



**SIX PHASE HEATING DNAPL REMEDIATION  
THAT ACHIEVED DRINKING WATER MCLs  
WITHOUT REBOUND!  
PHARMACEUTICAL MFG.  
PORTLAND, OR**

**SITE**

CES was contracted to perform Six Phase Heating services to remove DNAPL at a former pharmaceutical manufacturing facility. The site, located in Portland Oregon, was the home of a medical laboratory facility for 18 years until the lab was closed in 1979. Environmental investigations were performed at the site following the end of operations. The investigations confirmed the presence of TCE, DCE and VC, which are the constituents of concern (COC). The contamination was most likely due to past laboratory operations and illegal dumping performed at the site following the lab closure. It was suspected that the contamination entered the subsurface through a dry well located near the center of the site. The bottom of the dry well is approximately 22 ft bgs and the DNAPL and dissolved phase plume begins at this level and extends in a southwardly fashion. The depth of contamination was approximately 56 feet. The total surface area of the plume is approximately 20,000 ft<sup>2</sup>. The total volume of the subsurface contaminated region is approximately 26,900 yd<sup>3</sup>.

The site consisted of a silty layer from grade to 15 ft bgs. Below the silty unit is a gravelly layer known as the Overbank deposits. The Overbank extends from 15 ft bgs to approximately 60 ft bgs and typically has a hydraulic permeability of 10-2 cm/sec. Below the Overbank exists the Troutdale Gravel Aquifer (TGA). The velocity of the TGA is 5 ft/day. Silts and sands are discontinuously interlayered throughout the Overbank deposits except for the upper 15 feet to 30 feet bgs. This upper unit is predominately fine silts. The permeability of the upper layer is typically 10-6cm/sec. In general, soil-boring logs indicate the material encountered in the Overbank deposits becomes coarser with increasing depth. Groundwater in the Overbank is encountered at approximately 10 feet bgs. The following table shows the range of contaminant concentrations reported prior to treatment.

**TECHNOLOGY** SPH uses conventional three phase industrial type power and modifies it for input through specialty electrodes to the treatment volume. While the thermal energy increases the volatility of contaminants, steam generated acts to mobilize the contaminant, acting as a carrier gas as is pressures through tight soil pores. The steam is collected from the subsurface by a soil vapor extraction process, and treated aboveground by conventional means, including air stripping, activated carbon, or catalytic oxidization.

**APPLICATION** Each of 60 originally installed electrodes were divided into three heating zones at the following depth intervals within the Overbank Deposit: 20 to 30 ft bgs, 34 to 44 ft bgs, and to 58 ft bgs. They were installed 17.5 ft apart over approximately a 20,000 ft<sup>2</sup> area.

Separate heated zones were used below and around the treatment zone to prevent downward and lateral migration of contaminant. The electrode conductive intervals were designed to be operable either independently or simultaneously. The SVE installation consisted of 53 vapor extraction wells installed approximately 15 ft apart. Thirteen temperature monitoring wells were installed at strategic locations throughout the SPH array to monitor performance of the SPH system.

Treatment operations began at the site on May 8, 2000 and focused on applying power to the bottom electrode interval to create a thermal barrier. The heating of the region below the contamination was completed within the estimated time frame of approximately 60 days. The floor of the site was brought up to 100°C or greater as designed to create a lower thermal barrier. The next phase of the heating strategy was to form hot walls. The first thermal walls to be formed were down gradient, south and west of the suspected DNAPL area. This was accomplished in less than 30 days by adding the upper and middle electrode intervals in this region.

During mid August, hot water and steam was observed venting from monitoring wells. Additionally of concern, ground water temperatures in monitoring wells directly adjacent to but outside the treatment area wall were showing elevated temperatures. Eventually these monitoring wells intermittently emitted steam and hot water at the surface. Furthermore, there was an increase in concentrations of the COCs detected in some wells located to the south of the treatment array. The power level was reduced while this problem was investigated. Thorough investigation indicated that steam generated in the gravelly Overbank deposits was encountering the silt above and tending to migrate laterally. The installation of submerged vents to breach the less permeable silts was entirely successful in mitigating off site migration as monitored by temperature and groundwater monitoring wells.

By January, 2001, the Oregon Department of Environmental Quality issued a statement that the treatment objectives had been met and that there was no longer any evidence of DNAPL. However a decision was made to continue operations in order to obtain greater mass removal. Operations continued until November 14th, 2001, when ODEQ made the decision that further heating was not warranted and subsurface heating operations were terminated. In fact, the **Oregon DEQ reported that CES' Six Phase Heating technology had successfully achieved drinking water Maximum Contaminant Limits (MCLs).**

## CONCLUSIONS

There was no evidence of downward DNAPL migration based on site monitoring data, which indicates that the “hot-floor” strategy was effective. The highest concentrations remaining in the Overbank deposit were on the order of 1 ppm total VOCs. VOC concentrations in the TGA below the treatment zone also declined, to levels at or below MCLs. VOC concentrations in the recovered air stream generally reflected expected trends, with VC and DCE concentrations peaking first, followed by TCE. The vapor extraction system recovered approximately 93 gallons of total VOCs, of which 74 gallons were estimated as TCE-equivalent. The appearance of elevated chloride levels in the groundwater during and following thermal treatment suggested that additional VOCs were likely degraded in place. **In 2006, after more than 4 years of post remedial monitoring, there are no reports of any rebound in contaminant concentrations.**