assembly, and chemical cleaning lab facilities. Historically, Facility 1381 housed a metal cleaning lab and an area for tanker truck waste disposal.

Contaminants: The contaminants of concern were tetrachloroethene (PCE), trichloroethene (TCE), *cis*-1,2-dichloroethene (*cis*-1,2-DCE), and vinyl chloride. TCE was the dominant contaminant with soil concentrations detected up to 1,000 mg/kg. The highest concentrations were found at depths from 20 to 55 ft below ground surface (bgs). Calculations made during the cleanup estimated total volatile organic compound (VOC) concentrations in excess of 1,000 mg/kg. Source zones were defined as the volume where groundwater TCE concentration was greater than 10 parts per million (ppm) or about 1% of its solubility (Faircloth et al. 2010). Using this definition, the volume of soil to be treated was about 38,000 yd^3 at SLC-15, about 7,570 yd^3 at the SPCC, and 44,163 yd^3 at Facility 1381.

Hydrogeology: The geology underlying the facility can be generally defined by four stratigraphic units: the surficial sands, the Caloosahatchee Marl, the Hawthorn Formation, and the carbonate formations of the Floridan Aquifer. The surficial sands typically extend to depths of approximately 10 to 30 ft bgs. The Caloosahatchee Marl underlies the surficial sands and consists of sandy shell marl that extends to a depth of approximately 70 ft bgs. The Hawthorn Formation, which consists of sandy limestone and clays, underlies the Caloosahatchee Marl. It is generally 80 to 120 ft thick and typically extends to a depth of approximately 180 ft bgs. Depth to groundwater ranges from 3 to 18 ft bgs (CBP-AM 2010).

Project Goals: The goal of the project was to reduce the source zone flux to allow faster cleanup.

Cleanup Approach: Groundwater concentrations of TCE indicated the presence of dense non-aqueous phase liquid (DNAPL). Much of the contamination was limited to the saturated sandy calcareous clay of the Caloosahatchee Marl, which also can have discontinuous layers of silt and sand. The clay poses potential back diffusion problems.

Electrical heating of saturated clay can be expensive, and distribution in and contact with target compounds can be difficult in fine-grained soils when using in situ oxidants, reductants, or biostimulation. An evaluation of potential technologies led the Air Force to choose a combined remedy.

A large diameter (8-10 ft) two-bladed auger was chosen to deliver steam, hot air, and ZVI to the subsurface (Figure 1). The auger loosens the soil and mixes the steam and hot air with the soil to provide even heating and vaporization of contaminants. A hood at the surface applies a vacuum to the auger hole and captures the vaporized contaminants for surface treatment (Figure 2).

Figure 1. Large Diameter Auger

Courtesy Air Force

Mixing the ZVI into the soil column solves the contact problem and provides a long term treatment source.

Figure 2. Drill Rig with Capture Hood

Courtesy Air Force

Each site was gridded with treatment cells (Figure 3). Cells were overlapped at the initial site, but overlap was reduced or eliminated at the subsequent sites, with no apparent performance degradation.

As soil mixing began, steam and hot air were injected, while a vacuum was applied to ensure capture of vaporized contaminants. The collected gases were monitored in real time by flame ionization detectors that provided total VOC data, and by on-site in-line gas chromatographs that speciated the various volatile organic compounds every few minutes. As the auger made passes through the soil column, the monitoring data provided site personnel with estimates of how much contamination was encountered at a given depth, allowing real-time adjustments to treatment time and treatment depth. The data was also evaluated and used to adjust the overall treatment area, adding and dropping treatment cells (based on contaminant levels in adjacent cells) to maximize efficiency and treatment effectiveness. The target temperature for the soil was 160° F. Thermal mixing per cell usually lasted one to two hours. Typically ZVI was added to the cell on the last pass up. (Faircloth et al. 2010).

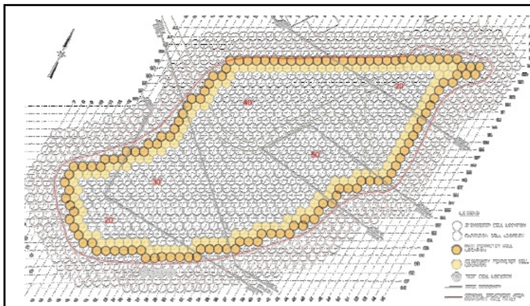

Figure 3. Treatment Cell Grid

Courtesy Air Force

Once extracted from the subsurface, the contaminated off-gas vapors were introduced to the treatment system by a blower. The front end of the treatment system consisted of a liquid vapor knock-out/demister tank, a coarse particulate filter (20 microns), a chiller (to cool the gas temperature from approximately 170° F to less than 100° F), a reheater (to raise the temperature by 10° F to 12° F to reduce the relative humidity to 80%), and a particulate filter of < 1 micron (Juriasingani et al. 2007). The conditioned vapors were then sent to a flameless thermal oxidizer (subject to 1,700° F). The oxidizer off-gas was quenched to about 180° F before being sent to an acid gas scrubber and released to the atmosphere. Activated charcoal tanks were maintained on site in the event the thermal oxidizer needed to be shut down (Figure 4).

When treatment at one cell was complete, the rig moved to the next scheduled cell. In advance of mobilization, a treatment schematic was developed to define the order in which cells would be treated. This minimized potential contaminant mobilization (by treating the perimeter first), reduced movement of the crane and treatment apparatus, and allowed cooling/stabilization in treated areas before using them to stage the crane. Performance monitoring of the off-gas and periodic monitoring of groundwater wells provide evidence of success. There were a total of 1,538 treatment cells between the three sites.

Figure 4. Flameless Thermal Oxidizer

Courtesy Air Force

Project Results: Approximately 13,272 lbs, 389 lbs, and 11,439 lbs of total VOCs were recovered from SLC-15, SPCC, and Facility 1381, respectively. The cleanup cost averaged at $\$190/\text{yd}^3$. A remedial efficiency of greater than 99.8% was found for both soil and groundwater. Post treatment sampling one year after remediation showed no rebound or back diffusion. Monitoring wells at Facility 1381 that showed values of up to 800 mg/L of TCE in 2006 before the remedial action had been reduced to 3 µg/L by 2008 (Faircloth, et al. 2010).

Sources:

Faircloth, Harlan, Elgin Kirkland, Phil La Mori, Mark Kershner, and John Matthews. 2010. Complete In Situ Reduction of DNAPL Source Zones Using Combined Thermal and ZVI Soil Mixing (PPT). Seventh International Conference on Remediation of Chlorinated and Recalcitrant Compounds, Monterey, CA; May 2010.

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CBP-AM (U.S. Customs and Border Protection Office of Air and Marine). 2010. Draft Environmental Assessment and Finding of No Significant Impact for the Beddown and Flight Operations of Unmanned Aircraft Systems at Cape Canaveral Air Force Station, Florida, 230 pp. http://ecso.swf.usace.army.mil/PublicReview/CCAFS_CBP_UAS_DEA_FONSI%20Draft%20July2010_SecurePDF.pdf

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