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FINAL REPORT
INTEGRATED DUAL VACUUM EXTRACTION/ PNEUMATIC FRACTURING PILOT STUDY

at the

LEICA OPTICAL SITE
CHEEKTOWAGA, NEW YORK

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DECEMBER, 1996

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1. INTRODUCTION

NES, Inc. and Terra Vac (the NES Team) were contracted by Leica, Inc., Optical Products Division, to design, install, operate, and monitor a dual vacuum extraction/air injection (DVE/AI) pilot study at the former Leica Optical Site in Cheektowaga, New York. The design parameters for this pilot study system were based on the information provided in previous site investigations conducted by Conestoga-Rovers & Associates (CRA). The pilot study was conducted in order to evaluate the effectiveness of dual vacuum extraction (DVE), combined with the enhancements of pneumatic fracturing (PF) and air injection (AI), to address subsurface volatile organic compound (VOC) contamination, and provide design parameters for a potential full-scale remedial program to be implemented at the site.

2. SITE DESCRIPTION

The former Leica Optical Site located on Eggert Road in Cheektowaga, New York. Site investigations conducted by CRA indicate that the subsurface has been contaminated as a result of past operations at the facility. Three separate areas of contamination consisting of the former drum storage area, the northeastern source area, and the southeastern area were identified during the investigations and designated as Areas A, B, and C, respectively.

The DVE/AI pilot study was conducted in a representative section of Area C. It was located in the grassy area southeast of the main building, on the edge of the paved parking lot. The contaminants of concern consisted of vinyl chloride, 1,1-dichloroethylene, 1,2-dichloroethylene (cis and trans), 1,1-dichloroethane, 1,2-dichloroethane, trichloroethylene, 1,1,1-trichloroethane, and the petroleum components of benzene, toluene, ethyl benzene, and total xylenes (BTEX).

3. PILOT STUDY OPERATIONS

During the pilot study, several remedial options were evaluated. In order to ensure an efficient and cost-effective collection of information for the preparation of a full-scale remedial design, the following tasks were completed.

- Subsurface classification
- Well installation
- Remedial system construction
- System operation and monitoring

Each of these tasks are discussed in greater detail below.

3.1 Subsurface Classification

Previous site investigations have identified four subsurface geologic zones in the overburden of the proposed remedial areas. Beneath an initial layer of asphalt lies a fill comprised of disturbed native soils, sand, gravel, and assorted building debris, extending between 2 and 5 feet below grade. A lake sediment layer consisting of a varved, red-brown clay and silt with minor amounts of sand and fine gravel underlies the fill layer. This native soil zone ranges in thickness from 5 to 9 feet, and laboratory analyses indicate a permeability of approximately 1 x 10^{-8} cm/sec. Beneath the lake sediments is a saturated silt and sand layer ranging in thickness from 2 to 8 feet. A thin, densely compacted till layer lies below the sandy zone, directly above a limestone bedrock.

During DVE and piezometer (PZ) well installation, soil samples were collected for careful inspection by the NES Team's on-site geologist to determine soil classification, screen intervals, and final well design. In the section of Area C selected for the pilot study, an initial 1-foot interval of fill and topsoil was underlain by a dry to barely moist, red/brown, stiff, hard clay. This clay layer, identified as native soils in previous investigations, extended to a depth of approximately 12.5 feet. Beneath the clay, a 1-foot layer of a wet, gray, loose, silty/clayey, fine to medium sand was encountered. The limestone bedrock was identified at 13.5 feet below grade. The thin till layer identified during previous investigations was not observed during DVE and PZ well installation.

3.2 Well Installation

Drilling activities took place on September 24 and 25, 1996. The installation of two DVE wells and four piezometer (PZ) well nests was performed by Maxim Technologies, Inc. of Hamburg, New York. In addition, five air injection probes were installed by the NES Team on October 5, 1996. All well installation activities were supervised by the NES Team's on-site personnel. Well locations are provided in Figure 1.

3.2.1 DVE Well Installation

In order to properly evaluate the effects of the DVE/AI process on the subsurface, two DVE wells were installed using hollow stem augers. DVE1 was designed to address the low permeability, native soils. The total depth of installation was 9 feet, and the well was screened from 4 to 9 feet below grade. DVE2 was installed to the limestone bedrock, located 13.5 feet below grade. A 2.5-foot screen interval, from 10.7 to 13.2 feet below grade, was utilized to address the lower zone of higher permeability in the saturated silty sand layer. This method of well installation was intended to allow pilot study activities to simultaneously address two isolated subsurface zones without the problems associated with the channeling of subsurface air flow through zones of higher permeability.

The two DVE wells were installed 6.5 feet apart. The wells were constructed using 4-inch diameter PVC, with intervals of 0.010-inch slot well screen. The annular space of each well was filled with filter sand to approximately 0.5 feet above the screen intervals. Each well was sealed with a 1-foot layer of bentonite, and the remaining space filled with portland cement. The wells were completed inside flush-mounted well boxes to provide security following pilot study operations. Construction diagrams of each DVE well are provided in Appendix A with the individual well logs.

3.2.2 Piezometer Well Nest Installation

Four piezometer well nests were installed at radial distances of approximately 5, 10, 15, and 20 feet from the DVE wells for the purpose of monitoring subsurface flows and pressures. Each PZ well nest boring contained two, 1-inch diameter schedule 40 PVC wells, with discrete, 0.010-inch slotted screen intervals across the upper clay and the lower sand intervals. The two screen intervals were isolated using a 1-foot layer of bentonite to ensure the results of system monitoring were representative of the discrete subsurface intervals. Each boring was sealed using a 2-foot layer of bentonite and a 1.5-foot interval of portland cement. The PZ well nests were completed inside flush-mounted well boxes to provide security following pilot study operations. Construction diagrams of each DVE well are provided in Appendix A with the individual well logs.

3.2.3 Air Injection Probes

Five air injection probes were installed at radial distances from the DVE wells ranging between 3 and 15 feet. Each probe was installed to a total depth of approximately 7 feet below grade using an electric rotohammer. The AI probes were comprised of 1/2-inch black iron pipe, equipped with a driving point. Figure 1 provides the AI probe design.

3.3 Remedial System Construction

The NES Team mobilized its mobile pilot study system to the site on September 30, 1996. System construction was completed on October 2. The pilot study system incorporated the following components into its design.

- Vacuum extraction unit (VEU)
- Air compressor
- Air/water separator
- Vapor/groundwater extraction manifold
- Vapor phase treatment system
- Liquid phase treatment system
- Groundwater recovery system
- Air compressor
- Air injection manifold

The DVE wells were connected to the remedial system through the use of a 2-inch, PVC manifold. An air injection manifold, consisting of 1/2-inch and 3/8-inch pressure rated hose, was used to connect the air compressor to the individual AI probes. Vapor treatment was accomplished using two, 1,000-pound activated carbon canisters prior to atmospheric discharge. Power was provided to the system by a 55-kW, diesel generator.

Each well was equipped with a groundwater recovery system utilizing the Entrainment Extraction™ technology. This allowed the recovery of both soil vapor and groundwater from the wells without the use of a groundwater pump. A 3/4-inch hose was attached to the system manifold on one end, while the other end was placed into the DVE well below the water table. Using the system vacuum, groundwater was entrained with the extracted airflow, and carried back through the system manifold to the air/water separator tank for collection.

A groundwater discharge manifold, consisting of 1-inch pressure rated hose and 2-inch schedule 40 PVC pipe, was used to connect the air/water separator tank to a groundwater treatment system comprised of two, 1,000-pound liquid phase carbon canisters connected in series. Following treatment, the groundwater was pumped to a 6500-gallon storage tank and discharged to the local sewer system under a temporary discharge permit (Permit No. 96-09-TP036). Figure 1 provides a Process Flow Diagram showing the individual components of the pilot study system. Photographs, taken during system operations, are provided in Appendix B.

3.4 System Operations and Monitoring

As previously stated, the purpose of this pilot study was to evaluate several enhancements to the dual vacuum extraction technology, and determine its feasibility as a potential full-scale remedial option for addressing subsurface contamination. In order to ensure sufficient evaluation during the pilot study, system operations were designed to be completed in a phased approach. The following progression of phases was implemented during the pilot study.

Phase 1 - Baseline Data Collection

Phase 2 - DVE Operations/Dewatering - DVE2 (sandy zone) only

Phase 3 - Continuous DVE Operations - DVE1 and DVE2

Phase 4 - PF/DVE Operations

Phase 5 - Continuous AI/DVE Operations

Phase 6 - System Demobilization

Monitoring of the system took place continuously during each phase of the pilot study. The parameters monitored include the following.

- Extracted vapor concentrations
- Extracted air flow rates
- Wellhead vacuum levels
- VOC extraction rates
- Subsurface vacuum levels
- Air injection pressures and airflows
- Groundwater levels
- Groundwater recovery rates
- Extracted dissolved-phase VOC concentrations
- Total system VOC emission rates

4. SITE OBSERVATIONS

4.1 Pilot Study Operations

Following collection of baseline groundwater level information, the pilot study system was started at 09:23 on October 2, 1996. Initial activities involved continuous DVE operations at DVE2. This well was screened in the water-bearing sandy zone, and provided the major source for groundwater recovery. One of the key elements in determining the success of this pilot study, would be whether or not dewatering efforts would result in a drawdown of the water table within the saturated portion of the low permeability, native soils. Therefore, Phase 2 represented the most important step of the pilot study, as the evaluation of subsequent technological applications would be greatly effected by the degree of dewatering achieved.

Groundwater recovery at DVE2 was optimized by slowly lowering the end of the vacuum entrainment tube to the bottom of the well. The applied wellhead vacuum was set at 19.5 inches of Mercury (" Hg), and Phase 2 continued overnight until October 3, 1996. At this time DVE1 was placed on line, and continuous DVE operations were conducted until October 5, 1996.

Initial air injection activities began on October 5, 1996 with pneumatic fracturing of the soils surrounding each of the AI probes. Fracturing of the subsurface was completed by connecting each individual AI probe to an industrial-grade compressed air cylinder using pressure rated hose and a regulator. Pressure was applied to each probe separately and slowly increased until the soils accepted the injected airflow. After pneumatic fracturing was completed at each of the five AI probes, the system was allowed to operate overnight in DVE mode.

Continuous air injection was initiated at 10:00 on October 6, 1996. The injection pressures applied to the individual probes ranged between 25 psi and 30 psi, with corresponding airflow rates from less than 1 cfm to 7 cfm. The system was operated in the DVE/AI mode until October 8, 1996, when pilot study operations were completed and system demobilization began.

The NES Team's mobile pilot study system was removed from the site on October 7, 1996. The four, 1,000-pound activated carbon canisters were secured on site to await shipment to the regeneration facility. Groundwater recovered during the pilot study was stored in the 6,500-gallon poly tank and discharged to the local sewer system under a temporary discharge permit.

4.2 Extracted Airflow Rates

During each phase of the pilot study, the extracted airflow rates were monitored at the DVE wells. A Dwyer DS-200 Series Flow Sensor was used at each wellhead manifold for flow measurement purposes. The manufacturer's formula, used to calculate airflow rates, is provided below. Vacuum levels were measured using a vacuum gauge.

DWYER FLOW SENSOR CALCULATION

$$Q = K * N * D^2 * (Ap * P/At)^{1/2}$$

Where:

Q = Volume flow rate in standard cubic feet per minute (scfm)

K = Flow Coefficient = 0.537 (1" pipe) and 0.585 (2" pipe)

N = Correction Factor, depends on units of measurement: using scfm and P in inches of water, N = 128.8

D = Exact inside diameter of pipe in inches

Ap = Absolute Pressure

At = Absolute Temperature

P = Pressure differential of flow sensor in inches of water ("w.c.")

Extracted airflow rates varied throughout the pilot study, as different system enhancements were evaluated. Tables 1 and 2 provide the extracted airflow rates observed at the individual DVE wells during pilot study operations.

Initial DVE operations at DVE2 started with an extracted airflow of 10 scfm. This rate increased to 14 scfm a day later, as dewatering efforts were optimized. This rate decreased back to 9 scfm once DVE1 was placed on line during continuous operations.

The creation of additional subsurface pathways during PF activities resulted in no observable increase in extracted airflow at DVE2, as fracturing was apparently isolated to the upper clay layer. However, communication between this clay layer and the lower sandy layer was evident during AI operations, as extracted airflow rates at DVE2 increased to 11 scfm.

Operations at DVE1 began with an extracted airflow of 3 scfm, before stabilizing at 2 scfm. As with DVE2, pneumatic fracturing resulted in no recordable increase in extracted airflow. An increase back to 3 scfm was observed following initiation of AI activities. This indicates, that a portion of the air injected into the subsurface traveled horizontally through the clay layer.

4.3 Extracted Vapor Concentrations

On-site analysis of the extracted vapors took place during the pilot study using a gas chromatograph (GC) equipped with a flame ionization detector (FID). This allowed for rapid turn-around of vapor phase analytical data to evaluate pilot study changes immediately following their implementation, and ensured compliance with regulatory discharge criteria. The data generated by the on-site analyses was used to determine full-scale system design and vapor treatment requirements.

The Target VOCs for on-site GC analyses included vinyl chloride, 1,1-dichloroethylene, 1,2-dichloroethylene (cis and trans), 1,1-dichloroethane, 1,2-dichloroethane, trichloroethylene, 1,1,1-trichloroethane, and the petroleum components of benzene, toluene, ethyl benzene, and total xylenes (BTEX) and other volatile petroleum components. Tables 1 and 2 provide the extracted vapor concentrations observed at DVE1 and DVE2, respectively. Table 9 lists the minimum detection limits for the on-site GC analyses.

Initial DVE operations began at DVE2. Extracted vapor concentration peaked at approximately 5.9 ppm before decreasing below detection limits during continuous operations. The two compounds detected were 1,1-dichloroethylene and cis-1,2-dichloroethylene. No beneficial increases were observed during PF activities as concentrations remained below detection limits. DVE/AI operations resulted in vapor concentrations reaching 30.3 ppm recorded at DVE2. In addition, the contaminant constituents detected were toluene, ethyl benzene, total xylenes, and additional petroleum related compounds, designated as Other VOCs. This appears to confirm that the airflow injected into the upper clay layer traveled downward into the sand. The presence of petroleum related compounds and the lack of chlorinated VOCs indicates that an area of the subsurface not previously influenced by DVE operations was now being addressed by the remedial system.

Initial vapor concentrations at DVE1 peaked at 102 ppm and steadily decreased as operations continued. As with monitoring at DVE2, the main compounds extracted from the subsurface were chlorinated VOCs, with 1,1,1-trichloroethane; cis-1,2-dichloroethylene; 1,1-dichloroethylene; and vinyl chloride detected. In addition, some petroleum related contamination was recovered and became more prevalent as operations continued. The immediate result of PF activities, was a decrease in extracted vapor concentrations at DVE1, as compounds reached levels below detection limits of the on-site GC. DVE/AI operations caused an increase in vapor concentrations to 30.3 ppm. As with DVE2, this increase was made up of petroleum related contamination.

During DVE/AI activities, monitoring of subsurface pressures and vacuums at the individual PZ wells showed that several of the wells were under pressure. Tedlar bag samples of the vapor were collected from PZ1S, PZ1D, and PZ3D. The results of GC analyses, performed on these samples are provided in Table 8. The highest concentrations were observed at the PZ wells screened within the lower sand layer, with the greatest concentrations recorded at PZ3D (1,985 ppm).

4.4 Vapor Phase Extraction Rates

The extracted vapor concentrations are used with airflow measurements to calculate the total system VOC extraction rates, expressed in terms of pounds per day. The equation is listed below.

Extraction rate (lbs/day) = Flow (scfm) * Concentration (mg/l) * CF

Where:

- Flow is calculated using Dwyer flow sensor instrument
- Concentration provided by GC analysis
- CF = 0.090, and is derived in the following manner:

$$0.090\ (l*min*lb/mg*day*ft^3) = 1440\ min/day * (12\ in/ft)^3 * (1\ m/39.37\ in)^3 * (100\ cm/m)^3 * 1\ l/1{,}000\ cm^3 * 1\ g/1{,}000\ mg * 1\ lb/453.6\ g$$

The total VOC extraction rates observed at each DVE well, during pilot study operations, are provided in Tables 1 and 2. These rates are depicted graphically versus time in Figures 3 and 6.

During DVE operations without PF/AI enhancements, VOC extraction rates peaked at 0.12 and 0.02 pounds per day for DVE1 and DVE2, respectively. Continued operations resulted in extraction rates decreasing to zero, as concentrations reached levels below detection limits at each DVE well. DVE/AI operations produced rate increases at DVE1 to 0.04 pounds per day, while extraction rates from DVE2 increased to peak, pilot study levels of 0.11 pounds per day.

The overall mass of VOCs extracted by each DVE well can be calculated by combining the individual extraction rates with system runtime. In 5.1 days of system runtime, an estimated 0.11 pounds of VOCs were extracted from the subsurface by DVE1. DVE2 extracted an estimated 0.15 pounds of VOCs in 6.1 days of runtime.

Figures 2 and 5 provide the contaminant profile for the vapors extracted by wells DVE1 and DVE2, respectively. The major compound extracted by DVE1 was 1,1,1-trichloroethane at 32.2% of the total, with total xylenes and other petroleum based compounds at 25% and 19.6%, respectively. Petroleum related contamination made up the bulk of the extracted vapors at DVE2, with other VOCs (69.4%), total xylenes (10.2%), ethyl benzene (10%), and toluene (8.6%) the major compounds identified.

4.5 Groundwater Recovery

Groundwater recovery was accomplished during pilot study operations, using the Entrainment Extraction™ technology. DVE2 provided the major source of subsurface dewatering, as this well was screened over the saturated sandy zone. DVE1 was also equipped for groundwater recovery; however, following an initial recovery of water derived from well installation, system operations resulted in the extraction of a negligible amount of soil moisture.

A total of approximately 530 gallons of groundwater were recovered from the subsurface and treated prior to storage on site and discharged to the local sewer system under a temporary discharge permit. Initial recovery rates peaked at approximately 0.3 gallons per minute (gpm), before stabilizing at 0.04 gpm for the duration of the pilot study. No beneficial increase in groundwater recovery was observed during PF and AI activities.

4.6 Groundwater Levels

Prior to remedial system start-up, depth-to-groundwater measurements were collected at each of the PZ wells and existing monitoring well MW6, located approximately 60 feet from the DVE wells. Throughout pilot study activities, measurements were collected to evaluate the effects of system operations on groundwater elevations. A summary of the groundwater measurements is provided in Table 10. Figure 8 shows the changes observed in groundwater elevations versus time for each of the monitoring points.

Pre-pilot study groundwater levels ranged from 8.3 feet below grade, at PZ2D and PZ4D, to approximately 10 feet below grade at MW6. Since measurements collected at the shallow PZ wells indicated that the depth to groundwater was below the wells' screen intervals, only the deep PZ wells were monitored for groundwater elevations during the pilot study. Dewatering efforts throughout system operations produced a steady drawdown of the water table in the vicinity of the DVE wells. Total drawdown over the course of the pilot study ranged from 2.2 feet at PZ3D to 3.0 feet at PZ4D.

The overall capture zone extended past 60 feet, as groundwater levels at MW6 dropped 2.2 feet. The relatively low groundwater recovery rates required to achieve this broad drawdown indicates that the aquifer is confined to semi-confined. The water-bearing sand layer does not possess a high recharge rate within the pilot study area from the upper clay layer or the bedrock. Present data indicates that dewatering the clay and sand layers is possible. The results of the bedrock pumping test, performed by CRA, may greatly influence full-scale design parameters for groundwater recovery and make it easier to dewater than currently anticipated.

4.7 Dissolved Phase VOC Concentrations

Extracted groundwater samples were screened on-site for the Target VOCs using the headspace method. Thirty (30) milliliters of groundwater were collected in a 40 ml VOA, equilibrated at 25.0 ± 0.1 degrees Celsius (°C), and analyzed using a direct injection method of the vapor headspace on the gas chromatograph. The concentration of VOCs in water was then calculated from known equilibrium constants relating the partitioning of the VOCs between the gas and aqueous phases.

$$K = \frac{C\ \text{liquid}}{C\ \text{gas}} = \frac{1}{Hc}$$

Where:

K	=	Partition Coefficient
C	=	Concentration
Hc	=	Henry's Law Constant

During system operations, the recovered groundwater was screened before and after the liquid phase carbon treatment system. Concentrations of the groundwater recovered from the subsurface by the DVE/AI system peaked at 48.2 ppb on October 2, 1996, and steadily decreased to 13.3 ppb on October 7. the major compounds identified were 1,1,1-trichloroethane and cis-1,2-dichloroethylene. The results obtained from the groundwater screening, prior to carbon treatment, are provided in Table 5. Minimum detection limits are listed in Table 9.

Groundwater samples were collected after the primary carbon unit and prior to discharge to the temporary holding tank. Concentrations remained below detection limits, except for 4.79 ppb of 1,1,1-trichloroethane detected in the post primary carbon sample, collected on October 4. The results of groundwater screening from the carbon treatment system are provided in Tables 6 and 7.

4.8 Subsurface Vacuum Levels

Subsurface vacuum levels were recorded throughout the pilot study at each of the piezometer wells. During continuous DVE operations, no measurable vacuum levels were detected at the PZ wells. While significant drawdown of the water table was observed, the screen intervals for the deep PZ wells remained submerged. Therefore, the vacuum zone of influence observed during pilot study operations was limited by subsurface conditions to less than 5 feet.

Pneumatic fracturing and air injection activities resulted in subsurface pathways being created. Monitoring at the PZ wells showed pressures ranging from non-measurable to 5 psi. However, these readings were isolated to the deep PZ wells, with the only exception being PZ1S which was within 5 feet of two AI probes. Since injected airflow follows the path of least resistance through the soil, the study indicates that, within the low permeability clay, this occurs horizontally as well as in the vertical plane towards the lower sand.

4.9 Air Injection Pressures and Airflows

Following completion of the continuous DVE operations phase, pneumatic fracturing of the subsurface was completed. The five AI probes were individually connected to a compressed air cylinder equipped with a two-stage regulator. Pressure was applied to the probe, and slowly raised until subsurface fractures were created. This was determined to be when the soils received the air, and the AI probe no longer held pressure. The applied pressures required for fracturing are listed below.

Probe	Pressure (psi)
AI1	220
AI2	180
AI3	170
AI4	220
AI5	170

Continuous air injection into the subsurface began on October 6, 1996. Initial, applied pressures ranged from 26 psi to 30 psi. Initially, only AI1 and AI4 showed measurable air flow rates, at 6.0 cfm and 6.8 cfm, respectively. The remaining AI probes possessed airflow rates less than 1 cfm. During the following two days of continuous DVE/AI operations, subsurface pathways began to open up, and the applied pressure required to force air into the soil decreased over time and measurable flow rates occurred at all AI points. The final injection pressures and flows are listed below.

Probe	Pressure (psi)	Airflow (cfm)
AI1	13	1.7
AI2	13	6.5
AI3	12	6.8
AI4	18	2.9
AI5	10	5.1

4.10 Total System VOC Emissions

During the pilot study, vapor samples collected after the primary and secondary carbon canisters were analyzed using the on-site GC. This was done to ensure compliance with regulatory emission criteria, and monitor vapor treatment efficiencies. Throughout the pilot study, all vapor treatment analyses remained below detection limits. The results of the vapor treatment system monitoring are provided in Tables 3 and 4.

5. PILOT STUDY SUMMARY

As previously stated, the purpose of this pilot study was to provide information regarding the subsurface of the Leica Optical site and potential full-scale remedial system design parameters. Based on the information obtained to date, the subsurface of the Leica site can be characterized as a complex, hydrogeologic formation which will require several integrated technologies incorporated into a full-scale remedial program. In order to achieve successful remedial efforts during the implementation of a full-scale program, effective dewatering of the soils will be required. The drawdown observed during pilot study operations indicates that the required dewatering can be accomplished. The results of the bedrock pumping test, performed by CRA, may greatly influence full-scale design parameters for groundwater recovery and make it easier to dewater than currently anticipated.

However, the data to be generated by the CRA bedrock pumping tests could greatly effect design parameters for a full-scale remedial system.

The data collected during the DVE/AI pilot study, indicates that dual vacuum extraction appears to be a feasible, base technology to remediate contaminated soils and groundwater at the Leica Optical site. The results of the DVE/AI pilot study are further summarized below:

- Vinyl chloride, 1,1-dichloroethylene, cis-1,2-dichloroethylene, 1,1,1-trichloroethane, benzene, trichloroethylene, toluene, ethyl benzene, total xylenes, and other petroleum related compounds were all detected in the extracted vapor stream, and can be recovered by the DVE/AI technology at the site.
- In 5.1 days of DVE/AI operations, an estimated 0.11 pounds of VOCs were extracted from the subsurface by DVE1. DVE2 extracted an estimated 0.15 pounds 6.1 days.
- Total VOC concentrations in the extracted vapors peaked at 102 ppm (DVE1) and 30.3 ppm (DVE2). The three major components identified in the extracted vapor stream from DVE1 were 1,1,1-trichloroethane, total xylenes, and other petroleum related compounds. The four major compounds extracted from DVE2 were other petroleum related compounds, total xylenes, ethyl benzene, and toluene.
- Applied wellhead vacuums ranged between 10.8 and 21.5" Hg, while the corresponding extracted airflows ranged between 2 and 3 scfm at DVE1, and 9 to 14 scfm at DVE2.
- 530 gallons of groundwater were recovered and treated by the DVE/AI system and stored on-site and discharged to the local sewer system under a temporary discharge permit. Recovery rates peaked at 0.25 gpm before stabilizing at approximately 0.04 gpm.
- Air injection into the subsurface resulted in increases in extracted VOC concentrations and extracted air flows at the DVE wells.

- At no time during pilot study operations were the regulatory discharge criteria exceeded, as VOC concentrations in the stack emissions remained below detection limits.

Pneumatic fracturing and air injection operations were successful in opening new subsurface pathways. Since the injected air follows the path of least resistance through the low permeability soils, it is impossible to predict which direction airflow will follow. Based on the information provided by system operations, it appears that, within the low permeability clay, this occurs horizontally as well as in the vertical plane towards the lower sand.

The pressures observed at the deep zone PZ wells, also indicate that a significant portion of the injected air may have headed away from the DVE wells. Full-scale remedial efforts will be conducted so that each AI probe is surrounded by DVE wells, in order to ensure recovery of injected air flow.

5.1 Subsurface Dewatering

Based on the information provided by CRA's site investigations and the results of the pilot study, the water-bearing sand zone has been determined to be a confined to semi-confined aquifer. Groundwater withdrawn from a confined to semi-confined water-bearing zone results from the expansion of the water and compression of the subsurface formation. The lowering of water levels in monitoring wells within the pumping area, is an indication of a reduction in artesian pressure, rather than conventional dewatering of the soils. A significant reduction in the piezometric head was observed during the pilot study, as water levels in the PZ wells and MW6 were lowered approximately 2 to 3 feet.

Complete dewatering of the lower sand will require a longer period of time than was available during the pilot study, due to the hydraulic characteristics of the water-bearing zone. Information from the CRA bedrock pumping tests will be beneficial in making a further evaluation of the hydraulic conditions and effect the design parameters for the full-scale system. Full-scale dewatering will likely eliminate the driving force behind the spreading of petroleum contamination within the lower portion of the clay, and the drop in piezometric head will prevent the re-saturation of the clays so that pneumatic fracturing/air injection will be more effective in this upper clay zone. It will also provide control over seasonal fluctuations which may adversely effect full-scale operations. In addition, DVE wells located in the sandy zone will provide a recovery point for contamination pushed out of the clay soils by pneumatic fracturing and air injection.

The NES Team has proposed design elements to address VOC contamination within the confined, water-bearing sand during implementation of the full-scale remedial program. The data indicates that significant dewatering of the narrow zone can be achieved with a 30 foot spacing of DVE wells screened over the sand interval. AI probes will be installed within this zone to provide an additional driving force for groundwater recovery and VOC transport. Even if limited dewatering occurs, VOC contamination will be addressed by what amounts to an air sparging subsystem installed within the sand layer.

5.2 PF/AI Effects on Extracted Airflow

Pneumatic fracturing is used to open subsurface pathways through low permeability soils. Air injection is used to keep the flow pathways created by pneumatic fracturing open and provide a driving force behind VOC transport towards the DVE wells. Typically, the injection of air into low permeability soils does not result in significant increases in extracted airflows. The restrictive nature of the micro-fractures created by pneumatic fracturing combine with the multiple, circuitous paths of least resistance through the soil to limit the amount of flow that actually reaches the DVE wells to rates on the order of cubic feet per hour (cfh) or less. Extracted airflows typically range between less than 1 and 10 scfm in clay soils. Therefore, the additional airflow from pneumatic fracturing and air injection does not result in measurable increases in the flow extracted from the DVE wells.

During pilot study operations, pneumatic fracturing and the injection of air in the clay soils was accomplished. No measurable increases in extracted airflow were observed. However, pressure readings collected at the PZ wells indicated that the influence of air injection within the clays reached 10 to 15 feet for some probes, and 15 to 20 feet within the sand. In addition, extracted VOC concentrations were observed and changes in the contaminant profile indicate that the low permeability subsurface was addressed by the DVE/AI system.

5.3 Subsurface Vacuum/Pressure Levels - System Influence

The propagation of subsurface vacuum and pressure zones of influence were monitored at each of the piezometer wells throughout each phase of pilot study operations. During continuous DVE operations, no measurable vacuum levels were recorded at the PZ wells indicating that the vacuum zones of influence observed during DVE operations (without PF/AI enhancement) were limited by subsurface conditions to less than 5 feet in both the clay and sand intervals. Dewatering efforts were successful in significantly reducing the piezometric head of the confined, water-bearing sand zone, but water level measurements made at the deep PZ wells indicated that screen intervals remained submerged.

Following completion of continuous DVE activities, the technology of pneumatic fracturing was used to create additional airflow pathways within the low permeability clay. Each AI probe was fractured and each PZ well was monitored to determine if an increase in the vacuum zone influence had occurred before beginning AI operations. No measurable vacuum levels were recorded, and the zone of influence remained less than 5 feet.

Continuous air injection into the subsurface was initiated on October 6, 1996. Injection pressures ranged between 10 and 30 psi as operational configurations were evaluated. Monitoring at the PZ wells showed pressures ranging from non-measurable to 5 psi. The development and opening of the new subsurface pathways was indicated by a steady increase in pressure at the PZ wells before stabilizing after approximately one day of DVE/AI operations. The majority of pressure influence was observed at the PZ wells screened within the sand interval.

The exception was PZ1S, which was within five feet of three AI probes. Pressure measurements reached 5 psi within the clay zone at this PZ well once air injection activities were initiated, indicating that an apparent channeling of injected airflow was occurring within the clay and injected air was reaching PZ1S. This airflow dissipated over time as additional pathways within the clay developed and readings decreased to 0.5 "w.c. pressure within PZ1S. The results of subsurface vacuum/pressure level monitoring are provided in Table 11.

On October 8, 1996 monitoring was conducted to determine the zone of influence for each of the AI probes. The probes were operated individually, and the resulting pressure readings were recorded at the PZ wells. The results obtained during this testing period are provided in Table 12. The readings indicate that the influence of each AI probe was highly directional based on the subsurface conditions immediately surrounding the probe. In the clay layer, influence ranged from less than six feet to approximately 15 feet. Influence in the water-bearing sand reached distances 15 to 20 feet away from the AI probes.

The total depth of AI probe installation was approximately 7 feet below grade. This placed the point of injection near the middle of the clay layer. Pressure readings in the shallow and deep PZ wells indicate that the injected air flow traveled horizontally and also vertically through a five foot interval of clay before reaching the sand. Based on the results obtained during the October 8, 1996 testing and the readings observed during continuous DVE/AI operations, the path of least resistance through the low permeability clay possesses a greater vertical vector component towards the sand. This indicates that PF and AI activities influenced an area in the clay below the point of injection.

As previously discussed, initial contamination recovery consisted of the chlorinated VOCs 1,1-dichloroethene and cis-1,2-dichloroethene. Following approximately 2.5 hours of system operations, levels of these chlorinated compounds dropped below detection limits. However, air injection resulted in high level recovery of VOCs consisting solely of petroleum related contamination. This indicates that the petroleum contamination was not previously addressed by the DVE process, and its location within the subsurface lies along the path of the injected airflow as it traveled down, through the clay, and into the lower sand zone.

The study data indicates that the low permeability clay acts as a confining layer for the water-bearing sand, which is located between the clay and the limestone bedrock. Groundwater within this confined water-bearing zone has an upward piezometric pressure against the clay. Because petroleum is an LNAPL, the upward pressure of the aquifer has probably pushed this contamination against the clay and has driven it into any naturally occurring fractures and sand lenses located at the clay/sand interface. Seasonal fluctuations in the piezometric head may also have placed the majority of the petroleum contaminants along a smear-zone within the lower portion of the clay layer.

As previously discussed, the majority of the airflow traveled downward into the sand. This represents a five foot interval of the clay which was addressed by the pilot study system. A review of the aforementioned change in contaminant profile, and the hydraulic characteristics of the subsurface, reveals that the petroleum related contamination observed at DVE2 probably originated within the lower portion of the clay. These results clearly demonstrate that this petroleum related contamination (in addition to the other chlorinated VOCs) can be remediated by the proposed system.

Based on these results, vacuum extraction alone, as anticipated, will not be sufficient in remediating the soil. Pneumatic fracturing and air injection will be required to expand the zone of influence of a full-scale remedial system past the 5-foot radius observed in the DVE wells. This condition is common for low permeability soils, as pressurized air travels more readily through the subsurface when compared to vacuum induced airflow. Injected airflow follows the path of least resistance within the subsurface. Under low permeability conditions, airflow typically moves along naturally occurring fractures and interbedded lenses of higher permeability. Pneumatic fracturing assists in providing connections between these areas by opening initial pathways using air pressure significantly greater than that used during AI activities.

5.4 VOC Extraction Rates and Cleanup Timeframes

The estimated full-scale VOC extraction rates and cleanup timeframe were calculated using a computer program developed by Terra Vac which utilizes empirical data collected from previous site remediations. The model is based on the concept of an extraction half-life; which is the time required to remove half of the VOCs within the soils. The model assumes that the extraction half-life is not **constant, and,** due to diffusion limitations tends to increase as the remediation progresses. This increase in half-life is consistent with observations made at other sites. At the beginning of a project, the bulk of the extraction comes from locations and pathways that have high yields (e.g. natural fissures and those created by fracturing) and thus the half-lives are shorter.

The first task was to estimate the mass-in-place of total VOC's in the soil volume influenced by pilot study. The estimate was made by extrapolating total VOC data at BH-G, BH-C, MW-21, and MW-4. The VOCs used in the extrapolation included TCE, 1,2 DCE, acetone, and toluene. Using this extrapolation method, a concentration-in-place value of 2,500 ug/kg total VOCs was estimated for purposes of continuing the calculations. The concentration was then converted to a mass-in-place assuming a clay depth of 12.5 feet and a radius of influence of 10 feet. This mass-in-place data was then entered into the program. The results of the model indicated that approximately 17 weeks would be required to clean the clay soils from a level of 2,500 ug/kg to the level of 700 ug/kg, using only TCE as the parameter in the model (see Figure 9). TCE was used as the parameter in the model based on its predominance in the soils and TCE has representative volatilization characteristics as the other parameters of concern. The value of 700 ug/kg TCE was used as the soil cleanup objective, in accordance with Table 6.1 of the Remedial Investigation/Feasibility Study prepared by CRA. Other parameters used in the model included airflow that was 75% diffusion-limited and an extracted airflow of 2.5 scfm.

Assuming an initial total VOC concentration of 2,500 ug/kg, and the removal of approximately 0.4 pounds of VOCs noted during the pilot study, the remaining total VOC concentration in the soils at the completion of the study would be 1,800 ug/kg. The model results indicated that approximately 3.5 weeks (see Figure 9) would be required to clean the clay soils to a level of 1,800 ug/kg, using TCE as the model parameter in lieu of the actual pilot study time period of 5 days (see Figure 10). This time difference between the pilot study observations and the model is likely due to pneumatic fracturing and air injection, which created a remedial progress that was not diffusion limited, but was controlled more by adjective flow.

The same program was used after inputting data from the previous site investigations. A TCE concentration of 320,000 ug/kg was entered as the highest concentration in the clay soils, and probably represents the limiting factor for cleanup. The results of this modeling indicate that approximately 122 weeks would be required to clean the clay soils to a level of 700 ug/kg (see Figure 11).

6. FULL-SCALE RECOMMENDATIONS

Based on the results of the pilot study, DVE represents a feasible base technology to address VOC contamination in the soils and groundwater at the Leica Optical site. The conventional approach to the application of the DVE process, is to dewater the soils in order to allow for the propagation of a subsurface vacuum. However, the low permeability clay soils indicate that the potential full-scale remedial program will require the technological enhancements of pneumatic fracturing and continuous air injection. These technologies will help provide an additional driving force behind VOC transport towards the vacuum zones of influence surrounding each DVE well.

The broad drawdown of the water table obtained during the pilot study, makes Entrainment Extraction™ a viable groundwater recovery technology for full-scale system operations. For purposes of providing a full-scale design, recommendations incorporate the implementation of this technology. The results of CRA's bedrock pump tests may dictate the implementation of a different technology, should significant dewatering of the overburden be observed.

It is the NES Team's understanding that the overall remedial program will be conducted to simultaneously address VOC contamination at three separate locations at the Leica Optical site. These consist of the former drum storage area, the northeastern source area, and the southeastern area, designated as Areas A, B, and C, respectively. Since the present plan is to have a centrally located equipment area, the following recommendations provide general design parameters to be considered when evaluating future full-scale system requirements. Should the DVE/AI technology be selected for the overall remedial program, the NES Team will prepare a more detailed system design package for full-scale operations.

6.1 DVE Well Spacing

The complex geologic conditions observed at the Leica Optical site will require that subsurface zones of contamination are addressed individually in order to provide a cost-effective and expeditious remedial program. The two main subsurface zones to be addressed consist of the low permeability clay and the underlying, waterbearing sand layer. Each zone will need to be isolated, and require different well designs/location in order to be effective.

The lower sand layer will be the major source for the dewatering efforts within the overburden. Each DVE well in this zone will be constructed of 4-inch diameter PVC, and installed approximately six inches into the bedrock to provide a sump for groundwater recovery. The screen interval within the sand layer will be established by the NES Team's on-site geologist based on actual observations made by during well installation. It is anticipated that well spacing for these deep-zone wells will be approximately 30 feet on center.

In order to minimize the preferential channeling of subsurface airflow through zones of higher permeability, separate vapor extraction (VE) wells will be installed to address VOC contamination within the upper clay layer. Each well will be 2-inch diameter PVC, and installed to a depth approximately 2 to 3 feet above the clay/sand interface. Screen interval will be determined by the NES Team's on-site geologist. Well spacing will be approximately 15 feet on center.

6.2 AI Probe Spacing

As previously discussed, the injection of air into the subsurface will provide the major driving force behind VOC transport towards the DVE wells. Each AI probe will be comprised of 1/2-inch black iron pipe, equipped with a driving point. Rows of AI probes will alternate with the DVE wells to ensure capture of the injected airflow. Probe spacing within the low permeability clay will be approximately 5 feet from each DVE well. This spacing will place two rows of AI probes between two rows of shallow DVE wells, with an AI probe located approximately 5 feet from each DVE well. In order to minimize the vertical transport of injected airflow observed during the pilot study, the AI probes will be driven to shallower depths, approximately 5 feet below grade.

During pilot study operations, a portion of the injected airflow traveled downward into the lower sand layer. Piezometer wells screened over this subsurface zone remained under pressure during air injection activities, with significant concentrations of VOCs detected in samples collected at these PZ wells. In order to ensure the contamination in this area is addressed, additional air injection probes will be driven into the lower sand layer to aid in subsurface dewatering and VOC recovery. The proposed spacing for these deep probes will be approximately 15 feet from each DVE well screened in the lower sand.

6.3 Full-scale Equipment Specifications

It is anticipated that full-scale operations will be conducted so that all remedial equipment is staged in a central location. A single vacuum extraction unit and air compressor will be used to simultaneously address VOC contamination in Areas A, B, and C. The vacuum extraction unit will be sized so that a vacuum level between 15" Hg and 20" Hg is applied at each DVE wellhead. It is anticipated that the corresponding extracted air flows will range between 2 scfm and 20 scfm. The air compressor will be capable of providing 5 to 10 cfm at each AI probe, with pressures ranging between 15 psi and 40 psi.

The actual size of the remedial equipment cannot be accurately determined until the location of the central equipment building is known. The lengths of the manifolds required to reach each area must be considered before properly sizing the remedial equipment. It is assumed that the installation of system manifolding will be below grade to minimize disruption to facility activities and provide winterization for cold-weather operations. A source of 480V, 3-phase power will be required in the proposed equipment building.

6.4 Vapor Treatment

Based on the elevated levels of subsurface contamination identified during previous site investigations, it is anticipated that initial full-scale operations will be conducted using a catalytic oxidation (CATOX) unit for vapor treatment. The CATOX unit will be replaced by an activated carbon, treatment system when VOC extraction rates reach economical levels. Typically, activated carbon is more cost-effective for extraction rates less than 20 pounds per day.

A source of natural gas or propane will be required to operate the CATOX unit. In addition, when chlorinated compounds are treated by this method, hydrochloric acid (HCl) is produced as the compounds are oxidized. Air permitting requirements are unknown at this time for full-scale operations. However, the elevated concentrations of chlorinated compounds identified in the subsurface, coupled with the proximity of housing areas surrounding the Leica Optical site, may require the installation of a scrubber system to remove the HCl prior to atmospheric discharge.

6.5 Groundwater Recovery and Treatment

Groundwater contamination has been identified in both the overburden and bedrock zones. Groundwater recovery from wells installed in the overburden zone and possibly the bedrock zone will be conducted during full-scale operations. Dewatering within the overburden wells will be accomplished using the Entrainment Extraction™ technology. Submersible pumps will be installed in the bedrock wells for groundwater recovery, if applicable. Since the majority of contamination is found within the overburden, groundwater pumping activities will not be initiated within the bedrock until sufficient dewatering of the overburden has been accomplished This will be conducted in order to minimize the drawdown of contamination into the bedrock.

Groundwater treatment will be accomplished using an air stripper during full-scale operations. The contaminant levels identified during previous site investigations, combined with the rates of groundwater recovery expected, make air stripping more economical when compared to activated carbon treatment. The off-gas produced by the air stripping tower will be routed to the vapor treatment system, prior to atmospheric discharge. The treated groundwater will be discharged to the local sewer system under a discharge permit.

Accurate specifications for the groundwater treatment system cannot be provided until the results of the CRA bedrock pumping tests are available. Since this subsurface zone could potentially provide an additional source for groundwater recovery during full-scale operations, proper sizing of the air stripper cannot be determined until potential recovery rates are known.

APPENDIX A

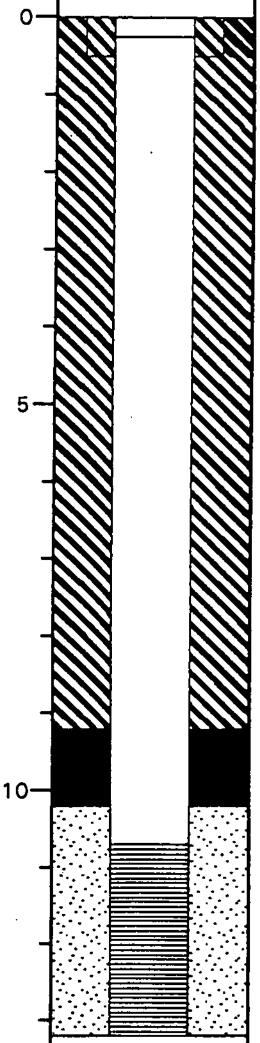
WELL LOGS

TERRA VAC
3200 West Temperance Road
Temperance, Michigan 48182-9477
(313) 847-4444 Fax (313) 847-4024

Client: NES		Project #: 60-1282	Boring/Well: DVE2
Project: Leica Optical		Well Construction Data	
Date Started: SEP 24 96	Date Completed: SEP 24 96	Screen: 4" PVC-0.10 slot	From 10.7 To13.2 ft
Logged By: T. Peters	Checked By: T. Peters	Pack: #5 silica	From 10.2 To13.2 ft
Drilling Co.: Maxim	Driller: Jerry Jones	Seal: Bentonite	From 9.2 To10.2 ft
Method: Hollow-stem-auger	Boring Diameter: 11"	Grout: Portland Cement	From 0 To 9.2 ft
Boring Depth: 13.5	Ground Surface Elevation:	Inner Casing: 4" Sch 40 PVC	
Initial GW Level: 12.5	GW Level: / Time/Date: 9/24/96	Outer Casing/Stick Up: None	

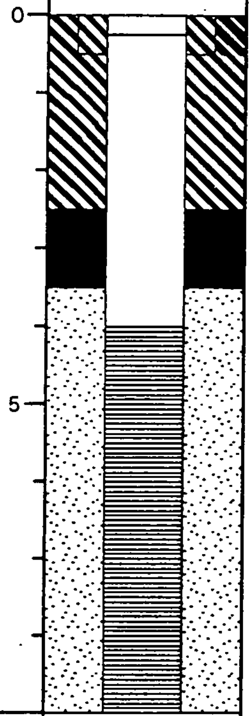
Depth	Sample	Sample Number	SPT Blows	% Recovery	PID/FID (ppm)	Lithology	Description	Remarks
0							0 to 1 foot - Grass & Topsoil	
		1			0			
		2			0			
5		3			0		1 foot to 12.5 feet = Red/Brown, stiff, hard, CLAY, dry to barely moist, contains a small amount of 1/4" to 1/2" gravel	
		4			0			
		5			0			
10		6			0			
		7			5		12.5 to 13.5 feet - Gray, loose, silty/clayey, fine to medium SAND, wet, contains some clasts of limestone	
							Limestone Bedrock	

Well Construction



TERRA VAC
3200 West Temperance Road
Temperance, Michigan 48182-9477
(313) 847-4444 Fax (313) 847-4024

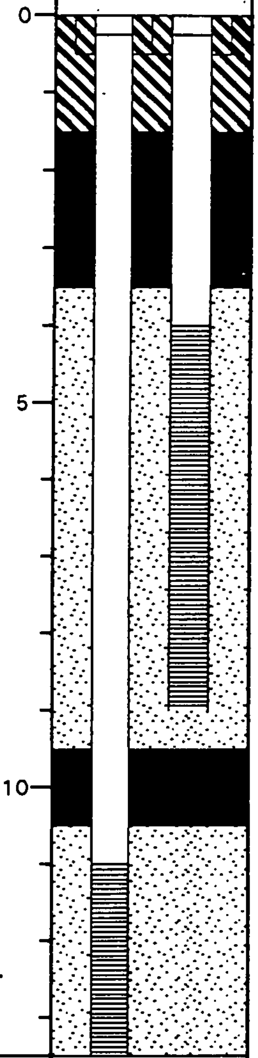
Client: NES		Project #: 60-1282	Boring/Well: DVE1
Project: Leica Optical		Well Construction Data	
Date Started: SEP 24 96	Date Completed: SEP 24 96	Screen: 4" PVC-0.10 slot	From 4 To 9 ft
Logged By: T. Peters	Checked By: T. Peters	Pack: #5 silica	From 3.5 To 9 ft
Drilling Co.: Maxim	Driller: Jerry Jones	Seal: Bentonite	From 2.5 To 3.5 ft
Method: Hollow-stem-auger	Boring Diameter: 11"	Grout: Portland Cement	From 0 To 2.5 ft
Boring Depth: 9.0	Ground Surface Elevation:	Inner Casing: 4" Sch 40 PVC	
Initial GW Level:	GW Level: / Time/Date:	Outer Casing/Stick Up: None	

Depth	Sample	Sample Number	SPT Blows	% Recovery	PID/FID (ppm)	Lithology	Description	Remarks	Well Construction
0							0 to 1 foot - Grass & Topsoil		
5							1 foot to 9 feet = Red/Brown, stiff, hard, CLAY, dry to barely moist, contains a small amount of 1/4" to 1/2" gravel	Auger soil cuttings were screened during drilling operations with an FID. All FID readings from the cuttings were 0 ppm	

TERRA VAC
3200 West Temperance Road
Temperance, Michigan 48182-9477
(313) 847-4444 Fax (313) 847-4024

Client: NES		Project #: 60-1282	Boring/Well: PZ1
Project: Leica Optical		Well Construction Data	
Date Started: SEP 24 96	Date Completed: SEP 24 96	Screen: 1" PVC-0.01 slot	From To
Logged By: T. Peters	Checked By: T. Peters	Pack: #5 Silica	From To
Drilling Co.: Maxim	Driller: Jerry Jones	Seal: Bentonite	From To
Method: Hollow-stem-auger	Boring Diameter: 9 inches	Grout: Portland Cement	From To
Boring Depth: 13.5	Ground Surface Elevation:	Inner Casing: 1" Sch 40 PVC	
Initial GW Level:	GW Level: / Time/Date:	Outer Casing/Stick Up: none	

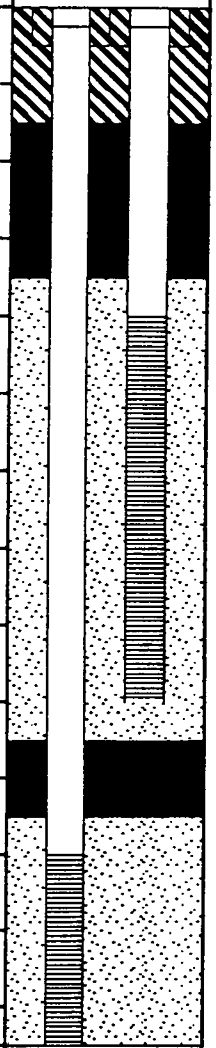
Depth	Sample	Sample Number	SPT Blows	% Recovery	PID/FID (ppm)	Lithology	Description	Remarks	Well Construction
0							0 to 1 foot - Grass & Topsoil		
5							1 foot to 12.5 feet = Red/Brown, stiff, hard, CLAY, dry to barely moist, contains a small amount of 1/4" to 1/2" gravel		
10							12.5 to 13.5 feet - Gray, loose, silty/clayey, fine to medium SAND, wet, contains some clasts of limestone		
							Limestone Bedrock		



TERRA VAC
3200 West Temperance Road
Temperance, Michigan 48182-9477
(313) 847-4444 Fax (313) 847-4024

Client: NES		Project #: 60-1282	Boring/Well: PZ2
Project: Leica Optical		Well Construction Data	
Date Started: SEP 24 96	Date Completed: SEP 24 96	Screen: 1" PVC-0.01 slot	From To
Logged By: T. Peters	Checked By: T. Peters	Pack: #5 Silica	From To
Drilling Co.: Maxim	Driller: Jerry Jones	Seal: Bentonite	From To
Method: Hollow-stem-auger	Boring Diameter: 9 inches	Grout: Portland Cement	From To
Boring Depth: 13.5	Ground Surface Elevation:	Inner Casing: 1" Sch 40 PVC	
Initial GW Level:	GW Level: / Time/Date:	Outer Casing/Stick Up: none	

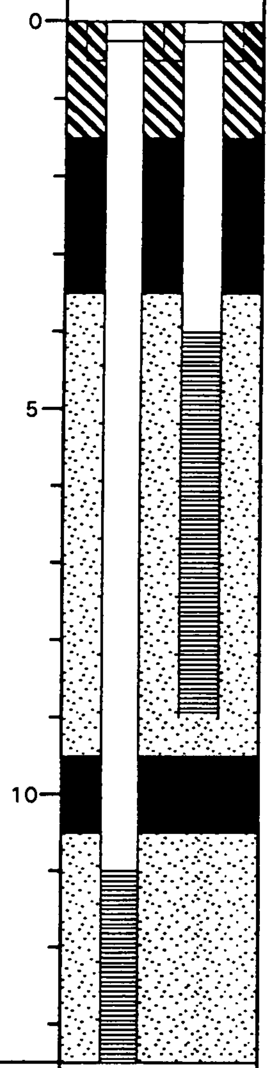
Depth	Sample	Sample Number	SPT Blows	% Recovery	PID/FID (ppm)	Lithology	Description	Remarks	Well Construction
0							0 to 1 foot - Grass & Topsoil		
5							1 foot to 12.5 feet = Red/Brown, stiff, hard, CLAY, dry to barely moist, contains a small amount of 1/4" to 1/2" gravel		
10									
							12.5 to 13.5 feet - Gray, loose, silty/clayey, fine to medium SAND, wet, contains some clasts of limestone		
							Limestone Bedrock		



TERRA VAC
3200 West Temperance Road
Temperance, Michigan 48182-9477
(313) 847-4444 Fax (313) 847-4024

Client: NES		Project #: 60-1282	Boring/Well: PZ3
Project: Leica Optical		Well Construction Data	
Date Started: SEP 25 96	Date Completed: SEP 25 96	Screen: 1" PVC-0.01 slot	From To
Logged By: T. Peters	Checked By: T. Peters	Pack: #5 Silica	From To
Drilling Co.: Maxim	Driller: Jerry Jones	Seal: Bentonite	From To
Method: Hollow-stem-auger	Boring Diameter: 9 inches	Grout: Portland Cement	From To
Boring Depth: 13.5	Ground Surface Elevation:	Inner Casing: 1" Sch 40 PVC	
Initial GW Level:	GW Level: / Time/Date:	Outer Casing/Stick Up: none	

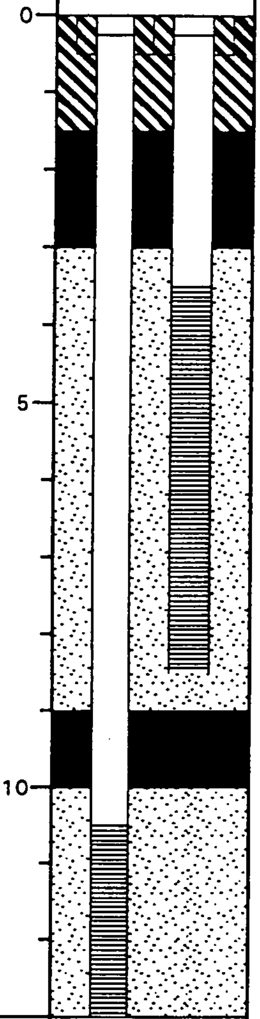
Depth	Sample	Sample Number	SPT Blows	% Recovery	PID/FID (ppm)	Lithology	Description	Remarks	Well Construction
0							0 to 1 foot - Grass & Topsoil		
5							1 foot to 12.5 feet = Red/Brown, stiff, hard, CLAY, dry to barely moist, contains a small amount of 1/4" to 1/2" gravel		
10									
							12.5 to 13.5 feet - Gray, loose, silty/clayey, fine to medium SAND, wet, contains some clasts of limestone		
							Limestone Bedrock		



TERRA VAC
3200 West Temperance Road
Temperance, Michigan 48182-9477
(313) 847-4444 Fax (313) 847-4024

Client: NES		Project #: 60-1282	Boring/Well: PZ4
Project: Leica Optical		Well Construction Data	
Date Started: SEP 25 96	Date Completed: SEP 25 96	Screen: 1" PVC-0.01 slot	From To
Logged By: T. Peters	Checked By: T. Peters	Pack: #5 Silica	From To
Drilling Co.: Maxim	Driller: Jerry Jones	Seal: Bentonite	From To
Method: Hollow-stem-auger	Boring Diameter: 9 inches	Grout: Portland Cement	From To
Boring Depth: 13.0	Ground Surface Elevation:	Inner Casing: 1" Sch 40 PVC	
Initial GW Level: ∇	GW Level: ▼ / Time/Date:	Outer Casing/Stick Up: none	

Depth	Sample	Sample Number	SPT Blows	% Recovery	PID/FID (ppm)	Lithology	Description	Remarks	Well Construction
0							0 to 1 foot - Asphalt & Fill		
5							1 foot to 12 feet = Red/Brown, stiff, hard, CLAY, dry to barely moist, contains a small amount of 1/4" to 1/2" gravel		
10									
							12 to 13 feet - Gray, loose, silty/clayey, fine to medium SAND, wet, contains some clasts of limestone		
							Limestone Bedrock		



APPENDIX B

DVE/AI PILOT STUDY SYSTEM PHOTOGRAPHS

Photograph #1 - Mobile Pilot Study System

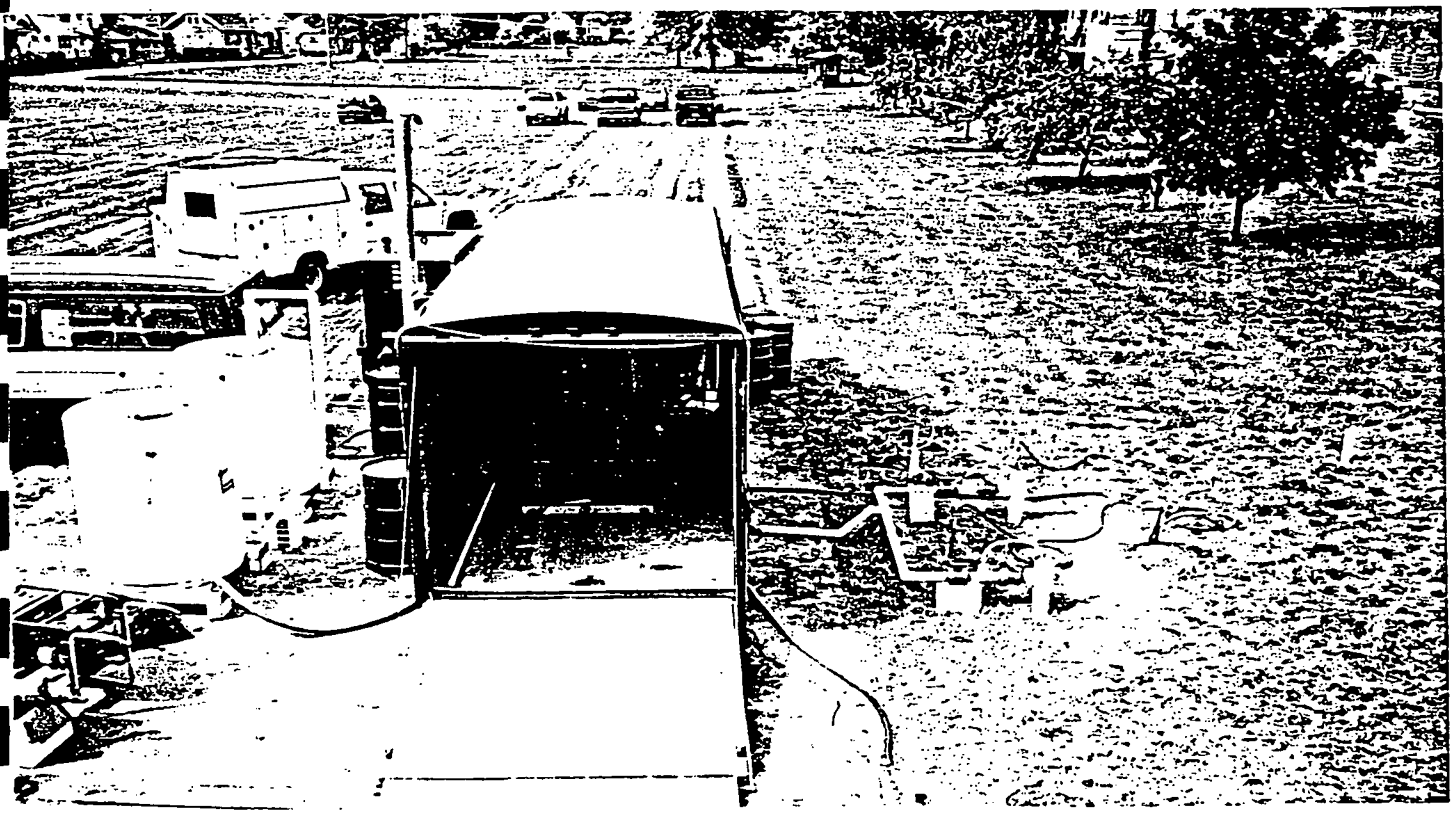
Photograph #2 - Mobile Pilot Study System

Photograph #3 - DVE Wellheads

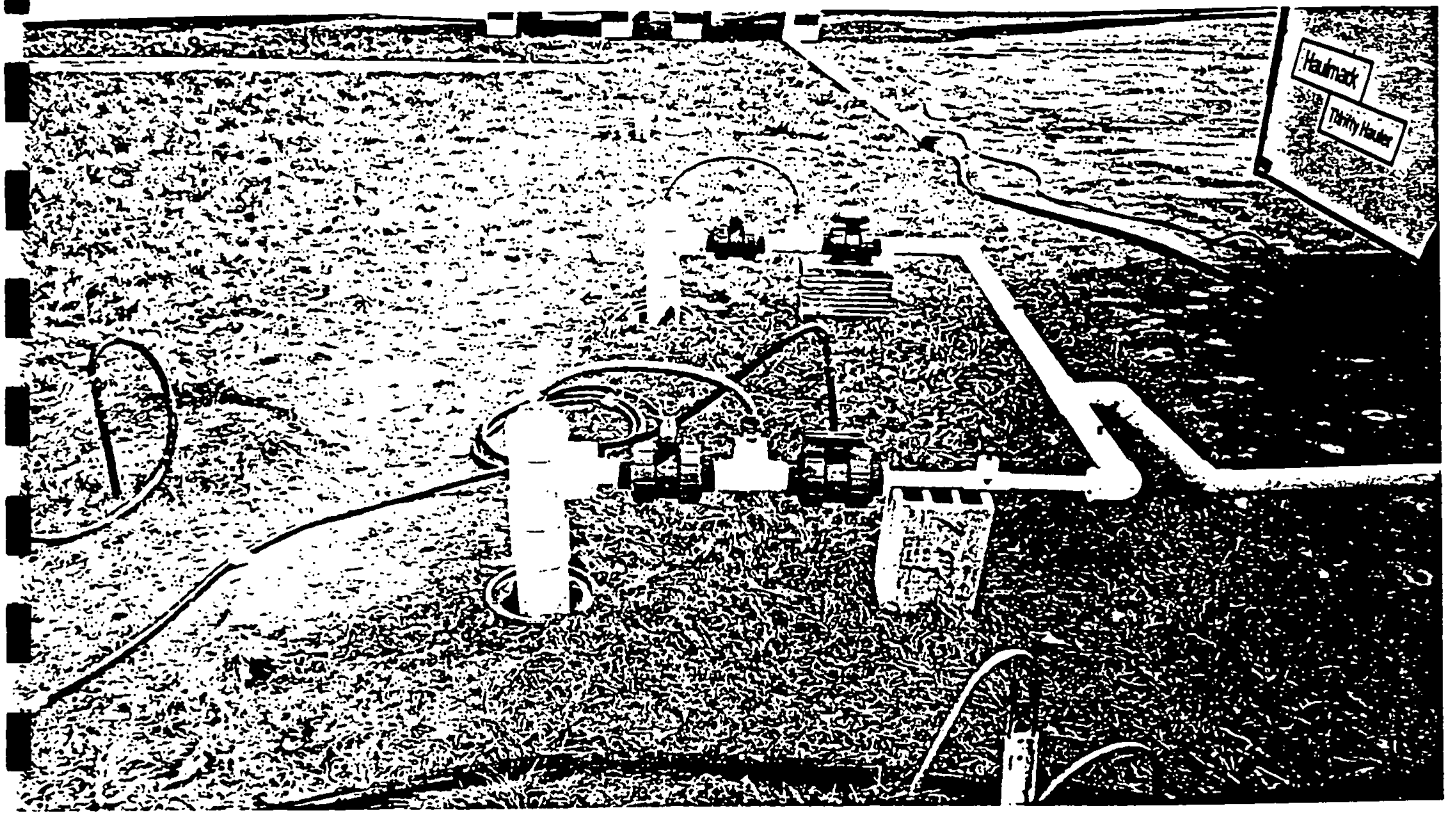
Photograph #4 - AI Probe with flow/pressure meter assemble

Photograph #5 - Groundwater Treatment System

Photograph #1



Photograph #2



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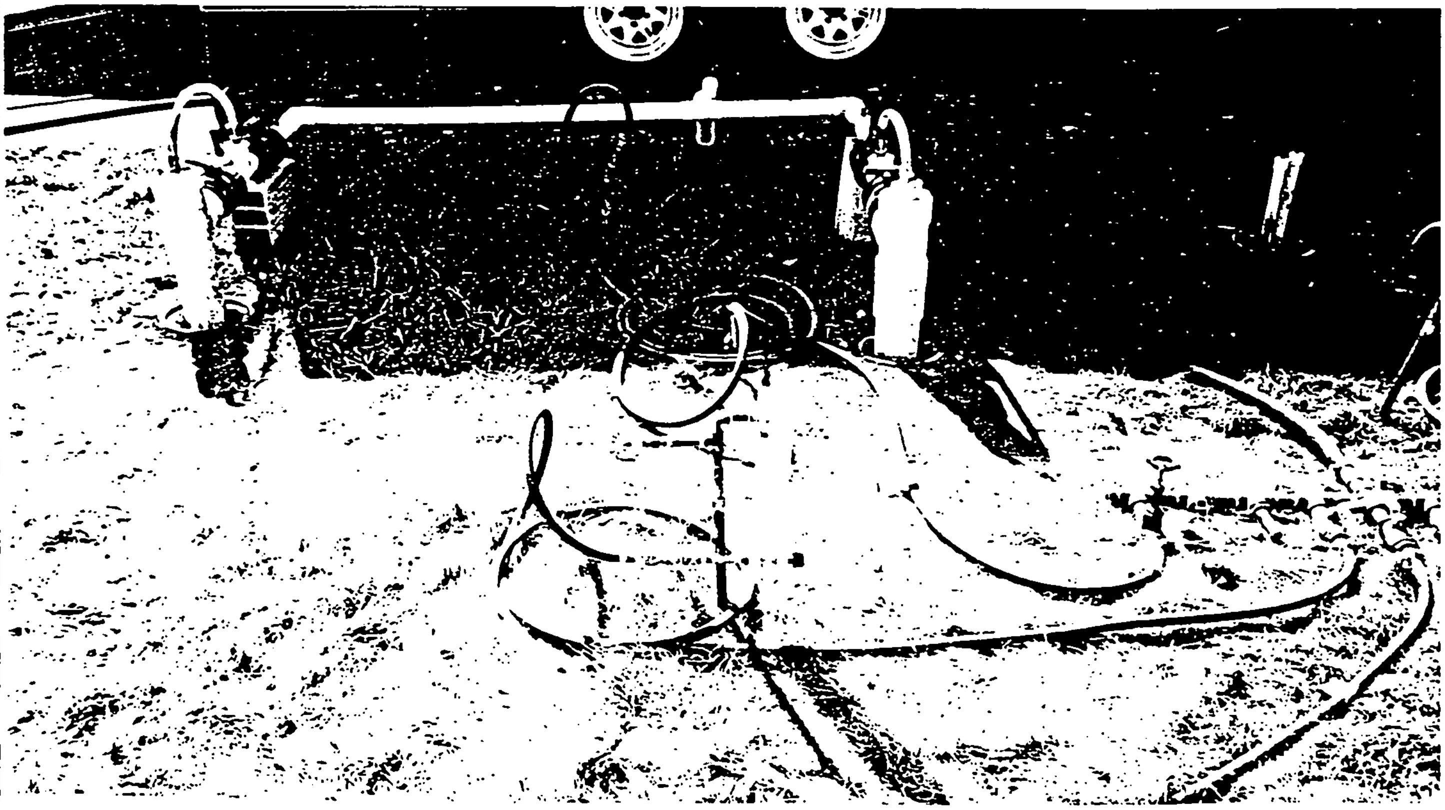


Photograph #4

Photograph #5

TABLES

DUAL VACUUM EXTRACTION/AIR INJECTION PILOT STUDY
LEICA OPTICAL SITE - CHEEKTOWAGA, NEW YORK
TERRA VAC PROJECT #60-1282
TABLE 1

	DATE	VINYL CHLORIDE	1,1-DCE	t-1,2-DCE	1,1-DCA	c-1,2-DCE	1,1,1-TCA	1,2-DCA	BENZENE	TCE	TOLUENE	ETHYL BENZENE	TOTAL XYLENES	OTHER VOCS	TOTAL VOCS	APPLIED SYSTEM VACUUM ("Hg)	EXTRACTED AIRFLOW (SCFM)	SYSTEM RUNTIME (HOURS)	VOC EXTRACTION RATE (#/DAY)	TOTAL VOCS EXTRACTED (POUNDS)
		EXTRACTED VOC VAPOR PHASE CONCENTRATIONS (PPMV) - DVE1																		
DVE OPERATIONS	03-Oct-96				DVE1 ONLINE													0.0	0.000	0.000
	03-Oct-96	BDL	1.93	BDL	BDL	1.59	7.16	BDL	BDL	BDL	BDL	BDL	BDL	9.39	20.1	14.5	3	0.3	0.022	0.000
	03-Oct-96	BDL	7.29	BDL	BDL	7.99	38.3	BDL	BDL	BDL	BDL	BDL	BDL	4.36	57.9	15.0	3	0.9	0.070	0.001
	03-Oct-96	BDL	7.49	BDL	BDL	7.29	34.6	BDL	BDL	BDL	BDL	BDL	BDL	3.94	53.3	15.0	3	1.3	0.064	0.002
	03-Oct-96	BDL	6.38	BDL	BDL	7.79	35.7	BDL	BDL	BDL	BDL	0.36	BDL	2.25	52.5	15.0	3	1.6	0.063	0.003
	03-Oct-96	0.74	12.2	BDL	BDL	13.0	50.4	BDL	BDL	BDL	0.32	BDL	BDL	25.5	102	15.0	3	3.0	0.115	0.009
	03-Oct-96	BDL	11.1	BDL	BDL	7.08	33.7	BDL	BDL	BDL	BDL	BDL	BDL	BDL	51.9	21.0	2	3.7	0.047	0.011
	03-Oct-96	BDL	6.05	BDL	BDL	4.48	24.7	BDL	BDL	BDL	BDL	BDL	BDL	BDL	35.2	21.0	2	4.6	0.032	0.012
	03-Oct-96	BDL	5.39	BDL	BDL	4.20	21.3	BDL	BDL	BDL	BDL	BDL	BDL	BDL	30.9	21.0	2	5.2	0.028	0.013
	04-Oct-96	BDL	BDL	BDL	BDL	BDL	6.00	BDL	BDL	3.44	BDL	3.53	13.2	BDL	26.2	21.5	2	23.3	0.022	0.032
	04-Oct-96	BDL	12.4	BDL	BDL	5.21	29.1	BDL	BDL	BDL	BDL	BDL	0.21	2.87	49.8	21.5	2	23.8	0.043	0.033
	04-Oct-96	BDL	7.11	BDL	BDL	3.09	19.7	BDL	BDL	BDL	BDL	BDL	1.49	6.09	37.5	21.5	2	29.0	0.032	0.040
	05-Oct-96	BDL	BDL	BDL	BDL	BDL	2.76	BDL	BDL	BDL	0.96	5.31	21.4	BDL	30.5	21.5	2	47.9	0.024	0.062
PSF/DVE OPERATIONS	05-Oct-96	8.12	3.52	BDL	BDL	BDL	7.60	BDL	BDL	BDL	BDL	BDL	0.15	5.13	24.5	21.5	2	48.6	0.017	0.062
	05-Oct-96	BDL	1.59	BDL	BDL	BDL	3.86	BDL	BDL	BDL	BDL	BDL	BDL	BDL	5.45	21.5	2	49.1	0.005	0.062
	05-Oct-96	BDL	BDL	BDL	BDL	BDL	5.10	BDL	BDL	BDL	BDL	BDL	BDL	1.82	6.92	21.5	2	49.5	0.006	0.062
	05-Oct-96	BDL	BDL	BDL	BDL	1.77	2.47	BDL	BDL	BDL	BDL	BDL	BDL	BDL	4.23	21.5	2	49.7	0.004	0.063
	05-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	21.5	2	50.0	0.000	0.063
	05-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	21.5	2	51.7	0.000	0.063
	05-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.63	1.97	2.60	21.5	2	52.6	0.002	0.063
	05-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	21.5	2	53.2	0.000	0.063
	06-Oct-96	BDL	BDL	BDL	BDL	3.44	BDL	BDL	BDL	BDL	BDL	2.63	8.57	BDL	14.6	21.5	2	71.2	0.011	0.067
AI/DVE OPERATIONS	06-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.64	1.64	21.5	2	72.1	0.001	0.067
	06-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	21.5	2	73.6	0.000	0.067
	07-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	3.72	15.0	7.69	26.4	21.5	3	95.3	0.034	0.082
	07-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.82	3.53	3.26	20.6	30.3	21.5	3	100	0.036	0.090
	08-Oct-96	5.75	BDL	BDL	BDL	BDL	2.70	BDL	BDL	BDL	BDL	BDL	0.64	1.37	10.5	21.5	3	119	0.012	0.109
DVE OPERATIONS	08-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.93	0.93	21.5	3	123	0.001	0.110

BDL = BELOW DETECTION LIMITS

TERRA VAC

DUAL VACUUM EXTRACTION/AIR INJECTION PILOT STUDY
LEICA OPTICAL SITE - CHEEKTOWAGA, NEW YORK
TERRA VAC PROJECT #60-1282
TABLE 2

	DATE	EXTRACTED VOC VAPOR PHASE CONCENTRATIONS (PPMV) - DVE2: VINYL CHLORIDE	1,1-DCE	t-1,2-DCE	1,1-DCA	c-1,2-DCE	1,1,1-TCA	1,2-DCA	BENZENE	TCE	TOLUENE	ETHYL BENZENE	TOTAL XYLENES	OTHER VOCS	TOTAL VOCS	APPLIED SYSTEM VACUUM ("Hg)	EXTRACTED AIRFLOW (SCFM)	SYSTEM RUNTIME (HOURS)	VOC EXTRACTION RATE (#/DAY)	TOTAL VOCS EXTRACTED (POUNDS)
DVE OPERATIONS DVE2 ONLY	02-Oct-96	SYSTEM START-UP																0.0	0.00	0 000
	02-Oct-96	BDL	2.61	BDL	BDL	3.26	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	5.87	18.8	10	0.3	0.02	0.000
	02-Oct-96	BDL	1.55	BDL	BDL	2.96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	4.51	16.5	11	0.8	0.02	0.001
	02-Oct-96	BDL	2.56	BDL	BDL	2.96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	5.52	20.0	9	2.4	0.02	0.002
	02-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	20.0	9	4.5	0.00	0.003
	02-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	15.8	12	4 9	0.00	0.003
	03-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	10.8	14	24.2	0.00	0 003
DVE OPERATIONS DVE1 AND DVE2	03-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	21.0	9	29.3	0.00	0.003
	04-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	21.5	9	49.0	0.00	0 003
	05-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	21.5	9	72.9	0.00	0 003
PSF/DVE OPERATIONS	05-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	21.5	9	76.8	0.00	0.003
	06-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	21.5	9	96.3	0.00	0 003
AI/DVE OPERATIONS	06-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.64	BDL	BDL	2.03	2.67	21.5	9	97.4	0.01	0.003
	06-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.69	0.44	0.29	3.56	4.99	21.5	9	98.6	0.01	0.003
	07-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.39	2.75	2.59	20.5	28.2	21.5	11	121	0.10	0.058
	07-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	2.82	3.53	3.26	20.6	30.3	21.5	11	126	0.11	0.081
	08-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1 28	0.33	1 20	12.9	15.7	21.5	11	144	0.06	0.147
DVE OPERATIONS	08-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	3 01	3.01	21.5	11	147	0.01	0.150

BDL = BELOW DETECTION LIMITS

DUAL VACUUM EXTRACTION/AIR INJECTION PILOT STUDY
LEICA OPTICAL SITE - CHEEKTOWAGA, NEW YORK
TERRA VAC PROJECT #60-1282
TABLE 3

DATE	VOC VAPOR PHASE CONCENTRATIONS (PPMV) - PRIMARY CARBON UNIT: VINYL CHLORIDE	1,1-DCE	t-1,2-DCE	1,1-DCA	c-1,2-DCE	1,1,1-TCA	1,2-DCA	BENZENE	TCE	TOLUENE	ETHYL BENZENE	TOTAL XYLENES	OTHER VOCS	TOTAL VOCS	APPLIED SYSTEM VACUUM ("Hg)	SYSTEM AIRFLOW (SCFM)	SYSTEM RUNTIME (HOURS)	VOC RATE (#/DAY)	TOTAL VOCS PASSED (POUNDS)
02-Oct-96	SYSTEM START-UP																0.0	0.000	0.000
02-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0	20.0	9	4.9	0.000	0.000
03-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0	21.0	11	29.8	0.000	0.000
04-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0	21.5	11	49.6	0.000	0.000
05-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0	21.5	11	77.6	0.000	0.000
06-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0	21.5	11	98.9	0.000	0.000
07-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0	21.5	14	122	0.000	0.000
08-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0	21.5	14	148	0.000	0.000

BDL = BELOW DETECTION LIMITS

DUAL VACUUM EXTRACTION/AIR INJECTION PILOT STUDY
LEICA OPTICAL SITE - CHEEKTOWAGA, NEW YORK
TERRA VAC PROJECT #60-1282
TABLE 4

DATE	VOC VAPOR PHASE CONCENTRATIONS (PPMV) - SECONDARY CARBON UNIT: VINYL CHLORIDE	1,1-DCE	t-1,2-DCE	1,1-DCA	c-1,2-DCE	1,1,1-TCA	1,2-DCA	BENZENE	TCE	TOLUENE	ETHYL BENZENE	TOTAL XYLENES	OTHER VOCS	TOTAL VOCS	APPLIED SYSTEM VACUUM ("Hg)	SYSTEM AIRFLOW (SCFM)	SYSTEM RUNTIME (HOURS)	VOC RATE (#/DAY)	TOTAL VOCS EMITTED (POUNDS)
02-Oct-96	SYSTEM START-UP																0.0	0.000	0.000
02-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0	20.0	9	4.9	0.000	0.000
03-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0	21.0	11	29.8	0.000	0.000
04-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0	21.5	11	49.6	0.000	0.000
05-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0	21.5	11	77.6	0.000	0.000
06-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0	21.5	11	98.9	0.000	0.000
07-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0	21.5	14	122	0.000	0.000
08-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0	21.5	14	148	0.000	0.000

BDL = BELOW DETECTION LIMITS

DUAL VACUUM EXTRACTION/AIR INJECTION PILOT STUDY
LEICA OPTICAL SITE - CHEEKTOWAGA, NEW YORK
TERRA VAC PROJECT #60-1282
TABLE 5

DATE	DISSOLVED PHASE VOC CONCENTRATIONS (PPB) - SYSTEM TOTAL														TOTAL GROUNDWATER GALLONS RECOVERED	GROUNDWATER RECOVERY RATE (GPM)	SYSTEM RUNTIME (HOURS)	VOC RECOVERY RATE (#/DAY)	TOTAL VOCS RECOVERED (POUNDS)
	VINYL CHLORIDE	1,1-DCE	t-1,2-DCE	1,1-DCA	c-1,2-DCE	1,1,1-TCA	1,2-DCA	BENZENE	TCE	TOLUENE	ETHYL BENZENE	TOTAL XYLENES	OTHER VOCS	TOTAL VOCS					
02-Oct-96				SYSTEM START-UP											0		0.0	0 00	0 00
02-Oct-96	BDL	5 87	BDL	BDL	9.55	21.4	BDL	BDL	BDL	1.93	1 00	1.43	7.16	48.3	26.8	0.25	1 8	0.15	0.01
03-Oct-96	BDL	4.72	BDL	1.03	6.55	19.8	BDL	BDL	BDL	1.06	BDL	1.03	6.15	40.3	194	0.12	25.1	0.06	0 07
04-Oct-96	BDL	10.1	BDL	BDL	11.7	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	21.8	338	0.10	49 9	0.03	0.09
07-Oct-96	BDL	BDL	BDL	BDL	5.36	6.80	BDL	BDL	BDL	BDL	BDL	BDL	1.15	13 31	506	0 04	120	0 01	0.11

BDL = BELOW DETECTION LIMITS

DUAL VACUUM EXTRACTION/AIR INJECTION PILOT STUDY
LEICA OPTICAL SITE - CHEEKTOWAGA, NEW YORK
TERRA VAC PROJECT #60-1282
TABLE 6

DATE	DISSOLVED PHASE VOC CONCENTRATIONS (PPB) - PRIMARY CARBON UNIT														TOTAL GROUNDWATER GALLONS RECOVERED	GROUNDWATER RECOVERY RATE (GPM)	SYSTEM RUNTIME (HOURS)	VOC RATE (#/DAY)	TOTAL VOCS PASSED (POUNDS)
	VINYL CHLORIDE	1,1-DCE	t-1,2-DCE	1,1-DCA	c-1,2-DCE	1,1,1-TCA	1,2-DCA	BENZENE	TCE	TOLUENE	ETHYL BENZENE	TOTAL XYLENES	OTHER VOCS	TOTAL VOCS					
02-Oct-96				SYSTEM START-UP											0		0.0	0.00	0 00
02-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	26.8	0.25	1.8	0.00	0.00
03-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	194	0.12	25.1	0 00	0 00
04-Oct-96	BDL	BDL	BDL	BDL	BDL	4.79	BDL	BDL	BDL	BDL	BDL	BDL	BDL	4.79	338	0.10	49 9	0.01	0 01
07-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	506	0.04	120	0 00	0 01

BDL = BELOW DETECTION LIMITS

DUAL VACUUM EXTRACTION/AIR INJECTION PILOT STUDY
LEICA OPTICAL SITE - CHEEKTOWAGA, NEW YORK
TERRA VAC PROJECT #60-1282
TABLE 7

DATE	DISSOLVED PHASE VOC CONCENTRATIONS (PPB) - SECONDARY CARBON UNIT														TOTAL GROUNDWATER GALLONS RECOVERED	GROUNDWATER RECOVERY RATE (GPM)	SYSTEM RUNTIME (HOURS)	VOC RATE (#/DAY)	TOTAL VOCS DISCHARGED (POUNDS)
	VINYL CHLORIDE	1,1-DCE	t-1,2-DCE	1,1-DCA	c-1,2-DCE	1,1,1-TCA	1,2-DCA	BENZENE	TCE	TOLUENE	ETHYL BENZENE	TOTAL XYLENES	OTHER VOCS	TOTAL VOCS					
02-Oct-96				SYSTEM START-UP											0		0.0	0.00	0.00
02-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	26.8	0.25	1.8	0.00	0.00
03-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0 00	194	0.12	25.1	0.00	0.00
04-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.00	338	0.10	49.9	0.00	0 00
07-Oct-96	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0 00	506	0.04	120	0.00	0 00

BDL = BELOW DETECTION LIMITS

DUAL VACUUM EXTRACTION/AIR INJECTION PILOT STUDY
LEICA OPTICAL SITE - CHEEKTOWAGA, NEW YORK
TERRA VAC PROJECT #60-1282
TABLE 8

VOC VAPOR PHASE CONCENTRATIONS (PPMV) - PIEZOMETER WELLS

	DATE	PRESSURE ("H2O)	VINYL CHLORIDE	1,1-DCE	t-1,2-DCE	1,1-DCA	c-1,2-DCE	1,1,1-TCA	1,2-DCA	BENZENE	TCE	TOLUENE	ETHYL BENZENE	TOTAL XYLENES	OTHER VOCS	TOTAL VOCS
PZ1S	06-Oct-96	5 PSI	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	0.0
	08-Oct-96	0.5	BDL	BDL	BDL	BDL	BDL	BDL	BDL	BDL	1.01	0.23	0.12	0.23	2.55	4.14
PZ1D	08-Oct-96	20.0	BDL	BDL	1.32	3.90	9.87	16.5	BDL	9.11	19.0	71.6	14.2	82.5	819	1047
	06-Oct-96	3.3	BDL	BDL	12.7	42.0	37.4	146	BDL	68.8	79.1	129	127	57.3	1287	1985
PZ3D	07-Oct-96	7.9	BDL	BDL	3.34	11.2	14.5	37.0	BDL	15.4	25.7	91.2	128	101	620	1047
	08-Oct-96	3.8	BDL	BDL	3.26	11.8	13.5	36.4	BDL	14.8	25.5	99.0	12.3	61.7	875	1153

BDL = BELOW DETECTION LIMITS

DVE/AI PILOT STUDY
LEICA OPTICAL SITE - CHEEKTOWAGA, NEW YORK
TERRA VAC PROJECT #60-1282
MINIMUM DETECTION LIMITS - ON-SITE GC ANALYSES
TABLE 9

COMPOUND	PPM VAPOR	PPB WATER
VINYL CHLORIDE	0.16	1.0
1,1-DICHLOROETHYLENE	0.13	1.0
trans-1,2-DICHLOROETHYLENE	0.15	1.0
1,1-DICHLOROETHANE	0.12	1.0
cis-1,2-DICHLOROETHYLENE	0.13	2.0
1,1,1-TRICHLOROETHANE	0.15	1.0
1,2-DICHLOROETHANE	0.15	1.0
BENZENE	0.05	1.0
TRICHLOROETHYLENE	0.15	1.0
TOLUENE	0.05	1.0
ETHYL BENZENE	0.04	1.0
TOTAL XYLENES	0.04	1.0

DVE/AI PILOT STUDY
LEICA OPTICAL SITE - CHEEKTOWAGA, NEW YORK
TERRA VAC PROJECT #60-1282
GROUNDWATER LEVEL MONITORING RESULTS
TABLE 10

	MONITORING DATE	MONITORING TIME	GROUNDWATER LEVEL (FEET BELOW GRADE) PZ1D	PZ2D	PZ3D	PZ4D	MW6
PRE-PILOT STUDY	02-Oct-96	08:35	9.23	8.33	9.73	8.31	9.98
DVE OPERATIONS DVE2 ONLY	02-Oct-96	09:45	9.99	8.62	10.42	9.35	9.98
	02-Oct-96	10:15	9.73	8.83	10.23	9.46	9.93
	02-Oct-96	11:08	9.78	8.82	10.19	9.42	9.98
	02-Oct-96	14:10	9.88	9.03	10.23	9.56	10.19
	03-Oct-96	08:05	10.27	9.34	10.69	9.96	10.04
DVE OPERATIONS DVE1 AND DVE2 ON-LINE	03-Oct-96	10:32	10.38	9.47	10.82	10.10	10.43
	03-Oct-96	11:45	10.42	9.52	10.82	10.09	10.03
	03-Oct-96	14:00	10.43	9.54	10.83	10.14	10.53
	03-Oct-96	15:15	10.54	9.60	10.97	10.23	10.53
	04-Oct-96	09:03	10.62	9.75	11.04	10.36	11.00
	04-Oct-96	11:25	10.62	9.75	11.04	10.36	11.11
	04-Oct-96	15:10	10.48	9.62	10.93	10.26	11.18
	05-Oct-96	09:38	10.80	9.93	11.28	10.59	11.53
DVE/PSF OPERATIONS	05-Oct-96	10:45	10.77	9.94	11.27	10.59	11.53
	05-Oct-96	14:15	10.78	9.91	11.26	10.55	11.23
	05-Oct-96	15:25	10.83	9.88	11.24	10.53	11.58
	06-Oct-96	09:20	11.07	10.20	11.49	10.82	11.83
DVE/AI OPERATIONS	06-Oct-96	10:22	10.57	9.89	11.35	10.60	11.80
	06-Oct-96	12:00	10.94	9.83	11.41	10.51	11.73
	07-Oct-96	10:00	11.33	10.27	11.63	10.78	11.94
	07-Oct-96	15:05	11.43	10.24	11.67	10.88	11.63
	08-Oct-96	10:00	11.32	9.78	11.73	10.71	12.18
	08-Oct-96	11:45	11.77	11.07	11.87	11.03	12.23
	08-Oct-96	13:25	11.90	11.23	12.13	11.46	12.40
	08-Oct-96	14:50	11.72	10.90	11.94	11.31	12.22
	TOTAL DRAWDOWN (FEET)		2.49	2.57	2.21	3.00	2.24

DVE/AI PILOT STUDY
LEICA OPTICAL SITE - CHEEKTOWAGA, NEW YORK
SUBSURFACE VACUUM/PRESSURE LEVEL MONITORING RESULTS
TABLE 11

	MONITORING DATE	MONITORING TIME	APPLIED VACUUM ("Hg)		APPLIED PRESSURE/AIRFLOW (PSI/SCFM)					SUBSURFACE VACUUM/PRESSURE LEVELS (INCHES OF WATER COLUMN)							
			DVE1	DVE2	AI1	AI2	AI3	AI4	AI5	PZ1S	PZ1D	PZ2S	PZ2D	PZ3S	PZ3D	PZ4S	PZ4D
PRE-PILOT STUDY	02-Oct-96	08:35	OL	OL	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
DVE OPERATIONS DVE2 ONLY	02-Oct-96	09:45	OL	17.0	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
	02-Oct-96	10:15	OL	15.5	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
	02-Oct-96	11:08	OL	16.5	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
	02-Oct-96	14:10	OL	15.0	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
	03-Oct-96	08:05	OL	17.0	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
DVE OPERATIONS DVE1 AND DVE2 ON-LINE	03-Oct-96	10:32	13.0	10.0	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
	03-Oct-96	11:45	15.0	11.0	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
	03-Oct-96	14:00	21.0	16.5	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
	03-Oct-96	15:15	21.0	17.0	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
	04-Oct-96	09:03	21.5	18.0	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
	04-Oct-96	11:25	21.5	18.0	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
	04-Oct-96	15:10	21.5	18.0	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
	05-Oct-96	09:38	21.5	17.0	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
DVE/PSF OPERATIONS	05-Oct-96	10:45	21.5	17.0	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
	05-Oct-96	14:15	21.5	17.0	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
	05-Oct-96	15:25	21.5	17.0	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
	06-Oct-96	09:20	21.5	18.5	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
DVE/AI OPERATIONS	06-Oct-96	10:22	21.5	19.0	20/2.6	30/<1.0	30/1.8	20/2.6	30/1.5	139 P	6.3 P	ND	ND	ND	3.3 P	ND	ND
	06-Oct-96	12:00	21.5	19.0	20/2.6	30/<1.0	30/1.8	20/2.6	30/1.5	139 P	8.3 P	ND	ND	ND	0.6 P	ND	ND
	07-Oct-96	10:00	21.5	19.0	13/1.9	13/6.5	13/6.4	19/2.3	11/5.1	1.3 P	19.2 P	ND	ND	ND	7.1 P	ND	0.2 P
	07-Oct-96	15:05	21.5	19.0	13/1.7	13/6.5	13/6.8	18/2.9	10/5.1	0.5 P	20.2 P	ND	0.7 P	ND	7.9 P	ND	0.2 P
	08-Oct-96	10:00	21.5	20.0	17/2.2	15/6.4	18/4.6	15/4.6	21/3.4	0.5 P	20.0 P	ND	ND	ND	3.8 P	ND	0.1 P
DVE OPERATIONS	08-Oct-96	11:45	21.0	19.5	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
	08-Oct-96	13:25	21.0	19.5	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND
	08-Oct-96	14:50	21.0	19.5	OL	OL	OL	OL	OL	ND	ND	ND	ND	ND	ND	ND	ND

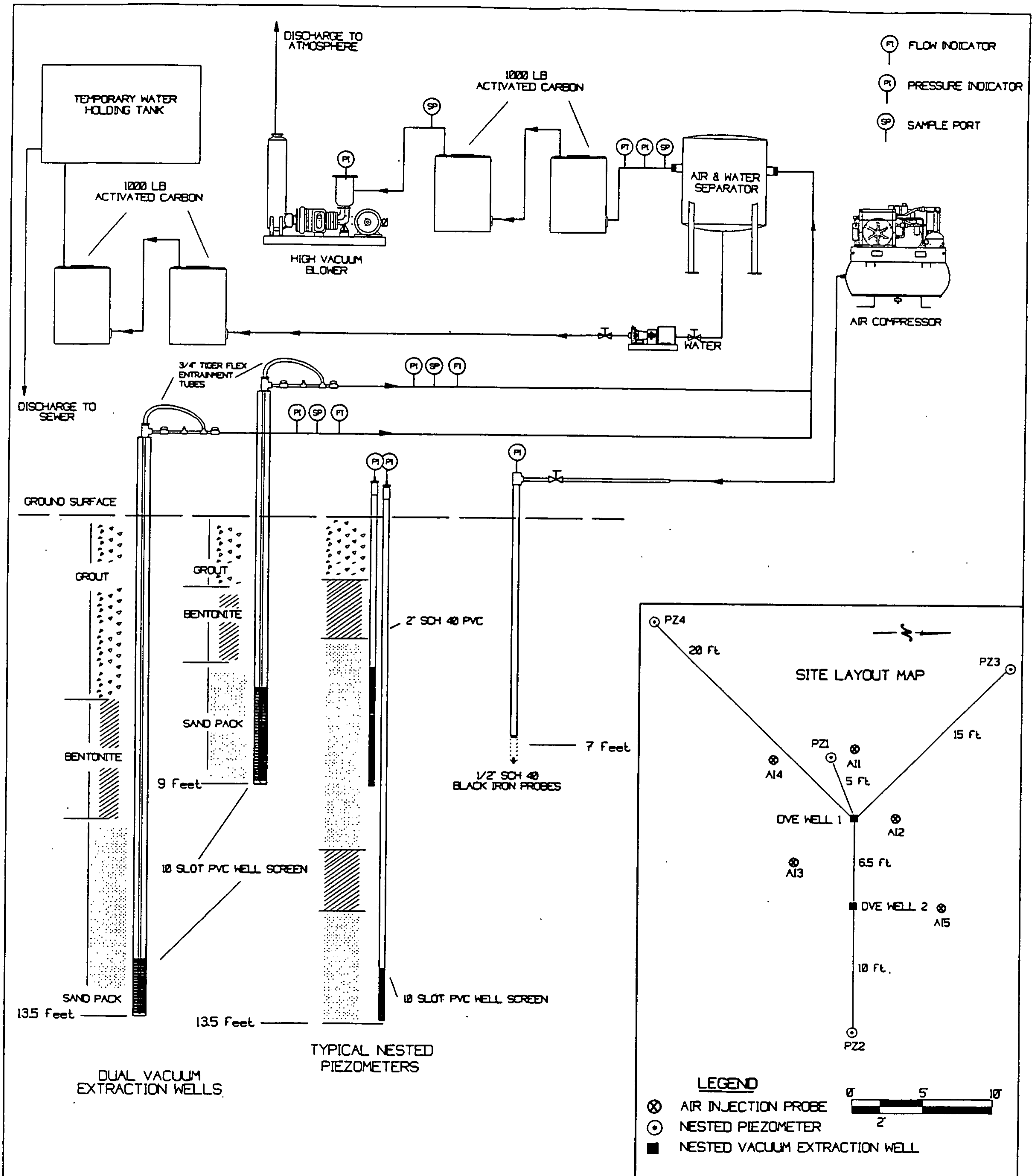
Notes: OL - Well/Probe Off-line ND - No Influence Detected

DVE/AI PILOT STUDY
LEICA OPTICAL SITE - CHEEKTOWAGA, NEW YORK
AI PROBE ZONE OF INFLUENCE - 10/9/96
TABLE 12

MONITORING PARAMETERS	AI1	AI2	AI3	AI4	AI5
APPLIED PRESSURE (PSI)	25	17	22	23	18
INJECTED AIRFLOW (SCFM)	2.2	2.4	6.0	2.5	2.1
PRESSURE INFLUENCE ("w.c.)					
PZ1S	0.8	0.25	0.1	ND	ND
PZ1D	0.9	2.5	2.7	0.7	1.2
PZ2S	ND	0.05	0.15	ND	0.1
PZ2D	ND	0.1	0.1	ND	0.1
PZ3S	ND	ND	ND	ND	ND
PZ3D	ND	0.1	0.25	0.1	0.1
PZ4S	ND	ND	ND	ND	ND
PZ4D	ND	ND	ND	0.1	ND
DVE1	ND	0.05	ND	ND	ND
APPROXIMATE ZONE OF INFLUENCE (FEET)					
SHALLOW CLAY ZONE	4 - 5	10 - 15	10 - 15	< 6	5 - 10
DEEP SAND ZONE	4 - 5	10 - 15	15 - 20	15 - 20	15 - 20

ND - NO INFLUENCE DETECTED

FIGURES



REV	DATE	DESIGN ENGINEER
0	04/16/96	T. PETERS
1	11/04/96	T. PETERS

SCALE: AS SHOWN

TERRA VAC

FORMER LEICA OPTICAL FACILTY
CHEEKTOWAGA, NEW YORK

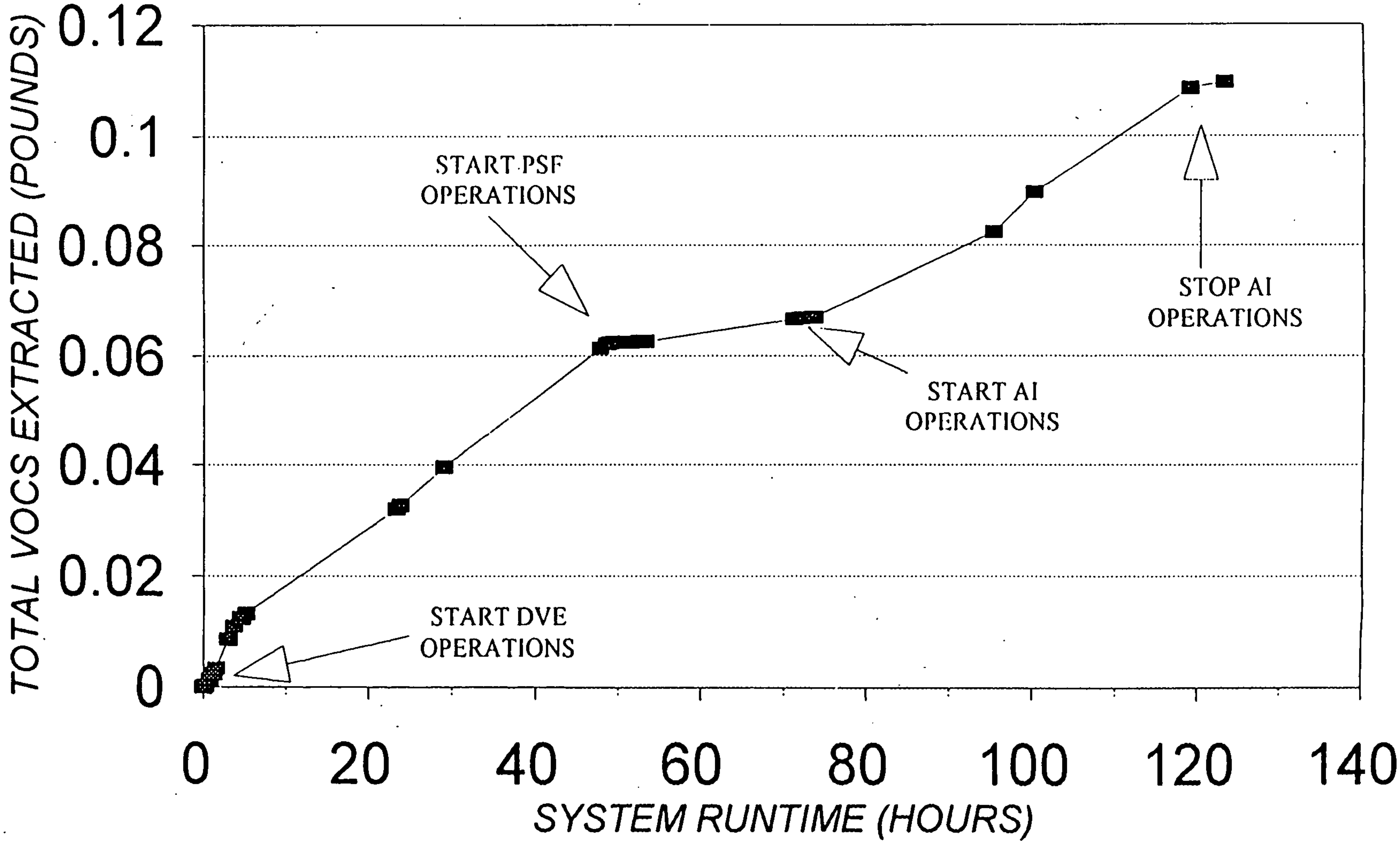
PROCESS FLOW DIAGRAM AND SITE LAYOUT

DRAWN: T. PETERS
PROJECT: 60-1282

FIGURE 1

TOTAL VOCS EXTRACTED VS TIME - DVE1
LEICA OPTICAL DVE/AI PILOT STUDY

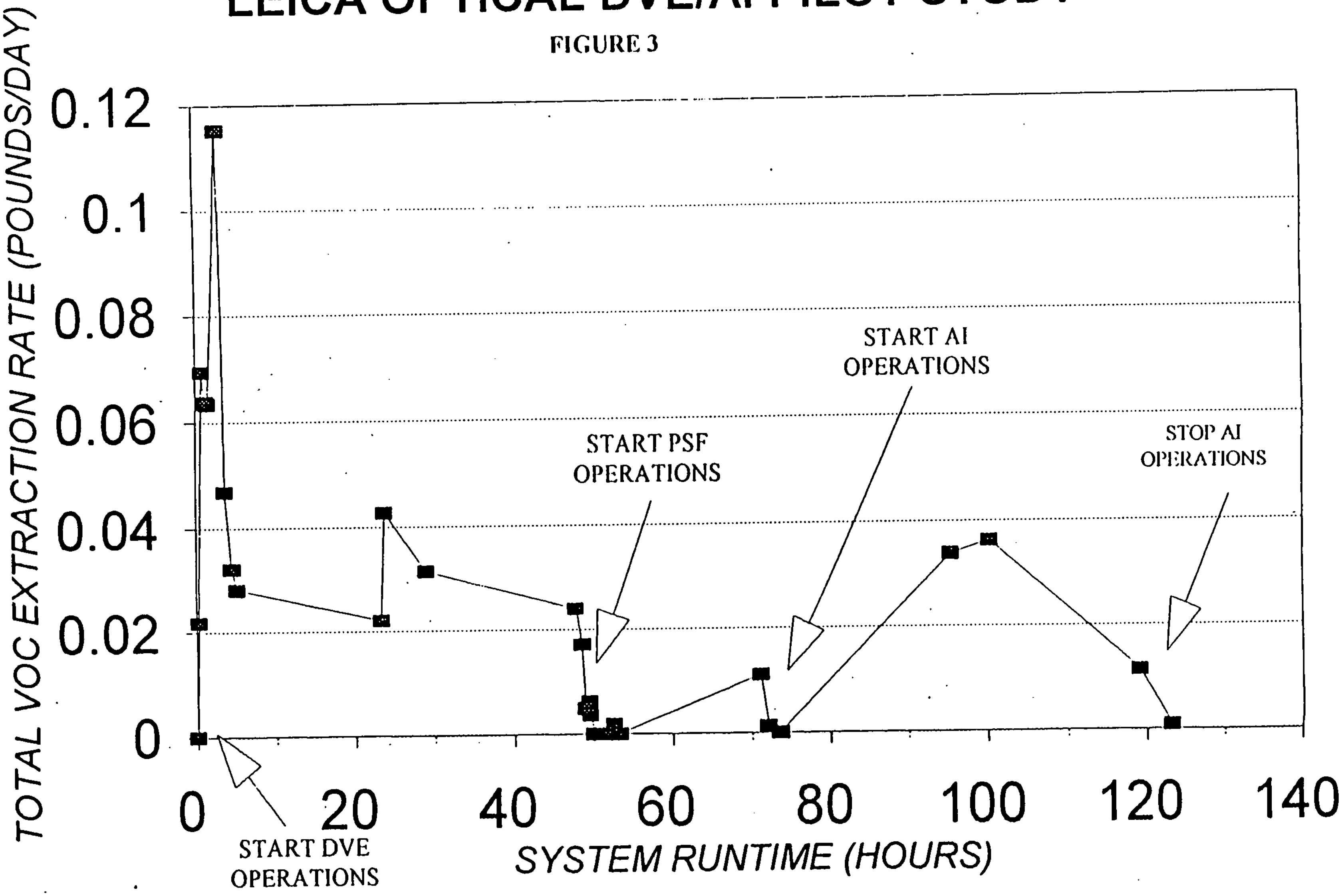
FIGURE 2



TERRA VAC

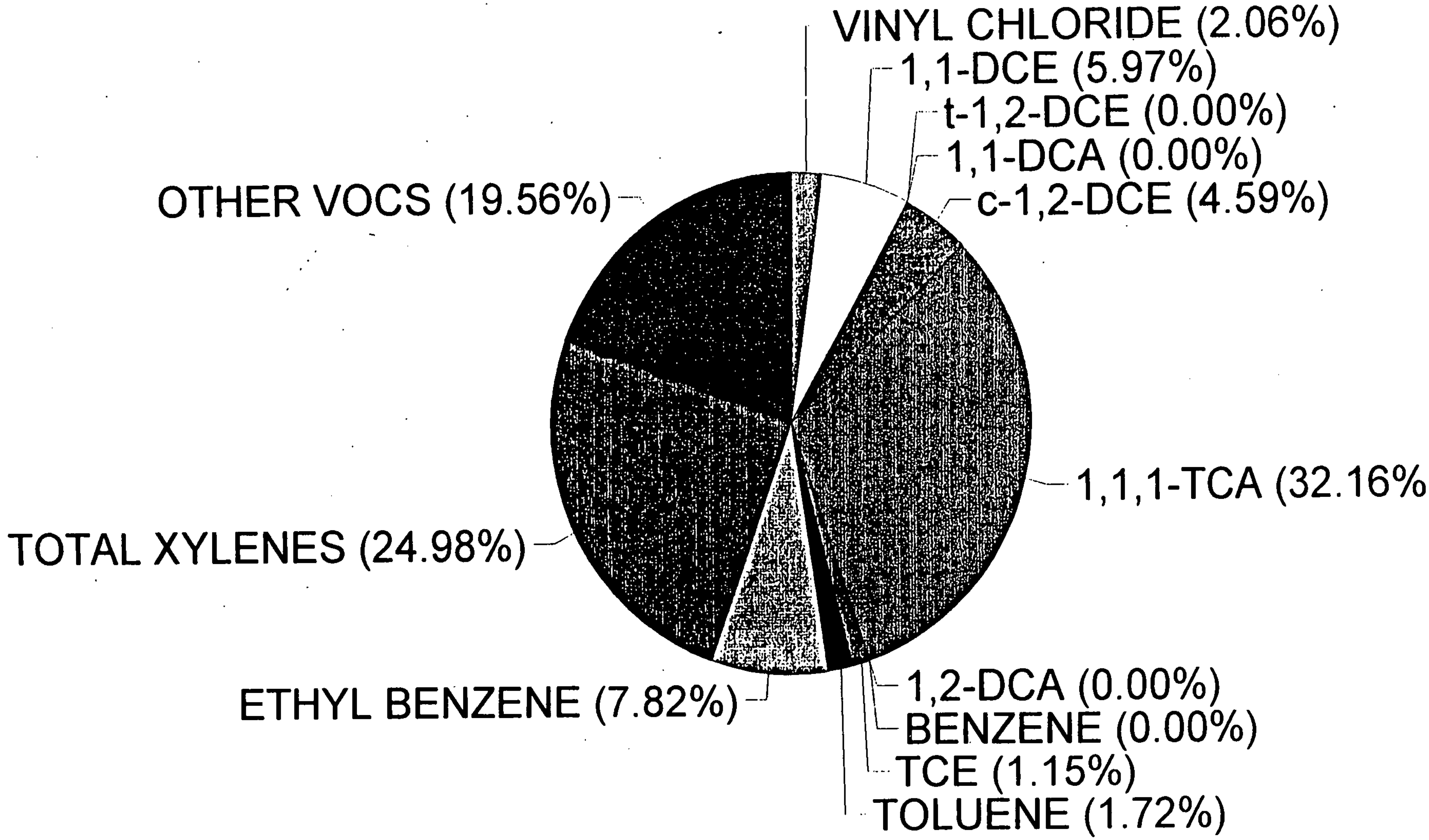
VOC EXTRACTION RATES VS TIME - DVE1
LEICA OPTICAL DVE/AI PILOT STUDY

FIGURE 3



LEICA OPTICAL SITE DVE/AI PILOT STUDY
CONTAMINANT PROFILE - DVE1

FIGURE 4

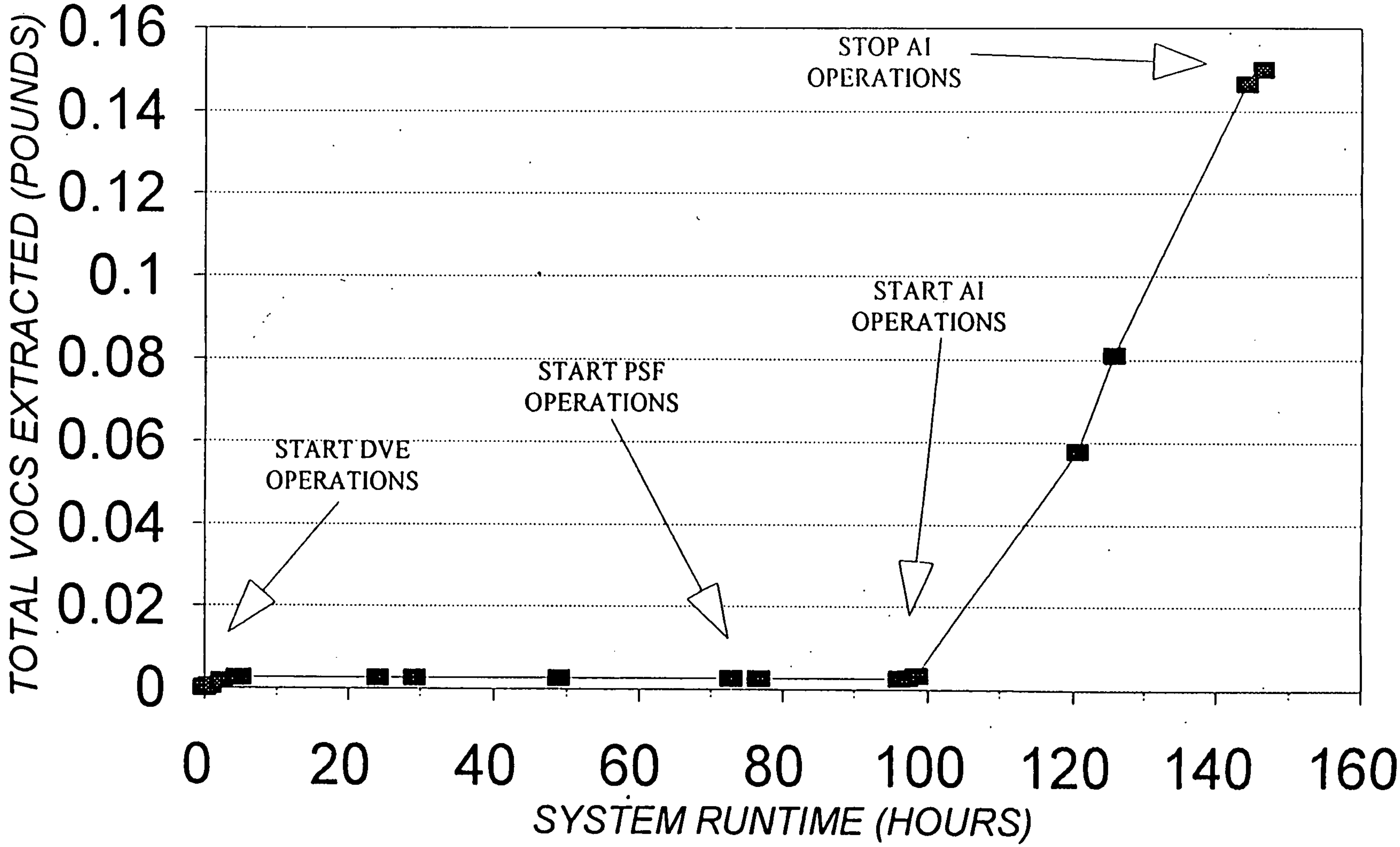


TERRA VAC

TOTAL VOCS EXTRACTED VS TIME - DVE2

LEICA OPTICAL DVE/AI PILOT STUDY

FIGURE 5

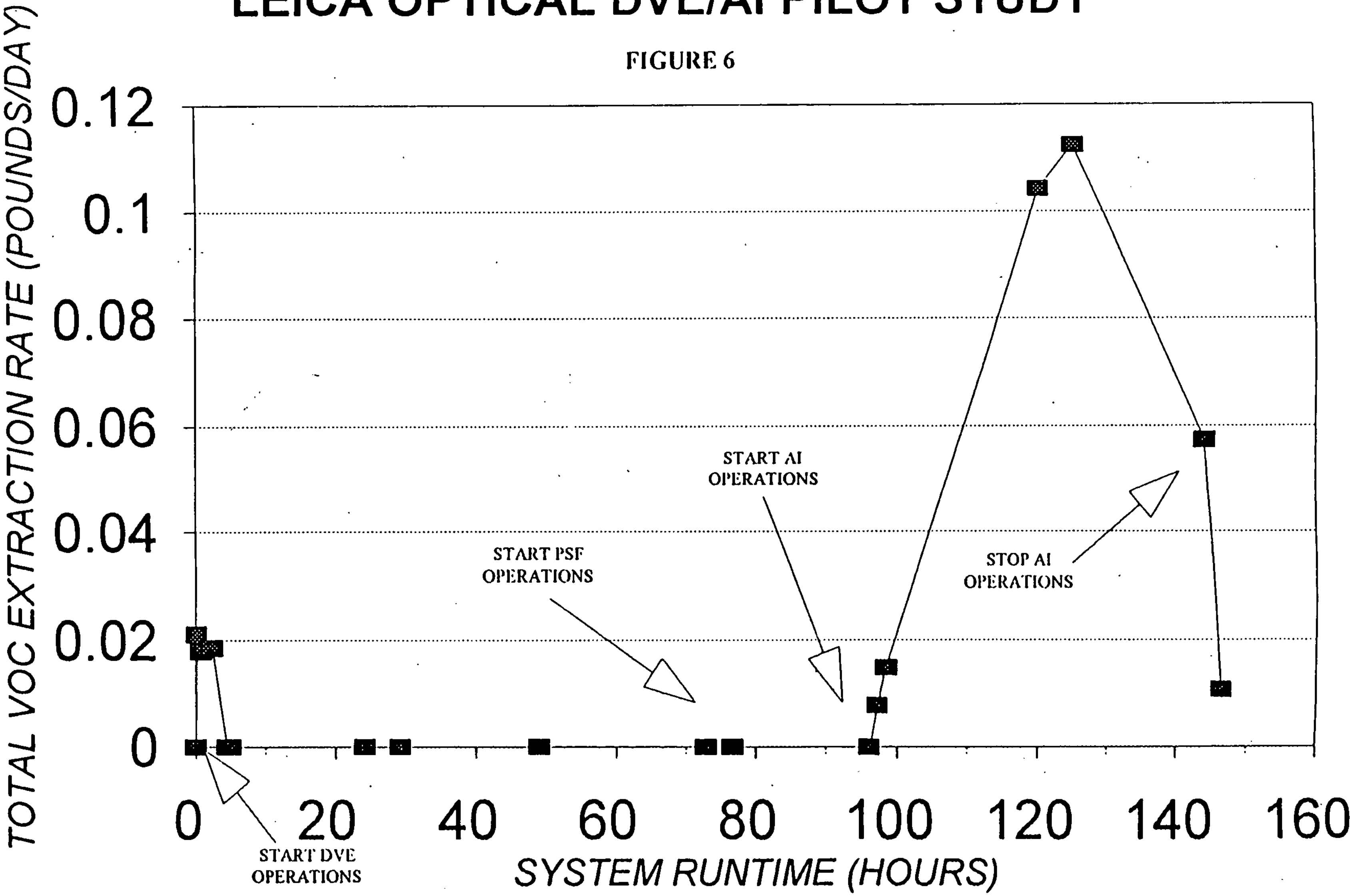


TERRA VAC

VOC EXTRACTION RATES VS TIME - DVE2

LEICA OPTICAL DVE/AI PILOT STUDY

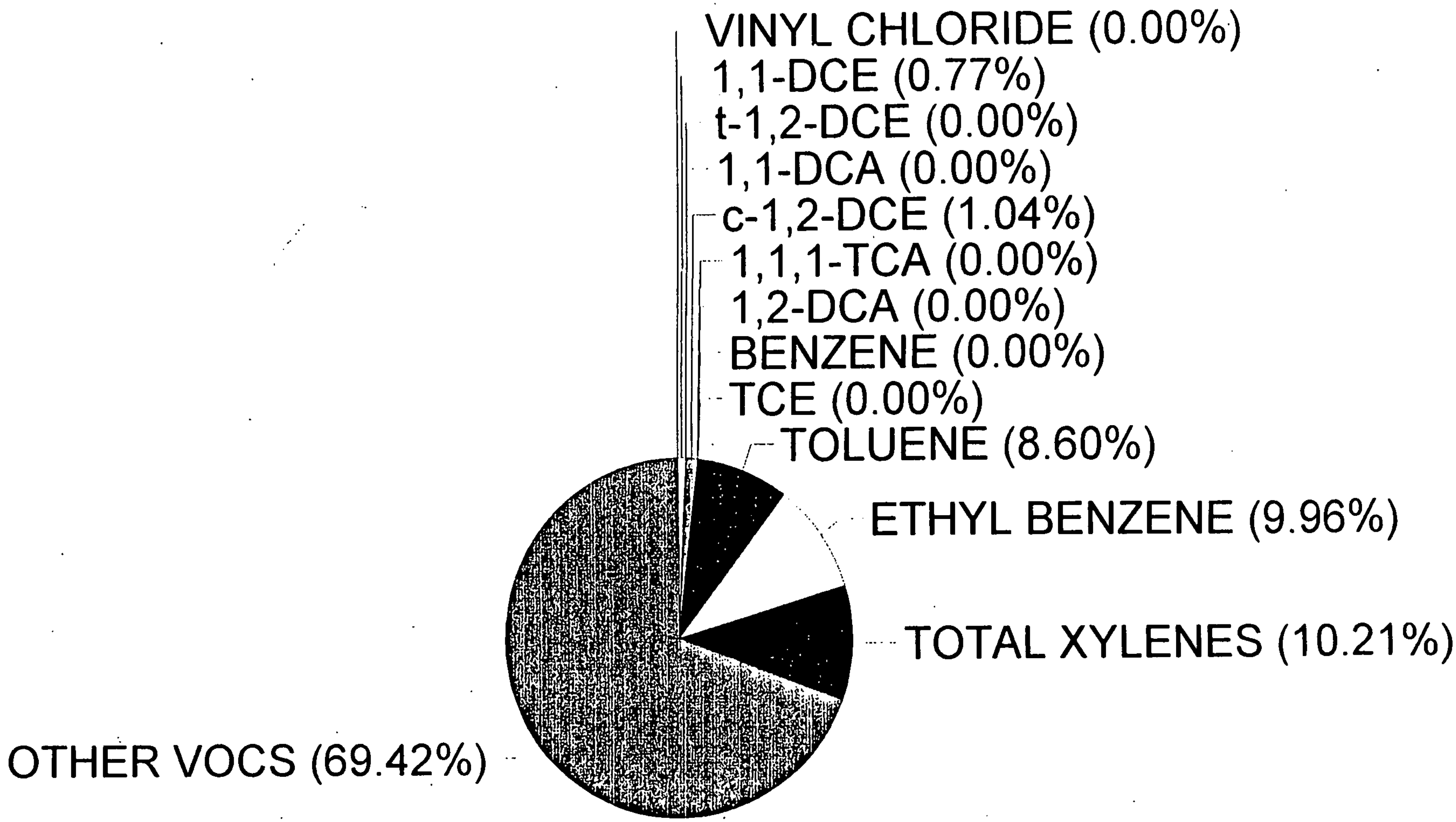
FIGURE 6



TERRA VAC

LEICA OPTICAL SITE DVE/AI PILOT STUDY
CONTAMINANT PROFILE - DVE2

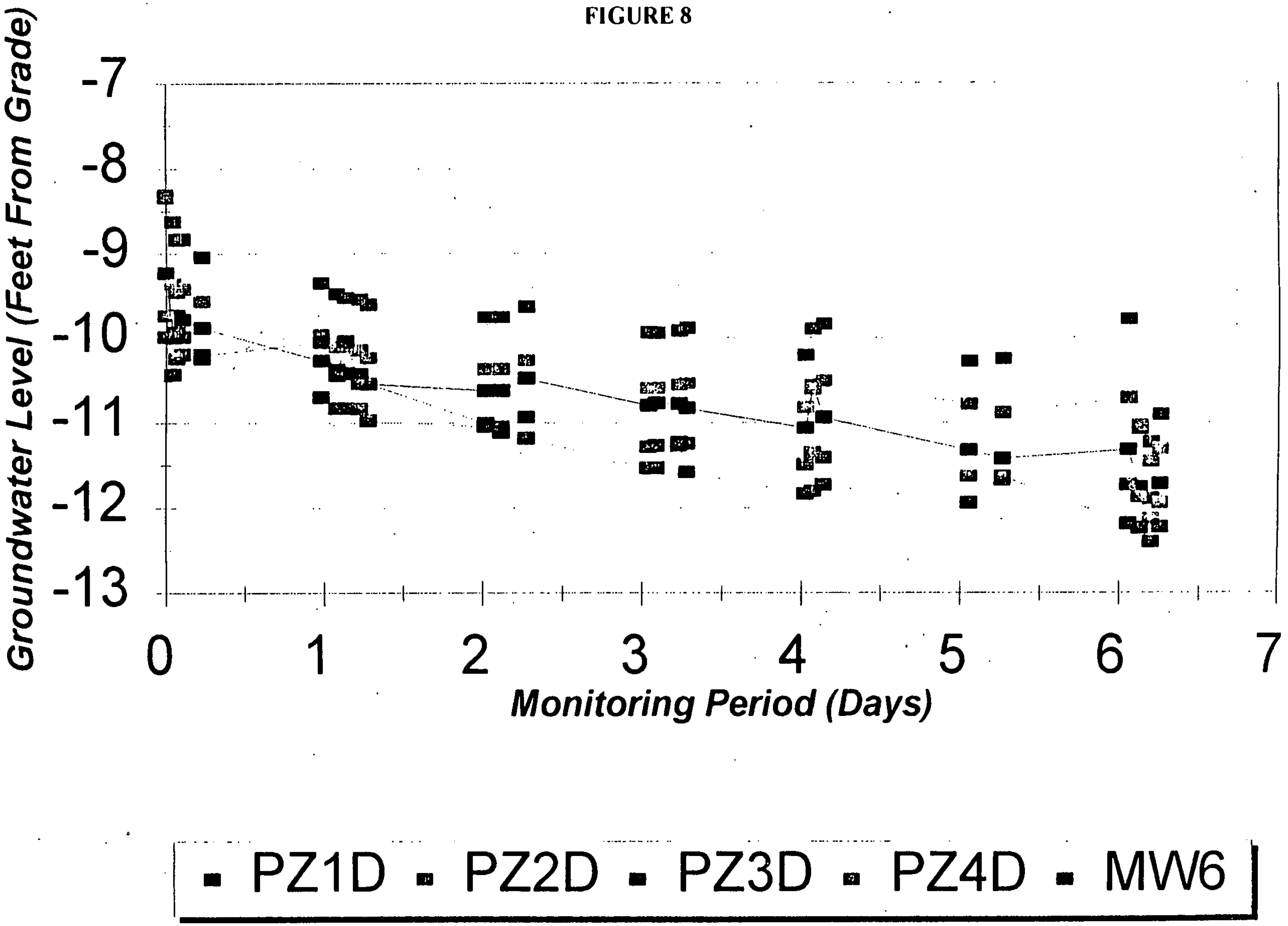
FIGURE 7



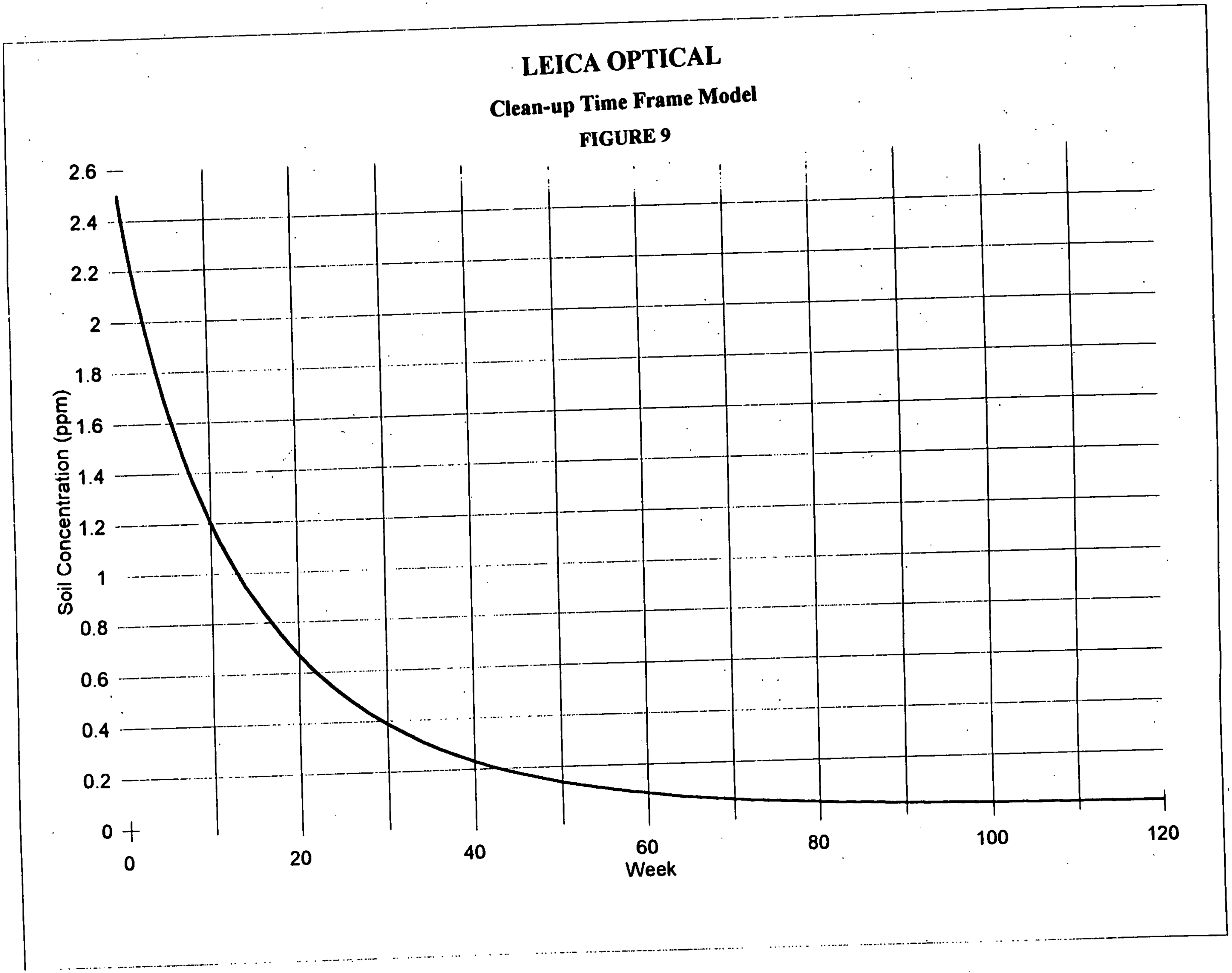
TERRA VAC

GROUNDWATER LEVELS VERSUS TIME
LEICA OPTICAL - DVE/AI PILOT STUDY

FIGURE 8



TERRA VAC

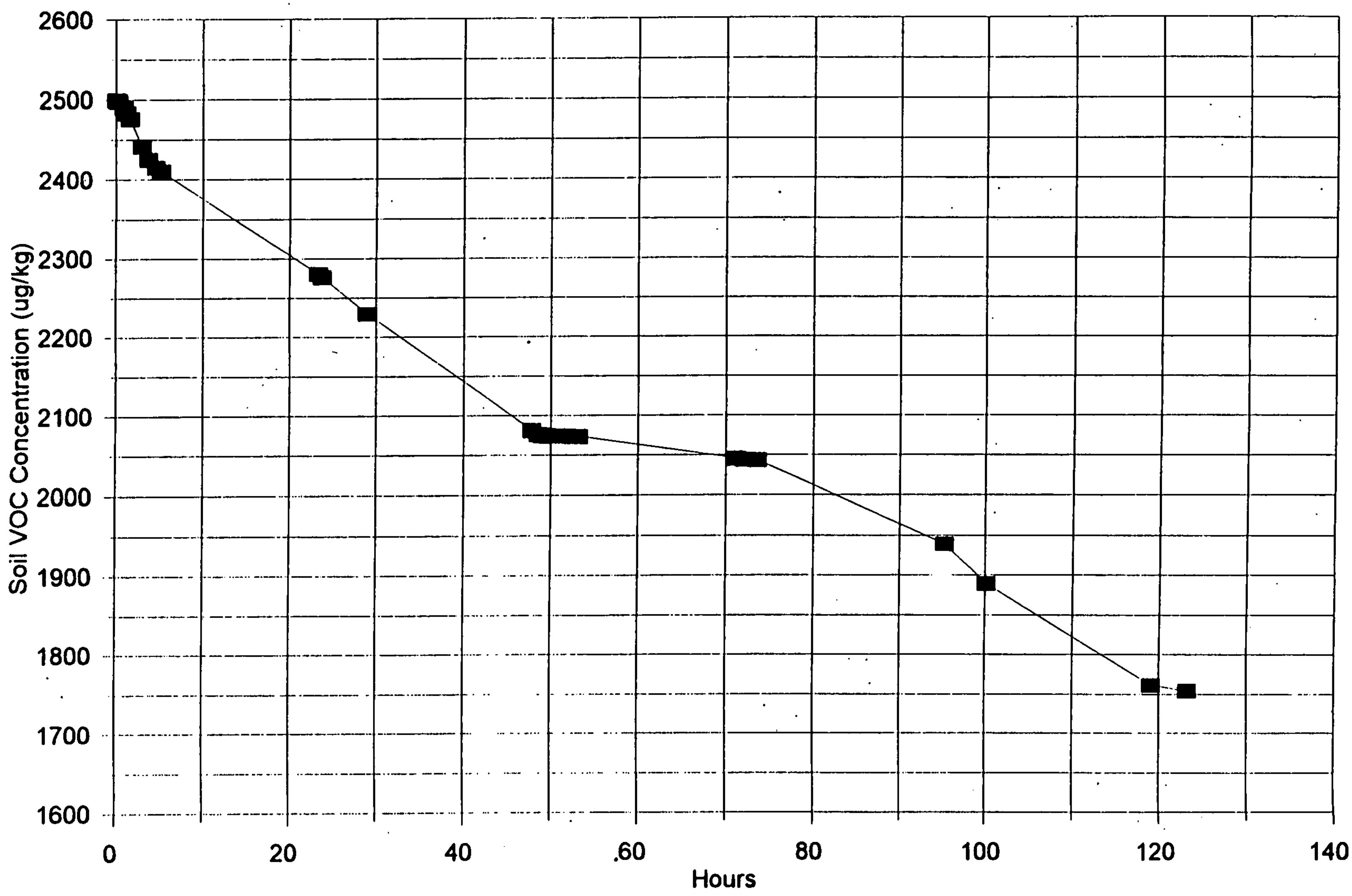


LEICA OPTICAL
Clean-up Time Frame Model
FIGURE 9
Soil Concentration (ppm)
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0.8
0.6
0.4
0.2
0
0
20
40
60
80
100
120
Week

Leica Optical Pilot Study

VOCs Removed From Soil vs Time

FIGURE 10



Leica Optical

Clean-up Time Frame Model

FIGURE 11