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**Project Example - Remediation of 1,1,1-Trichloroethane and Screening Analytes using
Six Phase Heating at the Alameda Navy Base, Alameda, California**

Client Reference: Mr. John McGuire, Shaw Environmental Inc., Concord, CA, (925) 288-2220.

Contaminants Treated: Vinyl chloride, 1,1-dichloroethane (DCA), 1,2-DCA, 1,1-dichloroethene (DCE), 1,2-DCE, 1,1,1-trichloroethane (TCA), 1,1,2-TCA, trichloroethene (TCE), and tetrachloroethene (PCE).

Technology Applied: Six Phase Heating (SPH) with heat enhanced hydrolysis.

Geology: Fill and fine grain soils.

Hydrology: Groundwater at 7 feet bgs.

Treatment Area, Depth Interval, and Volume: 34,400 square feet, 5 to 36 feet bgs, and approximately 40,000 cubic yards.

Site Constraints: Remediation below Building 360 with a 4-foot high sub floor supported by 4-foot wide piers on 12-foot centers.

Beginning Contaminant Levels: 100 mg/l of 1,1,1-TCA and 190 mg/l of 1,1-DCE.

Cleanup Goal: Reduce Screening Analytes (SA's) in groundwater to below 10 mg/l.

Period of Performance: 2006 – 2007.

Project Status: Installation in progress.

Total TRS Price: \$2,200,000.00.

Contracting: Standard Fixed Price (SFP).

Background

Thermal Remediation Services, Inc (TRS) as a subcontractor to Shaw Environmental, is providing Six Phase Heating (SPH) for remediation of Plume 4-2 at the Alameda Navy site. Plume 4-2 consists of soil and groundwater impacted by vinyl chloride, 1,1-DCA, 1,2-DCA, 1,1-DCE, 1,2-DCE, 1,1,1-TCA, 1,1,2-TCA, TCE, and PCE (Screening Analytes - SA's). The primary SA is 1,1,1-TCA, which rapidly hydrolyzes into 1,1-DCE at elevated temperatures (see Figure 1. Effects of Temperature on Hydrolysis Reaction Rates). 1,1-DCE is very volatile and will be recovered during ERH. For example, at 70°C the hydrolysis half-life of 1,1,1-TCA (red line on Figure 1) is one day and at 90°C it is a few hours.

Hydrolysis is a chemical substitution reaction in which hydrogen ions in water react with organic molecules, replacing chlorine atoms. Oxidizing conditions or available oxygen is not required for hydrolysis. Hydrolysis can be a significant degrader of some VOCs at room

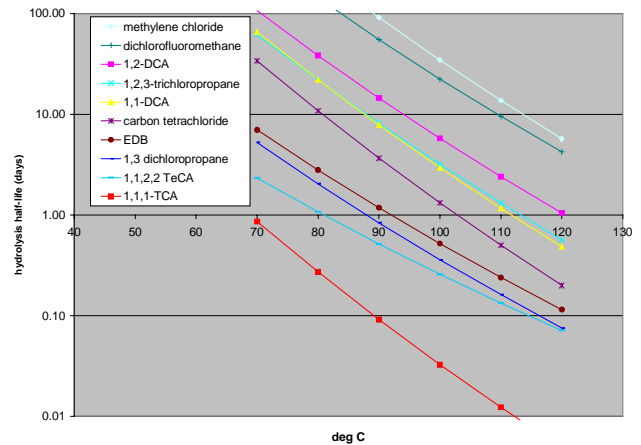


Figure 1. Effects of Temperature on Hydrolysis Reaction Rates

temperature; especially for halogenated alkanes. The rate of hydrolysis increases with temperature and clay soil types tend to accelerate hydrolysis. An example hydrolysis pathway is: 1,1,1-TCA → 1,1-DCE or ethene (mineralization). Hydrolysis will also significantly degrade 1,1-DCA and 1,2-DCA.

The Navy previously conducted a SPH pilot test at Plume 5-1 at the Alameda site a couple of years ago. As a result of this pilot test, the Navy elected to perform SPH on a full scale at both Plumes 4-2 and 5-1.

Site Information

The remediation region is located near and under Building 360. The target treatment area is 34,400 square feet, which is divided into five separate areas. Figure 2. Site Plot Plan below illustrates the separate treatment areas and the 10 mg/l SA's contour (orange line surrounding the treatment areas). Building 360 is supported on piers approximately 4 feet above the ground surface.

The average shallow and deep extent of treatment is approximately five and 36 feet below ground surface (ft bgs), respectively. The corresponding treatment volume is about 39,800 cubic yards (yd³). The floor of Building 360 is about 3.75 feet above the surrounding ground surface and all depths are referenced to the ground, not the building floor.

The geology consists generally of an interval of fill and fine-grained soil to about 18-ft bgs known as the upper fine-grained unit. The upper sandy unit extends from about 18-ft to 34-ft bgs. The middle fine-grained unit is found below about 34-ft bgs. The groundwater table is encountered at about 7-ft bgs. Tidal influence is negligible.

The highest known groundwater concentration of SAs in the SPH remediation region was found at a depth of 36 feet bgs. The highest total SAs concentration was 290 mg/l, consisting of 100 mg/l of 1,1,1-TCA and 190 mg/l of its volatile daughter 1,1-DCE.

When a VOC is immersed or dissolved in water, the combined boiling point is depressed as described by Dalton's Law of Partial Pressures. A VOC/water mixture will boil when the vapor pressure of the VOC plus the vapor pressure of water is equal to the ambient pressure. The effects of depth on the boiling points of the targeted SAs are summarized below in Table 1. Table 1 also accounts for the effects of Dalton's Law of Partial Pressures on the expected VOC/water mixtures. The data in Table 1 is presented only as an indication of the subsurface temperatures required to volatilize the contaminants present at the Plume 4-2 site and not as target subsurface temperatures for the remediation process.

TABLE 1. The Effect of Depth Below Groundwater on Boiling Temperatures			
Compound	Boiling Temperature of Compound		
	In Air (°C)	In Water at 7-ft bgs (°C)	In Water at 36-ft bgs (°C)
pure water	100	100	120
1,1-DCE	32	31	46
1,1,1-TCA	74	65	83
4-2-ADD16 VOC mixture*	43	36	52

* A mixture of VOCs will boil at an intermediate temperature, in proportion to the molar fraction of each in the liquid mixture as described by Raoult's Law. The calculated VOC mixture boiling temperature shown here is based on 4-2-ADD16 groundwater samples collected in 2002 in which the molar fractions of the VOCs were 72% 1,1-DCE and 28% 1,1,1-TCA.

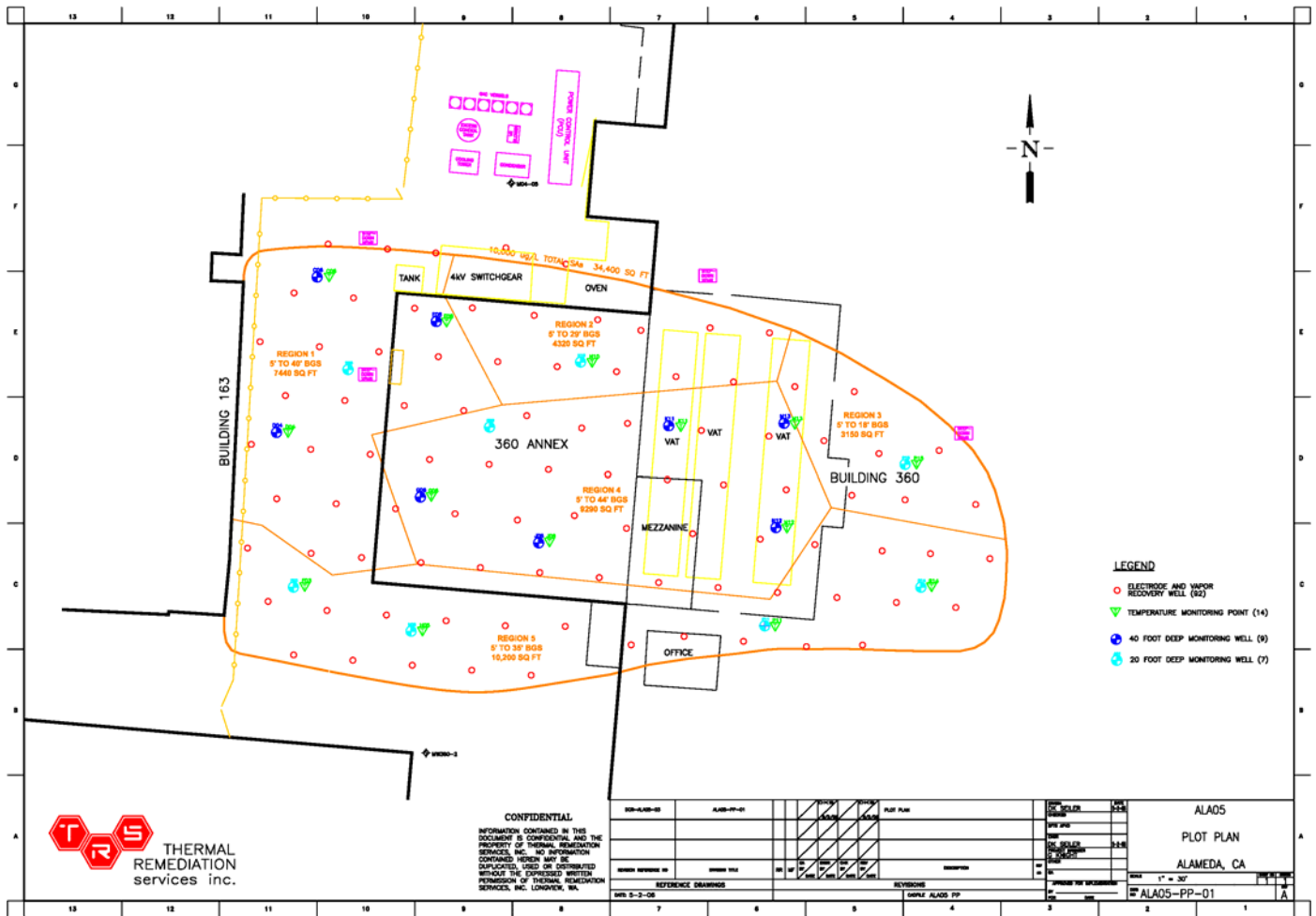


Figure 2. Site Layout

Site Constraints

Building 360 is supported by concrete piers. The top of the piers (the widest part of the concrete cone) are approximately 4 feet wide and are, for the most part, 12 feet center-to-center (see Figure 3). This presented a challenge to place the electrodes on 15-foot centers in preferred locations.



Figure 4. Electrical Conduit under Concrete Cut

We cut 18" x 18" squares in the building floor over our electrode locations. Sometimes, when removing the cuts, we encountered surprises such as the electrical conduit seen in Figure 4.



Figure 3. Concrete Pier Supports under Building 360

Construction

The SPH system includes 92 electrodes and co-located vapor recovery wells. Sixty-one electrodes are installed inside and 31 on the outside of Building 360. Subsurface temperatures will be measured at 14 TMPs placed throughout the treatment region. Each of the TMPs will average 8 thermocouples spaced vertically at set 5-foot subsurface intervals. This provides approximately 112 points within the subsurface where discrete temperatures will be recorded. These temperature readings are then used to calculate an average site temperature and average temperatures at the set depth intervals.

The subsurface temperature data will be continuously recorded and uploaded daily to our onsite control computer.

The remedial goal for this project is to reduce the groundwater-dissolved concentrations of total SA's within the 10 mg/l SA contour to below 10 mg/l. We have estimated that 2,974,000 kW-hrs will be required to reach the 10 mg/l goal.

Figure 5 illustrates the conditions of drilling and installing electrodes inside Building 360. The SPH system is presently being installed. Operations are planned for summer and fall of 2006.



Figure 5. Drilling inside Building 360, Alameda Naval Base, CA