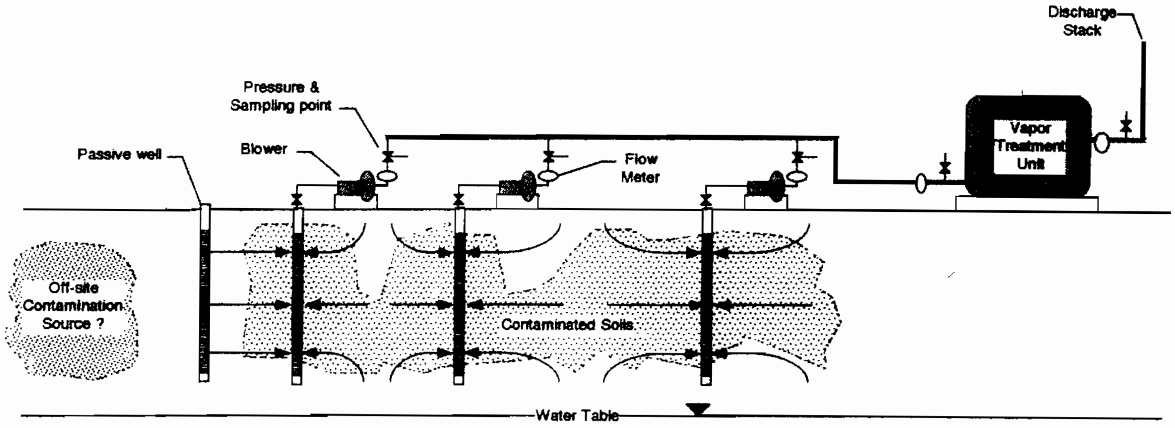
IN-SITU VAPOR EXTRACTION

PREPARED FOR ANORAD CORPORATION

110 OSER AVENUE
HAUPPAUGE, NEW YORK 11788



**Schematic
of
Vapor Extraction System**

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Remediation

MAY, 1992

fanning, phillips & molnar
ENGINEERS
RONKONKOMA NEW YORK

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SECTION 1.0
INTRODUCTION

In order to comply with the Suffolk County Department of Health Service (SCDHS) Order on Consent #IW 89-87, Fanning, Phillips and Molnar was contracted by Twomey, Latham, Shea and Kelley to perform hydrogeologic and engineering studies at the Anorad Corporation, Inc. site (Anorad) located at 100 Oser Avenue in Hauppauge, New York.

In July, 1990, Fanning, Phillips and Molnar conducted a <u>Phase I Investigation of Potential Sources of Contamination</u> at the site. The study included a historical review of site operations, identified areas of concern based on regulatory file reviews, and presented results of shallow soil sampling. In response to the conclusions and recommendations of this study, a Phase II investigation entitled <u>Follow-up Soil Investigation at 100 Oser Avenue, Hauppauge, New York</u> was performed in November, 1990.

The Phase II study included sampling and presentation of deep soil sample results, the installation of 2-inch diameter vapor extraction wells, and an assessment of the groundwater quality. The information obtained in the phase I and II studies identify the nature of contamination in the vadose zone and concluded that the soil has the potential to release contaminants to the groundwater below the site. It followed that Fanning, Phillips and Molnar recommended an Interim Remedial Measure (IRM) to address the vadose zone contamination and a Remedial Investigation (RI) to study the groundwater quality. This document focuses on the former and is based upon a work plan submitted to the SCDHS on August 2, 1991 and the SCDHS's subsequent comments found in a letter dated August 19, 1991.

The purpose of the following report is to determine the feasibility of soil vapor extraction at Anorad. As part of the feasibility analysis, the results of a pilot study conducted on December 17 through December 19, 1991 are presented and summarized.

SECTION 2.0
BACKGROUND

From previous investigations, Fanning, Phillips and Molnar determined that contamination in the vadose zone of the Anorad site was, in part, a result of point discharges by Sands Textile Corp. (the previous owner of the site). The investigations included an analysis of the soil vapor, storm drain sediment, shallow soil, deep soil and groundwater (see Fanning, Phillips and Molnar's Phase I Investigation of Potential Sources of Contamination at 100 Oser Avenue, July, 1990, Follow-up Soil Investigation at 100 Oser Avenue, Hauppauge, New York SCDHS Order on Consent #IW89-87, November, 1990 and Proposed Remedial Investigation at Anorad Corp. 100 Oser Avenue, Hauppauge, New York, June, 1991).

These investigations yield several conclusions, including:

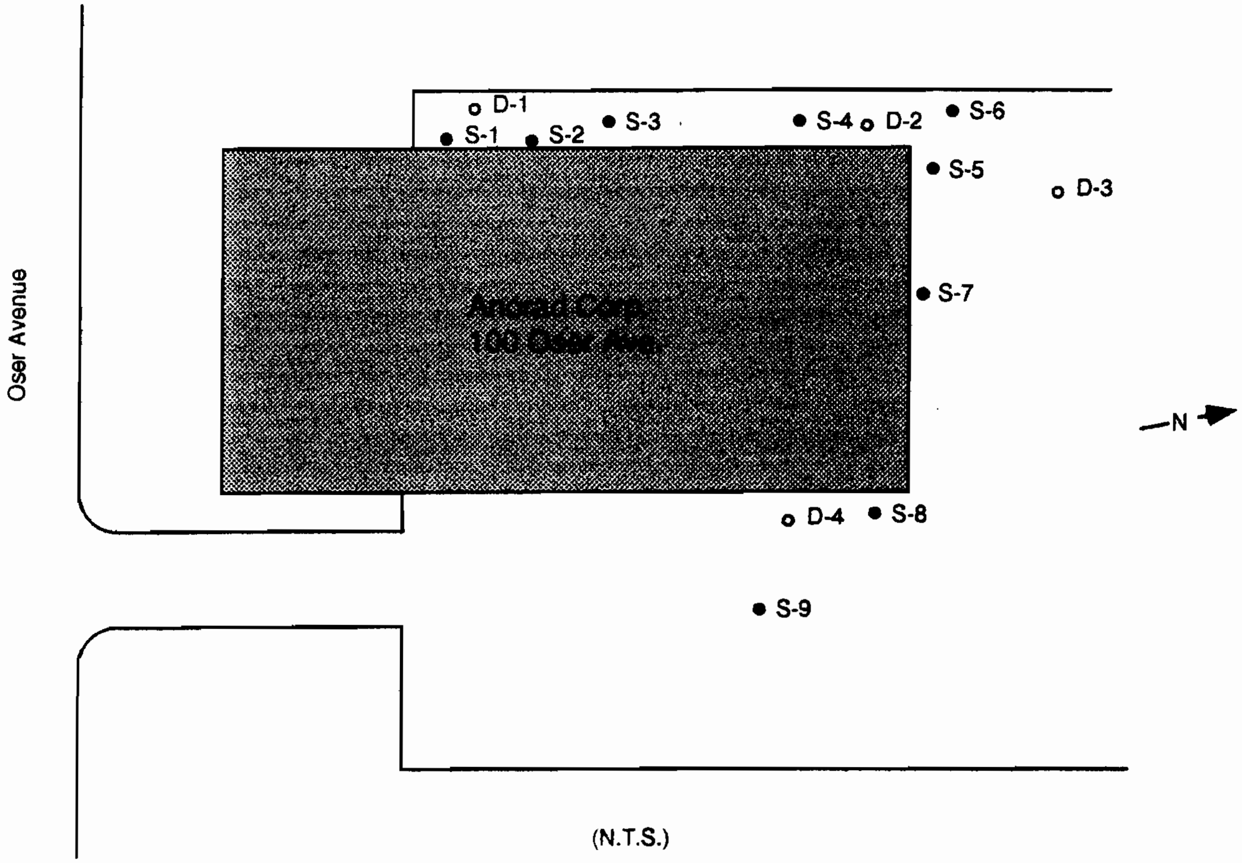
* the source(s) of contamination in the unsaturated zone are limited to three locations on the west side and northwest corner of the 100 Oser Avenue facility,

* the main constituent of the contamination is tetrachloroethene (perchloro-ethylene), and

* the compound has tended to be more concentrated in shallow soils with minimal concentrations at greater depths.

Figure 2.1 and Table 2.1 present the soil sample locations and summarize the analytical results, respectively.

The surficial contaminant concentrations indicate three specific point source discharge locations (S-1, S-2, and S-5). All other sampling of the shallow soils indicate very low levels of contamination. Conversely, the analytical results of the deep soils indicate a somewhat uniform distribution. This is suspected to be the result of the dissolved constituents in groundwater affecting the



Legend:

- ● Shallow Soil Sample Location
- ○ Deep Soil Sample Location/Vapor Well

Note lateral distances between vapor wells are:
D1 to D2 ≈ 72 feet
D1 to D3 ≈ 169 feet
D1 to D4 ≈ 173 feet
D2 to D3 ≈ 92 feet
D2 to D4 ≈ 140 feet
D3 to D4 ≈ 129 feet

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FIGURE 2.1- SOIL SAMPLE LOCATIONS

TABLE 2.1
ANALYTICAL RESULTS OF SHALLOW AND DEEP SOIL SAMPLING[1]
100 OSER AVENUE
HAUPPAUGE, NEW YORK

Location Date Depth of Sample	S-1 5-2-90	S-2 5-2-90	S-3 5-2-90	D-1 8-20-90	S-4 5-2-90	S-5 5-20-90	S-6 5-2-90	D-2 8-20-90	D-3 8-20-90	D-4 8-21-90
	West Side of Building						Northwest Side of Building			East-Northeast Side of Building
	Shallow			Deep		Shallow		Deep		Deep
Detected Compound										
Target Compound List (TCL)										
Volatile Organic Compounds (VOCs)[2]										
Vinyl Chloride	0.084	ND	5.8	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethene	0.030	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1-Dichloroethane	0.044	ND	ND	ND	ND	ND	ND	ND	ND	ND
cis/trans-1,2-Dichloroethene	6.4	12.0	50.0	ND	ND	6.2	ND	ND	ND	ND
Chloroform	0.076	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,1,1-Trichloroethane	1.9	ND	ND	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	48.0	15.0	6.20	ND	ND	170.0	ND	ND	ND	ND
Tetrachloroethene	2,700.0	130.0	8.4	0.015	4.5	12,000.0	ND	16	0.007	0.020
Toluene	0.031	ND	ND	ND	ND	ND	ND	ND	ND	ND
Xylenes	0.037	ND	ND	ND	ND	ND	ND	ND	ND	ND
1,2-Dichlorobenzene	ND	1.5	ND	ND	ND	ND	ND	ND	ND	ND
Acetone	ND	3.1	13.0	ND	2.6	5.9	ND	ND	ND	ND
2-Butanone (MEK)	ND	4.0	8.3	ND	9.6	11.0	2.8	ND	ND	ND
Styrene	ND	ND	ND	ND	ND	1.3	ND	ND	ND	ND
Total TCL VOCs	2,756.60	165.60	91.7	0.015	16.7	12,194.4	2.8	0.016	0.007	0.020

(1) This table presents detected compounds. Note that S-7, S-8 and S-9 have no detected compounds.

(2) All values in this table are in mg/kg.

ND Indicates not detected.

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soils above the water table through water table fluctuations and capillary action of the water.

During the Follow-up Soil Investigation, Fanning, Phillips and Molnar performed deep soil sampling via boreholes. Upon completion of the sampling activities, the boreholes were converted to vapor wells in an effort to aid future investigations and/or remediation. The location of the wells were based on knowledge of the site conditions and accessibility of the drill rig. As shown in Figure 2.1, the wells were installed with lateral distances ranging between 70 and 140 feet on center depending on the well combination.

The vapor wells were constructed to a depth of approximately sixty-three feet below the surface, rest approximately five feet above the water table, and consist of two-inch diameter slotted PVC pipe throughout the vadose zone. The upper three-feet is constructed of solid PVC pipe and is sealed by bentonite pellets and grout. One vapor well was placed on the west side (D-1), two near the northwest corner (D-2 and D-3) and one on the east side of the site (D-4). Appendix A presents the construction details of vapor wells D1, D2, D3 and D4.

SECTION 3.0
CONTAMINANT SUITABILITY, DISPERSION AND MASS

This section will analyze and estimate the contaminant's suitability to soil vapor extraction, dispersion characteristics and estimated mass in the unsaturated zone. The information presented in this section is necessary for the development and analysis of the pilot study which is presented in Section 4.

3.1 Suitability of Vapor Extraction Technology

Two physical characteristics of volatile organic compounds are used as guidelines to determine if soil vapor extraction will be successful: vapor pressure and the Henry's Law Constant of a given compound. In general, compounds with vapor pressures greater than or equal to 1.0 mm of Hg at 20°C and a Henry's Law Constant greater than 100 ATM/mole fraction are well suited. Table 3.1 summarizes the physical characteristics of the compounds detected at the site.

Table 3.1 presents some noteworthy facts. More than 97 percent of the contamination at the site is tetrachloroethene: an extremely volatile compound. The vapor pressure and Henry's Law Constant for the compounds evidence their suitability for vapor extraction (99.6% of the contamination is suitable). Two compounds, namely acetone and 2-butanone, because of their high water solubility have marginal Henry's constants. Table 3.2 lists a few soil extraction projects which remediation includes the extraction of both acetone and 2-butanone. In addition, it appears that sites with favorable conditions (i.e., soil permeability) have an additional influence on marginal compounds - bioremediation. With the increase in oxygen supply, degradation of both the volatiles and semi-volatiles are

TABLE 3.1
CONTAMINANT PROPERTIES AND AVERAGE CONCENTRATIONS

Detected Compound	Chemical Formula	Molecular Weight	Average Concentrations[1] µg/kg	Contaminant's % of The Total	Vapor Pressure @ 20°C mm of Hg	Henry's Constant ATM/Mole Fraction
Vinyl Chloride	C_2H_3Cl	62.50	655	<0.1	2530	1245
1,1-Dichloroethene	$C_2H_2Cl_2$	96.94	3	<0.1	510	834
1,1-Dichloroethane	$C_2H_4Cl_2$	98.96	5	<0.1	217	303
Cis/Trans-1,2-Dichloroethene	$C_2H_2Cl_2$	96.94	8,290	0.5	295	296
Chloroform	$CHCl_3$	119.37	8	<0.1	189	225
1,1,1-Trichloroethane	$C_2H_3Cl_3$	133.40	211	<0.1	100	274
Trichloroethene	C_2HCl_3	131.38	26,578	1.6	65	651
Tetrachloroethene	C_2Cl_4	165.82	1,649,216	97.5	15	1492
Toluene	C_7H_8	92.15	3	<0.1	26	367
Xylenes	C_8H_{10}	106.18	4	<0.1	7	313
1,2-Dichlorobenzene	$C_6H_4Cl_2$	147.00	167	<0.1	1	164
Acetone	C_3H_6O	58.09	2,733	0.2	216	2
2-Butanone (MEK)	C_4H_8O	72.12	3,966	0.2	84	3
Styrene	C_8H_8	104.16	144	<0.1	7	146

1- Average concentration of the detected compounds within the zone of contamination as presented on Plate 1.

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TABLE 3.2*
SOIL EXTRACTION OPERATIONS WHICH INCLUDE LOW HENRY'S CONSTANT COMPOUNDS

Site	Chemicals Present With Low Henry's Constants	Site Geology	Status of Cleanup
TIME OIL COMPANY Work Assignment No. 74-ON14.1 Tacoma, Washington	Naphthalene, 2-Methylnaphthalene 2-butanone (MEK) Acetone	Sand and gravel with some silt	240 lbs ongoing
PAINT STORAGE WAREHOUSE Dayton, Ohio	Acetone Ketones	Sandy soil with clay strata sands and gravels	>7800 lbs after 165 days ongoing
THOMAS SOLVENT COMPANY Superfund Site-Battle Creek, Michigan	Naphthalene 2-butanone (MEK) Acetone	Sand and gravel alluvial deposit over sandstone	ongoing

* Source - Hutzler, Neil J., State of Technology Review Soil Vapor Extraction Systems, 1989.

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enhanced. All of these facts lend to vapor extraction as an effective remedial technology.

3.2 Contaminant Dispersion Characteristics

At the Anorad site, nine shallow soil samples, four deep soil samples, four groundwater samples and soil vapor readings from 73 locations have assisted in delineating the extent of the contamination.

The gas plume has developed from three point source discharges at the surface (S-1, S-2, and S-5). In order to estimate the dispersion of the contaminated soil, Fanning, Phillips and Molnar consulted model experiments performed by Friedrich Schwille (Schwille, 1988). Schwille's experiments on dense chlorinated solvents spreading as a fluid phase in porous media indicate:

* Chlorinated solvents will penetrate a dry formation (air filled pores) more quickly than water due to their higher densities and lower viscosities.

* Chlorinated solvents will mound on water filled pours until the solvent develops sufficient head to drive out the water and penetrate the pore.

* In general, the chlorinated solvents penetrate porous media contracting (or becoming narrower) with depth - until a less permeable lens is intersected: a permeability of 1-2 x 10^{-2} cm/sec. will restrict the infiltration of chlorinated solvents.

An estimate of vertical dispersion had to be made to complete the 3 dimensional picture of soil contamination. Based on Schwille's findings and Fanning, Phillips and Molnar's knowledge of the site geology, very little a dispersion is expected from the surface.

A detailed review of the previous sampling data and our assumed limits of contamination is supported by the model experiments of Schwille.

3.3 Mass Calculations

Several assumptions were made to determine the average concentration in the unsaturated zone. First, the highest levels showed up in the shallow samples. In fact, only trace amounts of contamination is observed in the deep samples. Hence, the average concentration was calculated to be the highest level observed divided by 2 for the full length of the vadose zone. The results shown in Table 3.3 estimate the existence of 13,725 lbs of TCE at the locations displayed in Figure 3.1.

In addition to Schwille's experiments on dispersion, column and trough experiments investigated the retention capacities of porous media. Schwille determined that porous soils have a particularly high retention capacity with respect to draining time. This fact combined with the vertical separation between samples makes it difficult to estimate the mass of contaminates at the site. However, Fanning, Phillips and Molnar believes that several conclusions can be made regarding the contamination.

- Point sources have released contaminates to the subsurfaced in three locations (S-1, S-2, and S-5).
- The dispersion of the contamination is expected to be minimum vertically.
- The majority of the contaminates are bound in the surface or near surface soils.

TABLE 3.3
THEORETICAL MASS CALCULATION

Shallow Zone	Contaminated Zone	Average TCE Concentration	Mass[1] (lbs)
S1	10' Radius 60' Deep	$\frac{2.7 \times 10^6}{2}$ ug/kg	2,500
S2	10' Radius 60' Deep	$\frac{.130 \times 10^6}{2}$ ug/kg	125
S5	10' Radius 60' Deep	$\frac{12}{2} \times 10^6$ ug/kg	11,100

1 - Assuming a soil density of 98 lbs/cu. ft.

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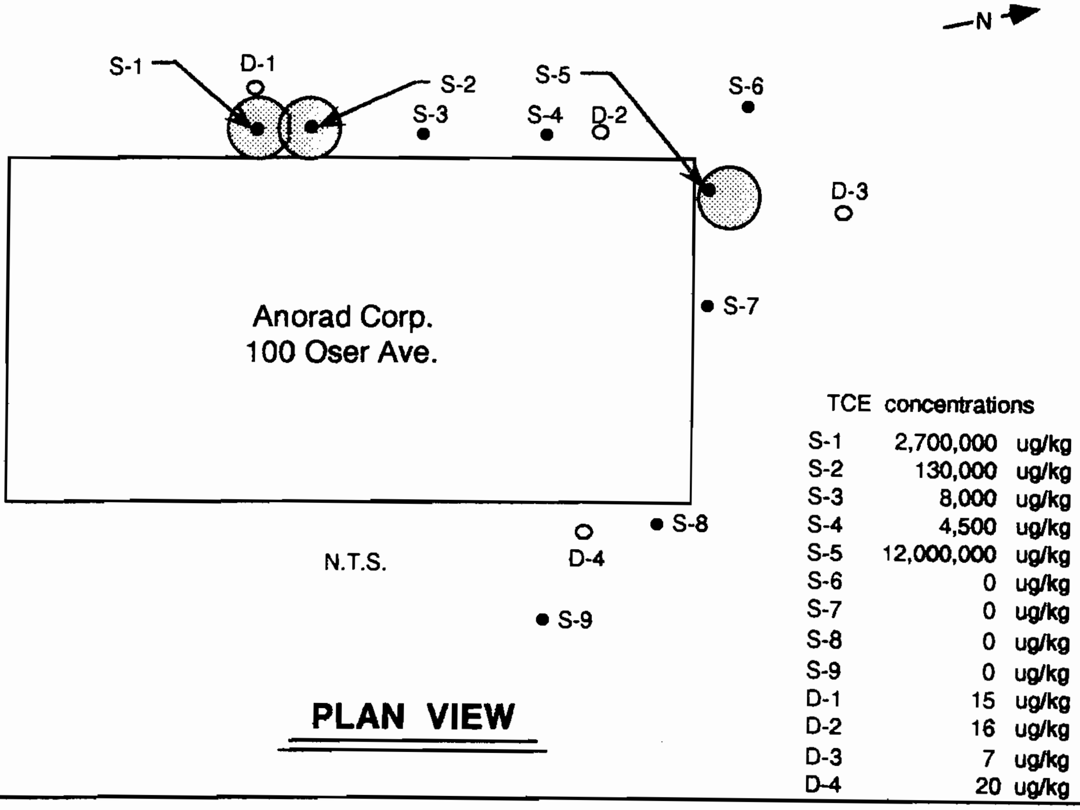
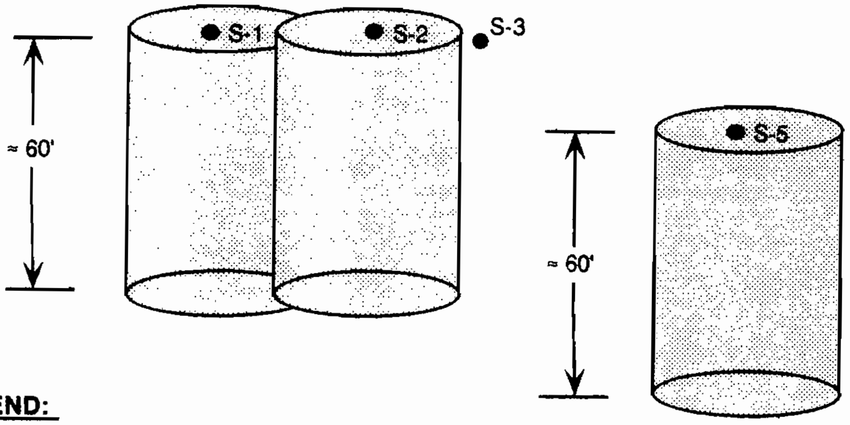


PLAN VIEW

TCE	concentrations	
S-1	2,700,000	ug/kg
S-2	130,000	ug/kg
S-3	8,000	ug/kg
S-4	4,500	ug/kg
S-5	12,000,000	ug/kg
S-6	0	ug/kg
S-7	0	ug/kg
S-8	0	ug/kg
S-9	0	ug/kg
D-1	15	ug/kg
D-2	16	ug/kg
D-3	7	ug/kg
D-4	20	ug/kg

ISOMETRIC VIEW



LEDEND:

● SHALLOW SOIL SAMPLE LOCATION

○ DEEP SOIL SAMPLE LOCATION/VAPOR WELL

☐ ESTIMATED LIMITS OF CONTAMINATION

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F,P & M **FIGURE 3.1- ESTIMATED LIMITS OF CONTAMINATION**

SECTION 4.0
PILOT STUDY

On December 17, 1991 through December 19, 1991, a pilot study was performed at the Anorad site. The objective of the pilot study was to verify vapor extraction as a feasible remedial technology at the site. This section addresses this objective by reviewing the theory of vapor extraction systems, discussing the rationale of the pilot study and presenting the pilot study results.

4.1 Theory of Soil Vapor Extraction

Soil vapor extraction is a technique where air is extracted from a contaminated soil by means of a vacuum pump. Air which is drawn through contaminated soils become laden with volatile organic compounds (VOCs) which have an affinity to vaporize from the adsorbed or liquid phase. The air containing VOCs is replaced by air from surrounding clean soils and/or the atmosphere: the movement of the air through the contaminated zone enhances the evaporation of VOCs.

As previously discussed, two chemical properties of VOCs are used to indicate the degree of soil vapor extraction success. The primary chemical properties of concern are the vapor pressure and Henry's Law Constant of a given compound. Soil vapor extraction systems are, therefore, most effective in removing compounds which are volatile at ambient subsurface temperatures. All compounds present at the site have been verified as suitable to vapor extraction as presented in Section 3.1.

The extraction of chemicals is also enhanced by geologic conditions, especially dry porous granular media such as sand and gravel. Previous investigations at the site have concluded that the geology found at 100 Oser Avenue consists of gravelly sands.

Furthermore, the asphalt pavement, which covers most of the area of concern, provides a barrier to the infiltration of rain water and atmospheric air. This barrier to weather elements increases the radius of influence from a vapor well. Figure 4.1 is a schematic of a vapor flow net and shows the qualitative effect of an impermeable surface. The figure illustrates how an impermeable asphalt surface magnifies equipotential pressure lines, and hence, the radius of influence, to propagate greater in lateral directions. Conversely, where no impermeable cap exists, smaller influence areas tend to form. It is important to note that under a perfect seal, equipotential lines are perpendicular to groundwater flow (a two barrier condition).

The flow of air through soils to an extraction well is analogous to groundwater dynamics. Since both air (at standard conditions) and groundwater are noncompressible fluids, their dynamic behavior is basically the same. Therefore, when a negative pressure is applied to an extraction well pressure gradients towards the well are formed. The pressure gradients are similar in appearance and function to drawdown cones in water wells.

Likewise, when applying a vacuum to a well, an area of influence is generated. Essentially, this influence area can be considered the area from which a well is removing vapors. The size and extent of the influence area is affected by many factors including: the vertical and horizontal pneumatic conductivities, the location of physical barriers in the subsurface and the existence of impermeable surface seals such as asphalt.

An important consideration in reference to the influence area is

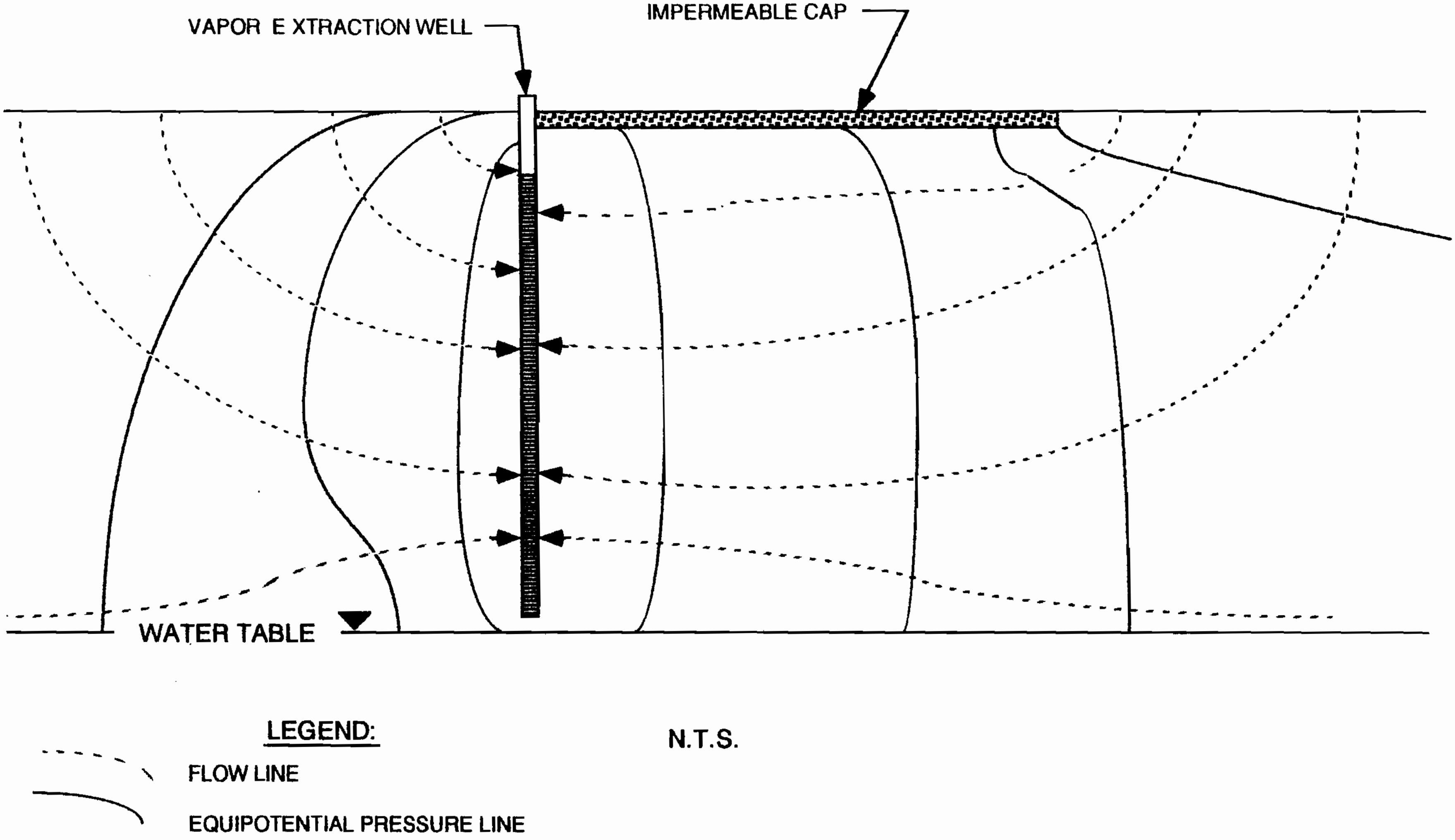

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FIGURE 4.1- VAPOR FLOW NET SCHEMATIC

potentially drawing contaminants from outside sources towards the site. This is especially critical at the subject since upgradient contaminant sources are suspected to exist nearby. Solutions to resolve this concern include: (1) adjusting the extraction rate to attain only the desired influence area, and (2) installing physical barriers. The former is dependent on geologic conditions and site constraints and requires an in depth knowledge of the subsurface conditions and costly trial and error fielding testing. The latter could be installed to control the flow from certain areas (for example, bentonite/slurry walls or sheeting). However, with a 60 foot unsaturated zone at the subject site, this alternative is not cost effective.

Alternatively, passive or forced injection wells can be installed between the extraction well and an off-site contaminant source. Passive wells are wells in the vadose zone which are open to the atmosphere. These wells, placed within the zone of influence of an extraction well, introduce atmospheric pressure to the subsurface; and hence, restrict the migration beyond the passive well. Forced injection wells, on the other hand, are wells in which clean air is reinjected into the subsurface. Similar to passive wells, they are placed between the extraction well and the suspected off-site source, and introduce pressure gradients which prevent the migration of off-site sources toward an extraction system. Forced injection wells also improve the efficiency of a treatment system by increasing pressure gradients to the extraction well.

4.2 Rationale of Study

The pilot study was performed to study the dynamic behavior of air flow through the vadose zone to verify that soil vapor extraction can influence all areas of concern.

To study the effects of pumping, pressure measurement in the subsurface was required at various times, depths and locations. This was achieved by installing and monitoring shallow vapor probes and vapor probe clusters. The shallow vapor probes consisted of a single well which penetrated the subsurface to a depth of 5 feet. The vapor probe clusters consisted of four individual 1 inch diameter wells screened and isolated from each other at various discrete depths. A schematic drawing of the shallow vapor probes and the vapor probe clusters are found in Figures 4.2 and 4.3, respectively.

The shallow vapor probes were set at a radial distance of twenty-five feet from each of the extraction wells and located ninety degrees apart to determine horizontal or lateral pressure gradients. These surface readings were targeted to identify any physical barriers in the subsurface (i.e., low permeability areas and/or atmospheric influences). The vapor clusters were placed in locations central to all of the extraction wells and facilitate vertical pressure readings. The data obtained from the deeper probes sought to identify pressure variations with depth, verify influences at all depths, and identify the depth with the least negative pressure thereby discovering one critical zone. Plate 1, the conceptual vapor extraction plan and site plan, depicts the locations of these devices.

To determine the dynamics of vapor flow, three extraction wells (D1, D2 and D3) were pumped during three individual tests. Prior to (background) and during the pumping of each well, the negative pressure at each shallow and deep vapor probe was measured. Each

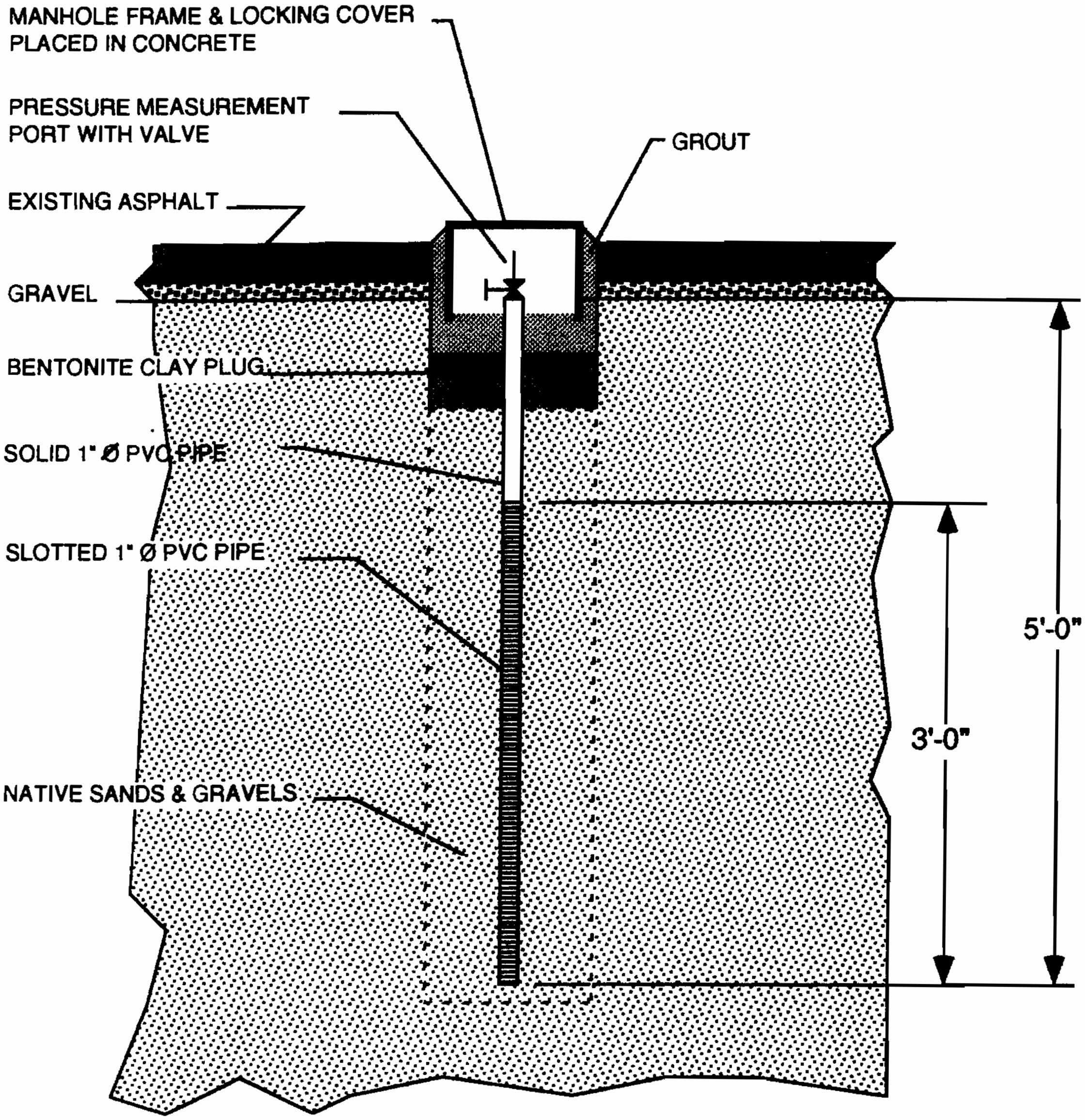

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FIGURE 4.2 - SHALLOW VAPOR PROBE CONSTRUCTION

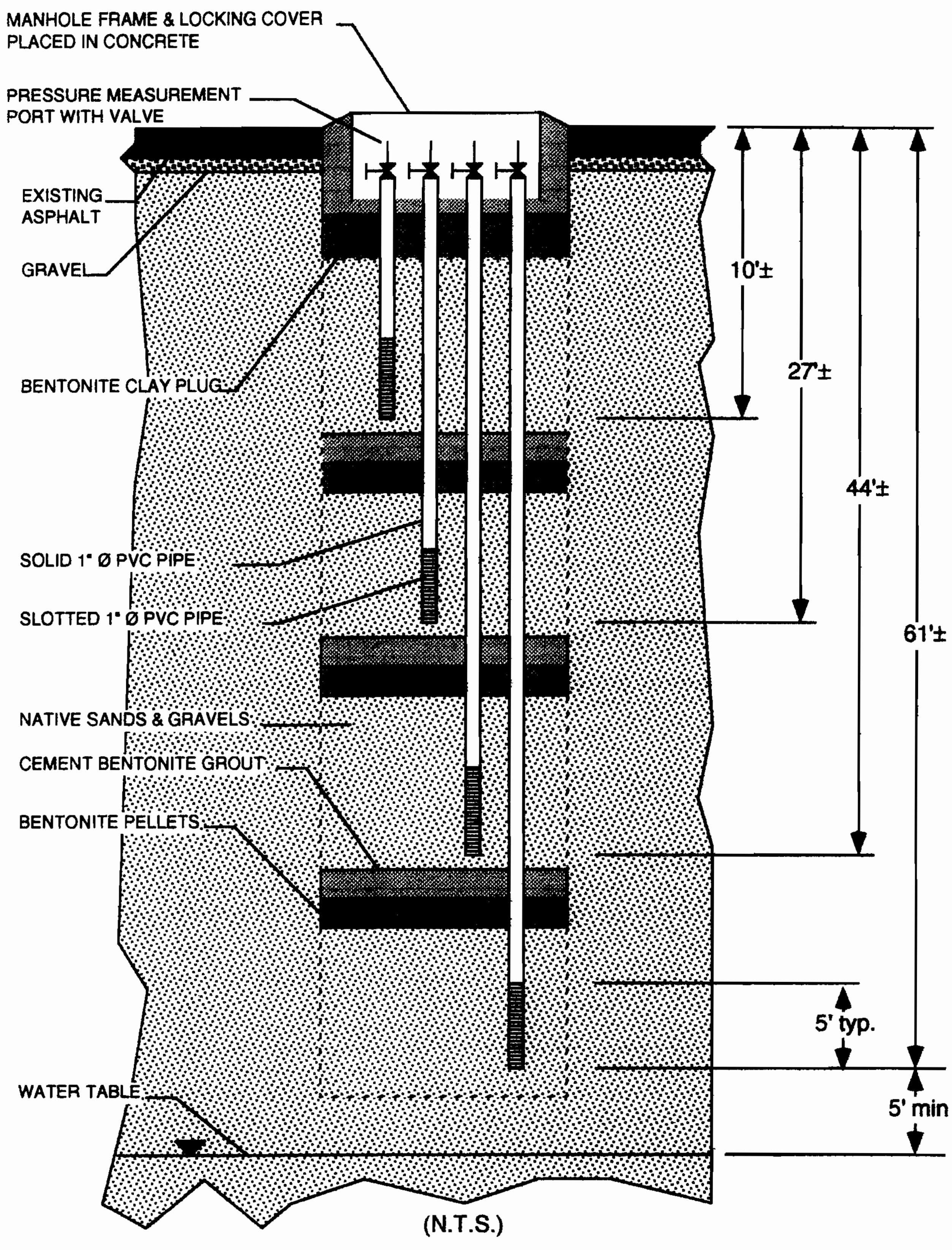

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FIGURE 4.3 - VAPOR PROBE CLUSTER CONSTRUCTION

measurement point was monitored approximately every fifteen minutes over a test period of roughly three hours for each test. This allowed the dynamic response from pumping in the subsurface to be determined. Pressure measurements were made using standard magnehelic vacuum gauges.

The approved work plan required pumping two wells at a single flowrate: the constant flowrate test was performed on D1 and D3. To supplement this data, the work plan detailed one of the wells to be pumped at varied rates to determine the effects on the influence area and contaminant removal. Vapor well D2 was utilized for this "step-pump" test.

In addition to the measurement of flowrates, total VOC concentrations were measured by a photoionization detector (PID) prior to and following treatment via a vapor phase granular activated carbon (GAC) filter.

4.3 Presentation of Results

Table 4.1 is a summary of the steady-state data collected during the vapor extraction from wells D-1, D-2, and D-3. A full presentation of the field data collected can be found in Appendix B of this report.

Due to variations in barometric pressure during the course of the pumping tests, some error in the pressure measurements was observed. The field error is attributed to three sources: atmospheric pressure, measurement, and equipment error. The effect of atmospheric pressure could be seen if atmospheric readings fluctuated during a given test (about 3 hours).

Typical variations in the pilot study data suggest an error range

TABLE 4.1

SUMMARY OF PILOT STUDY DATA
ANORAD CORPORATION, INC.

Extraction Well	D-1		D-2		D-2		D-2		D-3	
Influent Flow Rate (cfm)	72		42		56		72		72	
Influent Concentration (ppm)	6743		3726		4314		4370		1223	
Point	Radial Dist. feet	S.S. Δ P in. H2O	Radial Dist. feet	S.S. Δ P in. H2O	Radial Dist. feet	S.S. Δ P in. H2O	Radial Dist. feet	S.S. Δ P in. H2O	Radial Dist. feet	S.S. Δ P in. H2O
VP-1	25	-0.10	104	0.15	104	0.01	104	0.00	194	-0.03
VP-2	25	-0.11	54	0.09	54	0.00	54	-0.04	145	-0.02
VP-3	54	-0.01	25	0.07	25	-0.12	25	-0.08	116	-0.01
VC-1R	104	0.04	25	0.25	25	-0.03	25	-0.11	68	-0.14
VC-1B	104	0.02	25	0.26	25	-0.04	25	-0.09	68	-0.18
VC-1G	104	0.04	25	0.21	25	-0.07	25	-0.12	68	-0.15
VC-1W	104	0.01	25	0.18	25	-0.09	25	-0.13	68	-0.12
VP-4	148	0.02	69	0.10	69	-0.01	69	-0.03	24	-0.23
VP-5	178	0.02	100	0.14	100	0.00	100	-0.03	26	-0.20
VP-6	192	0.01	116	0.15	116	0.00	116	-0.01	25	-0.28
VP-7	165	0.00	92	0.11	92	-0.01	92	-0.02	25	-0.17
VC-2R	196	0.03	135	0.16	135	0.05	135	-0.04	76	-0.06
VC-2B	196	0.02	135	0.16	135	0.04	135	-0.04	76	-0.12
VC-2G	196	0.02	135	0.03	135	0.01	135	-0.06	76	-0.09
VC-2W	196	-0.01	135	0.12	135	0.00	135	-0.05	76	-0.08
VP-8	188	0.00	145	0.04	145	0.00	145	-0.03	118	-0.02
VP-9	191	0.01	163	0.07	163	-0.01	163	0.01	152	-0.01
VP-10	158	0.00	138	0.07	138	0.00	138	-0.01	144	0.00

Note: S.S. Δ P denotes the total change in pressure measured noted at steady state conditions.
Radial distance is the distance from the extraction well to the subject monitoring point.

of plus or minus 0.03 inches of water. Applying an additional factor of safety, a negative pressure of 0.05 inches of water was conservatively selected to account for field errors. Thus, the approximate radius of influence of the extraction wells was defined as the radius at which a pressure change of 0.05 inches of water was achieved.

Based upon the data and our defined limit of the radius of influence, the pressure drop versus radial distance from the extraction wells was plotted. Figures 4.4 through 4.6 illustrate the steady-state condition of this correlation. From these graphs, an approximate radius of influence of each well has been determined for a given flowrate. Figure 4.4 and 4.6 show a radius of influence of 42 and 96 feet for vapor well D1 and D3, respectively. The large disparity in the radius of influence is explained by two field observations: D-3 is primarily surrounded by impermeable surfaces and D-1 is located close to a drainpool causing saturated and clogged soil (fine silts) conditions.

As mentioned, in addition to pumping D1 and D3 at one flowrate, vapor well D-2 was tested at three flowrates to simulate a step-pump test. The purpose of this test was to identify the corresponding radius of influence of several flowrates. This data could then be utilized to develop a relationship between Q and R.

Vapor well D-2 was first pumped at approximately 42 cubic feet per minute (cfm). As presented in Table 4.1, data collected from this test had large variations in pressure readings. In fact, a close examination of this data indicates large increases in pressure. During the course of this test, the weather fluctuated between low to

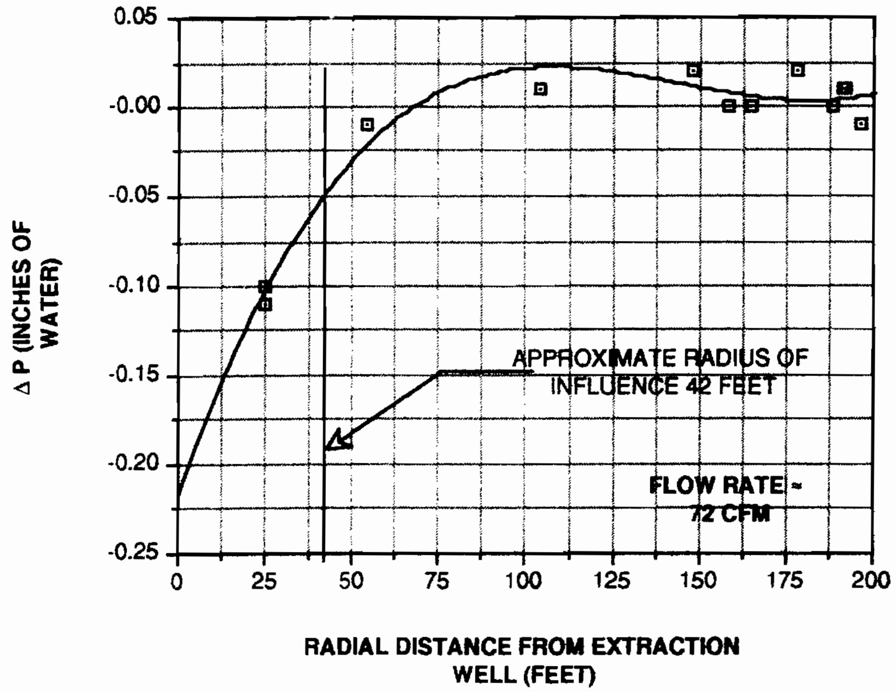

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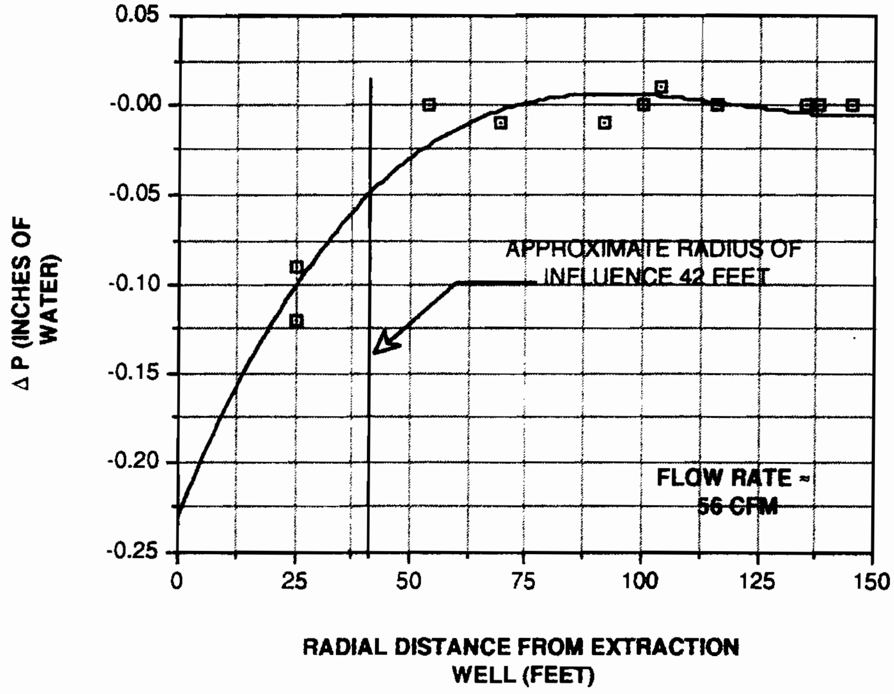
FIGURE 4.4 - INFLUENCE FROM EXTRACTION WELL D -1



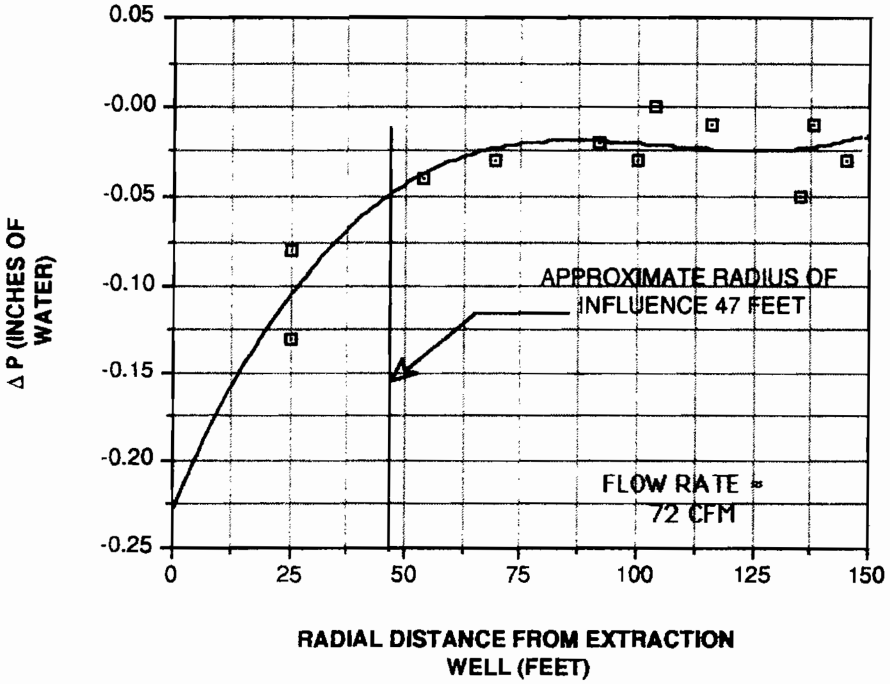


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FIGURE 4.5 INFLUENCE FROM EXTRACTION WELL D-2

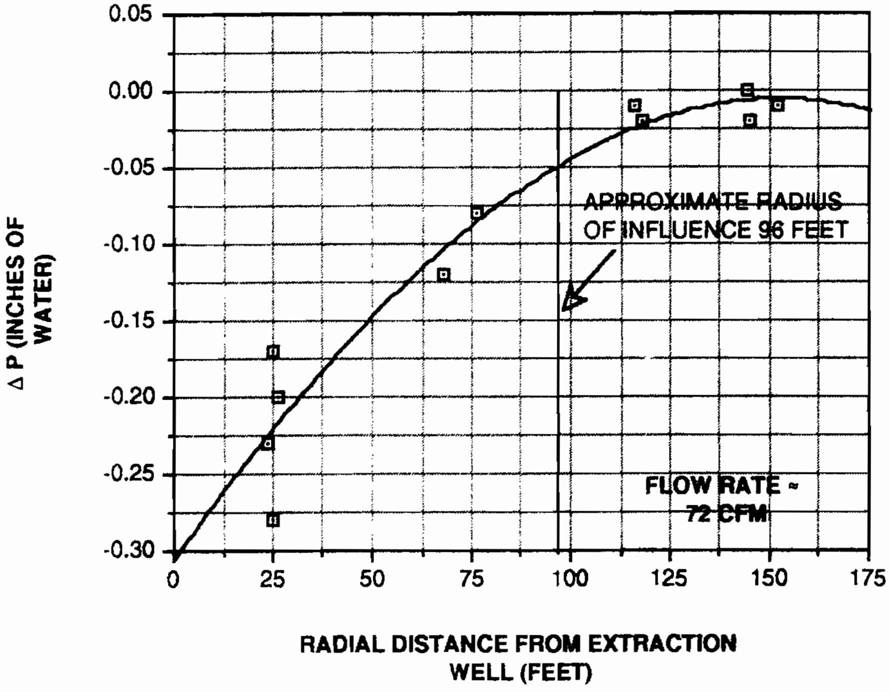

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FIGURE 4.6 INFLUENCE FROM EXTRACTION WELL D-3 high atmospheric pressures. The background fluctuation (and, hence, the subsurface readings for a given time period) follows the same pattern (refer to the field data for D-2 on 12/17/91). Fanning, Phillips and Molnar has concluded that the 42 cfm pump test on D-2 has produced unreliable data due to atmospheric changes.

On the next day, after the weather conditions subsided, the extraction rate from D-2 was increased to an intermediate flowrate of 56 cfm. As presented in Figure 4.5, a radius of influence of approximately 42 feet is associated with this flowrate. When the flowrate was increased to 72 cfm the radius of influence increases to about 47 feet. Therefore, at D-2, a 28% increase in flowrate results in a 12% increase in radius.

Based upon the data obtained from the tests at D-2, an empirical relationship can be defined for Q and R:

$$\frac{Q_1}{R_1^2} \approx \frac{Q_2}{R_2^2}$$

Where Q_1 = Flowrate 1
R_1 = Radius of influence at flowrate 1
Q_2 = Flowrate 2
R_2 = Radius of influence at flowrate 2

Again, the radius of influence was defined to be the distance from the well where the negative pressure is equivalent to 0.05 inches of water.

It is interesting to note that this relationship is representative of a theoretical situation in which the velocity beyond the radius of influence is zero and the velocity entering the system from top and bottom is constant for two different flowrates. Since the empirical data closely matches theoretical derivation (approximately 3% error), this relationship is a good model for well D-2. This suggests that at 42 cfm, D-2 would have yielded a 36 foot radius of influence.

SECTION 5.0
CONCEPTUAL DESIGN AND COST ESTIMATE

This section will explore the conceptual design of the remedial system. The conceptual design is based on design assumptions presented, an evaluation of alternatives and cost estimate.

5.1 Design Assumptions

Prior to developing alternatives for the site and a conceptual design, several design assumptions need to be identified:

- The contamination has predominantly resulted due to three point source discharges near S-1, S-2, and S-5.
- The site geology is predominantly porous granular media.
- Although a gas mound has laterally extended a number of feet beyond the point source discharges, the fluid contaminant is expected to be within a 10 - 15 foot radius of the discharge point.
- For the purposes of a conceptual design, the relationship developed in Section 4.3 ($Q_1/R_1^2 \approx Q_2/R_2^2$) can be assumed consistent for each well. Hence, with one set of data at each well, the design flowrate for a given well can be determined for a desired radius of influence.

5.2 Alternatives

There are three alternatives being considered for the solution of this contaminated soil problem:

1. Engineered vapor extraction system with three separate alternatives for handling the contaminated air that will be generated from this vapor extraction system[1].
2. Soil excavation of hot spots with natural soil vapor extraction and capping.
3. Capping.

---

[1] Appendix D verifies the need of air treatment at relatively high flow rates.

The first alternative deals with engineering a vapor extraction system. That conceptual design of the vapor extraction system is shown in Figure 5.1 and Plate 1. Figure 5.1 has three vapor extraction wells (D1, D-2, and D-3) connected by a header pipe and then by a blower system operating at 360 cfm[2]. The vapor extraction system would lead into one of three possible alternatives for handling the contaminated vapors:

1a. Engineered vapor extraction system with incineration: this system calls for the thermal destruction of the tetrachloroethylene molecule. Catalytic incineration is anticipated[3].

1b. Engineered vapor extraction system with granular activated carbon (GAC) and onsite carbon regeneration: this would entail capturing the tetrachloroethylene on an activated carbon bed with onsite regeneration with steam. The onsite regeneration would produce a pure tetrachloroethylene side stream and contaminated water which must be handled as a hazardous waste.

1c. Engineered vapor extraction system with GAC and off site regeneration: this is with off-site regeneration. The carbon beds would be filled and then shipped off-site for regeneration. No hazardous waste would be generated onsite except for the carbon itself.

2. The second alternative is soil excavation of hot spots natural venting and capping. There are three hot spots that are fairly close to the surface that can be remediated rather quickly, S-1, S-2, and S-5. It is proposed that three feet of soil be excavated here where a majority of the PCE is bound into the soil. In addition, deep vapor wells would be installed at these three locations; 1, 2, and 5. A turbine wind driven fan would be utilized to naturally draw out the gases from the contaminated zones. These vents would have to be slightly above rooftop level. It is estimated that the size of the pipe should be approximately 12". Finally, these areas would be capped with asphalt and a drain installed to seal these areas.

3. The final alternative would be paving over the area so that no

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[2] Appendix H derives this flow rate.

[3] Appendices E and F describe the catalytic oxidation of tetrachloroethylene and the resultant air emission levels.

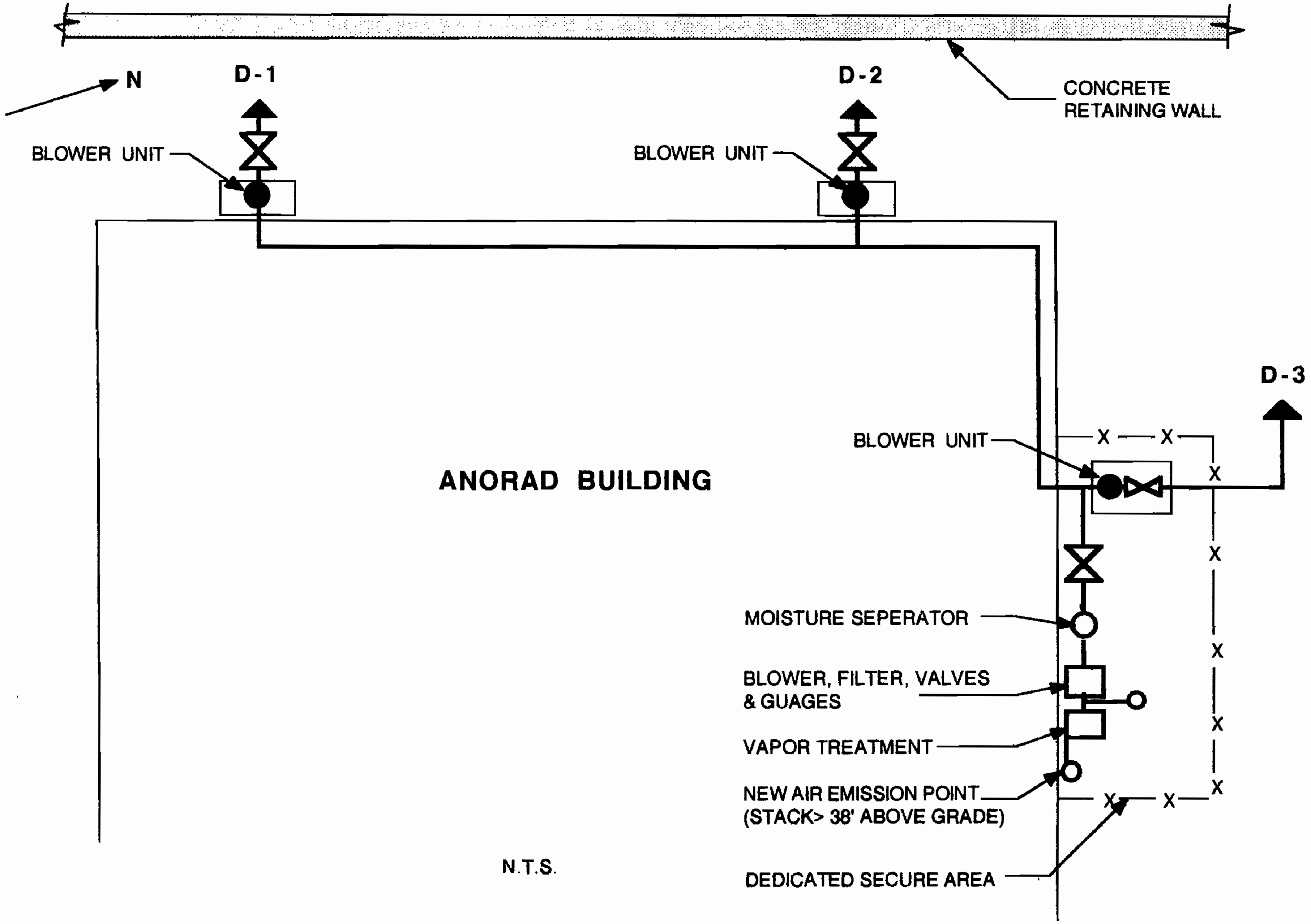

FIGURE 5.1 - CONCEPTUAL VAPOR EXTRACTION SYSTEM PLAN.

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TABLE 5.1
SUMMARY OF CLEANUP ALTERNATIVES[1]

ALTERNATIVES[2]		DESIGN FLOW	DURATION OF OPERATION	CAPITAL COST	AVERAGE ANNUAL O&M COST
1a.	Incineration	360 cfm	1-8 years	$250,000	$37,000
1b.	Onsite regeneration (VIC System)	360 cfm	1-8 years	280,000	30,000
1c.	Off-site Regeneration	360 cfm	1-8 years	145,000	Large Variation
2.	Soil excavation/natural flow and capping	15 cfm	2-30+ years	60,000	10,000
3.	Capping	0 cfm	N/A	10,000	N/A

(1) These prices do not include standard contingency factors of plus or minus 25%.

(2) Alternatives 1a-1c include capital costs of $54,000 attributed for blowers, piping, and other VES components and $40,000 towards engineering design, inspection and permitting. Alternative 2 includes capital costs of $40,000 for 3 feet of soil removal, wells, turbines, and $20,000 for design, inspection and permitting. Alternative 3 has no costs additional to capping.

ccr-ar2

water could infiltrate through the surface and cause any migration of the PCE into the groundwater.

Table 5.1 shows the summary of the cleanup alternatives, design flowrates, the duration of operation, capital costs, and O&M costs. The first three alternatives (1a, 1b, and 1c) have fairly quick time for cleanup of the soil, in one to eight years depending upon the true level of contamination. The second alternative really could take between two and thirty years to cleanup the operation. The second alternative would also have capping such that no water would be allowed to drain through this area.

SECTION 6.0
CONCLUSIONS AND RECOMMENDATIONS

This section will review the conclusions and recommendations of the pilot and feasibility study analysis for the Anorad site. In general, the findings of this report verify and confirm the application of soil vapor extraction.

Conclusions

The following conclusions can be drawn from Fanning, Phillips and Molnar's analysis.

- Contamination is present primarily on the western side of the site. The source of the contamination has been determined to be, in part, the result of discharges from Sands Textile Corp. (the previous owner of the site).

- The background (Section 2.0) summarizes previous Fanning, Phillips and Molnar's investigations and identifies contamination to be present on the west side and northwest corner of the facility. The primary constituent of contamination is tetrachloroethylene (refer to Figure 2.1 and Table 2.1). In addition, during previous investigations three vapor extraction wells were installed within the zone of contamination (D-1, D-2, and D-3).

- Of the detected compounds discovered at the site, tetrachloroethylene represents more than 97% of the total volatile organic compounds found at the site. All of the compounds detected have an infinity for soil vapor extraction: acetone and 2-butanone have been verified as compounds amenable to soil vapor extraction based upon case studies (refer to Table 3.2).

- The tetrachloroethylene was assumed to disperse in the vadose zone straight down. This is based upon model experiments performed by Frederick Schwille.

- The pilot study was performed in December, 1991 and consisted of monitoring several shallow vapor probes and deep vapor probe clusters, while performing three separate well pump tests (D-1, D-2, and D-3). Gas extraction well D-1 and D-3 were tested at a constant flowrate while extraction well D-2 was utilized as a pump test.

- Based upon the pilot study results, a relationship was defined for Q and R ($Q_1/R_1^2 \approx Q_2/R_2^2$). This relationship was found consistent with the theoretical situation, where velocity beyond the radius of influence is zero and the average velocity entering the system from top and bottom defines a radius of influence for a given flow. The field tests indicate a 3 percent error from the theoretical model.

- A PC-based interactive model was utilized to estimate the duration of cleanup. The model predicts D-1, D-2, and D-3 to attain 99% removal between 1 and 8 years. A sensitivity analysis of the model indicated that air permeability of the soil (assumed to be 0.1 darcy) can greatly influence the model results (i.e., as great as 50%). Based upon these findings, Fanning, Phillips and Molnar utilized an estimated cleanup duration of 1-8 years for cost purposes. Appendix C presents the model output.

- Based upon the relationship developed between Q and R, designed flowrates were developed: D-1, D-2, and D-3 require gas extraction rates of 100, 215, and 45 cfm, respectively. Based upon sound engineering practice, the blower system should be capable of pumping between 150 and 600 cfm.

- Several emission treatment alternatives were presented and analyzed based upon their anticipated removal efficiencies and costs. Based upon the analysis in Section 5.4, soil excavation and natural soil venting and capping is recommended. Although longer in duration, this alternative will remove the highly contaminated soils, cap the area and address the residual PCE with long term venting at a reasonable cost.

- Section 7.0 presents a schedule of implementation. Based upon the schedule, the cleanup project can begin operation in mid 1993.

Recommendations

Fanning, Phillips and Molnar recommends that this study be reviewed and submitted to the Suffolk county Department of Health Services for comments. Based upon the County's review and comments, a final design should be initiated according to the schedule presented in Section 7.0. Additional considerations during the design phase should include the following:

- Careful pneumatic considerations and controls should be performed and designed to conform with the most current air regulations. An evaluation of future Clean Air Act amendments may change the long-term treatment project.
- Rerouting of the surface drainage along the west and northwest side of the building to an area outside of the zone of contamination.
- Additional sealing of the asphalt above the zone of contamination (adjacent to the retaining wall in the ally and in the northwest corner of the site.

SECTION 7.0
SCHEDULE

In order to begin the remediation of the contaminated vadose zone, coordination among Fanning, Phillips and Molnar, Anorad Corporation, Suffolk County Department of Health Services and the New York State Department of Environmental Conservation will be imperative. Figure 7.1 illustrates the proposed schedule and the interaction required from these parties.

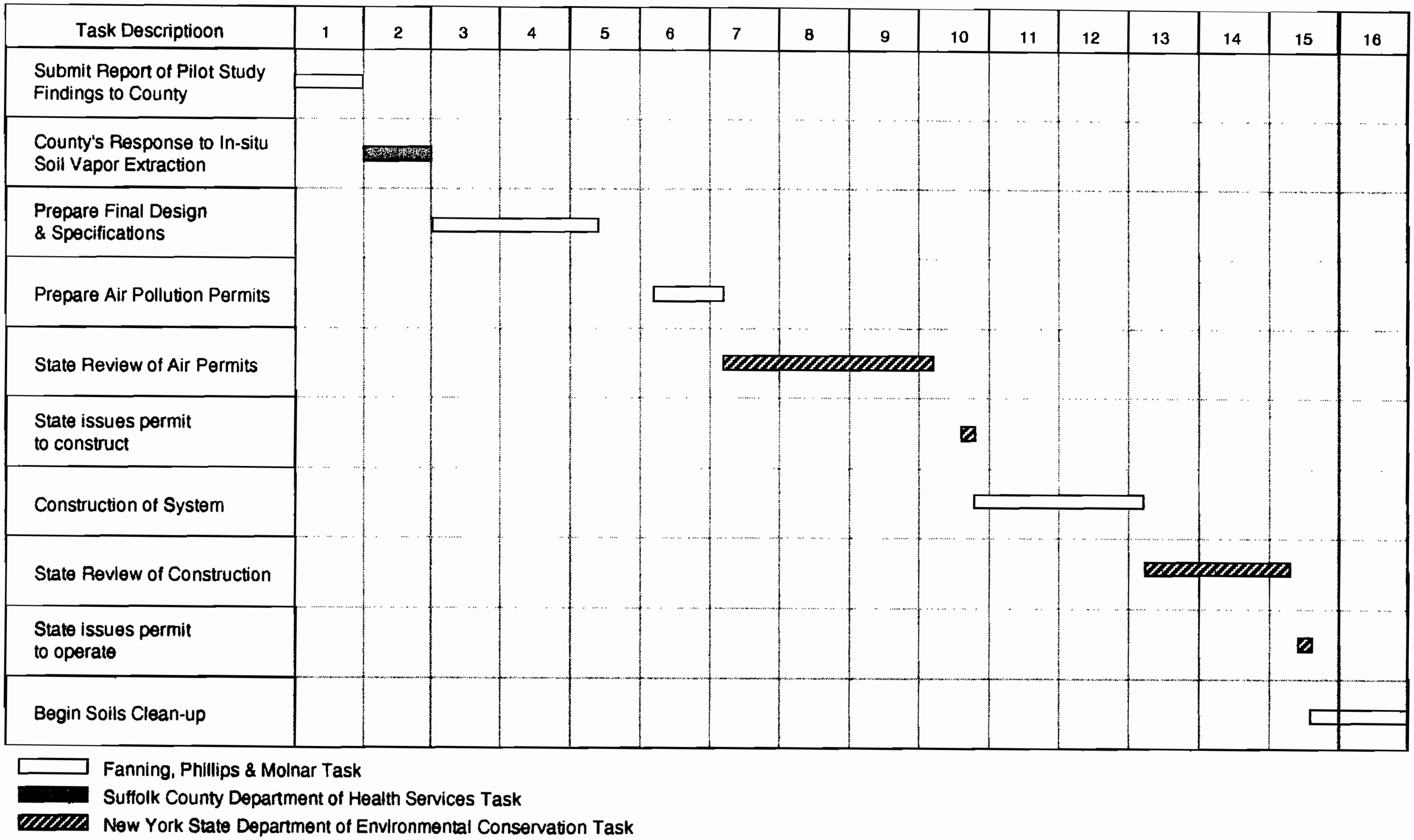

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FIGURE 7.1- PROPOSED SCHEDULE

SECTION 8.0
REFERENCES

Downey, D.C., R.E. Hinchee, M.S. Westray, and J.K. Slaughter, "Combined Biological and Physical Treatment of Jet Fuel-Contaminated Aquifer," in Proc. of NATO/CCMS Second International Conference, The Netherlands, 1988.

EPA, "Site Program Demonstration Test Terra Vac In Situ Vacuum Extraction System", Groveland, MA, EPA/540/5-89/003a, April, 1989.

Fanning, Phillips and Molnar's "Phase I Investigation of Potential Sources of Contamination at 100 Oser Avenue, July, 1990."

Fanning, Phillips and Molnar's Follow-up Soil Investigation at 100 Oser Avenue, Hauppauge, New York SCDHS Order on Consent #IW89-87, November, 1990."

Fanning, Phillips and Molnar's "Proposed Remedial Investigation at Anorad Corp. 100 Oser Avenue, Hauppauge, New York 11788."

Gierke, John S., Ph.D., UNIPAC Model, Michigan Technological University, Houghton, Michigan, June, 1990.

Hutzler, Neil J., Blane E. Murphy, John S. gierke, "State of Technology Review Soil Vapor Extraction Systems", US Department of Commerce, EPA/600/2-89/024, June, 1989.

Johnson, P.C., C.C. Stanley, M.W. Kemblowski, D.L. Byers & J.D. Colhart. "A Practical Approach to the Design, Operation and Monitoring of In Situ Soil-Venting Systems", <u>Ground Water Management Review</u>, Spring, 1990.

Johnson, Paul C., Marian W. Kemblowski, James Colthart, "Quantitative Analysis for the Cleanup of Hydrocarbon-Contaminated soils by In Situ Soil Venting", Ground Water, May-June, 1990.

Schwille, Friedrich, <u>Dense Chlorinated Solvents in Porous and Fractured Media</u>, 1988.

Yaws, Carl, Haur-Chung Yang, Xiang Pan "Henry's Law Constants for 362 Organic Compounds in Water", <u>Chemical Engineering</u>, November, 1991.

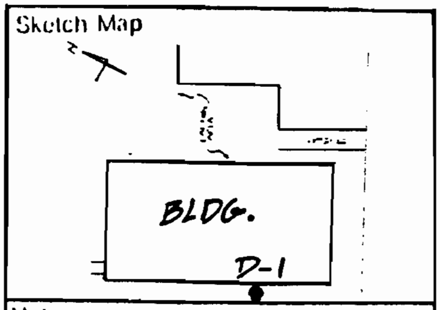
APPENDIX A

VAPOR WELL CONSTRUCTION LOGS

Drilling Log

Project ANORAD
Owner ANORAD
Location 100 OSER AVE.
W.O. Number —
Well Number D-1
Total Depth 63
Diameter ≈ 8"
Surface Elevation ≈130MSL
Water Level: Initial —
24-hrs —
Screen: Dia. 2"
Length 60'
Slot Size .020 inch
Casing: Dia. 2"
Length 3'
Type P.V.C.
Drilling Company R&L
Drilling Method HOLLOW STEM
Driller BOB NOUD
Log By P. DERMODY
Date Drilled 8/16/90

Sketch Map



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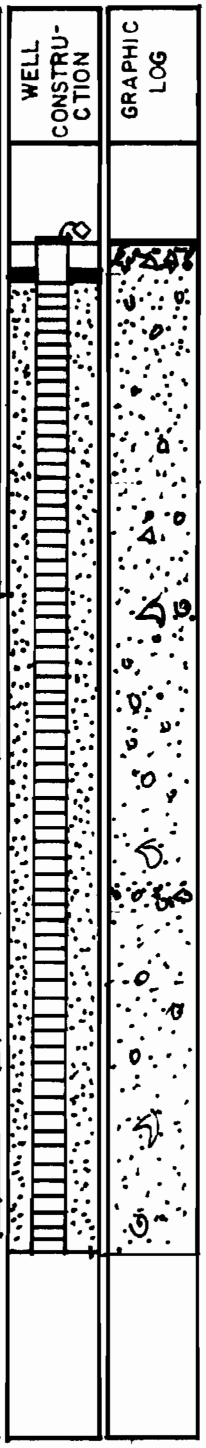

DEPTH (FEET)	SAMPLE NUMBER	DESCRIPTION/SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0		0-2" ASPHALT 2"-2' ARTIFICIAL FILL, INCLUDING BRICKS & ROCK FRAGMENTS
3		
6		
9		2'-15' FINE BROWN SAND W/ABUNDANT PEBBLES
12	SPOON	
15		
18		
21	SPOON	
24		15'-40' FINE TO COARSE BROWN SAND W/GRAVEL, PEBBELS & SOME SMALL COBBLES
27		
30	SPOON	
33		
36		
39		
42	SPOON	40'-42' COARSE LIGHT BROWN SAND WITH GRAVEL
45		
48		
51	SPOON	
54		42'-63' MEDIUM BLONDE SAND W/SOME GRAVEL.
57		
60	SPOON	
63		
66	▽	
69		

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Drilling Log

Project ANORAD Owner ANORAD

Location 100 OSER AVE. W.O. Number —

Well Number D-2 Total Depth 61.5 Diameter ≈ 8"

Surface Elevation ≈130MSL Water Level: Initial — 24-hrs —

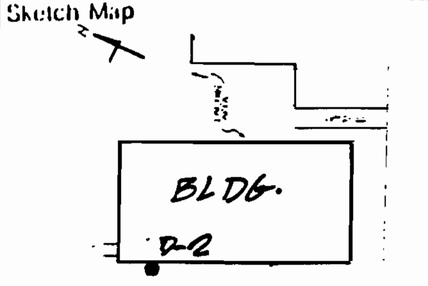
Screen: Dia. 2" Length 60' Slot Size .020

Casing: Dia 2" Length 1.5' Type PVC

Drilling Company R & L Drilling Method HOLLOW STEM

Driller BOB NOVD Log By P. DERMODY Date Drilled 8/17/90

Sketch Map



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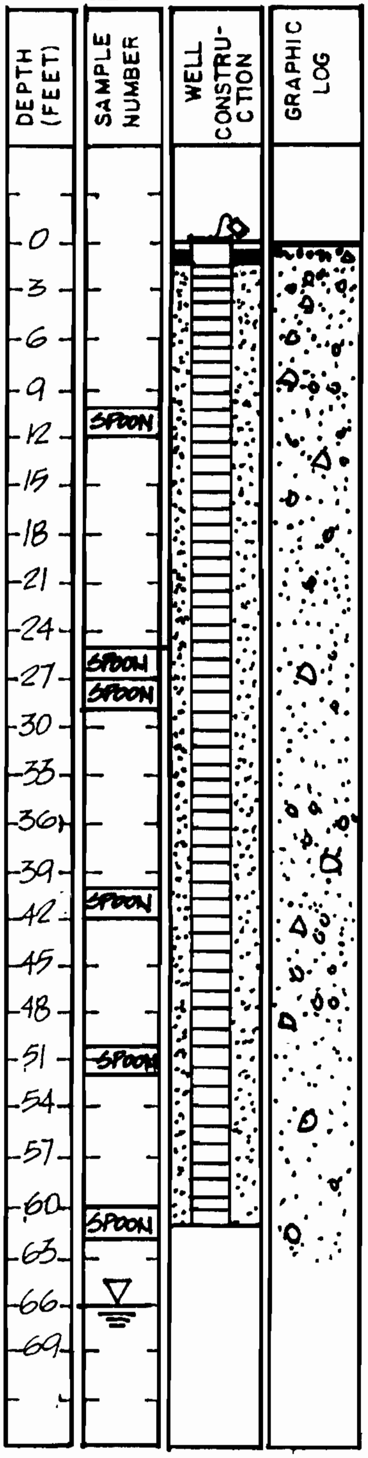


DESCRIPTION/SOIL CLASSIFICATION
(COLOR, TEXTURE, STRUCTURES)

0-2" ASPHALT

2"-1' ARTIFICIAL FILL

1'-10' BROWN FINE SAND W/ABUNDANT GRAVELS, PEBBLES & TRACE COBBLES

10'-40' BROWN FINE SAND W/ABUNDANT GRAVELS, PEBBLES & COBBLES

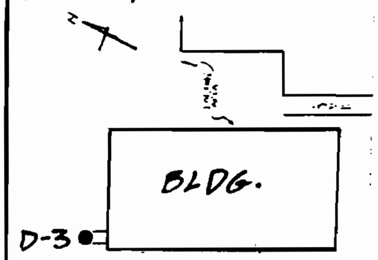
40'-50' MED. BROWN SAND W/SOME GRAVEL & PEBBLES

50'-64' MED. COARSE LIGHT BROWN SAND W/SOME GRAVEL nning, phillips & molnar

Drilling Log

Project ANORAD Owner ANORAD
Location 100 OSER AVE. W.O. Number —
Well Number D-3 Total Depth 63 Diameter ≈8"
Surface Elevation ≈130 MSL Water Level: Initial — 24-hrs —
Screen: Dia. 2" Length 60' Slot Size .020 inch
Casing: Dia. 2" Length 3' Type PVC
Drilling Company R & L Drilling Method HOLLOW STEM
Driller BOB NOUD Log By P. DERMODY Date Drilled 8/20/90

Sketch Map



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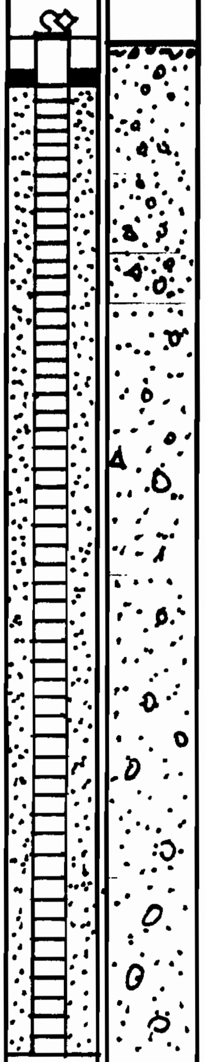


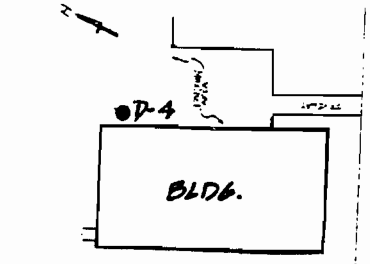
DEPTH (FEET)	SAMPLE NUMBER	DESCRIPTION/SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0		0-2" ASPHALT
3		2"-1' ARTIFICIAL FILL
6		1-8' MED. BROWN SAND W/PEBBLES & COBBLES
9		8'-13' MED. BROWN SAND W/GRAVEL & SOME PEBBLES
12	SPOON	
15		13'-16' MED. BROWN SAND W/GRAVEL & ABUNDANT COBBLES
18		
21	SPOON	
24		16'-33' MED. BROWN SAND W/GRAVEL & PEBBLES
27		
30	SPOON	
33		
36		
39		33'-52' MED. BROWN SAND W/ABUNDANT GRAVEL
42	SPOON	
45		
48		
51	SPOON	
54		
57		52'-63' MED. BROWN SAND W/ SOME GRAVEL
60	SPOON	
63		
66	∇	
69		

[redacted]

Drilling Log

Project ANORAD Owner ANORAD
Location 100 OSER AVE. W.O. Number —
Well Number D-4 Total Depth 63' Diameter ≈ 8"
Surface Elevation ≈ 130 MSL Water Level: Initial — 24-hrs —
Screen: Dia. 2" Length 60' Slot Size .020 inch
Casing: Dia 2" Length 3' Type PVC
Drilling Company R & L Drilling Method HOLLOW STEM AUGER
Driller BOB NOUD Log By P. DERMODY Date Drilled 8/21/90

Sketch Map



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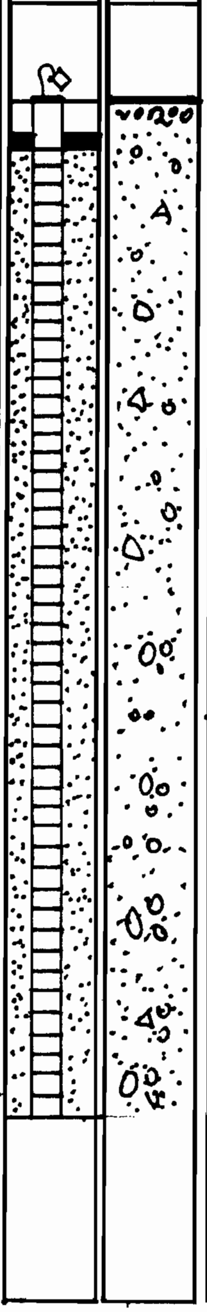

DEPTH (FEET)	SAMPLE NUMBER	WELL CONSTRUCTION	GRAPHIC LOG	DESCRIPTION/SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)
0				0-2' ASPHALT
3				2"-1' ARTIFICIAL FILL
6				
9				1'-15' FINE MED. BROWN SAND W/GRAVEL & PEBBLES
12				
15				
18				
21	SPOON			15'-30' MED. COARSE BROWN SAND W/GRAVEL, PEBBLES & COBBLES
24				
27				
30	SPOON			
33				
36				30-54' MED. BROWN SAND W/GRAVEL & FEW PEBBLES
39				
42	SPOON			
45				
48				
51	SPOON			
54				
57				54-63' COARSE LIGHT BROWN SAND W/ GRAVEL.
60	SPOON			
63				
66	▽			
69				

APPENDIX B

PILOT STUDY DATA

Vapor Extraction Pilot Study Data

Date	12/19/91
Location	D-1
Start Time	9:32
Throttling velocity	0 fpm
Throttling flow rate	0 cfm
Discharge Velocity	6167 fpm
Discharge Flow Rate	72 cfm
Influent Flow Rate	72 cfm
Mixed Concentration	6743 ppm
Influent Concentration	6743 ppm
Effluent Concentration	29 ppm

Time/Pressure Data

Point	Radial Dist. feet	Init. Press. in. of water	Time	Duration minutes	Press. in. H20	Δ P in. H2O	Time	Duration minutes	Press. in. H20	Δ P in. H2O	Time	Duration minutes	Press. in. H20	Δ P in. H2O	Time	Duration minutes	Press. in. H20	Δ P in. H2O	Time	Duration minutes	Press. in. H20	Δ P in. H2O
VP-1	25	-0.05	9:50	18	-0.17	-0.12	10:07	35	-0.17	-0.12	10:30	58	-0.17	-0.12	10:57	85	-0.17	-0.12	11:18	106	-0.15	-0.10
VP-2	25	0.00	9:51	19	-0.11	-0.11	10:08	36	-0.11	-0.11	10:31	59	-0.12	-0.12	10:58	86	-0.11	-0.11	11:19	107	-0.11	-0.11
VP-3	54	0.00	9:52	20	-0.04	-0.04	10:09	37	-0.04	-0.04	10:32	60	-0.05	-0.05	10:59	87	-0.03	-0.03	11:21	109	-0.01	-0.01
VC-1R	104	-0.04	9:53	21	-0.07	-0.03	10:10	38	-0.05	-0.01	10:34	62	-0.04	0.00	11:00	88	-0.05	-0.01	11:23	111	0.00	0.04
VC-1B	104	-0.05	9:52	20	-0.08	-0.03	10:09	37	-0.08	-0.03	10:33	61	-0.08	-0.03	11:00	88	-0.06	-0.01	11:22	110	-0.03	0.02
VC-1G	104	-0.05	9:54	22	-0.10	-0.05	10:11	39	-0.05	0.00	10:34	62	-0.05	0.00	11:00	88	-0.05	0.00	11:23	111	-0.01	0.04
VC-1W	104	-0.03	9:56	24	-0.06	-0.03	10:11	39	-0.04	-0.01	10:35	63	-0.06	-0.03	11:01	89	-0.05	-0.02	11:24	112	-0.02	0.01
VP-4	148	-0.02	9:55	23	-0.04	-0.02	10:12	40	-0.03	-0.01	10:35	63	-0.01	0.01	11:01	89	0.00	0.02	11:25	113	0.00	0.02
VP-5	178	-0.02	9:55	23	-0.05	-0.03	10:13	41	-0.01	0.01	10:36	64	-0.01	0.01	11:02	90	-0.02	0.00	11:27	115	0.00	0.02
VP-6	192	-0.01	9:56	24	-0.02	-0.01	10:13	41	0.00	0.01	10:36	64	-0.01	0.00	11:02	90	-0.01	0.00	11:27	115	0.00	0.01
VP-7	165	0.00	9:57	25	-0.04	-0.04	10:14	42	-0.03	-0.03	10:37	65	-0.02	-0.02	11:03	91	0.00	0.00	11:29	117	0.00	0.00
VC-2R	196	-0.04	9:53	21	-0.07	-0.03	10:15	43	-0.03	0.01	10:38	66	-0.04	0.00	11:04	92	-0.01	0.03	11:30	118	-0.01	0.03
VC-2B	196	-0.03	9:52	20	-0.07	-0.04	10:15	43	-0.03	0.00	10:38	66	-0.03	0.00	11:03	91	-0.02	0.01	11:31	119	-0.01	0.02
VC-2G	196	-0.03	9:54	22	-0.06	-0.03	10:16	44	-0.03	0.00	10:39	67	-0.01	0.02	11:05	93	-0.01	0.02	11:31	119	-0.01	0.02
VC-2W	196	-0.01	9:56	24	-0.06	-0.05	10:16	44	0.00	0.01	10:38	66	-0.02	-0.01	11:04	92	0.00	0.01	11:31	119	-0.02	-0.01
VP-8	188	0.00	10:00	28	-0.01	-0.01	10:17	45	0.00	0.00					11:05	93	0.00	0.00	11:32	120	0.00	0.00
VP-9	191	-0.01	10:01	29	-0.04	-0.03	10:18	46	0.00	0.01					11:06	94	0.00	0.01	11:35	123	0.00	0.01
VP-10	158	0.00	10:01	29	-0.03	-0.03	10:18	46	-0.01	-0.01					11:07	95	0.00	0.00	11:38	126	0.00	0.00

Vapor Extraction Pilot Study Data

Date	12/17/91
Lacation	D-2
Start Time	1:30
Throttling velocity	2700 fpm
Throttling flow rate	31 cfm
Discharge Velocity	6350 fpm
Discharge Flow Rate	74 cfm
Influent Flow Rate	42 cfm
Mixed Concentration	2142 ppm
Influent Concentration	3726 ppm
Effluent Concentration	0 ppm

Time/Pressure Data

Point	Radial Dist. feet	Init. Press. in. of water	Time	Duration minutes	Press. in. H20	Δ P in. H20	Time	Duration minutes	Press. in. H20	Δ P in. H20	Time	Duration minutes	Press. in. H20	Δ P in. H20	Time	Duration minutes	Press. In. H20	Δ P In. H20	Time	Duration minutes	Press. In. H20	Δ P In. H20
VP-1	104	-0.08	1:43	13	0.04	0.12	2:08	38	0.01	0.09	2:32	62	0.04	0.12	3:11	101	0.05	0.13	4:00	150	0.07	0.15
VP-2	54	-0.05	1:44	14	0.01	0.06	2:09	39	0.00	0.05	2:34	64	0.01	0.06	3:12	102	0.02	0.07	4:01	151	0.04	0.09
VP-3	25	-0.08	1:45	15	-0.01	0.07	2:10	40	-0.03	0.05	2:36	66	0.00	0.08	3:13	103	0.00	0.08	4:02	152	-0.01	0.07
VC-1R	25	-0.20	1:47	17	0.02	0.22	2:13	43	0.05	0.25	2:38	68	0.08	0.28	3:15	105	0.08	0.28	4:04	154	0.05	0.25
VC-1B	25	-0.19	1:46	16	0.01	0.20	2:12	42	0.04	0.23	2:37	67	0.06	0.25	3:15	105	0.07	0.26	4:03	153	0.07	0.26
VC-1G	25	-0.19	1:47	17	0.00	0.19	2:13	43	0.04	0.23	2:38	68	0.08	0.27	3:16	106	0.05	0.24	4:04	154	0.02	0.21
VC-1W	25	-0.17	1:49	19	-0.02	0.15	2:14	44	0.01	0.18	2:39	69	0.04	0.21	3:16	106	0.04	0.21	4:05	155	0.01	0.18
VP-4	69	-0.07	1:50	20	0.00	0.07	2:15	45	0.03	0.10	2:40	70	0.04	0.11	3:17	107	0.05	0.12	4:05	155	0.03	0.10
VP-5	100	-0.09	1:51	21	0.00	0.09	2:16	46	0.05	0.14	2:41	71	0.05	0.14	3:19	109	0.08	0.17	4:06	156	0.05	0.14
VP-6	116	-0.08	1:56	26	0.02	0.10	2:18	48	0.05	0.13	2:42	72	0.06	0.14	3:20	110	0.11	0.19	4:07	157	0.07	0.15
VP-7	92	-0.04	1:56	26	0.00	0.04	2:17	47	0.04	0.08	2:43	73	0.05	0.09	3:21	111	0.06	0.10	4:08	158	0.07	0.11
VC-2R	135	-0.07	1:58	28	0.01	0.08	2:21	51	0.10	0.17	2:45	75	0.07	0.14	3:23	113	0.16	0.23	4:09	159	0.09	0.16
VC-2B	135	-0.07	1:58	28	0.01	0.08	2:20	50	0.09	0.16	2:44	74	0.08	0.15	3:23	113	0.15	0.22	4:09	159	0.09	0.16
VC-2G	135	0.04	1:59	29	0.00	-0.04	2:23	53	0.08	0.04	2:47	77	0.08	0.04	3:25	115	0.18	0.14	4:10	160	0.07	0.03
VC-2W	135	-0.06	1:59	29	0.00	0.06	2:24	54	0.07	0.13	2:46	76	0.04	0.10	3:24	114	0.16	0.22	4:09	159	0.06	0.12
VP-8	145	-0.01	2:00	30	0.00	0.01	2:25	55	0.05	0.06	2:48	78	0.03	0.04	3:26	116	0.08	0.09	4:11	161	0.03	0.04
VP-9	163	-0.04	2:01	31	0.01	0.05	2:26	56	0.08	0.12	2:48	78	0.04	0.08	3:26	116	0.10	0.14	4:12	162	0.03	0.07
VP-10	138	-0.04	2:02	32	0.00	0.04	2:26	56	0.07	0.11	2:49	79	0.05	0.09	3:27	117	0.12	0.16	4:12	162	0.03	0.07

Vapor Extraction Pilot Study Data

Date	12/18/91
Lacation	D-2
Start Time	8:43
Throttling velocity	1410 fpm
Throttling flow rate	16 cfm
Discharge Velocity	6200 fpm
Discharge Flow Rate	72 cfm
Influent Flow Rate	56 cfm
Mixed Concentration	3333 ppm
Influent Concentration	4314 ppm
Effluent Concentration	29 ppm

Time/Pressure Data

Point	Radial Dist. feet	Init. Press. In. of water	Time	Duration minutes	Press. in. H20	Δ P in. H2O	Time	Duration minutes	Press. in. H20	Δ P in. H2O	Time	Duration minutes	Press. in. H20	Δ P in. H2O	Time	Duration minutes	Press. in. H20	Δ P in. H2O	Time	Duration minutes	Press. in. H20	Δ P in. H2O
VP-1	104	-0.04	8:52	9	-0.06	-0.02	9:13	30	-0.08	-0.04	9:39	56	-0.07	-0.03	10:08	85	-0.05	-0.01	10:38	115	-0.03	0.01
VP-2	54	0.00	8:53	10	-0.03	-0.03	9:13	30	-0.04	-0.04	9:40	57	-0.05	-0.05	10:09	86	-0.04	-0.04	10:39	116	0.00	0.00
VP-3	25	-0.02	8:54	11	-0.14	-0.12	9:14	31	-0.17	-0.15	9:41	58	-0.15	-0.13	10:09	86	-0.16	-0.14	10:40	117	-0.14	-0.12
VC-1R	25	-0.03	8:55	12	-0.16	-0.13	9:15	32	-0.17	-0.14	9:43	60	-0.15	-0.12	10:10	87	-0.12	-0.09	10:42	119	-0.06	-0.03
VC-1B	25	-0.04	8:55	12	-0.19	-0.15	9:15	32	-0.19	-0.15	9:42	59	-0.15	-0.11	10:10	87	-0.13	-0.09	10:41	118	-0.08	-0.04
VC-1G	25	-0.04	8:56	13	-0.20	-0.16	9:15	32	-0.22	-0.18	9:43	60	-0.18	-0.14	10:11	88	-0.16	-0.12	10:42	119	-0.11	-0.07
VC-1W	25	-0.03	8:56	13	-0.19	-0.16	9:17	34	-0.25	-0.22	9:44	61	-0.21	-0.18	10:11	88	-0.22	-0.19	10:43	120	-0.12	-0.09
VP-4	69	-0.01	9:00	17	-0.07	-0.06	9:18	35	-0.05	-0.04	9:45	62	-0.06	-0.05	10:12	89	-0.05	-0.04	10:44	121	-0.02	-0.01
VP-5	100	-0.02	9:00	17	-0.06	-0.04	9:18	35	-0.06	-0.04	9:46	63	-0.02	0.00	10:13	90	-0.06	-0.04	10:45	122	-0.02	0.00
VP-6	116	-0.01	9:01	18	-0.07	-0.06	9:19	36	-0.05	-0.04	9:46	63	-0.04	-0.03	10:14	91	-0.06	-0.05	10:46	123	-0.01	0.00
VP-7	92	-0.01	9:02	19	-0.06	-0.05	9:19	36	-0.05	-0.04	9:47	64	-0.05	-0.04	10:15	92	-0.05	-0.04	10:46	123	-0.02	-0.01
VC-2R	135	-0.04	9:04	21	-0.09	-0.05	9:21	38	-0.08	-0.04	9:50	67	-0.05	-0.01	10:16	93	-0.06	-0.02	10:48	125	0.01	0.05
VC-2B	135	-0.03	9:04	21	-0.08	-0.05	9:20	37	-0.07	-0.04	9:49	66	-0.04	-0.01	10:16	93	-0.05	-0.02	10:48	125	0.01	0.04
VC-2G	135	-0.02	9:05	22	-0.08	-0.06	9:22	39	-0.08	-0.06	9:52	69	-0.05	-0.03	10:18	95	-0.04	-0.02	10:50	127	-0.01	0.01
VC-2W	135	-0.01	9:05	22	-0.07	-0.06	9:21	38	-0.04	-0.03	9:51	68	-0.04	-0.03	10:17	94	-0.04	-0.03	10:49	126	-0.01	0.00
VP-8	145	0.00	9:06	23	-0.03	-0.03	9:23	40	-0.02	-0.02	9:52	69	-0.05	-0.05	10:19	96	-0.01	-0.01	10:51	128	0.00	0.00
VP-9	163	0.00	9:07	24	-0.04	-0.04	9:24	41	-0.05	-0.05	9:53	70	-0.03	-0.03	10:20	97	0.00	0.00	10:52	129	-0.01	-0.01
VP-10	138	0.00	9:07	24	-0.05	-0.05	9:24	41	-0.03	-0.03	9:54	71	-0.02	-0.02	10:21	98	-0.02	-0.02	10:52	129	0.00	0.00

Vapor Extraction Pilot Study Data

Date	12/18/91
Lacation	D-2
Start Time	11:00
Throttling velocity	0 fpm
Throttling flow rate	0 cfm
Discharge Velocity	6200 fpm
Discharge Flow Rate	72 cfm
Influent Flow Rate	72 cfm
Mixed Concentration	4370 ppm
Influent Concentration	4370 ppm
Effluent Concentration	24 ppm

Time/Pressure Data

Point	Radial Dist. feet	Init. Press. in. of water	Time	Duration minutes	Press. in. H20	Δ P in. H2O	Time	Duration minutes	Press. in. H20	Δ P in. H2O	Time	Duration minutes	Press. in. H20	Δ P in. H2O	Time	Duration minutes	Press. in. H20	Δ P in. H2O	Time	Duration minutes	Press. in. H20	Δ P in. H2O
VP-1	104	-0.03	11:06	6	-0.05	-0.02	11:22	22	-0.03	0.00	11:54	54	-0.03	0.00	12:12	72	-0.04	-0.01	12:34	94	-0.03	0.00
VP-2	54	0.00	11:07	7	-0.04	-0.04	11:23	23	-0.04	-0.04	11:55	55	-0.03	-0.03	12:13	73	-0.03	-0.03	12:35	95	-0.04	-0.04
VP-3	25	-0.14	11:08	8	-0.16	-0.02	11:23	23	-0.18	-0.04	11:56	56	-0.21	-0.07	12:13	73	-0.12	0.02	12:35	95	-0.22	-0.08
VC-1R	25	-0.06	11:09	9	-0.12	-0.06	11:25	25	-0.11	-0.05	11:57	57	-0.13	-0.07	12:15	75	-0.15	0.09	12:36	96	-0.17	-0.11
VC-1B	25	-0.08	11:08	8	-0.13	-0.05	11:24	24	-0.15	-0.07	11:56	56	-0.14	-0.06	12:16	76	-0.17	-0.09	12:36	96	-0.17	-0.09
VC-1G	25	-0.11	11:09	9	-0.16	-0.05	11:25	25	-0.21	-0.10	11:57	57	-0.22	-0.11	12:15	75	-0.25	-0.14	12:38	98	-0.23	-0.12
VC-1W	25	-0.12	11:10	10	-0.22	-0.10	11:26	26	-0.23	-0.11	11:58	58	-0.21	-0.09	12:16	76	-0.30	-0.18	12:38	98	-0.25	-0.13
VP-4	69	-0.02	11:11	11	-0.05	-0.03	11:27	27	-0.04	-0.02	11:59	59	-0.04	-0.02	12:17	77	-0.07	-0.05	12:39	99	-0.05	-0.03
VP-5	100	-0.02	11:12	12	-0.06	-0.04	11:28	28	-0.03	-0.01	12:00	60	-0.05	-0.03	12:18	78	-0.06	-0.04	12:40	100	-0.05	-0.03
VP-6	116	-0.01	11:13	13	-0.06	-0.05	11:29	29	-0.05	-0.04	12:00	60	-0.03	-0.02	12:18	78	-0.04	-0.03	12:41	101	-0.02	-0.01
VP-7	92	-0.02	11:13	13	-0.05	-0.03	11:29	29	-0.04	-0.02	12:01	61	-0.04	-0.02	12:19	79	-0.04	-0.02	12:41	101	-0.04	-0.02
VC-2R	135	0.01	11:15	15	-0.06	-0.07	11:31	31	-0.04	-0.05	12:02	62	-0.04	-0.05	12:21	81	-0.03	-0.04	12:43	103	-0.03	-0.04
VC-2B	135	0.01	11:14	14	-0.05	-0.06	11:30	30	-0.02	-0.03	12:02	62	-0.05	-0.06	12:20	80	-0.03	-0.04	12:42	102	-0.03	-0.04
VC-2G	135	-0.01	11:16	16	-0.04	-0.03	11:32	32	-0.01	0.00	12:03	63	-0.05	-0.04	12:22	82	-0.04	-0.03	12:44	104	-0.07	-0.06
VC-2W	135	-0.01	11:15	15	-0.04	-0.03	11:31	31	-0.03	-0.02	12:03	63	-0.03	-0.02	12:21	81	-0.04	-0.03	12:43	103	-0.06	-0.05
VP-8	145	0.00	11:17	17	-0.01	-0.01	11:33	33	-0.01	-0.01	12:04	64	0.00	0.00	12:23	83	-0.01	-0.01	12:45	105	-0.03	-0.03
VP-9	163	0.01	11:17	17	0.00	0.01	11:34	34	0.00	0.01	12.05	65	0.00	0.01	12:23	83	-0.02	-0.01	12:46	106	0.00	0.01
VP-10	138	0.00	11:18	18	-0.02	-0.02	11:34	34	0.00	0.00	12:05	65	-0.02	-0.02	12:26	86	0.00	0.00	12:46	106	-0.01	-0.01

Vapor Extraction Pilot Study Data

Date	12/18/91
Lacation	D-3
Start Time	2:33
Throttling velocity	0 fpm
Throttling flow rate	0 cfm
Discharge Velocity	6200 fpm
Discharge Flow Rate	72 cfm
Influent Flow Rate	72 cfm
Mixed Concentration	1223 ppm
Influent Concentration	1223 ppm
Effluent Concentration	17 ppm

Time/Pressure Data

Point	Radial Dist. feet	Init. Press. in. of water	Time	Duration minutes	Press. in. H20	Δ P in. H2O	Time	Duration minutes	Press. in. H20	Δ P in. H2O	Time	Duration minutes	Press. in. H20	Δ P in. H2O	Time	Duration minutes	Press. in. H20	Δ P in. H2O
VP-1	194	-0.03	2:46	13	-0.05	-0.02	3:01	28	-0.05	-0.02	3:36	63	-0.05	-0.02	3:53	80	-0.06	-0.03
VP-2	145	-0.01	2:47	14	-0.03	-0.02	3:02	29	-0.01	0.00	3:37	64	-0.04	-0.03	3:54	81	-0.03	-0.02
VP-3	116	-0.03	2:47	14	-0.07	-0.04	3:03	30	-0.06	-0.03	3:38	65	-0.04	-0.01	3:55	82	-0.04	-0.01
VC-1R	68	-0.05	2:43	10	-0.18	-0.13	3:04	31	-0.15	-0.10	3:39	66	-0.19	-0.14	4:00	87	-0.19	-0.14
VC-1B	68	-0.05	2:42	9	-0.21	-0.16	3:04	31	-0.21	-0.16	3:38	65	-0.21	-0.16	4:00	87	-0.23	-0.18
VC-1G	68	-0.05	2:43	10	-0.19	-0.14	3:06	33	-0.25	-0.20	3:40	67	-0.25	-0.20	3:59	86	-0.20	-0.15
VC-1W	68	-0.03	2:44	11	-0.18	-0.15	3:06	33	-0.15	-0.12	3:40	67	-0.22	-0.19	4:01	88	-0.15	-0.12
VP-4	24	-0.02	2:48	15	-0.22	-0.20	3:08	35	-0.25	-0.23	3:41	68	-0.20	-0.18	4:03	90	-0.25	-0.23
VP-5	26	-0.05	2:51	18	-0.30	-0.25	3:09	36	-0.30	-0.25	3:42	69	-0.30	-0.25	4:04	91	-0.25	-0.20
VP-6	25	-0.02	2:52	19	-0.25	-0.23	3:10	37	-0.25	-0.23	3:43	70	-0.25	-0.23	4:06	93	-0.30	-0.28
VP-7	25	-0.03	2:53	20	-0.22	-0.19	3:10	37	-0.21	-0.18	3:44	71	-0.25	-0.22	4:08	95	-0.20	-0.17
VC-2R	76	-0.11	2:55	22	-0.13	-0.02	3:13	40	-0.15	-0.04	3:46	73	-0.19	-0.08	4:11	98	-0.17	-0.06
VC-2B	76	-0.07	2:55	22	-0.18	-0.11	3:12	39	-0.22	-0.15	3:45	72	-0.19	-0.12	4:10	97	-0.19	-0.12
VC-2G	76	-0.06	2:57	24	-0.15	-0.09	3:16	43	-0.14	-0.08	3:47	74	-0.14	-0.08	4:13	100	-0.15	-0.09
VC-2W	76	-0.06	2:56	23	-0.13	-0.07	3:14	41	-0.15	-0.09	3:46	73	-0.16	-0.10	4:12	99	-0.14	-0.08
VP-8	118	-0.01	2:59	26	-0.01	0.00	3:17	44	-0.03	-0.02	3:49	76	-0.04	-0.03	4:14	101	-0.03	-0.02
VP-9	152	-0.03	2:59	26	-0.05	-0.02	3:17	44	-0.06	-0.03	3:49	76	-0.05	-0.02	4:16	103	-0.04	-0.01
VP-10	144	-0.02	2:59	26	-0.03	-0.01	3:18	45	-0.03	-0.01	3:50	77	-0.06	-0.04	4:18	105	-0.02	0.00

APPENDIX C

COMPUTER MODEL ANALYSIS

- D1
- D2
- D3

```
                    DATA SUMMARY
 1. Title: ancrai 31
 2. Air Flow Rate ============    2832.00  LITERS/MINUTE
 3. Spill Quantity ===========  .273E+04  GALLONS
 4. Venting Period ===========>  15000.00  DAYS
 5. Temperature ==============>     12.78  DEGREE C
 6. Spill Composition file ===>  PCE.CMP
 7. Minimum Time Step ========>      0.13  DAYS
 8. Maximum Time Step ========      90.00  DAYS
 9. Frequency of Printout=====     10      STEPS
10. Contaminated Soil Vol.====>  $155000.00FT^3
11. Organic Carbon Content ===>    0.0200
12. Vol. Water Content =======>   0.1100
13. Air Filled Porosity ======>   0.1900
14. Venting Efficiency Factor=>   0.0327


               Option:
         Compute ===============
         Redo from start =======
  Enter item number to modify ==
     Tab=>MoveCursor  Enter=>Execute  Esc=>LastScreen

ù

      Ctrl-A=>NextScreen Esc=>LastScreen Ctrl-P=>Help Tab=>MoveCursor
é
                 Calculation of Venting Efficiency Factor


          Variable                          Value          Unit

Total Porosity ============================> 30           %
Air Filled Porosity =======================> 19           %
Air Permeabilty of Soil ===================> 1E-09        CM^2
Thickness of Screened Interval ============> 1676.4       CM
Radius of Vacuum Well & Backfill ==========> 20.32        CM
Absolute Pressure at Vacuum Well ==========> 32359.5      GM/CM-S^2
Radius of Influence =======================> 1524         CM
Radius of Contaminated Zone ===============> 1219.2       CM


ù
```

```
      Ctrl-A=>NextScreen Esc=>LastScreen Ctrl-P=>Help Tab=>MoveCursor
é
                 Calculation of Venting Efficiency Factor

      Ctrl-A=>NextScreen Esc=>LastScreen Ctrl-P=>Help Tab=>MoveCursor
é
                 Calculation of Venting Efficiency Factor
```

```
       Variable                            Value        Unit

Total Porosity ============================> 30           %
Air Filled Porosity =======================> 19           %
Air Permeabilty of Soil ===================> 9.999999E-02 DARCYS
Thickness of Screened Interval ============> 55           FEET
Radius of Vacuum Well & Backfill ==========> 8            INCHES
Absolute Pressure at Vacuum Well ==========> 1.08333      FEET OF H2O
Radius of Influence =======================> 50           FEET
Radius of Contaminated Zone ===============> 40           FEET


      F1->METERS,   F2->FEET,   F5->CM
```

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+                    VENTING                       +
+                                                  +
+          COPYRIGHT 1991 VERSION 2.0              +
+                                                  +
+    Environmental Systems and Technologies Inc.   +
+                                                  +
+          BLACKSBURG, VA 24062, U.S.A.            +
+                                                  +
+                                                  +
+                                                  +
+ + + + + + + + + + + + + + + + + + + + + + + + + + + + + +

TITLE: anorad_d1
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 TOTAL MASS OF SPILL   = .16750E+05  [kg]
 AIR FLOW RATE         = .40781E+07  [L/day]
 TEMPERATURE           = .12778E+02  [c]
 STARTING TIME STEP    = .10000E-04  [days]
 MAXIMUM TIME STEP     = .90000E+02  [days]
 TOTAL SIMULATION TIME = .15000E+05  [days]
 TIME WEIGHTING FACTOR = .10000E+01  [-]
 EFFICIENCY FACTOR     = .32676E-01  [-]
 SOIL VOLUME           = .43891E+04  [m^3]
 FRAC. ORGANIC CARBON  = .20000E-01  [-]
 VOL. WATER CONTENT    = .11000E+00  [-]
 BULK DENSITY          = .18550E+01  [g/cm^3]
 AIR FILLED POROSITY   = .19000E+00  [-]


SPECIES                        MOL.   -|- VAP   -|- BOILING- |-SOLUB   -|- KOC -|
                              WEIGHT   PRESSURE    TEMP       ILITY

                              gm/mole    atm       deg. c      mg/L       g/g

tetrachloroethylene          .1660E+03 .1800E-01 .1210E+03 .1500E+03 .3980E+03


SPECIES                      SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                              MASS     CONCEN.    CONCEN.    PER SOIL MASS
                              [g]      [g/m^3]    [g/m^3]      [mg/kg]

tetrachloroethylene         .1675E+08  .0000E+00  .0000E+00  .2057E+04

TIME                                   =       .0000  [days]
TOTAL MASS OF HYDROCARBON              = .16750E+05  [kg]
TOTAL MASS IN VAPOR PHASE              = .00000E+00  [kg]
TOTAL MASS IN OIL PHASE                = .00000E+00  [kg]
TOTAL MASS IN WATER PHASE              = .00000E+00  [kg]
TOTAL MASS IN SOLID PHASE              = .00000E+00  [kg]
HYDROCARBON MASS PER SOIL MASS         = .20573E+04  [mg/kg]


SPECIES                                 SPECIES MASS [g] IN
                              GAS        OIL        WATER       SOLID

tetrachloroethylene         .7102E+05  .1056E+08  .7197E+05  .6087E+07
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     end of initial conditions
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 TIME                                       =      9.8289  [days]
 TOTAL MASS OF HYDROCARBON                  = .16638E+05  [kg]
 TOTAL MASS IN VAPOR PHASE                  = .71101E+02  [kg]
 TOTAL MASS IN OIL PHASE                    = .10391E+05  [kg]
 TOTAL MASS IN WATER PHASE                  = .72052E+02  [kg]
 TOTAL MASS IN SOLID PHASE                  = .60933E+04  [kg]
 CHANGE IN HYDROCARBON MASS FOR TIME STEP   = .22831E+00  [%]
 CUMULATIVE CHANGE IN HYDROCARBON           = .66770E+00  [%]
 HYDROCARBON MASS PER SOIL MASS             = .20436E+04  [mg/kg]


 SPECIES                     SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                              MASS       CONCEN. .  CONCEN.    PER SOIL MASS
                               [g]      [g/m^3]    [g/m^3]       [mg/kg]

tetrachloroethylene         .1664E+08  .1859E+01  .5688E+02  .2044E+04

 TIME                                       =    438.3666  [days]
 TOTAL MASS OF HYDROCARBON                  = .11931E+05  [kg]
 TOTAL MASS IN VAPOR PHASE                  = .71023E+02  [kg]
 TOTAL MASS IN OIL PHASE                    = .64063E+04  [kg]
 TOTAL MASS IN WATER PHASE                  = .71973E+02  [kg]
 TOTAL MASS IN SOLID PHASE                  = .60866E+04  [kg]
 CHANGE IN HYDROCARBON MASS FOR TIME STEP   = .57577E+01  [%]
 CUMULATIVE CHANGE IN HYDROCARBON           = .28770E+02  [%]
 HYDROCARBON MASS PER SOIL MASS             = .14654E+04  [mg/kg]


 SPECIES                     SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                              MASS       CONCEN. .  CONCEN.    PER SOIL MASS
                               [g]      [g/m^3]    [g/m^3]       [mg/kg]

tetrachloroethylene         .1193E+08  .2628E+01  .8042E+02  .1465E+04
 time step reduced

 TIME                                       =    977.4789  [days]
 TOTAL MASS OF HYDROCARBON                  = .58110E+04  [kg]
 TOTAL MASS IN VAPOR PHASE                  = .66250E+02  [kg]
 TOTAL MASS IN OIL PHASE                    = .00000E+00  [kg]
 TOTAL MASS IN WATER PHASE                  = .67136E+02  [kg]
 TOTAL MASS IN SOLID PHASE                  = .56776E+04  [kg]
 CHANGE IN HYDROCARBON MASS FOR TIME STEP   = .39178E+01  [%]
 CUMULATIVE CHANGE IN HYDROCARBON           = .65308E+02  [%]
 HYDROCARBON MASS PER SOIL MASS             = .71372E+03  [mg/kg]


 SPECIES                     SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                              MASS       CONCEN. .  CONCEN.    PER SOIL MASS
                               [g]      [g/m^3]    [g/m^3]       [mg/kg]

tetrachloroethylene         .5811E+07  .2726E+01  .8342E+02  .7137E+03

 TIME                                       =   1697.4360  [days]
 TOTAL MASS OF HYDROCARBON                  = .16965E+04  [kg]
 TOTAL MASS IN VAPOR PHASE                  = .19341E+02  [kg]
 TOTAL MASS IN OIL PHASE                    = .00000E+00  [kg]
 TOTAL MASS IN WATER PHASE                  = .19600E+02  [kg]
 TOTAL MASS IN SOLID PHASE
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 CHANGE IN HYDROCARBON MASS FOR TIME STEP  = .11059E+01  (%)
 CUMULATIVE CHANGE IN HYDROCARBON          = .89672E+02  (%)
 HYDROCARBON MASS PER SOIL MASS            = .20837E+03  (mg/kg)



 SPECIES                     SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                               MASS      CONCEN. .  CONCEN.    PER SOIL MASS
                               (g)       (g/m^3)   (g/m^3)      (mg/kg)

tetrachloroethylene          .1696E+07  .5052E+00  .1546E+02  .2084E+03

 TIME                                       =  2458.4390  (days)
 TOTAL MASS OF HYDROCARBON                  = .46372E+03  (kg)
 TOTAL MASS IN VAPOR PHASE                  = .52868E+01  (kg)
 TOTAL MASS IN OIL PHASE                    = .00000E+00  (kg)
 TOTAL MASS IN WATER PHASE                  = .53576E+01  (kg)
 TOTAL MASS IN SOLID PHASE                  = .45308E+03  (kg)
 CHANGE IN HYDROCARBON MASS FOR TIME STEP  = .45391E+00  (%)
 CUMULATIVE CHANGE IN HYDROCARBON          = .97232E+02  (%)
 HYDROCARBON MASS PER SOIL MASS            = .56956E+02  (mg/kg)



 SPECIES                     SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                               MASS      CONCEN. .  CONCEN.    PER SOIL MASS
                               (g)       (g/m^3)   (g/m^3)      (mg/kg)

tetrachloroethylene          .4637E+06  .2175E+00  .6657E+01  .5696E+02

 TIME                                       =  3215.8430  (days)
 TOTAL MASS OF HYDROCARBON                  = .12747E+03  (kg)
 TOTAL MASS IN VAPOR PHASE                  = .14533E+01  (kg)
 TOTAL MASS IN OIL PHASE                    = .00000E+00  (kg)
 TOTAL MASS IN WATER PHASE                  = .14727E+01  (kg)
 TOTAL MASS IN SOLID PHASE                  = .12455E+03  (kg)
 CHANGE IN HYDROCARBON MASS FOR TIME STEP  = .11883E+00  (%)
 CUMULATIVE CHANGE IN HYDROCARBON          = .99239E+02  (%)
 HYDROCARBON MASS PER SOIL MASS            = .15656E+02  (mg/kg)



 SPECIES                     SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                               MASS      CONCEN. .  CONCEN.    PER SOIL MASS
                               (g)       (g/m^3)   (g/m^3)      (mg/kg)

tetrachloroethylene          .1275E+06  .5979E-01  .1830E+01  .1566E+02

 TIME                                       =  3969.1650  (days)
 TOTAL MASS OF HYDROCARBON                  = .35267E+02  (kg)
 TOTAL MASS IN VAPOR PHASE                  = .40208E+00  (kg)
 TOTAL MASS IN OIL PHASE                    = .00000E+00  (kg)
 TOTAL MASS IN WATER PHASE                  = .40745E+00  (kg)
 TOTAL MASS IN SOLID PHASE                  = .34458E+02  (kg)
 CHANGE IN HYDROCARBON MASS FOR TIME STEP  = .31312E-01  (%)
 CUMULATIVE CHANGE IN HYDROCARBON          = .99789E+02  (%)
 HYDROCARBON MASS PER SOIL MASS            = .43316E+01  (mg/kg)



 SPECIES                     SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                               MASS      CONCEN. .  CONCEN.    PER SOIL MASS
                               (g)       (g/m^3)   (g/m^3)      (mg/kg)

tetrachloroethylene          .3527E+05  .1654E-01  .5063E+00  .4332E+01
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TIME                                     =  4718.6000  (days)
TOTAL MASS OF HYDROCARBON                = .98177E+01  (kg)
TOTAL MASS IN VAPOR PHASE                =  11193E+00  (kg)
TOTAL MASS IN OIL PHASE                  = .00000E+00  (kg)
TOTAL MASS IN WATER PHASE                = .11343E+00  (kg)
TOTAL MASS IN SOLID PHASE                = .95924E+01  (kg)
CHANGE IN HYDROCARBON MASS FOR TIME STEP = .83015E-02  (%)
CUMULATIVE CHANGE IN HYDROCARBON         = .99941E+02  (%)
HYDROCARBON MASS PER SOIL MASS           = .12058E+01  (mg/kg)


SPECIES                     SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                              MASS     CONCEN. .  CONCEN.    PER SOIL MASS
                              (g)     (g/m^3)    (g/m^3)      (mg/kg)

tetrachloroethylene         .9818E+04  .4605E-02  .1409E+00  .1206E+01

TIME                                     =  5464.3330  (days)
TOTAL MASS OF HYDROCARBON                = .27493E+01  (kg)
TOTAL MASS IN VAPOR PHASE                = .31345E-01  (kg)
TOTAL MASS IN OIL PHASE                  = .00000E+00  (kg)
TOTAL MASS IN WATER PHASE                = .31764E-01  (kg)
TOTAL MASS IN SOLID PHASE                = .26862E+01  (kg)
CHANGE IN HYDROCARBON MASS FOR TIME STEP = .22140E-02  (%)
CUMULATIVE CHANGE IN HYDROCARBON         = .99984E+02  (%)
HYDROCARBON MASS PER SOIL MASS           = .33768E+00  (mg/kg)


SPECIES                     SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                              MASS     CONCEN. .  CONCEN.    PER SOIL MASS
                              (g)     (g/m^3)    (g/m^3)      (mg/kg)

tetrachloroethylene         .2749E+04  .1290E-02  .3947E-01  .3377E+00

TIME                                     =  6206.5410  (days)
TOTAL MASS OF HYDROCARBON                = .77430E+00  (kg)
TOTAL MASS IN VAPOR PHASE                = .88277E-02  (kg)
TOTAL MASS IN OIL PHASE                  = .00000E+00  (kg)
TOTAL MASS IN WATER PHASE                = .89458E-02  (kg)
TOTAL MASS IN SOLID PHASE                = .75653E+00  (kg)
CHANGE IN HYDROCARBON MASS FOR TIME STEP = .59385E-03  (%)
CUMULATIVE CHANGE IN HYDROCARBON         = .99995E+02  (%)
HYDROCARBON MASS PER SOIL MASS           = .95102E-01  (mg/kg)


SPECIES                     SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                              MASS     CONCEN. .  CONCEN.    PER SOIL MASS
                              (g)     (g/m^3)    (g/m^3)      (mg/kg)

tetrachloroethylene         .7743E+03  .3632E-03  .1111E-01  .9510E-01

TIME                                     =  6945.3900  (days)
TOTAL MASS OF HYDROCARBON                = .21926E+00  (kg)
TOTAL MASS IN VAPOR PHASE                = .24997E-02  (kg)
TOTAL MASS IN OIL PHASE                  = .00000E+00  (kg)
TOTAL MASS IN WATER PHASE                = .25331E-02  (kg)
TOTAL MASS IN SOLID PHASE                = .21422E+00  (kg)
CHANGE IN HYDROCARBON MASS FOR TIME STEP = .16015E-03  (%)
CUMULATIVE CHANGE IN HYDROCARBON         = .99999E+02  (%)
HYDROCARBON MASS PER SOIL MASS           = .26930E-01  (mg/kg)
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                                MASS          N                 PER SO
                                 (g)      (g/m^3)   (g/m^3)    (mg/kg)

tetrachloroethylene          .2193E+03   1028E-03   .3147E-02   .2693E-01

 TIME                                           =   7681.0420  (days)
 TOTAL MASS OF HYDROCARBON                      = .62410E-01  (kg)
 TOTAL MASS IN VAPOR PHASE                      = .71153E-03  (kg)
 TOTAL MASS IN OIL PHASE                        = .00000E+00  (kg)
 TOTAL MASS IN WATER PHASE                      = .72105E-03  (kg)
 TOTAL MASS IN SOLID PHASE                      = .60977E-01  (kg)
 CHANGE IN HYDROCARBON MASS FOR TIME STEP       = .43415E-04  (%)
 CUMULATIVE CHANGE IN HYDROCARBON               = .10000E+03  (%)
 HYDROCARBON MASS PER SOIL MASS                 = .76653E-02  (mg/kg)


 SPECIES                         SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                                  MASS     CONCEN. .   CONCEN.    PER SOIL MASS
                                   (g)     (g/m^3)    (g/m^3)      (mg/kg)

tetrachloroethylene          .6241E+02   .2927E-04   .8959E-03   .7665E-02

 TIME                                           =   8413.6460  (days)
 TOTAL MASS OF HYDROCARBON                      = .17853E-01  (kg)
 TOTAL MASS IN VAPOR PHASE                      = .20354E-03  (kg)
 TOTAL MASS IN OIL PHASE                        = .00000E+00  (kg)
 TOTAL MASS IN WATER PHASE                      = .20627E-03  (kg)
 TOTAL MASS IN SOLID PHASE                      = .17443E-01  (kg)
 CHANGE IN HYDROCARBON MASS FOR TIME STEP       = .11828E-04  (%)
 CUMULATIVE CHANGE IN HYDROCARBON               = .10000E+03  (%)
 HYDROCARBON MASS PER SOIL MASS                 = .21928E-02  (mg/kg)


 SPECIES                         SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                                  MASS     CONCEN. .   CONCEN.    PER SOIL MASS
                                   (g)     (g/m^3)    (g/m^3)      (mg/kg)

tetrachloroethylene          .1785E+02   .5398E-05   .1652E-03   .2193E-02

..........FINAL RESULTS..........

 TIME                                           =   8822.7810  (days)
 TOTAL MASS OF HYDROCARBON                      = .89140E-02  (kg)
 TOTAL MASS IN VAPOR PHASE                      = .10163E-03  (kg)
 TOTAL MASS IN OIL PHASE                        = .00000E+00  (kg)
 TOTAL MASS IN WATER PHASE                      = .10299E-03  (kg)
 TOTAL MASS IN SOLID PHASE                      = .87094E-02  (kg)
 CHANGE IN HYDROCARBON MASS FOR TIME STEP       = .71785E-05  (%)
 CUMULATIVE CHANGE IN HYDROCARBON               = .10000E+03  (%)
 HYDROCARBON MASS PER SOIL MASS                 = .10948E-02  (mg/kg)


 SPECIES                                  SPECIES MASS (g) IN
                               GAS        OIL        WATER        SOLID

tetrachloroethylene          .1016E+00   .0000E+00   .1030E+00   .8709E+01


 SPECIES                         SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                                  MASS     CONCEN. .   CONCEN.    PER SOIL MASS
                                   (g)     (g/m^3)    (g/m^3)      (mg/kg)

tetrachloroethylene          .8914E+01   .4181E-05   .1280E-03   1095E-02

Total number of time steps =          135
Total number of iterations =          213

   Time when system becomes oil-free (days) = 708.37
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+++++++++++++++++++++++++++++
+                  VENTING                     +
+                                               +
+          COPYRIGHT 1991 VERSION 2.0          +
+                                               +
+  Environmental Systems and Technologies Inc. +
+                                               +
+          BLACKSBURG, VA 24062, U.S.A.        +
+                                               +
+                                               +
+                                               +
+++++++++++++++++++++++++++++

TITLE anorad d2
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 TOTAL MASS OF SPILL    = .11372E+05  [kg]
 AIR FLOW RATE          = .87679E+07  [L/day]
 TEMPERATURE            = .12778E+02  [c]
 STARTING TIME STEP     =  10000E-04  [days]
 MAXIMUM TIME STEP      = .90000E+02  [days]
 TOTAL SIMULATION TIME = .10000E+05  [days]
 TIME WEIGHTING FACTOR = .10000E+01  [-]
 EFFICIENCY FACTOR      = .55986E-01  [-]
 SOIL VOLUME            = .76455E+04  [m^3]
 FRAC ORGANIC CARBON    = .20000E-01  [-]
 VOL. WATER CONTENT     = .11000E+00  [-]
 BULK DENSITY           = .18550E+01  [g/cm^3]
 AIR FILLED POROSITY    = .19000E+00  [-]


SPECIES                    MOL.   -+- VAP   -+- BOILING- |-SOLUB  -+- KOC -+
                           WEIGHT   PRESSURE    TEMP       ILITY
-

                          gm/mole     atm       deg. c     mg/L         g/g

tetrachloroethylene       1660E+02  1800E-01  1210E+03  1500E+03  .3980E+03


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SPECIES                   SPECIES   WELL GAS  EQUIL. GAS  SPECIES MASS
                          MASS      CONCEN. .  CONCEN.     PER SOIL MASS
                          [g]       [g/m^3]   [g/m^3]     [mg/kg]

tetrachloroethylene     .1137E+08  .0000E+00  .0000E+00  .8018E+03

TIME                                 =        .0000  [days]
TOTAL MASS OF HYDROCARBON           = .11372E+05  [kg]
TOTAL MASS IN VAPOR PHASE           = .00000E+00  [kg]
TOTAL MASS IN OIL PHASE             = .00000E+00  [kg]
TOTAL MASS IN WATER PHASE           = .00000E+00  [kg]
TOTAL MASS IN SOLID PHASE           = .00000E+00  [kg]
HYDROCARBON MASS PER SOIL MASS      = .80181E+03  [mg/kg]
time step reduced


SPECIES                              SPECIES MASS [g] IN
                          GAS        OIL        WATER       SOLID

tetrachloroethylene     .1296E+06  .0000E+00  .1314E+06  .1111E+08
**************************************
        end of initial conditions
**************************************
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TIME                                         =      9.8289  [days]
TOTAL MASS OF HYDROCARBON                    = .10951E+05  [kg]
TOTAL MASS IN VAPOR PHASE                    = .12405E+03  [kg]
TOTAL MASS IN OIL PHASE                      = .00000E+00  [kg]
TOTAL MASS IN WATER PHASE                    = .12652E+03  [kg]
TOTAL MASS IN SOLID PHASE                    = .10699E+05  [kg]
CHANGE IN HYDROCARBON MASS FOR TIME STEP     = .12480E+01  [%]
CUMULATIVE CHANGE IN HYDROCARBON             = .37014E+01  [%]
HYDROCARBON MASS PER SOIL MASS               = .77213E+03  [mg/kg]


SPECIES                      SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                              MASS       CONCEN.    CONCEN.    PER SOIL MASS
                               [g]      [g/m^3]    [g/m^3]      [mg/kg]

tetrachloroethylene         .1095E+08  .3208E+01  .5730E+02  .7721E+03

TIME                                         =    250.5503  [days]
TOTAL MASS OF HYDROCARBON                    = .45525E+04  [kg]
TOTAL MASS IN VAPOR PHASE                    = .51903E+02  [kg]
TOTAL MASS IN OIL PHASE                      = .00000E+00  [kg]
TOTAL MASS IN WATER PHASE                    = .52597E+02  [kg]
TOTAL MASS IN SOLID PHASE                    = .44480E+04  [kg]
CHANGE IN HYDROCARBON MASS FOR TIME STEP     = 48618E+01  [%]
CUMULATIVE CHANGE IN HYDROCARBON             = .59966E+02  [%]
HYDROCARBON MASS PER SOIL MASS               = .32100E+03  [mg/kg]


SPECIES                      SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                              MASS       CONCEN.    CONCEN.    PER SOIL MASS
                               [g]      [g/m^3]    [g/m^3]      [mg/kg]

tetrachloroethylene         .4553E+07  .2100E+01  .3752E+02  .3210E+03

TIME                                         =    600.2153  [days]
TOTAL MASS OF HYDROCARBON                    = .12880E+04  [kg]
TOTAL MASS IN VAPOR PHASE                    = .14685E+02  [kg]
TOTAL MASS IN OIL PHASE                      = .00000E+00  [kg]
TOTAL MASS IN WATER PHASE                    = .14881E+02  [kg]
TOTAL MASS IN SOLID PHASE                    = .12585E+04  [kg]
CHANGE IN HYDROCARBON MASS FOR TIME STEP     = .13300E+01  [%]
CUMULATIVE CHANGE IN HYDROCARBON             = .88673E+02  [%]
HYDROCARBON MASS PER SOIL MASS               = .90820E+02  [mg/kg]


SPECIES                      SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                              MASS       CONCEN.    CONCEN.    PER SOIL MASS
                               [g]      [g/m^3]    [g/m^3]      [mg/kg]

tetrachloroethylene         .1288E+07  .5943E+00  .1061E+02  .9082E+02

TIME                                         =    938.3113  [days]
TOTAL MASS OF HYDROCARBON                    =  37903E+03  [kg]
TOTAL MASS IN VAPOR PHASE                    = .43213E+01  [kg]
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        SS I          SE                                         3 (kg)
CHANGE IN HYDROCARBON MASS FOR TIME STEP  = .37844E+00  (%)
CUMULATIVE CHANGE IN HYDROCARBON          = .96667E+02  (%)
HYDROCARBON MASS PER SOIL MASS            = .26725E+02  (mg/kg)


SPECIES                      SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                              MASS       CONCEN. .  CONCEN.    PER SOIL MASS
                              (g)       (g/m^3)    (g/m^3)     (mg/kg)

tetrachloroethylene          .3790E+06  .1749E+00  .3123E+01   .2673E+02

TIME                                      =  1280.5910  (days)
TOTAL MASS OF HYDROCARBON                 = .10997E+03  (kg)
TOTAL MASS IN VAPOR PHASE                 = .12537E+01  (kg)
TOTAL MASS IN OIL PHASE                   = .00000E+00  (kg)
TOTAL MASS IN WATER PHASE                 = .12705E+01  (kg)
TOTAL MASS IN SOLID PHASE                 = .10744E+03  (kg)
CHANGE IN HYDROCARBON MASS FOR TIME STEP  = .10616E+00  (%)
CUMULATIVE CHANGE IN HYDROCARBON          = .99033E+02  (%)
HYDROCARBON MASS PER SOIL MASS            = .77537E+01  (mg/kg)


SPECIES                      SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                              MASS       CONCEN. .  CONCEN.    PER SOIL MASS
                              (g)       (g/m^3)    (g/m^3)     (mg/kg)

tetrachloroethylene          .1100E+06  .3221E-01  .5754E+00   .7754E+01

TIME                                      =  1627.1510  (days)
TOTAL MASS OF HYDROCARBON                 = .31447E+02  (kg)
TOTAL MASS IN VAPOR PHASE                 = .35852E+00  (kg)
TOTAL MASS IN OIL PHASE                   = .00000E+00  (kg)
TOTAL MASS IN WATER PHASE                 = .36332E+00  (kg)
TOTAL MASS IN SOLID PHASE                 = .30725E+02  (kg)
CHANGE IN HYDROCARBON MASS FOR TIME STEP  = .29355E-01  (%)
CUMULATIVE CHANGE IN HYDROCARBON          = .99723E+02  (%)
HYDROCARBON MASS PER SOIL MASS            = .22173E+01  (mg/kg)


SPECIES                      SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                              MASS       CONCEN. .  CONCEN.    PER SOIL MASS
                              (g)       (g/m^3)    (g/m^3)     (mg/kg)

tetrachloroethylene          .3145E+05  .9212E-02  .1645E+00   .2217E+01

TIME                                      =  1977.5640  (days)
TOTAL MASS OF HYDROCARBON                 = .88751E+01  (kg)
TOTAL MASS IN VAPOR PHASE                 = .10118E+00  (kg)
TOTAL MASS IN OIL PHASE                   = .00000E+00  (kg)
TOTAL MASS IN WATER PHASE                 = .10254E+00  (kg)
TOTAL MASS IN SOLID PHASE                 = .86714E+01  (kg)
CHANGE IN HYDROCARBON MASS FOR TIME STEP  = .12617E-01  (%)
CUMULATIVE CHANGE IN HYDROCARBON          = .99922E+02  (%)
HYDROCARBON MASS PER SOIL MASS            = .62578E+00  (mg/kg)
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                                MASS     CONCEN.   CONCEN.   PER SOIL MASS
                                (g)                (g/m^3)   (mg/kg)

tetrachloroethylene          .3677E+04  .4035E-02  .7314E-01  .2596E+00

 TIME                                         =  2331.9360  (days)
 TOTAL MASS OF HYDROCARBON                    = .24712E+01  (kg)
 TOTAL MASS IN VAPOR PHASE                    = .28174E-01  (kg)
 TOTAL MASS IN OIL PHASE                      = .00000E+00  (kg)
 TOTAL MASS IN WATER PHASE                    = .28551E-01  (kg)
 TOTAL MASS IN SOLID PHASE                    = .24145E+01  (kg)
 CHANGE IN HYDROCARBON MASS FOR TIME STEP     = .33968E-02  (%)
 CUMULATIVE CHANGE IN HYDROCARBON             = .99978E+02  (%)
 HYDROCARBON MASS PER SOIL MASS               = .17425E+00  (mg/kg)


 SPECIES                        SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                                 MASS       CONCEN. .  CONCEN.    PER SOIL MASS
                                 (g)       (g/m^3)    (g/m^3)     (mg/kg)

tetrachloroethylene          .2471E+04  .1140E-02  .2036E-01  .1742E+00

 TIME                                         =  2680.3720  (days)
 TOTAL MASS OF HYDROCARBON                    = .67867E+00  (kg)
 TOTAL MASS IN VAPOR PHASE                    = .77375E-02  (kg)
 TOTAL MASS IN OIL PHASE                      = .00000E+00  (kg)
 TOTAL MASS IN WATER PHASE                    = .78410E-02  (kg)
 TOTAL MASS IN SOLID PHASE                    = .66310E+00  (kg)
 CHANGE IN HYDROCARBON MASS FOR TIME STEP     = .90199E-03  (%)
 CUMULATIVE CHANGE IN HYDROCARBON             = .99994E+02  (%)
 HYDROCARBON MASS PER SOIL MASS               = .47853E-01  (mg/kg)


 SPECIES                        SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                                 MASS       CONCEN. .  CONCEN.    PER SOIL MASS
                                 (g)       (g/m^3)    (g/m^3)     (mg/kg)

tetrachloroethylene          .6787E+03  .3131E-03  .5593E-02  .4785E-01

 TIME                                         =  3036.9490  (days)
 TOTAL MASS OF HYDROCARBON                    = .19402E+00  (kg)
 TOTAL MASS IN VAPOR PHASE                    = .22120E-02  (kg)
 TOTAL MASS IN OIL PHASE                      = .00000E+00  (kg)
 TOTAL MASS IN WATER PHASE                    = .22416E-02  (kg)
 TOTAL MASS IN SOLID PHASE                    = .18957E+00  (kg)
 CHANGE IN HYDROCARBON MASS FOR TIME STEP     = .24933E-03  (%)
 CUMULATIVE CHANGE IN HYDROCARBON             = .99998E+02  (%)
 HYDROCARBON MASS PER SOIL MASS               = .13680E-01  (mg/kg)


 SPECIES                        SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                                 MASS       CONCEN. .  CONCEN.    PER SOIL MASS
                                 (g)       (g/m^3)    (g/m^3)     (mg/kg)

tetrachloroethylene          .1940E+03  .8951E-04  .1599E-02  .1368E-01

 TIME                                         =  3387.5600  (days)
 TOTAL MASS OF HYDROCARBON                    = .54712E-01  (kg)
 TOTAL MASS IN VAPOR PHASE                    = .62377E-03  (kg)
 TOTAL MASS IN OIL PHASE                      = .00000E+00  (kg)
 TOTAL MASS IN WATER PHASE                    = .63212E-03  (kg)
 TOTAL MASS IN SOLID PHASE                    = .53457E-01  (kg)
 CHANGE IN HYDROCARBON MASS FOR TIME STEP     = .67984E-04  (%)
 CUMULATIVE CHANGE IN HYDROCARBON             = .10000E+03  (%)
 HYDROCARBON MASS PER SOIL MASS               = .28577E-02  (mg/kg)
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SPECIES                       SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                               MASS      CONCEN.    CONCEN.    PER SOIL MASS
                               (g)       (g/m^3)    (g/m^3)      (mg/kg)

tetrachloroethylene          .5471E+02  .2524E-04  .4509E-03  .3858E-02

TIME                                      =  3742.3070  (days)
TOTAL MASS OF HYDROCARBON                 = .15214E-01  (kg)
TOTAL MASS IN VAPOR PHASE                 = .17345E-03  (kg)
TOTAL MASS IN OIL PHASE                   = .00000E+00  (kg)
TOTAL MASS IN WATER PHASE                 = .17577E-03  (kg)
TOTAL MASS IN SOLID PHASE                 = .14865E-01  (kg)
CHANGE IN HYDROCARBON MASS FOR TIME STEP  = .18279E-04  (%)
CUMULATIVE CHANGE IN HYDROCARBON          = .10000E+03  (%)
HYDROCARBON MASS PER SOIL MASS            = .10727E-02  (mg/kg)


SPECIES                       SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                               MASS      CONCEN.    CONCEN.    PER SOIL MASS
                               (g)       (g/m^3)    (g/m^3)      (mg/kg)

tetrachloroethylene          .1521E+02  .7019E-05  .1254E-03  .1073E-02


..........FINAL RESULTS..........

TIME                                      =  3868.0580  (days)
TOTAL MASS OF HYDROCARBON                 = .96309E-02  (kg)
TOTAL MASS IN VAPOR PHASE                 = .10980E-03  (kg)
TOTAL MASS IN OIL PHASE                   = .00000E+00  (kg)
TOTAL MASS IN WATER PHASE                 = .11127E-03  (kg)
TOTAL MASS IN SOLID PHASE                 = .94098E-02  (kg)
CHANGE IN HYDROCARBON MASS FOR TIME STEP  = .95196E-05  (%)
CUMULATIVE CHANGE IN HYDROCARBON          = .10000E+03  (%)
HYDROCARBON MASS PER SOIL MASS            = .67907E-03  (mg/kg)


SPECIES                                  SPECIES MASS (g) IN
                                GAS        OIL       WATER       SOLID

tetrachloroethylene          .1098E+00  .0000E+00  .1113E+00  .9410E+01


SPECIES                       SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                               MASS      CONCEN.    CONCEN.    PER SOIL MASS
                               (g)       (g/m^3)    (g/m^3)      (mg/kg)

tetrachloroethylene          .9631E+01  .4443E-05  .7937E-04  .6791E-03

Total number of time steps =        124
Total number of iterations =        158

   Time when system becomes oil-free (days) =    .00
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                      DATA SUMMARY
 1. Title: anorad_d2
 2. Air Flow Rate ============>  6088.80  LITERS/MINUTE
 3. Spill Quantity ===========> .185E+04  GALLONS
 4. Venting Period ===========> 10000.00  DAYS
 5. Temperature ==============>    12.78  DEGREE C
 6. Spill Composition file ===> PCE.CMP
 7. Minimum Time Step ========>     0.13  DAYS
 8. Maximum Time Step ========>    90.00  DAYS
 9. Frequency of Printout=====>    10     STEPS
10. Contaminated Soil Vol====> $270000.00FT^3
11. Organic Carbon Content ===>   0.0200
12. Vol. Water Content =======>   0.1100
13. Air Filled Porosity ======>   0.1900
14. Venting Efficiency Factor=>   0.0560


               Option:
         Compute ==============
         Redo from start ======
 Enter item number to modify ==>
     Tab=>MoveCursor  Enter=>Execute  Esc=>LastScreen

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     Ctrl-A=>NextScreen Esc=>LastScreen Ctrl-P=>Help Tab=>MoveCursor
é
                  Calculation of Venting Efficiency Factor

          Variable                                  Value         Unit

Total Porosity ==============================> 30            %
Air Filled Porosity ==========================> 19            %
Air Permeabilty of Soil ======================> 1E-09         CM^2
Thickness of Screened Interval ===============> 1676.4        CM
Radius of Vacuum Well & Backfill =============> 20.32         CM
Absolute Pressure at Vacuum Well =============> 32359.5       GM/CM-S^2
Radius of Influence ==========================> 2468.88       CM
Radius of Contaminated Zone ==================> 1981.2        CM


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     F1->METERS.   F2->FEET.   F5->CM
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     +                                                        +
     +               COPYRIGHT 1991 VERSION 2.0               +
     +                                                        +
     +       Environmental Systems and Technologies Inc.      +
     +                                                        +
     +               BLACKSBURG, VA 24062, U.S.A              +
     +                                                        +
     +                                                        +
     +                                                        +
     ++++++++++++++++++++++++++++++++++++++++++++++++++++++++++

   TITLE: anorad d3
   -----


    TOTAL MASS OF SPILL    = .11064E+05  [kg]
    AIR FLOW RATE          = .18351E+07  [L/day]
    TEMPERATURE            = .12778E+02  [c]
    STARTING TIME STEP     = .10000E-04  [days]
    MAXIMUM TIME STEP      = .90000E+02  [days]
    TOTAL SIMULATION TIME  = .10000E+05  [days]
    TIME WEIGHTING FACTOR  = .10000E+01  [-]
    EFFICIENCY FACTOR      = .55536E-01  [-]
    SOIL VOLUME            = .56634E+04  [m^3]
    FRAC. ORGANIC CARBON   = .20000E-01  [-]
    VOL. WATER CONTENT     = .11000E+00  [-]
    BULK DENSITY           = .18550E+01  [g/cm^3]
    AIR FILLED POROSITY    = .19000E+00  [-]


  SPECIES                        MOL.   -I- VAP   -I- BOILING- I-SOLUB    -I- KOC -I
                                 WEIGHT    PRESSURE    TEMP       TLITY

                                 gm/mole    atm       deg. c      mg/L          g/g

 tetrachloroethylene          .1660E+03  1800E-01  .1210E+03  .1500E+03  3980E+03



  SPECIES                    SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                              MASS       CONCEN. .  CONCEN.    PER SOIL MASS
                              [g]       [g/m^3]    [g/m^3]      [mg/kg]

 tetrachloroethylene        1106E+08   .0000E+00   .0000E+00   .1053E+04

  TIME                                  =       .0000  [days]
  TOTAL MASS OF HYDROCARBON             = .11064E+05  [kg]
  TOTAL MASS IN VAPOR PHASE             = .00000E+00  [kg]
  TOTAL MASS IN OIL PHASE               = .00000E+00  [kg]
  TOTAL MASS IN WATER PHASE             = .00000E+00  [kg]
  TOTAL MASS IN SOLID PHASE             = .00000E+00  [kg]
  HYDROCARBON MASS PER SOIL MASS        = .10532E+04  [mg/kg]
  time step reduced


  SPECIES                                SPECIES MASS [g] IN
                             GAS         OIL         WATER         SOLID

 tetrachloroethylene       .1261E+06   .0000E+00   .1278E+06   .1081E+08
 ***************************************
          end of initial conditions
 ***************************************
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TIME                                    = [illegible]  (days)
TOTAL MASS OF HYDROCARBON               = .10948E+05  (kg)
TOTAL MASS IN VAPOR PHASE               = .12481E+03  (kg)
TOTAL MASS IN OIL PHASE                 = .00000E+00  (kg)
TOTAL MASS IN WATER PHASE               = .12648E+03  (kg)
TOTAL MASS IN SOLID PHASE               = .10696E+05  (kg)
CHANGE IN HYDROCARBON MASS FOR TIME STEP = .35940E+00  (%)
CUMULATIVE CHANGE IN HYDROCARBON        = .10546E+01  (%)
HYDROCARBON MASS PER SOIL MASS          = .10421E+04  (mg/kg)


SPECIES                        SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                                MASS       CONCEN. .  CONCEN.    PER SOIL MASS
                                (g)        (g/m^3)    (g/m^3)     (mg/kg)

tetrachloroethylene           .1095E+08   .4294E+01   .7733E+02   .1042E+04

TIME                                    =    438.3686  (days)
TOTAL MASS OF HYDROCARBON               = .70054E+04  (kg)
TOTAL MASS IN VAPOR PHASE               = .79868E+02  (kg)
TOTAL MASS IN OIL PHASE                 = .00000E+00  (kg)
TOTAL MASS IN WATER PHASE               = .80936E+02  (kg)
TOTAL MASS IN SOLID PHASE               = .68446E+04  (kg)
CHANGE IN HYDROCARBON MASS FOR TIME STEP = .61532E+01  (%)
CUMULATIVE CHANGE IN HYDROCARBON        = .36685E+02  (%)
HYDROCARBON MASS PER SOIL MASS          = .66683E+03  (mg/kg)


SPECIES                        SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                                MASS       CONCEN. .  CONCEN.    PER SOIL MASS
                                (g)        (g/m^3)    (g/m^3)     (mg/kg)

tetrachloroethylene           .7005E+07   .4122E+01   .7422E+02   .6668E+03

TIME                                    =   1338.3690  (days)
TOTAL MASS OF HYDROCARBON               = .27710E+04  (kg)
TOTAL MASS IN VAPOR PHASE               = .31592E+02  (kg)
TOTAL MASS IN OIL PHASE                 = .00000E+00  (kg)
TOTAL MASS IN WATER PHASE               = .32015E+02  (kg)
TOTAL MASS IN SOLID PHASE               = .27074E+04  (kg)
CHANGE IN HYDROCARBON MASS FOR TIME STEP = .24339E+01  (%)
CUMULATIVE CHANGE IN HYDROCARBON        = .74955E+02  (%)
HYDROCARBON MASS PER SOIL MASS          = .26377E+03  (mg/kg)


SPECIES                        SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                                MASS       CONCEN. .  CONCEN.    PER SOIL MASS
                                (g)        (g/m^3)    (g/m^3)     (mg/kg)

tetrachloroethylene           .2771E+07   .1631E+01   .2936E+02   .2638E+03

TIME                                    =   2238.3690  (days)
TOTAL MASS OF HYDROCARBON               = .10961E+04  (kg)
TOTAL MASS IN VAPOP PHASE               = .12496E+02  (kg)
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TOT        WATE                                .126
TOTAL MASS IN SOLID PHASE                  = .10709E+04  [kg]
CHANGE IN HYDROCARBON MASS FOR TIME STEP  = .96276E+00  [%]
CUMULATIVE CHANGE IN HYDROCARBON           = .90093E+02  [%]
HYDROCARBON MASS PER SOIL MASS             = .10433E+03  [mg/kg]


 SPECIES                     SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                               MASS      CONCEN.    CONCEN.    PER SOIL MASS
                               [g]       [g/m^3]    [g/m^3]     [mg/kg]

tetrachloroethylene          .1096E+07   .6450E+00   .1161E+02   .1043E+03

 TIME                                      =  3138.3690  [days]
 TOTAL MASS OF HYDROCARBON                 = .43357E+03  [kg]
 TOTAL MASS IN VAPOR PHASE                 = .49431E+01  [kg]
 TOTAL MASS IN OIL PHASE                   = .00000E+00  [kg]
 TOTAL MASS IN WATER PHASE                 = .50092E+01  [kg]
 TOTAL MASS IN SOLID PHASE                 = .42362E+03  [kg]
 CHANGE IN HYDROCARBON MASS FOR TIME STEP  = .38082E+00  [%]
 CUMULATIVE CHANGE IN HYDROCARBON          = .96081E+02  [%]
 HYDROCARBON MASS PER SOIL MASS            = .41270E+02  [mg/kg]


 SPECIES                     SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                               MASS      CONCEN.    CONCEN.    PER SOIL MASS
                               [g]       [g/m^3]    [g/m^3]     [mg/kg]

tetrachloroethylene          .4336E+06   .2551E+00   .4594E+01   .4127E+02

 TIME                                      =  4038.3690  [days]
 TOTAL MASS OF HYDROCARBON                 = .17150E+03  [kg]
 TOTAL MASS IN VAPOR PHASE                 = .19553E+01  [kg]
 TOTAL MASS IN OIL PHASE                   = .00000E+00  [kg]
 TOTAL MASS IN WATER PHASE                 = .19814E+01  [kg]
 TOTAL MASS IN SOLID PHASE                 = .16756E+03  [kg]
 CHANGE IN HYDROCARBON MASS FOR TIME STEP  = .15064E+00  [%]
 CUMULATIVE CHANGE IN HYDROCARBON          = .98450E+02  [%]
 HYDROCARBON MASS PER SOIL MASS            = .16325E+02  [mg/kg]


 SPECIES                     SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                               MASS      CONCEN.    CONCEN.    PER SOIL MASS
                               [g]       [g/m^3]    [g/m^3]     [mg/kg]

tetrachloroethylene          .1715E+06   .1009E+00   .1817E+01   .1632E+02

 TIME                                      =  4938.3690  [days]
 TOTAL MASS OF HYDROCARBON                 = .67838E+02  [kg]
 TOTAL MASS IN VAPOR PHASE                 = .77341E+00  [kg]
 TOTAL MASS IN OIL PHASE                   = .00000E+00  [kg]
 TOTAL MASS IN WATER PHASE                 = .78376E+00  [kg]
 TOTAL MASS IN SOLID PHASE                 = .66281E+02  [kg]
 CHANGE IN HYDROCARBON MASS FOR TIME STEP  = .59585E-01  [%]
 CUMULATIVE CHANGE IN HYDROCARBON          = .99387E+02  [%]
 HYDROCARBON MASS PER SOIL MASS            = .64573E+01  [mg/kg]


 SPECIES                     SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                               MASS      CONCEN.    CONCEN.    PER SOIL MASS
                               [g]       [g/m^3]    [g/m^3]     [mg/kg]

tetrachloroethylene          .6784E+05   .3992E-01   .7188E+00   .6457E+01
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TOTAL MASS OF HYDROCARBON                    = .26834E+02  [kg]
TOTAL MASS IN VAPOR PHASE                    = .30593E+00  [kg]
TOTAL MASS IN OIL PHASE                      = .00000E+00  [kg]
TOTAL MASS IN WATER PHASE                    = .31002E+00  [kg]
TOTAL MASS IN SOLID PHASE                    = .26218E+02  [kg]
CHANGE IN HYDROCARBON MASS FOR TIME STEP     = .23569E-01  [%]
CUMULATIVE CHANGE IN HYDROCARBON             = .99757E+02  [%]
HYDROCARBON MASS PER SOIL MASS               = .25542E+01  [mg/kg]


SPECIES                       SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                               MASS      CONCEN.    CONCEN.    PER SOIL MASS
                               [g]      [g/m^3]    [g/m^3]     [mg/kg]

tetrachloroethylene           .2683E+05  .1579E-01  .2843E+00  .2554E+01

TIME                                         =  6738.3690  [days]
TOTAL MASS OF HYDROCARBON                    = .10614E+02  [kg]
TOTAL MASS IN VAPOR PHASE                    = .12101E+00  [kg]
TOTAL MASS IN OIL PHASE                      = .00000E+00  [kg]
TOTAL MASS IN WATER PHASE                    = .12263E+00  [kg]
TOTAL MASS IN SOLID PHASE                    = .10371E+02  [kg]
CHANGE IN HYDROCARBON MASS FOR TIME STEP     = .93230E-02  [%]
CUMULATIVE CHANGE IN HYDROCARBON             = .99904E+02  [%]
HYDROCARBON MASS PER SOIL MASS               = .10103E+01  [mg/kg]


SPECIES                       SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                               MASS      CONCEN.    CONCEN.    PER SOIL MASS
                               [g]      [g/m^3]    [g/m^3]     [mg/kg]

tetrachloroethylene           .1061E+05  .6246E-02  .1125E+00  .1010E+01

TIME                                         =  7638.3690  [days]
TOTAL MASS OF HYDROCARBON                    = .41985E+01  [kg]
TOTAL MASS IN VAPOR PHASE                    = .47867E-01  [kg]
TOTAL MASS IN OIL PHASE                      = .00000E+00  [kg]
TOTAL MASS IN WATER PHASE                    = .48507E-01  [kg]
TOTAL MASS IN SOLID PHASE                    = .41021E+01  [kg]
CHANGE IN HYDROCARBON MASS FOR TIME STEP     = .36878E-02  [%]
CUMULATIVE CHANGE IN HYDROCARBON             = .99962E+02  [%]
HYDROCARBON MASS PER SOIL MASS               = .39965E+00  [mg/kg]


SPECIES                       SPECIES   WELL GAS   EQUIL. GAS  SPECIES MASS
                               MASS      CONCEN.    CONCEN.    PER SOIL MASS
                               [g]      [g/m^3]    [g/m^3]     [mg/kg]

tetrachloroethylene           .4199E+04  .2470E-02  .4448E-01  .3996E+00

TIME                                         =  8538.3690  [days]
TOTAL MASS OF HYDROCARBON                    = .16608E+01  [kg]
TOTAL MASS IN VAPOR PHASE                    = .18934E-01  [kg]
TOTAL MASS IN OIL PHASE                      = .00000E+00  [kg]
TOTAL MASS IN WATER PHASE                    = .19187E-01  [kg]
TOTAL MASS IN SOLID PHASE                    = .16226E+01  [kg]
CHANGE IN HYDROCARBON MASS FOR TIME STEP     = .14587E-02  [%]
CUMULATIVE CHANGE IN HYDROCARBON             = .99985E+02  [%]
HYDROCARBON MASS PER SOIL MASS               = .15808E+00  [mg/kg]
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SPECIES                   SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                           MASS       CONCEN.    CONCEN.    PER SOIL MASS
                           [g]        [g/m^3]    [g/m^3]     [mg/kg]

tetrachloroethylene       .1661E+04  .9772E-03  .1760E-01  .1581E+00

TIME                                      =  9438.3690  [days]
TOTAL MASS OF HYDROCARBON                 = .65692E+00  [kg]
TOTAL MASS IN VAPOR PHASE                 = .74895E-02  [kg]
TOTAL MASS IN OIL PHASE                   = .00000E+00  [kg]
TOTAL MASS IN WATER PHASE                 = .75897E-02  [kg]
TOTAL MASS IN SOLID PHASE                 = .64184E+00  [kg]
CHANGE IN HYDROCARBON MASS FOR TIME STEP  = .57701E-03  [%]
CUMULATIVE CHANGE IN HYDROCARBON          =  99994E+02  [%]
HYDROCARBON MASS PER SOIL MASS            = .62531E-01  [mg/kg]


SPECIES                   SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                           MASS       CONCEN.    CONCEN.    PER SOIL MASS
                           [g]        [g/m^3]    [g/m^3]     [mg/kg]

tetrachloroethylene       .6569E+03  .3865E-03  .6960E-02  .6253E-01


..........FINAL RESULTS..........

TIME                                      = 10068.3700  [days]
TOTAL MASS OF HYDROCARBON                 = .34321E+00  [kg]
TOTAL MASS IN VAPOR PHASE                 = .39129E-02  [kg]
TOTAL MASS IN OIL PHASE                   = .00000E+00  [kg]
TOTAL MASS IN WATER PHASE                 = .39652E-02  [kg]
TOTAL MASS IN SOLID PHASE                 = .33533E+00  [kg]
CHANGE IN HYDROCARBON MASS FOR TIME STEP  = .30146E-03  [%]
CUMULATIVE CHANGE IN HYDROCARBON          = .99997E+02  [%]
HYDROCARBON MASS PER SOIL MASS            = .32669E-01  [mg/kg]


SPECIES                              SPECIES MASS [g] IN
                            GAS        OIL        WATER        SOLID

tetrachloroethylene       .3913E+01  .0000E+00  .3965E+01  .3353E+03


SPECIES                   SPECIES    WELL GAS   EQUIL. GAS  SPECIES MASS
                           MASS       CONCEN.    CONCEN.    PER SOIL MASS
                           [g]        [g/m^3]    [g/m^3]     [mg/kg]

tetrachloroethylene       .3432E+03  .2019E-03  .3636E-02  .3267E-01

Total number of time steps =         127
Total number of iterations =         170

    Time when system becomes oil-free (days) =    .00
```

```
                    DATA SUMMARY
 1  Title: anoraq_d3
 2. Air Flow Rate ============>   1274.40  LITERS/MINUTE
 3. Spill Quantity ==========>  .180E+04  GALLONS
 4. Venting Period ==========>  10000.00  DAYS
 5. Temperature ==============>      12.78  DEGREE C
 6. Spill Composition file ===>  PCE.CMP
 7. Minimum Time Step ========>       0.13  DAYS
 8. Maximum Time Step =======>      90.00  DAYS
 9. Frequency of Printout=====>      10      STEPS
10. Contaminated Soil Vol.====>  $200000.00FT^3
11. Organic Carbon Content ===>     0.0200
12. Vol. Water Content =======>    0.1100
13. Air Filled Porosity ======>    0.1900
14. Venting Efficiency Factor=>    0.0555


                 Option:
         Compute ===============
         Redo from start =======
  Enter item number to modify ==>
     Tab=>MoveCursor  Enter=>Execute  Esc=>LastScreen

ù
```

```
  Ctrl-A=>NextScreen Esc=>LastScreen Ctrl-P=>Help Tab=>MoveCursor

              Calculation of Venting Efficiency Factor
```

```
  Ctrl-A=>NextScreen Esc=>LastScreen Ctrl-P=>Help Tab=>MoveCursor

              Calculation of Venting Efficiency Factor

          Variable                               Value          Unit

 Total Porosity ============================> 30            $
 Air Filled Porosity =======================> 19            $
 Air Permeabilty of Soil ===================> 1E-09         CM^2
 Thickness of Screened Interval ============> 1676.4        CM
 Radius of Vacuum Well & Backfill ==========> 20.32         CM
 Absolute Pressure at Vacuum Well ==========> 32359.5       GM/CM-S^2
 Radius of Influence =======================> 2286          CM
 Radius of Contaminated Zone ===============> 1981.2        CM


 ù


     F1->METERS,   F2->FEET,   F5->CM
```

APPENDIX D

COMPARISON OF VAPOR EXTRACTION SYSTEM'S TETRACHLOROETHYLENE EMISSIONS TO PREVAILING STANDARDS

APPENDIX D

COMPARISON OF VAPOR EXTRACTION SYSTEM'S TETRACHLOROETHYLENE EMISSIONS TO PREVAILING STANDARDS[1]

To determine the loading rate of tetrachloroethylene, the derivation of the calculation is shown below: let

Loading rate - L (lbs/hr)
Flowrate - Q (ft^3/min)
Volumetric parts per million - PPM_v

for tetrachloroethylene:

$$L\left[\frac{lbs}{hr}\right]=Q\left[\frac{ft^3}{min}\right]x\,PPM_v\,x\,\frac{1}{24.4}\left[\frac{mole}{l}\right]x\,168\left[\frac{g}{mole}\right]x\,60\left[\frac{min}{hr}\right]x\,28.32\left[\frac{l}{ft^3}\right]x\,\frac{2.205}{1000}\left[\frac{lbs}{g}\right]$$

$$\therefore,\ \left[\frac{lbs}{hr}\right]=Q\left[\frac{ft^3}{min}\right]x\ PPM_v\ x\ 25.80$$

Since the extraction system will operate within a wide window of flow rates and concentration, expected scenerios with their corresponding loading rates are listed below.

Q (ft^3/min)	PPM_v ($1/10^6$)	L (lbs/hr)
500	0.009	116
500	0.008	103
400	0.008	83
360	0.0075	70
200	0.004	21
180	0.001	4.6

---

[1] NYSDEC Air Guide 1 is considered the primary reference. 1989 printing edition was used, while verbal update of latest levels was obtained.

A screening analysis of ambient air quality impact due to emission of tetrachloroethylene from a 38 ft^2 stack outlet is carried out in accordance with the procedure described in I(A), Appendix A, Pg. 14 of Air Guide 1, as follows:

1) NYSDEC Air Guide 1 classifies tetrachloroethylene as a "Moderate Toxicity Air Contaminant" with an Ambient Guideline Concentration (AGC) of 1.2 ug/m^3.

2) The "New York County" test:

$$Q_c = AGC/200/ = 1.2/200 = 0.006 \text{ lbs/hr}$$

This loading rate corresponds to a 100 cfm/hr and a 2 ppm concentration of tetrachloroethylene. That is, our emission rate during remediation will always exceed Q_c. Thus, we continue with Step 3 on Page 14.

3) In-Stack Concentration = $\dfrac{\text{Loading Rate}}{\text{Flow Rate}}$

$$\therefore, \left[\frac{L}{Q}\right]\left[\frac{lb/hr}{ft^3/\text{min}}\right] x \frac{1}{60}\left[\frac{hr}{\text{min}}\right] = \frac{L}{60Q}\left[\frac{lbs}{ft^3}\right]$$

$$\frac{L}{60Q}\left[\frac{lb}{ft^3}\right] x\ 1.602\ x\ 10^{10} = 2.67\ x\ 10^{8}\ \frac{L}{Q}\left[\frac{\mu g}{m^3}\right]$$

Divide above ratio by 100 and compare to AGC.

Therefore, $2.67 \text{ x } 10^6 \text{ x } \dfrac{\text{Max L}}{\text{Corresponding Q}} = 2.67 \text{ x } 10^6 \text{ x } \dfrac{116}{500}$

$$= 619.440\ \mu g/m^3 > 1.2\ \mu g/m^3$$

To determine the critical concentration at which the above condition is satisfied, we recall the loading rate equation as:

$L = Q \text{ x } PPM_v \text{ x } 25.8$

or $L/Q = PPM_v \text{ x } 25.8$

---

[2] This height is assumed to simplify the analysis concerning cavity impact and is based upon one and a half time the building height. A less conservative height can be designed.

Moreover, the in-stack concentration upper limit was defined by:

$$\frac{L}{60Q} \times \frac{1.602 \times 10^{10}}{100} < 1.2 \qquad \text{or } L/Q < 4.49 \times 10^{-7}$$

At the critical concentration:

$$PPM_v \times 25.8 = 4.49 \times 10^{-7}$$

That is, the concentration is 0.02 ppm. We thus proceed to (4) (a)

(4)(a) $h_c = 1.5 * h_b = 1.5 * 25 = 37.5$ ft.

Since our stack height is 38 ft., "no cavity impacts need be considered", and thus we can skip to step 5 on page 16.

(5)(b)(i) $h_c = 38$ ft. $\quad Ca = \dfrac{4218 \times AER}{h_c^{2.16}}$

where: Ca is annual concentration ($\mu g/m^3$)
AER is annual emission rate (lbs/hr)

To find critical AER, let Ca = AGC (1.2 ug/m^3), therefore, Ca = 1.2 ug/m^3.

Therefore, $\dfrac{(1.2)(38^{2.16})}{4218} = AER = 0.74$ lb/hr

Thus, the vapor extraction system (VES) design must be capable of maintaining treatment below 0.74 lb/hr.

To maintain an emission rate of 0.74 lb/hr or under, a removal efficiency of tetrachloroethylene greater than 99.4% is required if our maximum loading is in fact experienced. This illustrated by:

$$Removal\ Efficiency(\%) = \left[1 - \frac{AER}{L}\right] * 100$$

APPENDIX E

CATALYTIC OXIDATION OF TETRACHLOROETHYLENE

APPENDIX E

CATALYTIC OXIDATION OF TETRACHLOROETHYLENE

The catalytic oxidation of tetrachloroethylene with the presence of some water moisture from soil vapors can be represented by the following balanced chemical reaction:

$$C_2Cl_{4(g)} + O_{2(g)} + 2H_2O_{(g)} \xrightarrow[750-1000°F]{\text{Engelhard Catalyst}} 4HCl_{(g)} + 2CO_{2(g)}$$

The above reaction indicates that the molar ratio between tetrachloroethylene and hydrogen chloride is 1:4. From this ratio, the relationship between the loading rate of the two chemicals can be determined in the following manner:

	$C_2\ Cl_{4(g)}$	$\longrightarrow$	$HCl_{(g)}$
Molar Ratio	1	:	4
Molecular Mass	168 g/Mole	:	37 g/Mole
Mass Ratio	1 x 168	:	4 x 37
or	1	:	0.881
Loading Rate = $\frac{\text{Mass}}{\text{Time}}$, Thus	1	:	0.881

$$L\ (HCl) = 0.881*L\ (C_2Cl_4)$$

For the flows, concentration and corresponding loading rates of tetrachloroethylene, we can now also present the emission rate of hydrogen chloride and observe how it might vary throughout the remediation period.

Q (Ft^3/Min)	PPM_V ($1/10^6$)	L(C_2Cl_4) (lbs/hr)	L(HCl) (lbs/hr)
500	0.009	116	102
500	0.008	103	91
400	0.008	83	73
360	0.0075	70	62
200	0.004	21	19
180	0.001	46	4 ≤ AER critical

APPENDIX F

AIR EMMISION LEVELS DUE TO CATALYTIC OXIDATION

APPENDIX F

AIR EMMISION LEVELS DUE TO CATALYTIC OXIDATION

To determine whether HCL emissions from catalytic oxidation meet NYSDEC guidelines:[1]

Oxidizing tetrachloroethylene in the presence of water moisture and a catalyst at 750°-1000° F results in the formation of carbon dioxide, water, and hydrogen chloride vapors. With a maximum tetrachloroethylene loading rate of 116 lbs/hr, a maximum hydrogen chloride loading rate of 1024 lbs/hr is expected. This emission rate of hydrogen chloride is a subject of concern.

A screening analysis of ambient air quality impact due to emission of hydrogen chloride from a 38 ft. stack outlet[2] is carried out in accordance with the procedure described in I(A), Appendix A, P. 14 of NYS Air Guide 1, as follows:

(1) Hydrogen chloride is classified as a "Low Toxicity Air Contaminant"[3] with an AGC of 7 $\mu g/m^3$.

(2) It is assumed that the source and the environs meet the "New York County" criteria. Thus, the "3)New York County" test on Page 22 follows: Q_c = AGC/200 = 0.035 < 102 lbs/hr. Since our emission rate exceeds Q_c, we will continue with step 3 on page 14.

(3) Following the same procedure as in Appendix D, (3).

From Appendix F, L_{max} = 102 lb/hr, Q = 500 cfm

Therefore, $L/Q \times 2.67 \times 10^8 = 544{,}680\ \mu g/m^3 > 7\ \mu g/m^3$

To determine the critical concentration at which the above condition is satisfied, we derive the loading rate equation for hydrogen chloride gas as:

$L = Q \times ppm_v \times 5.68$ or $L/Q = ppm_v \times 5.68$

Moreover, the in-stack concentration upper limit was defined by: $L/Q < 2.62 \times 10^{-6}$

---

[1] NYS Air Guide 1, September 1989 printing edition is the primary reference used in this analysis.

[2] A less conservative stack height can be designed by analyzing cavity impact. AGC levels, however, are current.

[3] Table IV, Page 56, NYS Air Guide 1.

At the critical condition: ppm_v x 5-68 = 2-62 x 10^{-6} That is initial concentration is 0-5 ppm. We, thus proceed to (4)(a).

(4)(a) $h_c = 1.5*h_b = 1.5*25 = 37.5$ Ft. Since our stack height is 38 Ft., "no cavity impacts need be considered", and thus we can skip to Step 5 on Page 16.

(5)(b)(i) $h_e = 38$ ft.
From Figure VII on page 28, the point (102,38) corresponds to a C_a value of 166 $\mu g/m^3$. Thus, AGC is exceeded. To identify critical loading rate, let C_a = 7 $\mu g/m^3$, therefore, AER = 4.3 lb/hr. Therefore, efficiency of scrubber $\geq 1 - \dfrac{4.3}{102} * 100$

$$\geq 95.8\%$$

APPENDIX G

FIELD REPORTS

FIELD REPORT
ANORAD CORPORATION
HAUPPAUGE, NY
VAPOR CLUSTER AND PROBE INSTALLATIONS

DATE: December 2, 1991

PRESENT:	Scott Stehlik	Fanning, Phillips & Molnar
	John Paul Schepp	Fanning, Phillips & Molnar
	Carl Pedersen	Land, Air, Water Environmental Services
	Kevin McGourty	Land, Air, Water Environmental Services
	Steven Mandell	Land, Air, Water Environmental Services

WEATHER: 45°F Overcast

OBJECTIVE: Construct vapor clusters and probes as per Fanning, Phillips & Molnar Specifications

DETAILS:

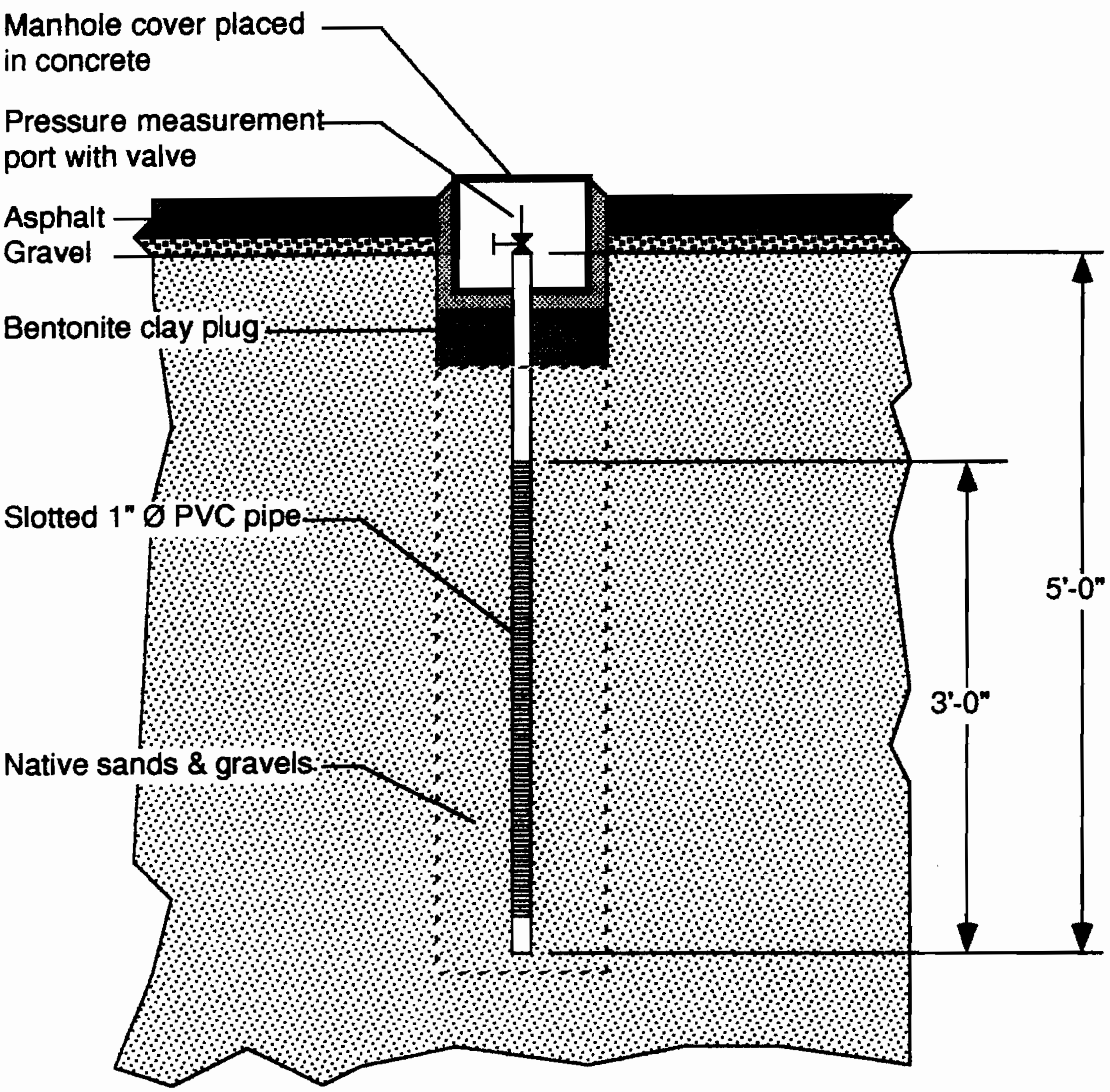
Arrived on site at 7:00 AM and met drillers from Land, Air, Water Environmental Services. Microtip (TIP) calibrated to 101 ppm isobutylene. Drillers steam cleaned augers on site and set up over location of vapor cluster-1. Drilled through asphalt and post hole dug to 3 1/2 feet. Encountered portion of drain pool pipe, therefore, relocated cluster.

Background readings on microtip 5 to 10 ppm. At 17-feet 20 ppm detected with TIP in the breathing zone. Backed off and vented hole. TIP readings lower to background. At 20-feet saturated soil was encountered. At 25-feet obtained split spoon sample to try to locate clay layer. Obtained continuous split spoon samples to 32-feet. All samples were saturated. At 28.5-feet sample measured >10,000 ppm on tip. At 32-feet top 2" of sample were dry. Continued drilling, puffs of contaminated vapor reached 150 ppm in breathing zone.

Personal safety equipment raised to level C. Due to the water intrusion and saturated conditions a 4-inch PVC groundwater well was constructed, instead of the vapor cluster. Grab samples of soil obtained at approximately 8' and 25' - 30' below grade and contained in one quart mason jars. Fifteen feet of screen and 18' of casing was lowered to 33-feet below grade. Drillers gravel packed to 16-feet (2 feet above screen). During auger withdrawal breathing zone readings range from background to 400 ppm. Readings can be described as puffs of contaminated air from the augers. Drillers added 2-feet of pellets/chips and grouted to 2-feet below grade. The well was covered with a pallet. Excess cuttings were placed in 55-gallon drums. Materials used by drillers: 18-feet of 4-inch schedule 40 PVC; 15-feet of 4-inch PVC screen; 4 bags of gravel pack; One 4-inch lock-in cap; 1 end cap; 1 lock; 1 1/2 bags of bentonite chips; 3 DOT 17-H drums; 1/2 bag of bentonite granular for bentonite grout some of these materials were utilized by John Paul to seal his 5-foot vapor wells (refer to attached Drilling Log).

Vapor probes were constructed by John Paul Schepp as shown in the figure labeled "Typical Shallow Vapor Probe Construction"; with the exception of manhole covers which were placed by Land, Air and Water. During the course of the day vapor probes (VP) 1, 5, 6, and 7 were constructed. This was achieved by cutting the asphalt with an electric hammer drill and plunger bar, post hole digging and hand augering. Native materials were returned to the auger hole to pack the slotted pipe. Volvlay sodium bentonite chips were then added and activated with tap water to seal the screened section of pipe from the atmosphere. Left over soils were placed in the drums used by Land, Air, and Water Environmental Services. Left site 5:00 PM.

dd155



Typical shallow vapor probe construction

DRILLING LOG

Depth	Description
0 - 3"	Asphalt
3" - 17'	Light Brown, Medium-Fine Sand, Some Gravel, Trace Pebbles
17' - 25'	Wet, Brown, Medium-Fine Sand, Some Gravel, Trace Pebbles
25' - 33'	Wet, Brown, Medium Sand, Some Gravel (at 32' Soil Dry)

dd155

LAND, AIR, WATER
ENVIROMENTAL SERVICES, INC.
P.O BOX 372 • 16 COZINE ROAD
CENTER MORICHES, NEW YORK 11934-0372
(516) 874-2112

RECEIVED DEC 1[illegible] 1991

DAILY JOB REPORT

DATE Dec 2, 1991

CUSTOMER Anorad Corp.

BILLING ADDRESS 110 Oser Ave, Hauppauge

LOCATION OF WORK Same

JOB DESCRIPTION Install (1) 4" well to a depth of (33') as per Fanning, Phillip & Molnar Specifications, Also grouted 14' of BoreHole

MATERIALS (5') 4" sch 40 pvc Blank ([illegible]') 4" pvc Screen (4) bags gravel pack (1) 4" locking cap (1) End cap (1) Lock (1½) bg bentonite chips (½) bg bentonite granuala for Bentonite grount (

EQUIPMENT Rig - #4 Grouter
Support truck - #6 Steam Cleaner
Box truck - #5 Generator

PERSONNEL	TOTAL HOURS	PERSONNEL	TOTAL HOURS
C. Pedersen - D/M	[illegible]	On site [illegible]	
M. McGourty - E/O	[illegible]	[illegible]	
[illegible] Randall - S/T	[illegible]	0	

TOTAL MEN ON JOB 3

DAILY OPERATIONS COMMENCED 0600 0700 on site

HOUR SECURED 1700 site 1800 yard

NO. OF DISPOSAL LOADS [illegible] drums on site

SUBSISTENCE

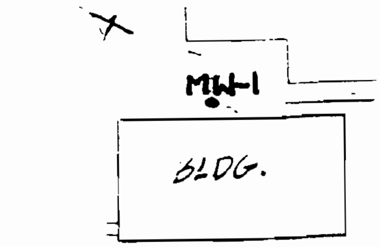
APPROVED Matt [illegible]
CUSTOMER REPRESENTATIVE

fanning, phillips & molnar
ENGINEERS
RONKONKOMA NEW YORK

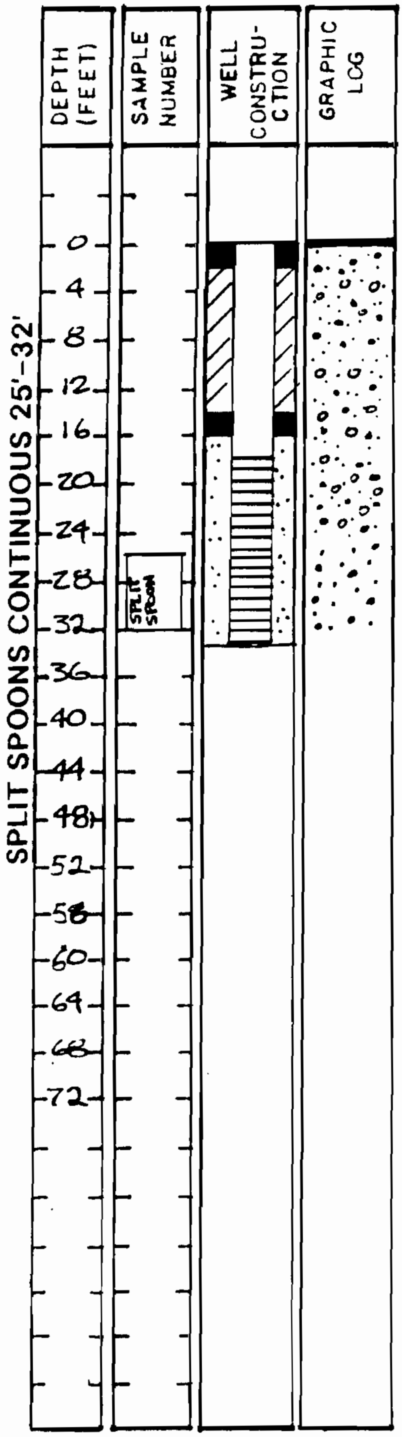
Drilling Log

Project ANORAD PILOT STUDY Owner ____
Location 100 OSER AVE. HAUPPAUGE, N.Y. W.O. Number 180-91-07
Well Number MW-1 Total Depth 33' Diameter ≈10"
Surface Elevation ____ Water Level: Initial ____ 24-hrs ____
Screen: Dia. 4" Length 15' Slot Size ____
Casing: Dia 4" Length 18' Type PVC
Drilling Company LAND, AIR, WATER Drilling Method HOLLOW STEM AUGER
Driller CARL PEDERSEN Log By ____ Date Drilled 12/2/91

Sketch Map



Notes



DESCRIPTION/SOIL CLASSIFICATION
(COLOR, TEXTURE, STRUCTURES)

0 - 3"	Asphalt
3" - 17'	Light Brown, Medium-Fine Sand, Some Gravel, Trace Pebbles
17' - 25'	Wet, Brown, Medium-Fine Sand, Some Gravel, Trace Pebbles
25' - 33'	Wet, Brown, Medium Sand, Some Gravel (at 32' Soil Dry,

FIELD REPORT
ANORAD CORPORATION
HAUPPAUGE, NY
VAPOR CLUSTER AND PROBE INSTALLATIONS

DATE:	December 3, 1991	
PRESENT:	Scott Stehlik	Fanning, Phillips & Molnar
	John Paul Schepp	Fanning, Phillips & Molnar
	Carl Pedersen	Land, Air, Water Environmental Services
	Kevin McGourty	Land, Air, Water Environmental Services
	Steven Mandell	Land, Air, Water Environmental Services
WEATHER:	45°F Raining	
OBJECTIVE:	Construct vapor probe and clusters as per Fanning, Phillips & Molnar specifications.	

DETAILS:

Arrived on site at 7:00 AM and met drillers from Land, Air, Water Environmental Services. Microtip (TIP) calibrated to 101 ppm isobutylene. Set up over location of vapor cluster 2. Post hole dug to 3 1/2 feet. Drilled 5 feet and encountered cobble refusal. Location was moved 2 feet north. Depth to water measured on west side of building (66 feet 8 inches). Change in elevation approximately 6 -inches. Depth to water at well approximately 66-feet. Well drilled to 62-feet. Grab samples of soil cuttings obtained at approximately 10', 25', 42', and 60' below grade and contained in one quart mason jars. Driller noticed an odor at 62-feet checked with microtip. Greater than 1000 ppm in the auger head, 0 ppm in the breathing zone. After lunch casing was lowered in. Brief puffs of contaminated vapor were noted out of the auger head reaching 75 ppm. Completed vapor cluster installation with sand, bentonite pellets, and grout. Left hole open and covered with pallet and cone. Excess cuttings were placed in 55-gallon drums. Augers steamed cleaned on site. Materials utilized by drillers: 125-feet 1 inch schedule 40 PVC casing; 20-feet 40 PVC 1-inch screen; 3 bags of bentonite; 6 bags cement; 5 DOT17-H drums; 6 gloves; 6 boots; 4 1-inch end caps (refer to attached Drilling Log). John Paul installed VP-2, VP-3 and VP-4 using the same procedures as described in the December 2, 1991 field report. Left the site at 5:30 PM.

dd155

DRILLING LOG

Depth	Description	Comments
0 - 3"	Asphalt	
3" - 5"	Brown, Medium-Fine Sand, Trace Gravel, Trace Pebbles, Cobbles	At 3' TIP Reading 0 ppm
5' - 15'	Brown, Medium-Fine Sand, Abundant Gravel, Some Pebbles, Trace Silt	At 15' TIP Reading 0 ppm
15' - 20'	Brown, Medium-Fine Sand, Abundant Gravel, Increased Pebbles, Trace Silt	At 20' TIP Reading 0 ppm
20' - 30'	Brown, Medium Gravelly Sand, Trace Pebbles	At 30' TIP Reading 12 ppm at Cuttings .9 in Breathing Zone
30' - 35'	Brown, Medium Gravelly Sand, Increased Gravel, Some Pebbles	At 40' TIP Reading 0 ppm
35' - 45'	Brown, Medium Sand, Gravel, Some Pebbles	At 42' TIP Reading 2.8 ppm in Cuttings 1 ppm in Breathing Zone
45' - 62'	Brown, Medium Sand, Abundant Gravel	At 60' TIP Reading 0 ppm

dd155

LAND, AIR, WATER
ENVIROMENTAL SERVICES, INC.
P.O BOX 372 • 16 COZINE ROAD
CENTER MORICHES, NEW YORK 11934-0372
(516) 874-2112

DAILY JOB REPORT

DATE 3 Dec '91 Monday

CUSTOMER Anorad Corp.

BILLING ADDRESS 110 Oser Ave Hauppauge

LOCATION OF WORK Same

JOB DESCRIPTION Install 1" Cluster well as per Fanning Phillips & Molnar specifications dated 11/15/91

MATERIALS (125)' Sch 40 1" pvc casing
(30)' Sch 40 PVC 1" Screen (3) bags bentonite
(0) manholes (6) bags Cement
(5) DOT 17-H drums (6) Pairs Gloves
(0) Tyveks (6) Pairs boots. (4) 1" End caps

EQUIPMENT Drill Rig #4 Steam Cleaner
Box Truck #5 Generator
Support Truck #6
Rosewall Grouter

PERSONNEL	TOTAL HOURS	PERSONNEL	TOTAL HOURS
C. Pedersen D/H			
K. McGourty D/H			
S. Mandell E/O			

TOTAL MEN ON JOB 3

DAILY OPERATIONS COMMENCED 0600

HOUR SECURED

NO. OF DISPOSAL LOADS (5) - 17-H Drums left on site

SUBSISTENCE X

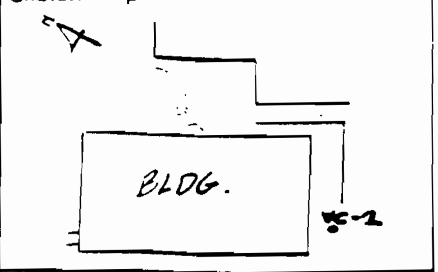
APPROVED
CUSTOMER REPRESENTATIVE

fanning, phillips & molnar
ENGINEERS
RONKONKOMA NEW YORK

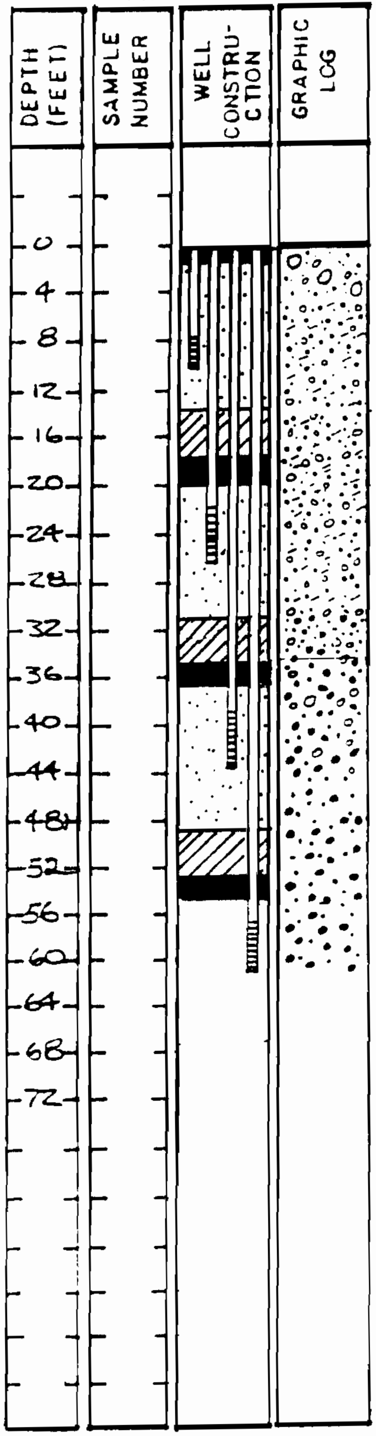
Drilling Log

Project ANORAD PILOT STUDY Owner
Location 100 OSER AVE. HAUPPAUGE, N.Y. W.O. Number 180-91-07
Well Number VC-2 Total Depth 62' Diameter ≈10'
Surface Elevation ≈130' AMSL Water Level: Initial — 24-hrs —
Screen. Dia. 1" Length FOUR 5' SECTIONS Slot Size .020"
Casing: Dia 1" Length 57' Type PVC
Drilling Company LAND, AIR, WATER Drilling Method HOLLOW STEM AUGER
Driller CARL PEDERSON Log By Date Drilled 12/3/91

Sketch Map



Notes



DESCRIPTION/SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)

0 - 3"	Asphalt
3" - 5'	Brown, Medium-Fine Sand, Trace Gravel, Trace Pebbles, Cobbles
5' - 15'	Brown, Medium-Fine Sand, Abundant Gravel, Some Pebbles, Trace Silt
15' - 20'	Brown, Medium-Fine Sand, Abundant Gravel, Increased Pebbles, Trace Silt
20' - 30'	Brown, Medium Gravelly Sand, Trace Pebbles
30' - 35'	Brown, Medium Gravelly Sand, Increased Gravel, Some Pebbles
35' - 45'	Brown, Medium Sand, Gravel, Some Pebbles
45' - 62'	Brown, Medium Sand, Abundant Gravel

FIELD REPORT
ANORAD CORPORATION
HAUPPAUGE, NY
VAPOR CLUSTER AND PROBE INSTALLATIONS

DATE: December 4, 1991

PRESENT:

Scott Stehlik	Fanning, Phillips & Molnar
John Paul Schepp	Fanning, Phillips & Molnar
Carl Pedersen	Land, Air, Water Environmental Services
Kevin McGourty	Land, Air, Water Environmental Services
Steven Mandell	Land, Air, Water Environmental Services

WEATHER: 30°F Overcast, Flurries

OBJECTIVE: Construct vapor clusters and probes as per Fanning, Phillips & Molnar specifications.

DETAILS:

Arrived on site at 7:00 AM and met drillers from Land, Air, Water Environmental Services. Set-up over location of vapor cluster 1. The new location is a previous shallow vapor location from John Paul. Microtip (Tip) calibrated to 101 ppm isobutylene. Background reading on (TIP) 1 to 2 ppm (ambient air). Grab samples of soil cuttings obtained at approximately 9', 25', 42', and 62' below grade and contained in one quart mason jars. A plug in the bottom of the auger delayed setting the screen. PVC removed and plug driven out. Set well at 61-feet 6-inches. Check from Bill Zerella (Anorad) given to Carl Pedersen at Land Air Water Environmental Services. Cemented all manholes. Newly installed groundwater well was dry. Vapor cluster 1 constructed as per Fanning, Phillips & Molnar specifications. 13 manholes, 13 drums of cutting unlabeled material used by drillers: 112- feet 1-inch PVC; 20-feet 1-inch screen; 13 manholes; 4 1-inch end caps; 8 bags cement; 3 bags bentonite chips, 5 DOT 17-H drums, 10 bags of sand refer to attached Drilling Log. All cuttings not returned as sand pack were drummed. John Paul installed VP-8, VP-9 and VP-10 using the procedures outlined in the December 2, 1991 field report. Left site 6:00 PM.

dd155

DRILLING LOG

Depth	Description	Comments
0 - 3"	Asphalt	
3" - 5'	Brown, Silty Fine Sand,	TIP Reading at 3' 0 ppm
5' - 15'	Brown, Fine Sand, Abundant Gravel, Trace Pebbles	TIP Reading at 12' 1 ppm in Cuttings .5 ppm Breathing Zone
15' - 45'	Brown, Medium Gravelly Sand, Some Pebbles	TIP Reading at 28' 0 ppm 33' 0 ppm 38' 4 ppm Cuttings 0 ppm Breathing Zone 43' 3 ppm Cuttings 0 ppm Breathing Zone
45' - 62'	Brown, Medium Sand, Some Gravel, Trace Pebbles	TIP Reading at 60' 0 ppm in Breathing Zone 90 ppm Inside Auger

LAND, AIR, WATER
ENVIROMENTAL SERVICES, INC.

P.O BOX 372 • 16 COZINE ROAD
CENTER MORICHES, NEW YORK 11934-0372
(516) 874-2112

DAILY JOB REPORT

DATE 12/4/91

CUSTOMER Fanning, Phillips & Molnar

BILLING ADDRESS

LOCATION OF WORK 100 Oser Ave, Hauppauge

JOB DESCRIPTION Installed PNEUmatic monitoring well Clusters. Also Cemented in (13) of manholes

MATERIALS (112) - PVC 1" Blank (20) - PVC 1" Screen (13) - Manholes (4) - 1" End caps (8) - Cement (3) - Bentonite Chips (0) - gloves (0) - Suits (0) - Boots (5) - 17-H Dr
(10) - Bg Sand for Cement

EQUIPMENT Drill Rig - #4 Steam cleaner
Box truck - #5 Rotary Grouter
Support truck - #6 Generator

PERSONNEL	TOTAL HOURS	PERSONNEL	TOTAL HOURS
C. Pedersen D/M	13 hrs		
K. McGovity - E/O	9½ hrs		
S. Mandell - S/T	13 hrs		

TOTAL MEN ON JOB 3

DAILY OPERATIONS COMMENCED 0600

HOUR SECURED 1900

NO. OF DISPOSAL LOADS (13) - 17-H drums left on Site (Total 3 days)

SUBSISTENCE

APPROVED Scott Kelly
CUSTOMER REPRESENTATIVE

fanning, phillips & molnar

Drilling Log

Project ANORAD PILOT STUDY Owner

Location 100 OSER AVE. HAUPPAUGE, N.Y. W.O. Number 180-91-07

Well Number VC-1 Total Depth 61'-6" Diameter ≈ 10"

Surface Elevation ≈ 130' AMSL Water Level: Initial — 24-hrs —

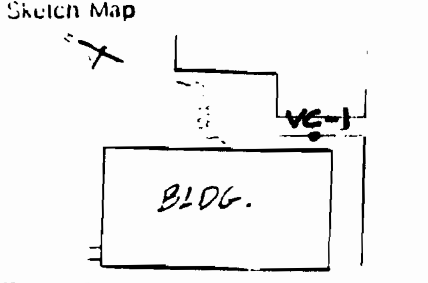
Screen: Dia. 1" Length FOUR 5' SECTIONS Slot Size .020

Casing: Dia 1" Length Type PVC

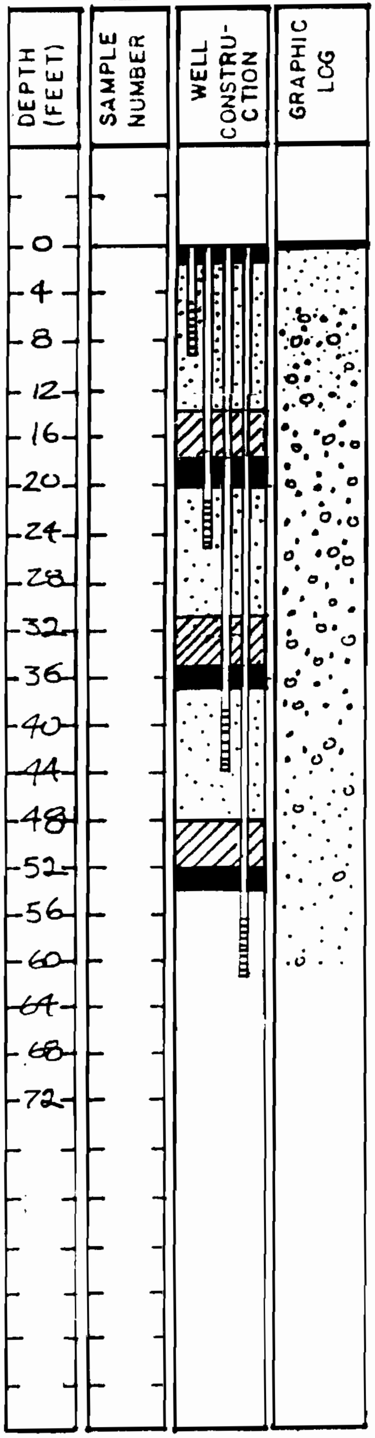
Drilling Company LAND, AIR, WATER Drilling Method HOLLOW STEM AUGER

Driller CARL PEDERSON Log By Date Drilled 12/4/91

Sketch Map



Notes



DESCRIPTION/SOIL CLASSIFICATION (COLOR, TEXTURE, STRUCTURES)	
0 - 3"	Asphalt
3" - 5'	Brown, Silty Fine Sand,
5' - 15'	Brown, Fine Sand, Abundant Gravel, Trace Pebbles
15' - 45'	Brown, Medium Gravelly Sand, Some Pebbles
45' - 62'	Brown, Medium Sand, Some Gravel, Trace Pebbles

FIELD REPORT
ANORAD CORPORATION
HAUPPAUGE, NEW YORK
VAPOR WELL FOLLOW UP INSPECTION

DATE: December 10, 1991

PRESENT: Scott Stehlik - Fanning, Phillips and Molnar

WEATHER: 50° F, Sunny

OBJECTIVE: Check condition of all newly installed vapor wells.

DETAILS:

Arrived on site at 11:00 a.m. and checked surficial conditions of all newly installed vapor wells. All wells flush to grade with no noticeable damage. Vapor Cluster 2 barricaded with cone and lath with ribbon. Opened VC-2 and inspected PVC cluster. Cluster intact, but caps must be installed soon due to weathering of temporary duct tape caps. Closed manhole and replaced barricade. Left site at 12 noon.

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FIELD REPORT
ANORAD CORPORATION
100 OSER AVENUE
HAUPPAUGE, NY

DATES:	12/17/91 - 12/19/91	
PRESENT:	Gaby A. Atik	Fanning, Phillips & Molnar
	John Paul Schepp	Fanning, Phillips & Molnar
WEATHER:	Variable, 30°F	
OBJECTIVE:	To Conduct In-Situ-Vapor Extraction Tests	

DETAILS:

Fanning, Phillips and Molnar arrived on site at 8:00 AM on 12/17. We received a carbon barrel that was delivered by Carbtrol to Dave McManus of Anorad.

Fanning, Phillips and Molnar checked all extraction wells for water intrusion, of which none was found. We then connected the blower to the carbon barrel and to the extraction Well D-2.

Prior to extraction, we measured the initial vapor pressures at all vapor probes and cluster vapor pressures were all measured by connecting a magnehelic pressure gauge to a vapor probe and then releasing a pinch clamp.

The blower was then turned on and allowed to operate at an extraction flow rate of 42 cfm. This rate was determined by measuring the throttling and effluent velocities, and then multiplying their difference by the area of either the throttling or effluent pipe (they were equal).

Following start-up, pressure at all vapor probes and clusters, and there time of measurement were recorded at intervals of about 15 minutes (see Table 1), until steady state was reached. Steady state is typically assumed to have been reached when pressures at monitoring wells, closer to the extraction well, seize to continue decreasing (i.e. become more negative). December 17, 1992 pressure data do not follow that pattern as a result of fluctuating atmosphere pressures. Such fluctuations can result in a a 1.3 inches of water pressure change, a change enough to offset extraction pressure at 42 cfm. Furthermore, the atmospheric changes were visible as the weather changed from clear, to cloudy with snow and rain, and back to clear over the course of the day.

Moreover, throughout the operation of the extraction system, the following readings were recorded (see Table 1):

- Effluent and throttling velocities using a velocity probe.

- Blower pressure gauge reading (remained at about 13-16 inches of water)

- Atmospheric Pressure (malfunction?)

- PID readings of influent and effluent. (The photoization detector (PID) was calibrated using a 100 ppm standard of isobutylene every morning and end-of-day calibration checks were performed daily. Tedlar bags were purged several times before each use.

Following completion of monitoring, the blower was switched off and separated from the suction port and the carbon barrel. We then capped all wells and left the site at 4:50 PM.

Fanning, Phillips and Molnar arrived on site at 7:45 AM on 12/18/91. We connected the extraction system to well D-2 and allowed it to operate at a flow rate of 56 cfm for 129 minutes (see Table 2). We then stepped-up the flow rate to 72 cfm and allowed the blower to operate for 106 minutes, by which time steady state was reached (see Table 3).

We then moved the extraction system and connected it to Well D-3. Extraction at D-3 took place at a rate of 72 cfm for 105 minutes (see Table 4). Fanning, Phillips and Molnar left the site at 5:10 PM.

Fanning Phillips & Molnar arrived on site at 8:15 AM on 12/19/91. We connected the extraction system to well D-1 and allowed it to operate at a flow rate of 72 cfm for 126 minutes (see table 5).

Throughout field operations on 12/18 and 12/19, Fanning, Phillips and Molnar performed procedures similar to ones described during the activities of 12/17.

Following the completion of the In-Site-Vapor Extraction tests, we surveyed the site to obtain more accurate coordinates of the well and probe locations. Fanning, Phillips and Molnar then left the site at 1:00 PM.

Note: On 12/17/91, R&L reset the manholes of Wells D-2 and D-3, which had risen several inches above the surrounding pavement and were in risk of being damaged by snow plows.

APPENDIX H

SYSTEM DESIGN FLOWS

APPENDIX H
SYSTEM DESIGN FLOWS

Pumping Well	Radius of Influence Required	Design Radius of Influence[1]	Pilot Study Data (Q, R)	Design Flow[2]
D-1	40	50	72 cfm, 42 ft	100 cfm
D-2	65	81	72 cfm, 47 ft	215 cfm
D-3	60	75	72 cfm, 96 ft	45 cfm
			System Design Flow =	360 cfm

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[1] Based on a factor of safety of 1.25.

[2] An example calculation for D1:

$$Q = \frac{(72\text{ cfm})\,(50\text{ ft})^2}{(42\text{ ft})^2} \approx 100\text{ cfm}$$