In Situ Steam-Enhanced Extraction (SEE) for CVOC Removal and NAPL Recovery

Panther Technologies, Inc.

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SITE BACKGROUND

The subject property is approximately 15 acres (650,000 square feet [SF]) in size and includes approximately 250,000 SF of building footprint, 250,000 SF of asphalt pavement, and 150,000 SF of grass cover. The facility is bordered by a stream to the north and multiple residential and commercial properties to the south, east and west. The surrounding area has been heavily developed for a mixture of residential, commercial, and industrial uses. A river is located approximately 1,000 feet southwest of the site. The facility was originally constructed in the late 1880s for rolled steel and steel parts manufacturing and remained in operation until the early 2000s.

Several petroleum products were used at the facility including fuel oil, lubrication oils, and unleaded gasoline. A 20,000-gallon fuel oil underground storage tank (UST) was present on the property. A lubricating oil distribution system was present inside the production building, which circulated lubricating oil to the plant machinery via piping located underneath the building floor slab. Waste oils, cleaning fluids, spent solvents, and anodizing acids were reportedly disposed to an unlined pit located near the northwest corner of the building.

In 1985, an investigation to assess the environmental conditions of the property commenced. The investigation included soil and groundwater sampling, analysis of aquifer parameters, and an evaluation of risks to human health and the environment. During the initial site investigation, five source areas were identified including a 20,000-gallon #2 Fuel Oil UST, a drum storage area, a pit area for water/lube oil and boiler cleaning waste, a 25,000-gallon spent chemical pit (Pit 1), and a 25,000-gallon waste pit (Pit 2). Remedial action (RA) activities implemented at the site included soil excavation and removal, slurry wall construction, soil vapor extraction, light non-aqueous-phase liquid (LNAPL) recovery and disposal, groundwater recovery and treatment, and groundwater quality monitoring. Of these RA activities, operation and maintenance (O&M) of an on-site groundwater extraction and treatment system and groundwater quality monitoring remain on-going. Primary constituents of concern include chlorinated volatile organic compounds (CVOCs; 1,1,1-TCA, TCE, 1,1- and cis-1,2-DCE, 1,1-DCA, VC) and PCBs. Wastes containing CVOCs are classified as RCRA F002-listed hazardous waste and managed accordingly. PCB wastes have not historically required management under TSCA.

SITE CHARACTERIZATION

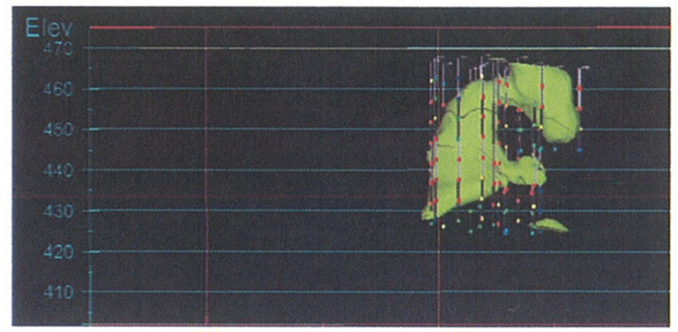
Prior to remedy implementation, a soil investigation was completed within the CVOC source area using a grid system. Continuous split-spoon sampling and PID soil screening was completed from ground surface to the top of bedrock (approx. 40 feet). Pertinent observations were recorded regarding the presence of phase-separated LNAPL. Co-located samples were collected at selected borings within three lithologic (upper fill, intermediate silty-clay and deep sand-gravel) units for total CVOCs and SPLP CVOCs. This data was used to refine the existing conceptual site model and confirm the hypothesis that leachable CVOC mass was strongly correlated with LNAPL presence, including a broad smear zone spanning two water bearing units (fill and sand-gravel). In addition to defining the extent of impacts, the data was also used to develop a 3-D model and define the target remediation volume within the residual source area based upon cumulative CVOC impact to groundwater.

CDM used the 3-D model to visualize the complex interaction between stratigraphy, and petroleum liquid LNAPL and CVOC contamination at the site. The 3-D model was used as a dynamic tool during strategic analysis and management planning meetings, whereby the existing data were queried against potential cleanup end points and visualized for analysis and discussion in real time. Value-added returns on this investment continued to be realized during subsequent remedy selection and implementation phases involving the use of *in situ* steam-enhanced extraction to remediate the residual petroleum LNAPL and CVOC source mass.

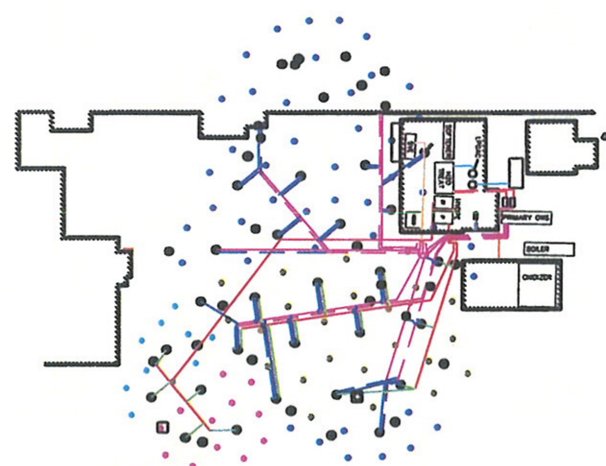
During remedy implementation, the model was used to track *in situ* heating progress within the target remediation volume and within each lithologic unit. The geostatistical tools for the 3-D model were used to calculate average temperatures. 3-D analyses were also completed to evaluate temperature distribution across different elevation horizons and support O&M decisions regarding steam system optimization.

REMEDIAL OBJECTIVES

- Removal of solvenated drainable LNAPL within shallow fill and deep sand-gravel unit;
- Removal of sorbed phase CVOC mass (estimated 22,000 lbs);
- Eliminate CVOC mass flux to groundwater;
- Shutdown of existing pump and treat system; and
- Expedite site closure under applicable environmental regulations.



3-D OUTPUT OF AREAS OF CONTAMINATION



SITE PLAN WITH REMEDIATION SYSTEM LAYOUT

AERIAL PHOTO FOLLOWING SYSTEM INSTALLATION

TECHNOLOGY EVALUATION/SELECTION

Evaluation of potential remedies to remediate the 55,000 cubic yards of impacted soil in the shallow fill layer and the deep sand-gravel layers and shallow groundwater were short-listed based on a weighted criteria including effectiveness in meeting remedial objectives, overall duration, potential to mobilize contaminants and the potential creation of more toxic byproducts. The short listed remedies included:

- Shallow excavation (onsite and offsite treatment/disposal) with SVE utilized in inaccessible areas;
- Excavation and offsite disposal of all impacted soils; and
- Insitu Thermally Enhanced Extraction including RF heating, Resistive heating, SEE and hot air injection.

Based upon screening criteria developed and the interest in development of a performance based contract, thermally enhanced extraction in both units was selected. The RFP was developed based upon a design/build contract that included project goals of minimum achievable subsurface temperatures throughout the remedial volume, as measured in discreet 5-foot intervals of 100 degrees C; minimum 95% uptime for all extraction and treatment equipment, and finally a cost cap guarantee of utilities over the duration of the remediation.

DESIGN AND IMPLEMENTATION

Following competitive procurement and award of the contract on a lump sum basis, Panther Technologies, Inc. was selected to perform the work; and tasks included extensive design, construction, and operation and maintenance activities for the following systems:

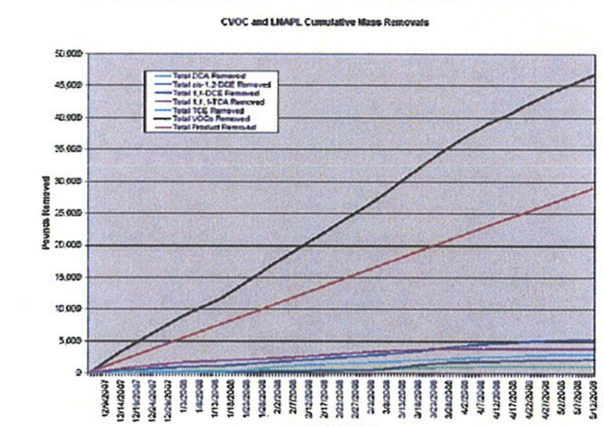
- Twin 300-acfm shallow fill HVDPE from 17 total shallow extraction wells;
- 175-gpm sand-gravel layer groundwater/product extraction and depression system with 26 groundwater extraction wells and custom pneumatic high temperature, top loading extraction pumps;
- 1,000-acfm deep sand-gravel SVE within the depressed GW extraction area within the 26 extraction wells;
- 200-gpm groundwater treatment train including primary and secondary oil water separation, twin 100-gpm shallow tray air strippers, primary/secondary bag filtration and liquid phase granular activated carbon;
- 3,000 scfm twin bed regenerative thermal oxidizer and wet scrubber system;
- 800-hp natural gas fired, low NOx recirculation steam boiler capable of 20,000 lbs/hr at 150-psi steam delivery to 124 shallow and deep steam injection wells with up to 200 lbs/hr steam injection per point;
- Miles of extensive surface piping system consisting of progressive 2-inch to 8-inch steam manifold system, 4-inch groundwater and vapor extraction header system and 2-inch high temp hose connections to wellheads;
- Central MCC managing 11 subsystem control panels all communicating through a digital data highway that includes remote shutdown and restart control, alarm logging and automated critical shutdown controls; and
- Ability to implement a post SEE chemical oxidation polish for residual GW mass.

RESULTS

The full system was commissioned on December 11, 2007 after six months of construction and demonstration of hydraulic and pneumatic control from the various extraction systems. The system has performed extremely well with achievement of the 90 degree C minimum requirement as of February 23, 2008 across all areas of interest. Since that achievement of operational temperature, temperatures have continued to increase during the pressure cycling phases of the project, with current average temperatures across the site of approximately 99 degrees C including isolated areas of the site targeted with high concentration of LNAPL and sorbed phase CVOCs in the 110 – 115 degree C range. A side benefit realized due to the conservatively designed heating and extraction systems was the heating of the intermediate silty/clay unit that was initially thought to provide a vertical barrier to migration. As this unit was heated to above 80 degrees C, it is currently believed that migration pathways that historically resulted in CVOC and LNAPL migration between the shallow fill layer and the deeper sand-gravel unit has also been addressed and will accelerate the time to ultimate site closure.

Throughout the duration of operation, the extraction and treatment system has averaged approximately 75-gpm with isolated river influenced rain events increasing short durations of treatment to approximately 120-gpm. Thus far, the system has maintained a 98% uptime, far better than the 95% uptime requirement within the contract. Although originally scheduled for completion by the end of June 2008, the period of operation under full heated conditions has been extended due to better than expected mass removal rates. To date, approximately 30,000 lbs of separate phase LNAPL have been extracted, separated and disposed of offsite in addition to extraction of approximately 18,000 lbs of CVOCs from the groundwater, SVE and HVDPE systems or nearly 50,000 lbs of total COC mass removed. It is currently projected, based upon trends within the mass removal rates, that system shutdown will occur at the end of May 2008 with 2 months of continued groundwater extraction system operation that encompass the verification sampling phase of the project.

GROUND WATER TREATMENT SYSTEM DURING INSTALLATION



CUMULATIVE MASS REMOVAL GRAPH

TWIN HVDPE SYSTEMS WITH SVE IN BACKGROUND