

TRENCH-BASED DUAL PHASE EXTRACTION IN A LOW PERMEABILITY SOIL

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ABSTRACT: Three sources of contamination have resulted in groundwater quality impacts at the New Mexico Department of Transportation (NMDOT) Las Vegas Service Center in Las Vegas, New Mexico. Leaking underground storage tanks, leaking distribution piping, and formerly unlined, salted cinder storage have contaminated groundwater with petroleum hydrocarbons, 1,1,1-trichloroethane (TCA), and total dissolved solids (TDS), respectively. The plumes are distinct at the source areas, but commingle downgradient. The low permeability of the shallow water-bearing zone makes groundwater extraction via wells impractical due to low production rates. The nature of the commingled contaminants and low permeability of the subsurface, were considered in the selection of an extraction and ex-situ treatment remedy for contaminated groundwater. Because a trench has greater access to contaminant flow pathways (fractures and bedding planes) than a single, or multiple wells, trench-based dual phase extraction (DPE) was piloted to evaluate its ability to dewater a significantly larger volume of the subsurface, and to provide a higher groundwater production rate than extraction wells. During a 2-week pilot test, the DPE trench achieved a steady state groundwater extraction rate of approximately 2.5 gallons per minute (gpm). This pumping rate represents an average groundwater extraction rate 10 times greater than was attainable with the previous multi-well groundwater extraction system.

INTRODUCTION

Groundwater impacts at the New Mexico Department of Transportation (NMDOT) District 4 Service Center in Las Vegas, New Mexico, are attributed to three sources. Former unlined storage of salted cinders produced a chloride and total dissolved solids (TDS) plume in the north portion of the site. Leaking underground storage tanks in the center of the site created a plume of petroleum hydrocarbons. Finally, leaking distribution piping at the District Laboratory facility produced a 1,1,1-trichloroethane (TCA) plume. Figure 1 illustrates the approximate extent of the three plumes. Camp Dresser & McKee Inc. (CDM) was retained by the NMDOT to develop a remedy to abate the groundwater contamination.

A pump-and-treat remediation system was previously employed at this site to address the hydrocarbon impacted groundwater. This system, composed of four groundwater extraction wells, treated groundwater through an air stripper before upgradient re-injection to the aquifer. Over the operational life of the pump-and-treat system the average groundwater extraction rate was approximately 0.2 gallons per minute (gpm). This system was discontinued upon discovery of the TCA plume.

The contaminated shallow water-bearing zone is characterized by weathered shale with low primary permeability and secondary permeability resulting from fractures or joints and bedding planes. The lithology of the vadose zone, derived from the weathered shale,

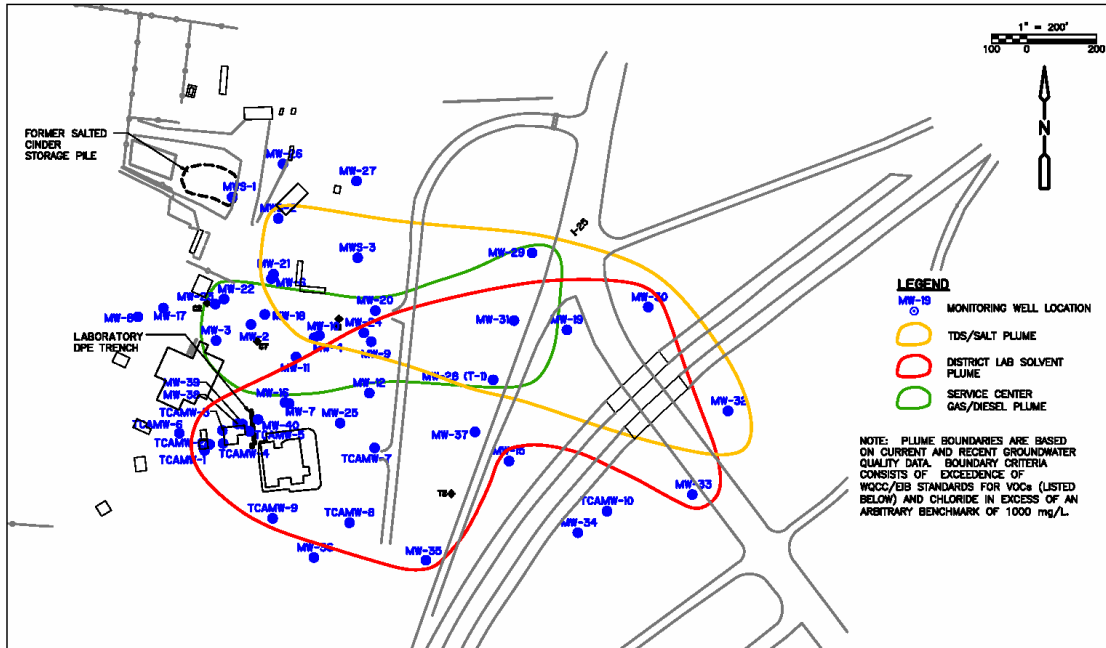


FIGURE 1. Site map.

consists of clay with occasional gravel lenses. Clay and shale in the shallow subsurface present challenges with respect to groundwater remediation. As evidenced by the operational record of the previous remediation system, low permeability soils cause extraction wells to be impractical for the purpose of groundwater extraction due to low production rates.

Though hydrogeologic conditions at this site are not conducive to classic pump-and-treat operations, they are well suited for DPE. DPE is capable of removing contaminants from both the vapor phase in the vadose zone soils and dissolved phase in groundwater. This technology typically involves the application of a vacuum to an extraction well, resulting in the extraction of contaminants in multiple phases—non-aqueous phase liquids (NAPLs) if present, dissolved phase, and/or soil vapor phase. DPE also enhances aeration and raises oxygen levels in the subsurface promoting aerobic biodegradation. The radius of influence of a DPE well is dependent, in part, on the extent of groundwater drawdown achieved. Low permeability soils allow for rapid depression of the water table, improving removal of contaminants in the vapor phase. DPE trenches allow for dewatering and remediation of a significantly larger volume of subsurface soil as compared to individual DPE wells. Trenches have greater access to fractures and bedding planes (contaminant flow pathways) than multiple vertical extraction wells. To test the effectiveness of DPE trenches at this site, a DPE trench was installed and pilot tested near the source area of the TCA contamination near the District Laboratory.

MATERIALS AND METHODS

DPE Trench Construction and Equipment. The Laboratory DPE trench was constructed on the east side of the Laboratory Building. The trench is 98 feet long and 27 feet deep. The lower 16 feet of the trench is filled with a high permeability sand and gravel. A 2-foot thick low permeability cap, composed of native material amended with

bentonite, was placed on top of the sand and gravel layer and acts as a seal minimizing short-circuiting of airflow from the subsurface. Native material was placed on top of the low permeability cap and compacted to bring the trench up to the existing grade. Two DPE wells and three vapor/groundwater monitoring wells were completed in the trench. The DPE wells are both 6-inches in diameter and were drilled to a total depth of 30 feet below ground surface (BGS). The bottom 4 feet of each well is blank casing to form a sump. Both wells are screened from 26 to 21 feet BGS (the saturated section) with 0.010” slot screen and from a depth of 21 to 11 feet BGS (the vadose or vapor section) with 0.020” slot screen. The vapor/groundwater monitoring wells are 1-inch wells completed to 25 feet BGS and screened from 25 to 15 feet BGS with 0.010” slot screen. Figure 2

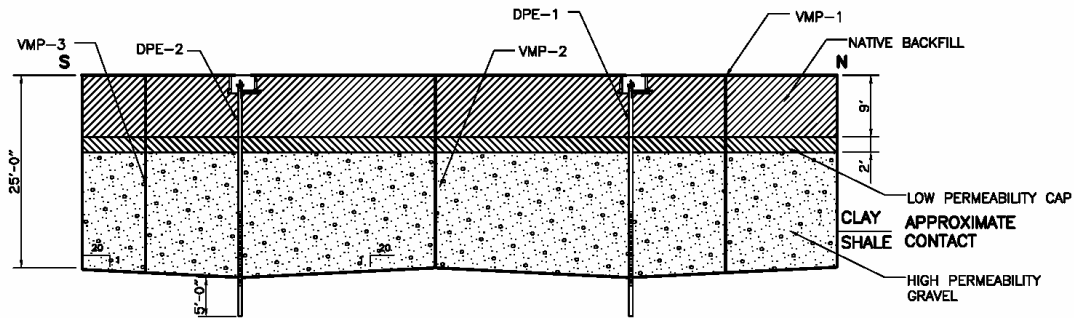


FIGURE 2. Laboratory DPE trench cross section.

shows the cross section of the completed trench.

A package vapor extraction system, including vapor extraction blower, moisture separator, moisture separator pump, and all related controls were rented for the pilot test. The vapor extraction blower was a Rietschle model VLR300 vacuum pump with a 7.5 horsepower (hp) motor capable of 23 inches of mercury ("Hg) maximum vacuum at 210 standard cubic feet per minute (scfm) maximum flow rate. A submersible pump was placed in each of the DPE wells for the pilot test. Each pump had a ½ hp motor, internal pump controller, and was capable of extracting at a rate up to 20 gpm. Separate pipes conveyed water and vapor from each of the DPE wells. Water and vapor were conveyed in 1-inch and 4-inch high-density polyethylene (HDPE) pipe, respectively.

Water extracted from the DPE wells during the pilot test was stored in 21,000-gallon tanks. Three of these tanks were mobilized to the site to contain the water and were plumbed together in series.

Numerous groundwater monitoring wells have been installed at the site and several of these were used to monitor groundwater levels during DPE operations. In addition, three new monitoring wells (MW-38, MW-39, and MW-40) were installed to monitor groundwater and induced vacuum near the extraction trench. Each of the new wells is 2 inches in diameter, with total depth of 30 feet BGS, and screened with 0.010” slot screen between 15 and 30 feet BGS. Figure 1 shows the locations of all site monitoring wells.

Pilot Testing. Pilot testing of the Laboratory DPE trench was conducted in four phases: pre-test monitoring, groundwater extraction, dual-phase extraction, and post-test monitoring. Depth to groundwater was measured to define a water level baseline to calculate drawdown during the pilot test.

The groundwater extraction phase of the pilot test ran from February 24 at 1:09 p.m., when the pumps were turned on, until March 4, 2003 at 10:45 a.m. when the DPE stage began. Drawdown calculated from these water level measurements is shown in Table 1. Figure 3 shows the groundwater extraction rate from DPE-1, DPE-2, and the combined extraction rate during the pilot test.

Table 1. Drawdown in Monitoring Wells over Time

Date	Time	MW -7 (ft)	MW -16 (ft)	MW -25 (ft)	MW -38 (ft)	MW -39 (ft)	MW -40 (ft)	TCA MW-1 (ft)	TCA MW-4 (ft)	TCA MW-5 (ft)	TCA MW-6 (ft)	TCA MW-8 (ft)	TCA MW-9 (ft)
2/21/2003	11:00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00
2/24/2003	12:36		0.19		0.26	0.27	0.26	0.30	0.20	0.27			
2/24/2003	14:34		0.18		0.78	0.77	1.88	0.33	0.34	2.41			0.12
2/25/2003	15:28		0.06		2.38	2.48	2.39	0.90	1.35	3.17			0.40
2/26/2003	7:09		0.05		2.55	2.64	2.44	1.09	1.57	3.25			0.50
2/26/2003	10:05		0.07	0.12	2.61	2.71	2.48	1.13	1.62	3.32	-0.10	0.12	0.53
3/3/2003	9:24	1.35		-0.26				1.48			0.01	0.33	0.89
3/4/2003	8:55	1.27		0.30				1.41			-0.05	0.26	0.86
3/4/2003	10:16				2.78	2.85	2.57			3.38			
3/4/2003	11:19				2.82	2.87	2.60			3.41			
3/4/2003	12:20				2.83	2.88	2.60			3.41			
3/4/2003	13:08				2.84	2.89	2.62			3.42			
3/4/2003	13:45				2.86	2.90	2.63			3.44			
3/4/2003	14:33				2.87				2.18				
3/4/2003	15:44				2.88	2.92	2.65			3.46			
3/4/2003	15:55	1.36		0.32				1.43	2.20		-0.04	0.25	0.87
3/11/2003	11:45	1.45			2.90		2.67	1.58			0.10		1.02
3/11/2003	13:35	1.44			2.78	2.89	2.49	1.53		3.26	0.07		1.01
3/12/2003	11:00	1.11			1.90	1.98	1.66	1.46		1.91	0.11		0.93

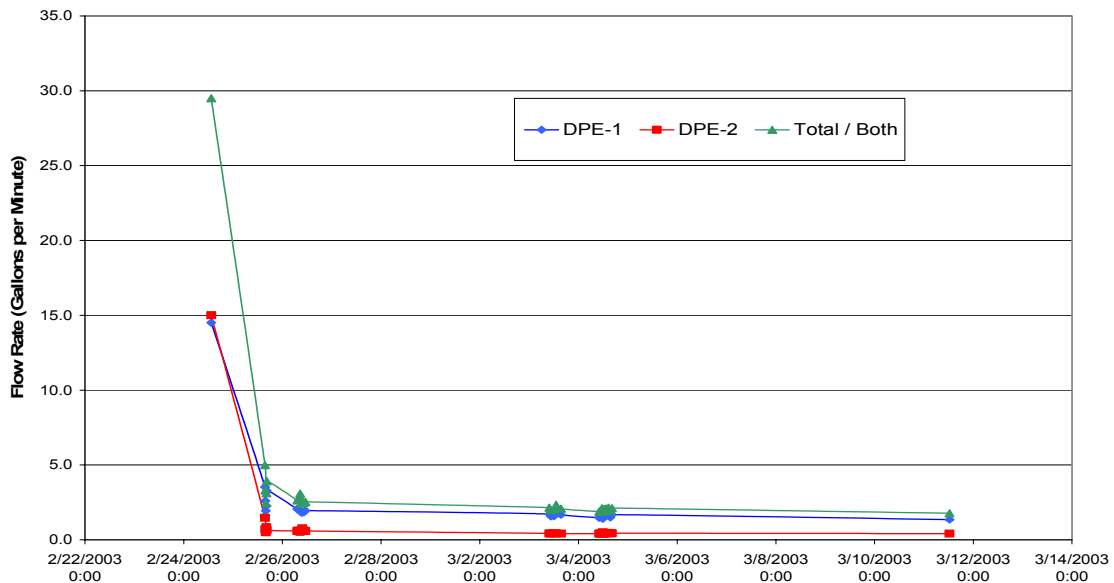


FIGURE 3. Groundwater extraction rate during pilot testing.

The DPE phase was performed on March 4, 2003 in a series of six steps of increasing vacuum. During step one, the blower dilution valve was fully opened. The system pressure measured 3.5 inches of water ("H₂O) vacuum. The incoming flow rate from

DPE-1 and DPE-2 was measured using pitot tube-style flow meters. After recording influent and effluent flow meter readings, vacuum readings were taken at MW-39, MW-40, TCAMW-5, VMP-1, VMP-2, VMP-3, DPE-1, and DPE-2. Step two began by closing the dilution valve until the system pressure measured 4.5 "H₂O vacuum. The influent and effluent flow meter readings and vacuum measurements at the same monitoring wells as in step one were recorded. These steps were repeated for steps 3, 4, and 5 at system pressures of 5.5, 6.5, and 7.5 "H₂O vacuum, respectively. For step six, the dilution valve was fully closed and a system pressure of 7.9 "H₂O vacuum was recorded. A summary of system pressures, flow rates, and wellhead vacuums is shown in Table 2. The vacuum blower was turned off at the end of the DPE phase.

TABLE 2. Summary of Vacuum and Air Flow in Wells

Distance from Extraction Trench (ft)		Date Time	4-Mar 11:02	4-Mar 12:00	4-Mar 12:32	4-Mar 13:30	4-Mar 14:25	4-Mar 15:20
<u>Influent Vacuum (in. H₂O)</u>			3.5	4.5	5.5	6.5	7.5	7.9
<u>Vacuum at Wellheads in Extraction Trench ("H₂O)</u>								
DPE-1	NA		1	1.4	1.75	2.3	2.5	2.6
DPE-2	NA		0.6	0.85	1.05	1.25	1.46	1.45
Average of DPE-1 and DPE-2			0.8	1.1	1.4	1.8	2.0	2.0
VMP-1	NA		0.6	0.93	1.2	1.4	1.57	1.55
VMP-2	NA		0.35	0.55	0.77	0.95	1.05	1.1
VMP-3	NA		0.35	0.6	0.75	0.9	1.05	1.1
<u>Vacuum at Observation Wellheads ("H₂O)</u>								
MW-38	57		NM	NM	NM	NM	NM	NM
MW-39	25		ND	ND	> 0.0	> 0.0	> 0.0	> 0.0
MW-40	22		ND	ND	ND	ND	ND	ND
TCAMW-5	10		0	0.03	0.12	0.15	0.2	0.25
<u>Air Flow from Extraction Wells (scfm)</u>								
DPE-1			35.7	44.4	51.7	57.5	62.6	63.6
DPE-2			41.2	50.4	58.1	64.9	71.3	74.7
Total			76.9	94.8	109.8	122.4	133.9	138.3

ft - feet
("H₂O) = vacuum in inches of water column
NM = not measured
ND = not detected

The groundwater extraction pumps were turned off on March 11, 2003. Depth to groundwater was recorded approximately 1 hour after the pumps were turned off. Depth to groundwater was measured again on March 12, 2003. Post-test drawdown data are also shown in Table 1.

RESULTS AND DISCUSSION

Groundwater Data. Groundwater extraction rates over time are shown in Figure 3. The average flow rate throughout the test was about 6.8 gpm, with the highest flow during the first 24 hours of the test at around 29.9 gpm. The high initial flow rate likely represents dewatering of the trench cavity and portions of the water-bearing formation in direct

contact with the trench walls via fracture flow. After the first day of groundwater extraction, the average flow rate decreased to about 2.5 GPM until the end of the test. This latter rate represents the rate of groundwater flow from the formation into the porous trench materials.

The groundwater drawdown observed in monitoring wells versus distance from the DPE trench is plotted in Figure 4. Drawdown values used for this plot were those observed on February 26, 2003, representing groundwater conditions at near steady-state pumping conditions. Note that the x-axis in Figure 4 is a logarithmic scale. The resulting distance-drawdown relationship is shown with the best-fit line. To determine the distance from the trench at which groundwater may be influenced, the best-fit line was extended until it intercepted the x-axis (a drawdown value of zero feet). The line intercepts the x-axis at approximately 364 feet, suggesting that groundwater drawdown from the trench would be minimal beyond this distance. Four drawdown values collected on March 4 during the DPE step test at a system pressure of 7.9 "H₂O are also plotted on Figure 4. A line that approximates these data points is parallel with the February 26 data for distances less than 100 feet from the trench. Since no monitoring wells with distances greater than 100 feet from the trench were monitored on March 4, a meaningful best-fit line cannot be created for this data set.

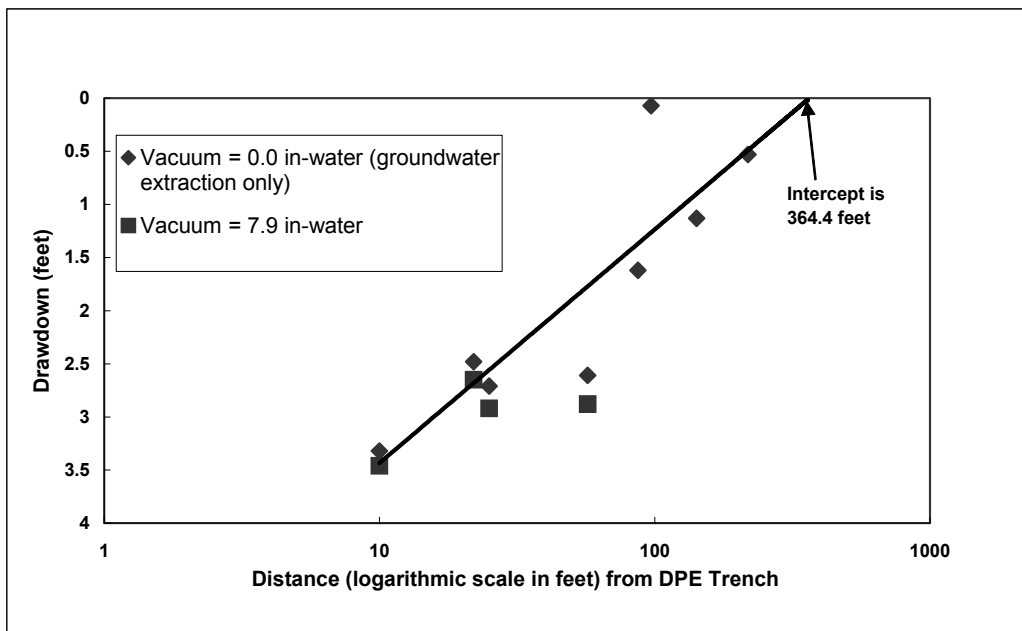


FIGURE 4. Distance vs. groundwater drawdown in observation wells.

Vacuum Data. Vacuum data collected at extraction and observation wells are presented in Table 2 along with the influent vacuum at the extraction blower. These data are also plotted in Figure 5 where the x-axis is system pressure measured at the inlet to the blower (influent vacuum), and the y-axis represents vacuum at the wellheads. Influent vacuum for the pilot test was maintained within a vacuum range of 3.5 to 7.9 "H₂O. The data show a positive relationship between influent vacuum and increased vacuum at the extraction wells (DPE-1 and DPE-2), the observation wells in the trench (VMP-1, -2, and -3), and an observation well completed in the formation (TCAMW-5).

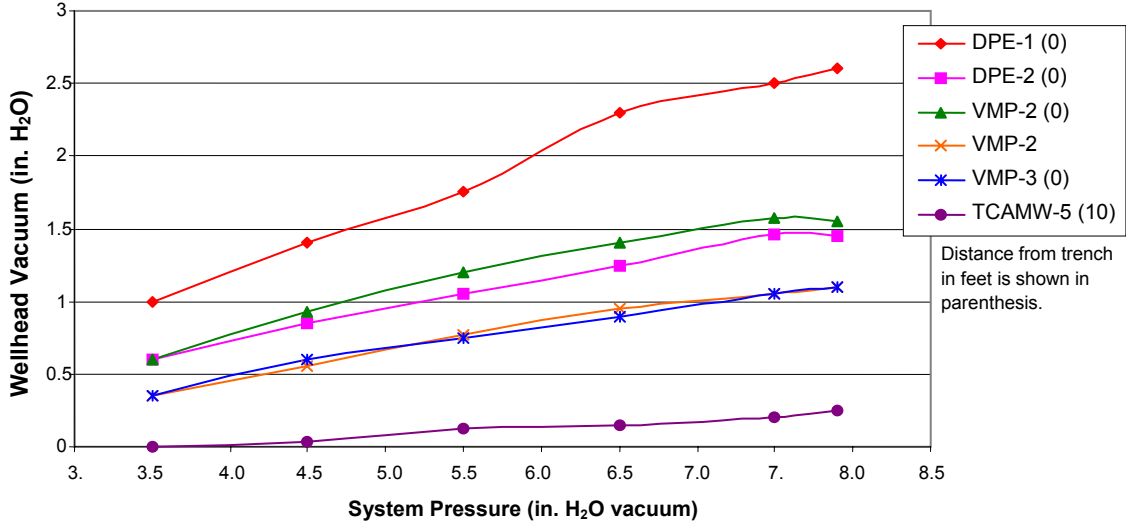


FIGURE 5. Vacuum measurements observed at extraction and monitoring

The flow rate of vapor extracted from each DPE well was measured separately. Air flow data are summarized in Table 2 along with vacuum measurements. The air flow and vacuum data for DPE-1, DPE-2, and the average of DPE-1 and DPE-2 are plotted in Figure 6 with wellhead vacuum on the x-axis and air flow rate on the y-axis. A positive correlation was seen between increasing wellhead vacuum and increasing flow rate. Only one monitoring well outside the DPE trench yielded consistent and reliable vacuum measurements during the test: TCAMW-5. When vacuum measured inside the trench (extraction wells DPE-1 and DPE-2) is plotted versus vacuum in monitoring well TCAMW-5, a very linear relationship exists.

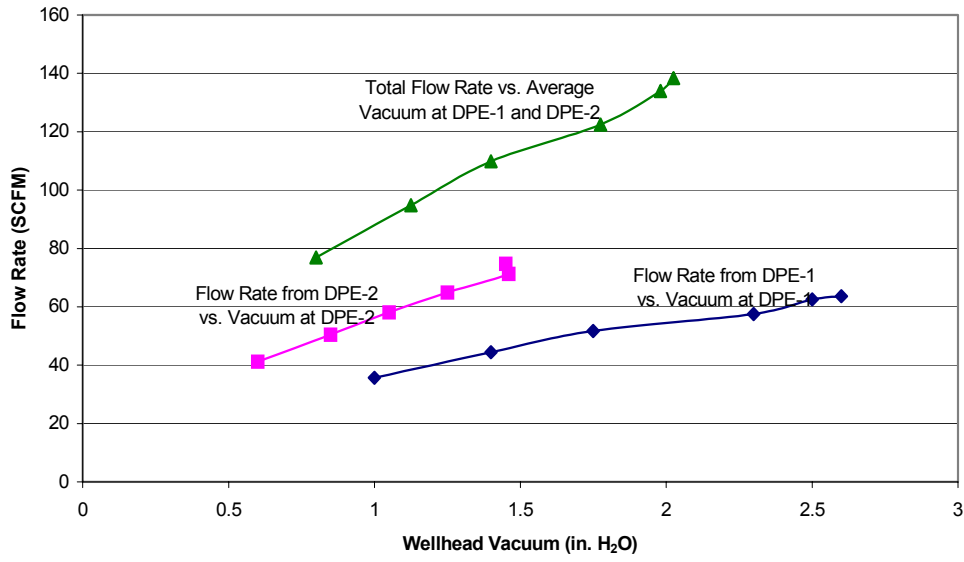


FIGURE 6. Vapor extraction flow rate vs. wellhead vacuum

Analytical Data. Water samples were collected on February 21 and March 11, 2003 from water extracted from DPE-1, DPE-2, and grab samples from the water storage tank. Concentrations of TCA and 1,1-dichloroethene (DCE) increased in the second sample from all three sources. The average TCA and DCE concentrations for the February 21, 2003 sampling event were 472 parts per billion (ppb) and 62 ppb, respectively. The average TCA and DCE concentrations for the March 11, 2003 sampling event were 660 ppb and 117 ppb, respectively.

Two effluent vapor samples were collected approximately 5 hours apart on March 4, 2003. The first vapor sample had a TCA concentration of 30 milligrams per cubic meter (mg/m^3) and a DCE concentration of $7.5 \text{ mg}/\text{m}^3$. The later vapor sample had a TCA concentration of $13 \text{ mg}/\text{m}^3$ and a DCE concentration of $3.4 \text{ mg}/\text{m}^3$.

If the water from the trench is treated by air stripping and vapor is vented, it was calculated that approximately 8 pounds of volatile organic compounds (VOCs) would be introduced to the atmosphere per year. This level is well below the current regulatory threshold.

CONCLUSIONS

The data illustrates that the Laboratory DPE trench is more effective at intercepting fractures that transport water and produces greater groundwater flow than anticipated. Groundwater extraction rates from the DPE trench were 10 times that of the former remediation system. The pilot data indicate that the DPE trench has the potential to influence groundwater flow up to 300 feet from the trench.

Wellhead vacuums observed during the pilot test were lower than expected; however, applying a higher vacuum to the trench will result in a larger treatment zone in unsaturated soils. Another pilot test using a vapor extraction blower capable of 500 scfm is proposed to achieve greater wellhead vacuum levels.

The pilot results indicate that trench-based DPE technology can be effective remediation method at this site. This technology has been recommended for the extended corrective action.

ACKNOWLEDGMENTS

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