Dense Non Aqueous Phase Liquid Source Area Delineation Using Membrane Interface Probe and Hydraulic Profile Tool Technology at Space Launch Complex 16, Cape Canaveral Air Force Station, Florida - 16352

Presented by: Mr. Ronald B. Jackson, P.G. USACE Mobile District; Mr. Paul V. Fluck, P.G.; Mr. John Langett AFCEC/CZOE, Installation Support Team, Restoration Project Manager, Cape Canaveral Air Force Station, Florida; Mr. Timothy Jellett, Hydrogeologic, Inc.

ABSTRACT

The historical use and disposal of chlorinated solvents throughout Department of Defense and Department of Energy sites has resulted in subsurface contamination by dense non-aqueous phase liquids (DNAPL). The nature and environmental persistence of DNAPLs makes delineation and remediation of these compounds challenging and costly. This paper examines the utilization of data from a membrane interface probe (MIP) and hydraulic profile tool (HPT) to reduce a typical 18 to 24 month field investigation to 3 months; thereby, significantly reducing costs and resulting in a three-dimensional (3D) imagery of a deep DNAPL plume in order to support an aggressive remedial design for Space Launch Complex 16 (SLC16) at Cape Canaveral Air Force Station, Florida.

During the early stages of the U.S. space program, chlorinated solvents were routinely used at space complexes. Spent solvents were discharged to surface impoundments where they migrated into the subsurface. Over time, these chlorinated solvents reached concentrations high enough to form a DNAPL plume. Recent investigations near SLC16 identified a previously unknown DNAPL plume comingled with dissolved-phase chlorinated compounds. The DNAPL source area (concentrations of trichloroethene [TCE] as high as 1,000,000 micrograms per liter [µg/L]) was discovered approximately 1,200 feet (ft) west of the existing monitoring network area.

The U.S. Air Force, along with the U.S. Army Corps of Engineers, developed data quality objectives (DQO) to delineate the extent of the DNAPL and the dissolved-phase contaminant plume. A multi-phase investigation approach was developed by HydroGeoLogic, Inc. (HGL) emphasizing the use of MIP and HPT sampling technologies, conventional direct push technology (DPT), and monitoring well sampling methods. This approach allowed the collection of real-time data that supported the project DQOs and significantly reduced overall project costs and the field implementation schedule.

INTRODUCTION

Site Setting

SLC16 is located in the eastern portion of Cape Canaveral Air Force Station, Florida, approximately 1,000 ft west of the Atlantic Ocean and 3,000 ft east of the Banana

River Lagoon. The former launch site was constructed in the late 1950s for the Titan I Missile Program (Figure 1A). In 1973, the site was used for the Pershing Follow-On Test, and subsequently was used for the Pershing II Engineering Development Program.

Figure 1A – CIRCA 1960 aerial photograph showing mission support infrastructure located 1,200 ft west of the Launch Pads SLC16 and SLC19.

A surface water drainage canal that flows predominantly east to west is located south of SLC16 and north of SLC15. Following the discovery of the solvent source area, the solid waste management unit (SWMU) boundary expanded from 30 acres to approximately 100 acres at the inactive launch complex consisting of a former blockhouse, former launch stand and ramp, various launch support buildings and deluge basin, and associated flume trench located in the northeast area of the site (Figure 1B).

Figure 1B – Site SWMU Boundary

Long Term Monitoring Program

SLC16 groundwater sampling for long term monitoring was initiated in 2001, and continued through 2012. The long term monitoring program included the semi-annual collection of groundwater samples from 15 monitoring wells. Samples were analyzed for volatile organic compounds (VOC), ethene, ethane, and methane.

2008–2010: Groundwater Assessment Project

Based on the static contaminant trends identified during the initial long term monitoring events, additional delineation was recommended via direct push technology in 2008. DPT groundwater sampling began in 2009, and was completed in 2010. Vertical profiling of the VOC contamination was conducted with DPT at 40 locations. The sample locations are shown on Figure 2. Grab groundwater samples for VOC analysis were collected at 5-ft intervals. The results identified a TCE hot spot area (concentrations above 10,000 µg/L) located 600 ft east of Heavy Launch Road and ICBM Road (3E, 2010).

2012–2013: Groundwater Source Characterization and Delineation Project

In 2012, an additional assessment of the source area was conducted. Field activities included the collection of grab groundwater samples from 68 additional DPT borings for vertical profiling at 5-ft intervals (Figure 2). The most shallow groundwater sample was collected at 5-10 ft below ground surface (bgs) and the deepest sample was collected at 95-100 ft bgs. The grab groundwater samples were analyzed for VOCs (3E, 2013a).

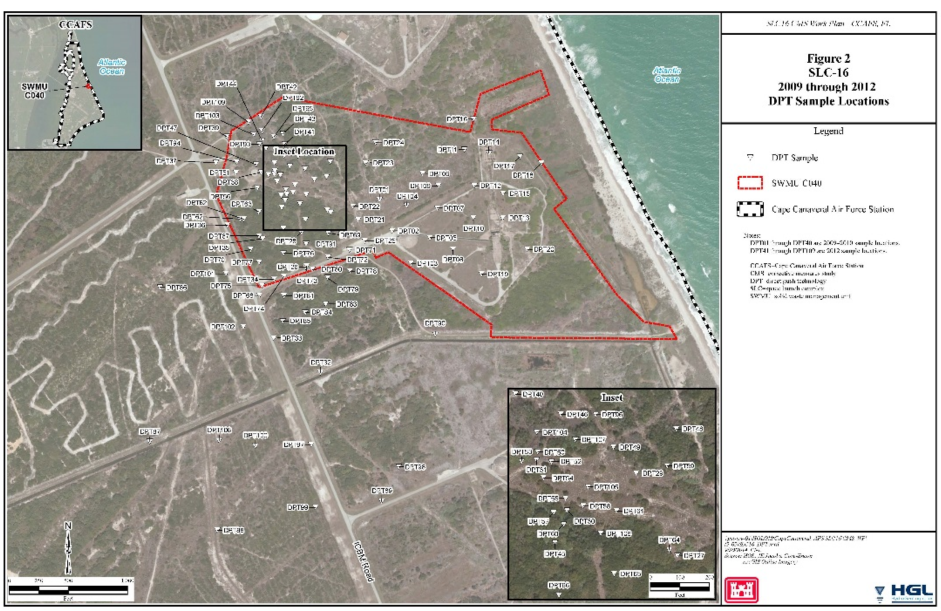


Figure 2 – 2008 to 2012 DPT Sample Locations

Following evaluation of the DPT data, 53 shallow/intermediate and 15 deep monitoring wells were installed in October/November 2012. Monitoring well locations are shown on Figure 3.

Figure 3 – SLC16 Monitoring Well Sample Locations

All wells were sampled for VOCs, and 23 wells were sampled for monitored natural attenuation parameters (chloride, nitrate/nitrite, sulfate, sulfide, methane, ethene, ethane, alkalinity, iron, ferrous iron, manganese, total organic carbon, and Dehalococcoides). At 22 wells, 1,4-dioxane was also analyzed. Finally, five surface water samples were collected and analyzed for VOCs and 1,4-dioxane. Surface water sample locations are shown on Figure 4.

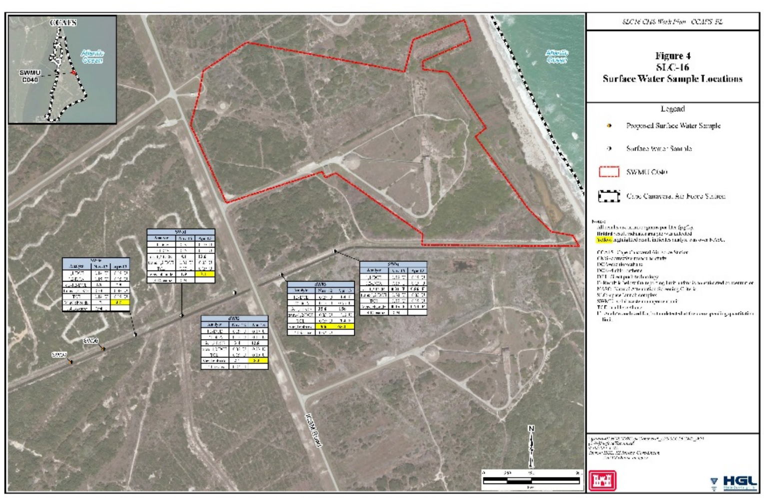


Figure 4 – SLC16 Surface Water Sample Locations

The 2012 – 2013 analytical results identified TCE concentrations greater than 100,000 µg/L across an estimated area of 2.7 acres (Figure 5). Included in the report was a focused corrective measure study (CMS) indicating potential remedial alternatives. The 2013 report recommended that additional investigations using MIP sampling, 3D visualization imaging, DPT sampling, and monitoring well installation be conducted (3E, 2013b). The multi-phase investigation approach designed and implemented by HGL emphasized the use of MIP and HPT sampling technologies allowing for the collection of real-time data in order to support the project DQOs (HGL, 2014).

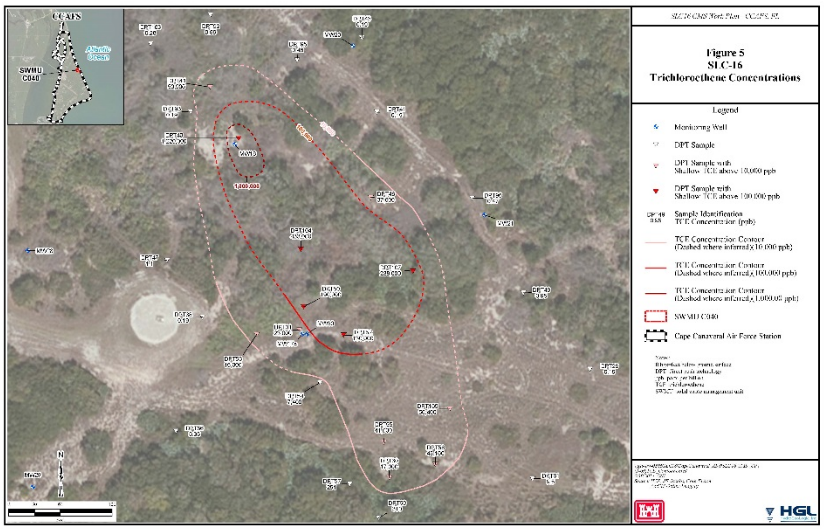


Figure 5 - SLC16 Trichloroethene Concentrations

Investigation Implementation Summary

HGL developed a sampling strategy consisting of MIP/HPT and DPT groundwater sampling to efficiently conduct the multiphase approach for the delineation of the DNAPL source area. This was followed by installing conventional well, sampling the new well network, and sampling down gradient surface water in the drainage canal. The SLC16 multiphase approach was different from conventional work strategies in that the activities were based on planning documents that included real-time decision logic when complexities were encountered. This allowed field personnel to modify the site activities as data was being collected and evaluated in order to continue to achieve the project DQOs with increased quality and control. This did not require decision makers be present on site during data collection, only that they were accessible to immediately evaluate data and provide direction to the field staff. A key cost-saving component of this strategy was the ability to complete fieldwork in about 3 months rather than a typical 18 to 24 month period.

The SLC16 investigation approach using the MIP and HPT sampling methodologies specifically supported:

- Accurate daily interpretation of real-time data;
- Use of lines of evidence in evaluation;
- Proper placement of confirmation samples, not just a random percentage of samples, to confirm plume geometry; and
- A well-distributed sample database yielding accurate assessment of contaminant mass removal requirements.

MIP Sampling Overview

A total of 65 MIP sample locations with boring completion depths ranging from 45 ft bgs to 88 ft bgs were completed in a 2 month time frame. The work plan sampling locations were based on two cross sections, A to A' and B to B', which were generated based on previous investigation activities from 2008 through 2012.

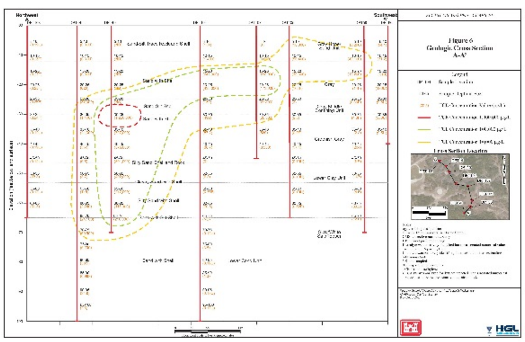


Figure 6 - Cross Section A to A'

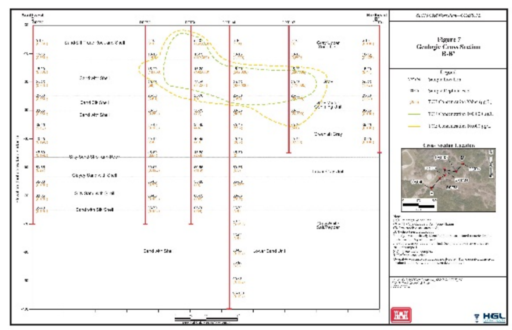
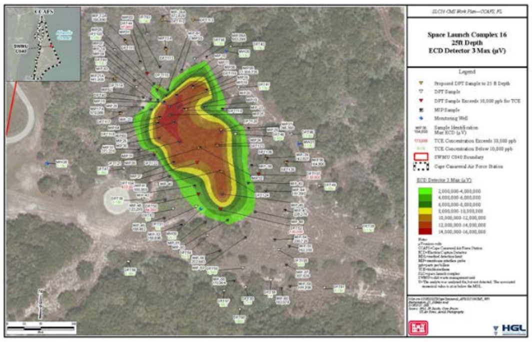


Figure 7 - Cross Section B to B'

The Site was broken down into a southern half sampling area and a northern sampling area. A total of 23 sample locations were completed in the southern half of the site where dissolved phase VOC concentrations were limited to the shallow/intermediate zone of the surficial aquifer (0 to 45 ft bgs). A total of 42 locations in the northern half of the site were completed to depths ranging from 68 ft bgs to 88 ft bgs. Depths varied due to drilling refusal. MIP data were recorded on 1-foot sampling intervals and detectors on the MIP would screen the subsurface for chlorinated compounds trichloroethene, dichloroethene, vinyl chloride (e.g., TCE, DCE, VC) and aliphatic hydrocarbons (e.g., methane). An electrical conductivity meter on the MIP was used to aid in distinguishing between the silt/clay lenses and the sand/shell layers. Once the vertical profile of contamination was obtained from one location, it was compared against the data obtained at the other points to select the next sampling location. The original sampling grids that had been established were considered a guide, and MIP points were adjusted to better define the source area. This enabled the project team to generate a detailed conceptual model of the contaminant distribution in both the saturated and unsaturated zones in an efficient, effective, and sustainable manner. The MIP investigation was designed to start at the existing outer edges of the data gaps and proceed in toward the source area, but the exact placement and order of the locations was a dynamic process based upon the data obtained daily and best professional judgment.

These data were used to generate 3D images of the DNAPL source area (on a qualitative level) in micro volt µv to support investigation planning. Phase 2 and 3 activities would generate quantitative concentrations of the contaminants of concern (CoC).



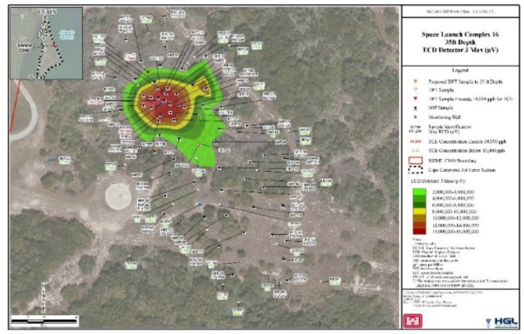
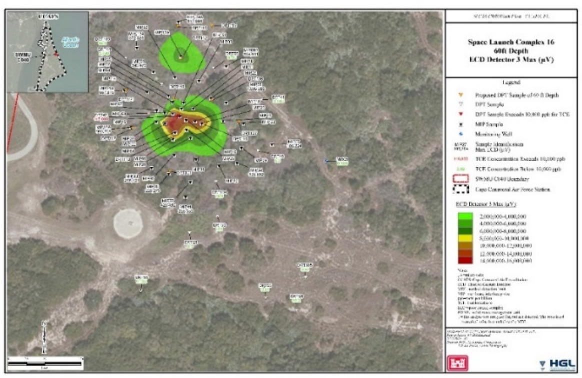


Figure 7 - Shallow depth 25 ft bgs ECD µv Results

Figure 8 - Intermediate depth 35 ft bgs ECD µv Results



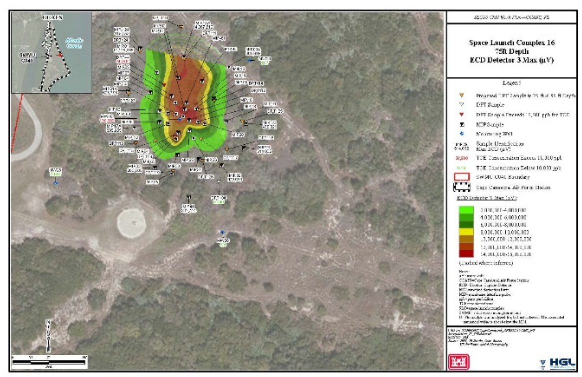
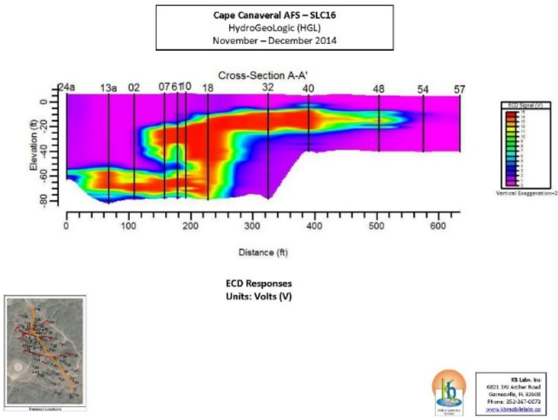


Figure 9 Deep depth 60 ft bgs ECD µv Results

Figure 10 Deep depth 75 feet bgs ECD µv Results



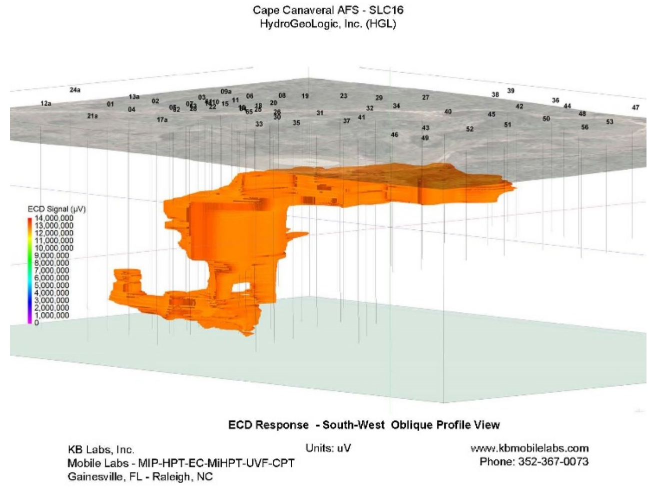
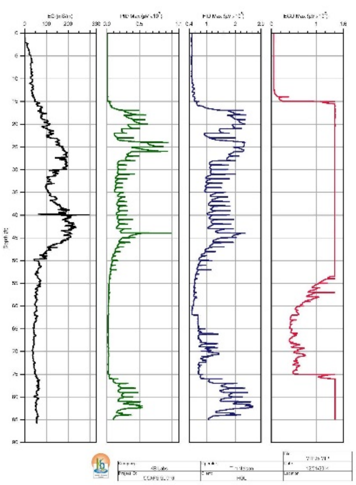


Figure 11 ECD Signal Cross Section

Figure 12 ECD Signal 3D Visual Image

Section

Completion of the Phase 1 activities included the five HPT borings that were drilled from land surface to 85 ft bgs. Two transects using the five HPT borings were generated, one north to south and one east to west. The HPT logs provided hydraulic conductivity, electrical conductivity, and hydrostatic profiles across the site. The system evaluated the hydraulic behavior of unconsolidated materials. Injection pressure, which was monitored and plotted with depth, was an indication of the hydraulic properties of the site as well as potential preferential flow zones for contaminant migration.



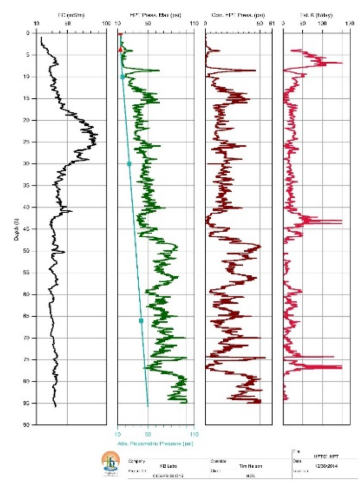


Figure 13 MIP25 Sample Log (µv) total depth 85 bgs

Figure 14 – HPT01 Sample Log (uv) total depth 85 bgs

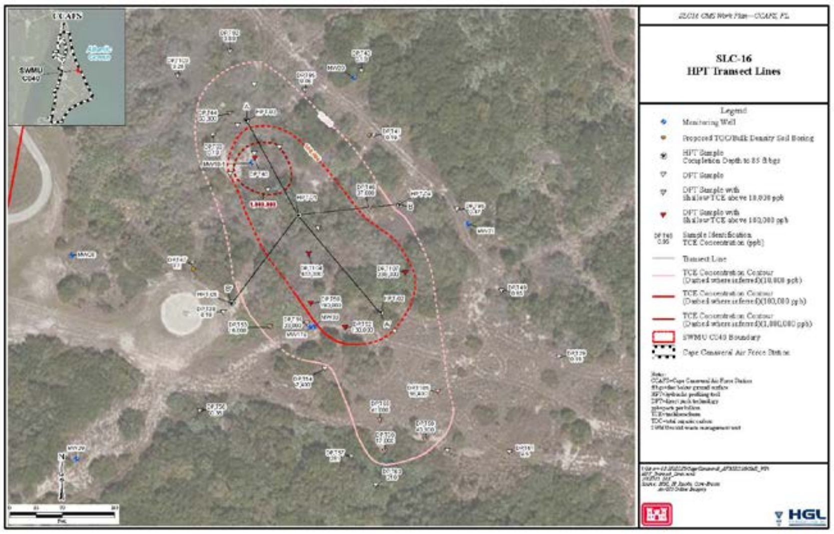


Figure 15 HPT Transects A to A' and B to B'

DPT Groundwater Sampling

Phase 2 included reviewing the MIP/HPT investigation and collecting confirmation groundwater samples using DPT methods from 20 locations. Utilizing the MIP and HPT logs, a discrete number of samples and intervals were chosen. The DPT data validated the MIP results confirming VOC source area concentrations greater than 100,000 µg/L that were observed from 10 ft bgs to 80 ft bgs. The source material concentrations greater than 10,000 µg/L span across a 3.6-acre area in the shallow zone (30 ft bgs) and 0.65 acres in the deep zone to a depth of approximately 90 ft bgs.

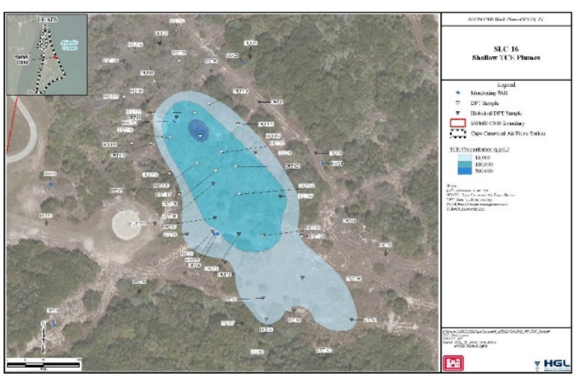


Figure 16 Shallow Depth TCE Groundwater Results

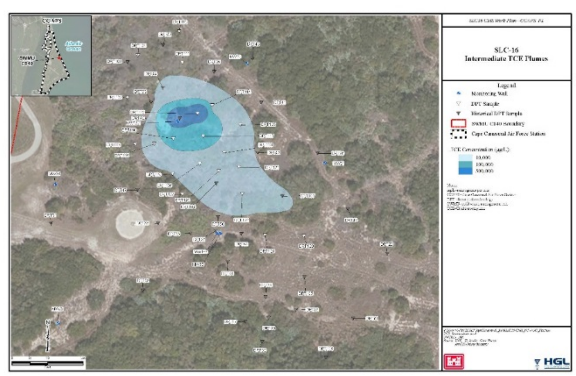


Figure 17 Intermediate Depth TCE Groundwater Results

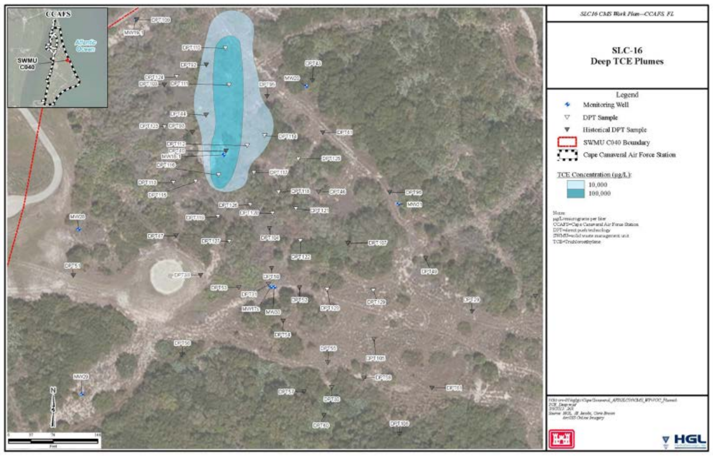


Figure 18 – Deep Depth TCE Groundwater Results

Monitoring Well Installation/ Sampling

Phase 3 included utilizing the initial phase investigation approaches. The HGL project team was able to strategically design and install (15 new wells) an effective monitoring well network to confirm the source material limits (10,000 µg/L) of TCE; cis-1,2-DCE; and VC in each of the three sample depth intervals (shallow 10 to 20 ft bgs, intermediate 30 to 45 ft bgs, and the deep zone 60 to 90 ft bgs).

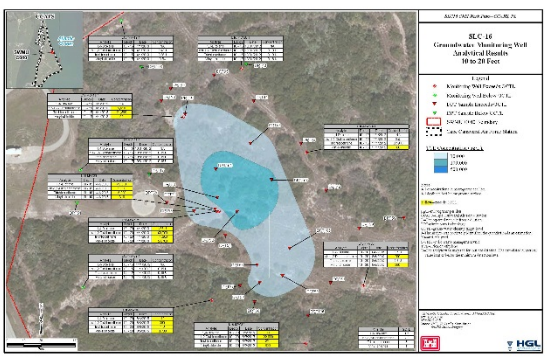


Figure 15 Shallow Depth (20 ft bgs) GW Results

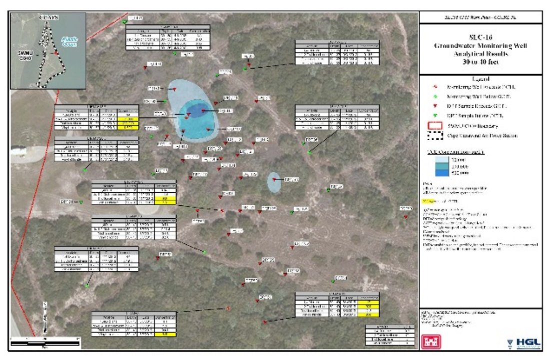


Figure 16 Interm. (30-45 ft bgs) Depth GW Results

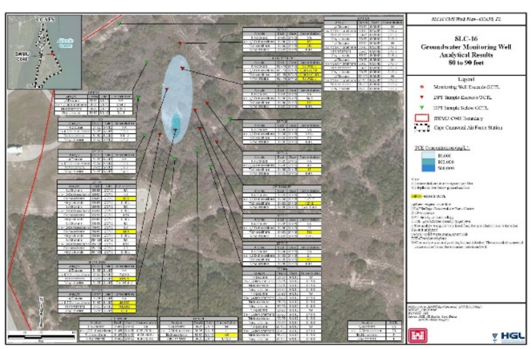


Figure 17 Deep Depth 80-90 ft bgs Groundwater Sampling Results

CONCLUSIONS

The presence of the DNAPL plume indicates the groundwater remedy was no longer effective and the site boundary was adjusted to include approximately 100 additional acres. Contaminant concentrations greater than 10,000 µg/L encompassed an estimated 3.6 acres and extended from 10 ft bgs to approximately 90 ft bgs. Dissolved chlorinated VOC daughter products extended laterally 2,000 ft down gradient toward a drainage canal. Data collected during this investigation was verified to have met the project DQO,s and will support future decisions and remedial actions.

The use of the MIP/HPT enabled the project team to rapidly locate and identify chlorinated solvents by viewing real-time data and facilitating technically defensible decisions during field data collection. Using an innovative combination of MIP, HPT, and conventional investigation methods, the lateral and vertical extent of groundwater characterized by TCE concentrations greater than 1,000,000 µg/L, 100,000 µg/L, and 10,000 µg/L was defined. The results of this investigation are being used to support remedial design development and programmatic planning.

Project Benefits

Use of MIP and HPT technologies allows the user to produce reliable estimates of the lateral and vertical extents of chlorinated solvents and subsurface hydraulic properties that are crucial in designing and implementing a cost-effective remediation. When applied to the appropriate site, the MIP and HPT real-time results provide better outcomes in shorter time frames at lower costs than conventional site investigation approaches and minimizes investigation derived waste generation and disposal cost.

The CMS sampling approach for SLC16 was intended to provide additional characterization data for TCE source area. This CMS found that, using the MIP/HPT phase sampling strategy, combined with the proper placement of confirmatory samples, had the following effect on the DQOs:

- Expedited delineation;
- Avoidance on late discovery of unknown sources;
- Accurately evaluated risks, remedial alternatives, and remedy selection;
- Optimized design for increased efficiency; and
- Increased probability of remedial success.

The Investigation activities at SLC16 were developed based on previous groundwater investigation and monitoring results, the 2013 Five-Year Review results and recommendations, visual inspections, and the potential fate and transport of the groundwater contaminants. Utilizing the above phased approach saved the government both time and funding to complete the project DQOs. Activities that conventionally would have taken 18 to 24 months to complete took approximately 3 months by eliminating multiple mobilizations/demobilization and reduction in IDW management.

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