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PILOT TEST OF A VACUUM EXTRACTION SYSTEM FOR ENVIRONMENTAL REMEDIATION OF CHLORINATED SOLVENTS AT THE SAVANNAH RIVER SITE (U)

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1.0 SUMMARY

Vacuum extraction is an environmental restoration technique that is currently being applied to the remediation of soils and shallow sediments that are contaminated with volatile constituents. In 1987, a research study was performed to evaluate the performance and potential applicability of this technology at the Savannah River Site (SRS). Vacuum extraction is useful when volatile constituents are present in the vadose zone. The technology has been used to remediate a number of sites across the country, including leaking underground storage tanks, spill sites, landfills, and production facilities. The primary objective of the pilot study was to test the performance of the technology under the conditions specific to many of the potential areas of application at SRS. There is only a limited body of literature documenting field studies in similar environments with interbedded sands and clayey zones and a relatively thick vadose zone. Careful studies of this type are needed to develop full scale designs at SRS. The vacuum extraction pilot study at SRS was performed by a team consisting of technical representatives of the Environmental Sciences Section in the Savannah River Laboratory (SRL), the Raw Materials Engineering and Technology Section of SRS, and Terra Vac Inc., a subcontractor with experience in this field.

Vacuum extraction induces a flow of air through the vadose zone that strips and volatilizes residual contaminants. The simplest implementation of this technology consists of a perforated pipe placed in a borehole to a depth above the water table. A vacuum blower is used to withdraw large volumes of air (hundreds of standard cubic feet per minute). Fresh air enters through the ground surface and acts to purge the organics from the pore space and residual water in the vadose zone. A variety of associated technologies have been developed (e.g., directional drilling, surface treatment systems, etc.) that may be coupled to simple vacuum extraction to optimize a particular application.

The SRS pilot study was performed along the abandoned process sewer line between the metallurgical fabrication facilities in M–Area and the settling basin that received process waste. Leaks in the sewer line during operation of the settling basin resulted in release of contaminants including chlorinated solvents such as trichloroethylene and tetrachloroethylene, to the subsurface. The SRS pilot study yielded promising results. The zone of influence of the vacuum was estimated to be at least 75 ft from the borehole. A total of approximately 1500 lb of chlorinated solvents was extracted from the vadose zone during the three week period of the test. The concentrations of contaminants in the extracted gas decreased significantly during the test. Modeling of the pressures in the vicinity of the test indicate that the gas flow in this interbedded vadose system is similar to water flow in a leaky confined aquifer system; a shallow clay zone at 30 to 40 ft deep acts as an "aquitard" overlying a relatively thick zone of higher permeability. The data from the pilot study indicate that vacuum extraction will be an effective tool for cleaning up volatile contaminants in the vadose zone at SRS.

2.0 INTRODUCTION

Investigations in the vicinity of the metallurgical fabrication area (M Area) of SRS have documented that chlorinated solvents, primarily trichloroethylene (TCE) and tetrachloroethylene (PCE), have been released to the subsurface from a variety of sources (Gordon, 1982; Marine and Bledsoe, 1984; Pickett, 1985). Figure 1 shows the general location of M Area at SRS. One of the sources of solvents to the subsurface was a process sewer line (abandoned in 1985) between the M Area production facilities and the M Area Settling Basin (Figure 2). Elevated concentrations of solvents have been measured in both the vadose zone and groundwater underlying the abandoned sewer line (Pickett 1985). The data indicated that solvents migrated downward from the leaking pipeline to the groundwater, leaving a significant residual in the vadose zone. The contaminated vadose zone represents a long–term source of groundwater contamination as percolating rainwater leaches the solvents into the groundwater over time. Treatment of the groundwater by pumping and air stripping began in 1985. A pilot test of vacuum extraction was initiated in 1987 to determine the potential for this technology at SRS. Vacuum extraction of the vadose zone coupled with groundwater treatment represent a promising overall approach to minimizing treatment time and costs. The long–term source of chlorinated solvents in the vadose zone might be reduced significantly using vacuum extraction, minimizing the operating period for the groundwater treatment system.

Vacuum extraction is a process to treat volatile contaminants in soils and shallow sediments in place. The primary objective of the pilot test was to develop site specific performance data for the performance of this type of system in M Area. Vacuum extraction induces a flow of air through the vadose zone. The vacuum facilitates volatilization and the flowing air removes the residual contaminants. The simplest implementation of this technology consists of a perforated pipe placed in a borehole to a depth above the water table. A vacuum blower is used to withdraw large volumes of air (hundreds of standard cubic feet per minute). Fresh air enters through the ground surface and acts to purge the organics from the vadose zone. Subsurface vacuum propagates laterally, causing in–situ volatilization of residual contaminants from the soil, pore space and water. The removed contaminants and the subsurface air migrate to the extraction point(s); stripping the soil in place. Many modifications of the basic approach are feasible.

This report addresses the project organization, field activities, results, modeling and evaluation of the pilot test conducted in March 1987. Sampling and analytical methods, well installation procedures, and well construction details are provided in Appendix A. Geologic logs are provided in Appendix B.

3.0 PROJECT ORGANIZATION

Several work tasks were conducted during the pilot test:

- Evaluation of subsurface conditions and design of vacuum extraction system.
- Determination of the extent and amount of contaminants in the substrata at test boring locations.

- Installation of vacuum extraction wells and vacuum monitoring wells according to the contaminant profile.
- Measurement of the radius of influence of subsurface vacuum within different substrata.
- Quantification of the rate of extraction of VOCs from the soils.
- Evaluation of the time frame for cleaning up the contaminated soils at the site.

4.0 FIELD ACTIVITIES

Initial subsurface conditions were evaluated by the project team. Three locations were considered as potential sites for the pilot test: pipeline, seepage basin and storage tank area. After review of available data (soil core, soil gas, and groundwater) the pipeline area near monitoring well MSB-15 was selected for the pilot test. Preliminary design of the vacuum extraction system was completed prior to drilling test boreholes.

In order to establish the extent and quantity of contaminants prior to the pilot test, three test borings were drilled to the water table. The wells were located 5 feet away from the center line of the abandoned process sewer pipeline extending from the M-Area to the seepage basin. The first test boring , VB-1, was located along the pipe where elevated levels of solvents have been previously observed. After contamination in the first boring was confirmed by sediment testing, two other test borings, VB-2 and VB-3, were drilled 25 and 50 feet away from VB-1, parallel to the pipeline (Figures 2 and 3).

Two of three boreholes were completed as multiple well monitoring /extraction nests. Measurement of the subsurface vacuum in multiple monitoring/extraction nests provided data for evaluating the radius of influence of the vacuum extraction system. The purpose of installing multiple monitoring/extraction points in each well bore was to define the radius of influence of the vacuum system within each of three stratigraphic units (Figure 4). The primary extraction well, VB-1, was installed as a fully penetrating well; the screen intersects the three major stratigraphic units. When a vacuum was developed on the well, subsurface vacuum was exerted throughout the radius of influence in each stratigraphic unit (most of the vacuum propagated in the sand zone, however). Because screens in the other boreholes were isolated within each stratigraphic unit, the radius of influence of the vacuum system could be measured separately in each unit. The test boring and vacuum extraction well profile is shown in Figure 3.

In order to determine the rate of contaminant extraction, gas samples were obtained from each wellhead. During the first phase of the pilot test, each well was tested individually for VOC extraction rates. Gas samples were analyzed on site using a portable gas chromatograph. Specific analyses were made for two compounds: Trichloroethylene (TCE) and Tetrachoroethylene (PCE).

Following initial vacuum extraction from each well, all the wells were connected together for about 24 hours to measure the maximum contaminant extraction rate. The remainder of the pilot test involved extraction from VB-1 alone while subsurface contaminant concentrations in other wells were monitored. Extraction rates of PCE and TCE were monitored several times per day during the pilot test.

SRP safety guidelines were followed during the pilot test. For example, the drilling site was barricaded and labeled as a work zone. Drilling crew, subcontractor personnel and visitors inside the barricade were required to use hard hats, steel toe shoes, and safety glasses. Drilling operations were under the direct technical supervision of a technical oversight geologist. (Terra Vac). A certified driller was on location at all times during the drilling operations. Air samples were obtained near the borehole and analyzed for vapors to verify that air in the work zone was below the 8 hour Threshold Limit Value (OSHA TLV). Background levels of VOCs were measured before and during the vacuum extraction process.

5.0 RESULTS

5.1 Stratigraphy and Concentration Profiles

Three stratigraphic zones were observed above the water table in the pilot test area. These zones are illustrated in Figure 4. The upper zone consists of interbedded sands, silts, and clay. Thickness of the upper zone ranges from 30 to 50 feet in the pilot test area. The middle zone is predominantly sands, approximately 45 to 60 feet thick. Beneath the sand strata, interbedded sand, and clay extended at least to the water table, about 125 feet below the ground surface.

Based on the contaminant profile measured in each of the three test boring locations, subsurface contaminants, TCE and PCE, are present in significant amounts. Figures 5, 6 , and 7 show the concentrations of PCE and TCE in samples taken from VB–1, VB–2, VB–3, respectively. The raw data are provided in Appendix C. Some trends can be observed from these data.

TCE and PCE were detected in each borehole, ranging in concentration from 0.03 to 203 ppm . The highest concentrations in the profile were observed at depths between 30 and 50 feet, corresponding to the clays within the upper zone. This observation is consistent with the expected behavior of these solvents. TCE and PCE are "wetting" solvents relative to water in the vadose zone. Thus, as solvents contacted the vadose zone clays for an extended period of time, they entered these zones and were held in the fine grained materials by capillary forces. Release from these zones will primarily result from diffusion. The relatively higher permeability of the middle unit results in concomitant rapid migration down through this zone to the lower zone of interbedded sands and clays. The middle sand zone and the lower zone have relatively consistent levels of VOCs present, averaging about 4 ppm.

Contaminant concentrations in sediment samples beneath the water table, are lower than those above the water table. The subsurface contaminant profile at the site has a significant effect on the recovery rates from each of the stratigraphic units and the effectiveness of the clean–up operation within each of these units.

5.2 Recovery Rates

Well screen locations were selected to monitor each of three stratigraphic units and to extract from zones with the highest concentrations. The highest initial concentrations in soils were observed across the screened portion of VB–2C. Also, the highest concentration of TCE and PCE were observed in vapors extracted from this well (Figure 12). Similarly, the lowest average soil concentration across a screened interval yielded the lowest concentration of extracted vapors. Thus, there was correlation between initial concentrations of VOCs in soils at screened intervals and the initial concentration of VOCs in vapors extracted from a well utilizing the vacuum process.

TCE and PCE vapors were extracted for a period of about one day from each well at the startup of the pilot test. Extraction rates from the five wells ranged from 52 to 243 lb per day of TCE and 9 to 69 lb per day of PCE. The highest recovery rates were from VB–1. The initial recovery rates of TCE and PCE from each well are shown in Figure 8. Vacuum extraction from all five wells simultaneously during the sixth day of the pilot test yielded 180 lb per day of VOCs. An air flow of 400 to 500 scfm was used throughout the test.

After the initial one–day well tests and one day of combined extraction, VB–1 was extracted for the remainder of the pilot test. During this time period the total pounds of VOCs (TCE and PCE) extracted were monitored on a daily basis. Figure 9 illustrates the accumulated pounds of VOCs extracted from the subsoils during this phase of the test. A total of 1,036 lb of TCE and 460 lb of PCE were extracted from the vadose zone.

5.3 Observed Radius of Influence

The radius of influence of the vacuum extraction process was measured while extracting from each well individually and monitoring the subsurface vacuum present in nearby wells. There were significant variations in the barometric pressure during the pilot test that impacted the relative pressure in each zone.

For example, at the beginning of the test after the wells had been sealed in and before the vacuum system was operated, there was an initial vacuum in the well relative to ambient conditions. The initial vacuum measured at the wellheads ranged from 1/8 in. to 2–3/4 in. of water vacuum. The highest readings were observed in the deeper vacuum monitoring wells. In order to compensate for the initial vacuum in the wells and changing barometric conditions, all wellhead vacuum measurements used for evaluating the radius of influence were first corrected using continuous barometric records from the site (Appendix D).

Subsurface vacuum was evident (after correction) in all vacuum monitoring wells while extracting from VB–1, indicating a radius of influence of more than 50 ft. Similarly, vacuum extraction from VB–2A within the middle sand unit induced a subsurface vacuum of 4.4 in. water in VB–3B, 75 ft away. Within the upper unit of interbedded clays, silts, and sands, the corrected subsurface vacuum measured in VB–3C while extracting from VB–2 indicated 3 in.

water vacuum 75 ft away. The lower hydrogeologic zone indicated significant vacuum in VB-2B of 8 in. water while extracting from VB-3A, 75 ft away.

Simple extrapolation of these data to estimate the radius of influence of the vacuum extraction system indicated that subsurface vacuum propagates laterally within the middle sand zone over 230 ft. The lower zone has an extrapolated radius of influence that extends more than 400 ft. The extrapolated radius of influence within the upper stratigraphic unit is estimated between 60 and 160 ft. Since the upper unit is highly stratified, the evidence of lateral radius of influence is predominantly through lateral propagation of vacuum within the sandy beds of the upper unit and probably is reduced significantly within the clayey layers of soils, as well as by "recharge" from the atmosphere. These simple extrapolations for the middle sand are refined in the modeling section below.

5.4 Time-Frame for Cleanup

At the startup of VB-1, vapors were extracted from the subsoils at an average concentration of 2,650 and 960 ppm for TCE and PCE, respectively. By the end of the pilot test, 15 days of vacuum extraction from VB-1 had been performed. The average concentration of TCE and PCE were 147 and 61 ppm, respectively by the end of the pilot test. Figure 10 shows the relative cleanup of VOCs from the substrata in VB-1 as a result of the vacuum extraction process.

As VOCs are extracted from the substrata, the removal rate declines with time, indicating cleanup of the vadose zone. During the vacuum extraction process, vapors extracted at the wellhead represent essentially an aggregate soil gas concentration near the screened interval. Under static conditions and relatively low soil concentrations of VOCs, the soil gas concentration is proportional to aggregate soil concentration.

Evidence of the behavior of the system during active vacuum extraction can be observed when vacuum extraction is interrupted and the wells are allowed to "rest". If the mass transfer from the fine grained zones is sufficiently rapid, and the system is significantly removed from static equilibrium, the concentrations would be higher when vacuum extraction is started after the "rest period". After the vacuum extraction system had been operating from VB-1 for two weeks it was shut down for two days. The vapor concentrations the day before this shutdown of VB-1 averaged 188 ppm TCE and 81 ppm PCE, the day of startup the average concentration was 175 ppm TCE and 74 ppm PCE. Thus, the contaminant concentration remained essentially constant before and after the two day rest period, suggesting:

(1) the process is operating near static equilibrium, or
(2) mass transfer from the fine grained zones is relatively slow but continued during the "rest" period.

The second hypothesis is strengthened by operational considerations; upon shut down, atmospheric air was allowed to enter the well. This volume of air started at a concentration of approximately 0 ppm. Thus, the measured concentration following the interruption represents a significant mass transfer component.

During the continuous extraction from VB–1 each extraction/monitoring well at VB–2 and VB–3 was temporarily connected to the vacuum system to obtain a representative sample of the soil gas at the screened locations of VB–2A, VB–2C, VB–3A, and VB–3B. Results of vapor sampling from these wells indicated substrata within the middle sands and the lower hydrogeologic unit were significantly remediated at distances 25 and 50 ft from the central extraction well, VB–1. Soil vapor concentrations from each well during the pilot test are shown in Figures 11 to 14.

Extrapolation of these data indicates that cleanup of the sediments in the middle and lower zones utilizing the vacuum extraction process may occur in less than one year. However, cleanup of the upper zone of interbedded sands, silts, and clay would require significant additional cleanup time.

6.0 MODELING

The pressure response in the central sand zone during the initial pumping of the primary extraction well, VB–1, was modeled to assist in interpreting the study results. The raw data consisted of the measured pressures, corrected for barometric pressure changes that occurred during the test (Appendix D). As shown in Figure 15, the system configuration can be idealized as a pump test in a leaky confined aquifer. In this case, the fluid is air rather than water, the "aquitard" that confines the system is the upper clayey zone identified in the logs, and the "aquifer" is the central sand zone. The pumping well is fully penetrating. Thus, except for the compressibility of the fluid, the test was configured exactly as required to meet the boundary conditions of the available analytical solutions of a leaky confined pump test. Massmann (1989) demonstrated that standard groundwater models may be used to model vadose zone pressure responses, under certain conditions. The linearized modeling approach requires that (1) a series of unit transformations and corrections are performed, and (2) the overall change in the pressure field is less than 0.5 atmospheres (prediction errors under these conditions are less than 10%). Extraction of approximately 500 cfm from VB–1 resulted in a change in pressure of approximately 0.3 atmospheres (the associated prediction error is less than 2%). Using the transformed data, key modeling parameters were derived for the vadose zone in the vicinity of the test using the method of Hantush and Jacobs (1955) to solve the inverse problem. A standard groundwater pump test interpretation program (Duffield, 1989) was used to derive parameters. These parameters were then used to refine the estimates of zone of influence and are intended to provide design data for future tests.

The test data are listed in Appendix C. The model results, model assumptions, theoretically calculated comparison values and comparison results from nearby pump tests/groundwater models are summarized in Table 1. The model results closely match the comparison values and fall within the expected range. As shown in Figure 16, the model results for the screens within the central sand zone closely match the observed pressure response at all locations and times. The calculated zone of influence for this system using the method of Bear 1979 suggested a large radius of influence. Four times the leakage factor (λ) provides an estimate of the radius of the cylinder in which 95% of the flow is provided by recharging air. The resulting value, approximately 1400 ft, is larger than the simple extrapolations discussed earlier. Note however, that the calculated drawdowns over most of this radius away from the well are very low–much lower than typical diurnal variations in barometric pressure ($\simeq$ 4 cm of water). If the magnitude of diurnal variation in barometric pressure is used as a reasonable estimate of capture zone (beyond this line, natural variations in pressure may limit efficient stripping) then the calculated zone of capture in the central sand zone would be approximately 300 ft. This value represents a reasonable compromise between the simple extrapolation and the theoretical approach based on 4 λ.

7.0 EVALUATION

The results of the vacuum extraction pilot test near the pipeline of M–Area indicate:

1. The vacuum extraction process was effective in removing volatile contaminants from the subsoils of M–Area.
2. The vacuum extraction process has a large radius of influence, ranging from 60 to 400 ft., in each of the three stratigraphic zones observed at the site.
3. Significant rates of VOC recovery were achieved during the pilot test. Individual wells produced as much as 312 lb per day of VOCs.
4. During the operational portion of the pilot test a total of 1,036 and 460 lb of TCE and PCE, respectively, were extracted from the substrata.
5. The time frame for cleanup of the substrata near the pilot test area was estimated to be less than one year in the lower two stratigraphic units. The time frame for cleanup of the upper zone is significantly longer. Note that system design in M Area should be optimized to remediate the relatively high concentration residual solvents that are present in the fine grained zones. This means (a) maximizing vertical flow through the upper clay zone(s), (b) minimizing lateral flow in the central sand zone (i.e., installation of lateral passive or active vent wells in this zone would reduce the drawdown and thus the vertical flow cleaning up the shallow clays), and (c) evaluation of the need for inducing flow in the lower clayey zones (dry screens in water table wells will induce some flow through these zones with minimal impact on the overall (drawdown). Also, because the contaminant release from the fine grained zones is flow and mass transfer limited, the only way to decrease the remediation time for these zones is to (a) induce more flow through these zones or (b) increase the mass transfer (e. g., by heating or increasing surface area using a process like fracturing).

Recommendations for testing and cleanup of the site include:

1. Continue research and development related to vacuum extraction applications at SRS.

2. Perform vapor tracer tests to more precisely define the flow regime in the vadose zone.

3. Evaluate post test soil/sediment sampling to quantify concentration changes following vacuum extraction.

4. Design, install, and operate full scale systems to cleanup the vadose zone in known areas of contamination near the solvent storage tank, beneath the M-Area Basin, near the A-14 outfall, and at some of the burning/rubble pits.

5. Evaluate effects of changing system geometry (e. g., horizontal wells) to improve performance.

6. Use the calibrated model from the pilot test to perform scoping calculations for application sites in M Area. Operate systems (as they are installed) to allow for data collection upon start up to refine modeling.

8.0 REFERENCES

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Table 1

Model Assumptions, Comparison Data and Results

(A) Assumptions

b = pumping zone thickness = 70 ft = 2.13×10^3 cm
b' = confining clay zone thickness = 2 ft = 60.96 cm
μ = gas viscosity = 1.8×10^{-4} g/cm/sec
ρ = gas density = 1.3×10^{-3} g/cm^3
g = gravitational constant = 980 cm/sec
MW = molecular weight of gas = 28
RT = gas constant * absolute temperature = 2.5×10^{10} cm^{2}*g/sec^2
ϕ_t = total porosity = 0.4 (Eddy et al., 1991)
θ_s = saturation = 0.3 (Eddy et al., 1991)
ϕ_a = available porosity = $\phi_t\,(1-\theta_s)$ = 0.28

conversions:

1 atm = 1013 mbar = 33.9 ft water = 1033 cm water
= 7.95×10^5 cm air

(B) Comparison Values
K_{ref} = reference permeability = 10 darcies
= 1×10^{-7} cm^2 (see note 1, Eddy et al., 1991)

$S_{s,c}$ = theoretical specific storage
= $(g\ \phi_a\ MW)/(RT)$ = 3.1×10^{-7} cm^{-1}

$K_{gas,c}$ = calculated "hydraulic" conductivity for gas
= $(\rho\ g\,K_{ref})/\mu$ = 7.1×10^{-4} cm/sec

(C) Model Results (see note 2)

S_s = model specific storage = S/b = 3.05×10^{-7} cm^{-1}

K_{gas} = model "hydraulic" conductivity for gas =
= T/b = 3.0×10^{-3} cm/sec (42 darcies)

clay zone parameters –
K'_{gas} = $(T\,b')/(\lambda^2)$ = 3.3×10^{-6} (0.05 darcies)

Notes:

1. Value for permeability is a median value based on pump test of underlying aquifers and groundwater model calibrations. This value is provided as a rough comparison only since it does not represent the same zone.

2. Best fit values:

$T = 5.5\times10^5$ cm^2/day
$S = 6.5\times10^{-4}$
$\lambda = 20886$ cm

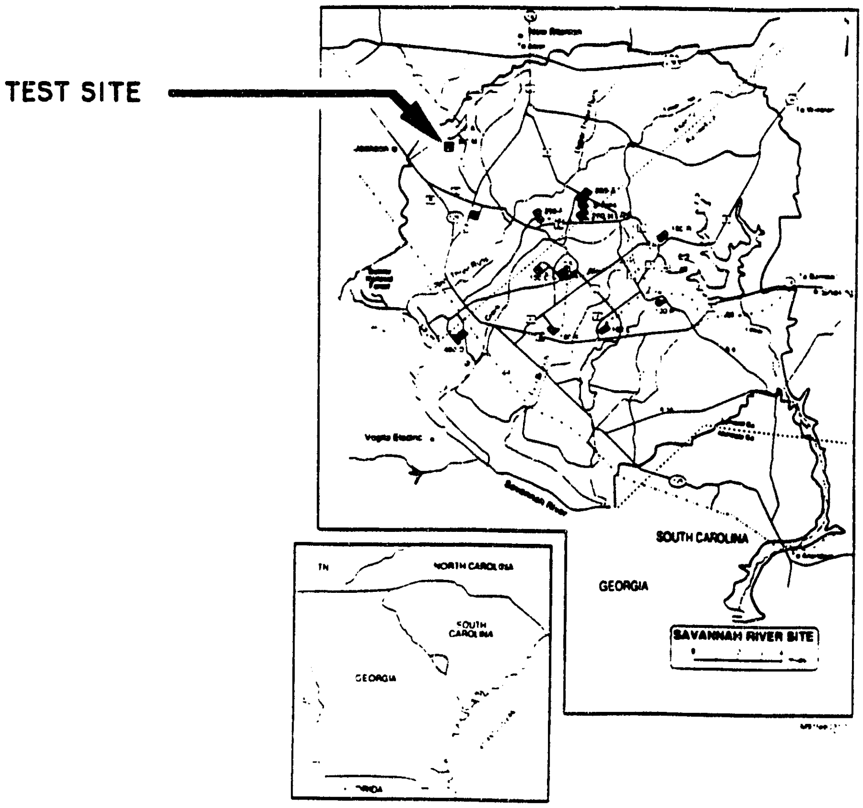
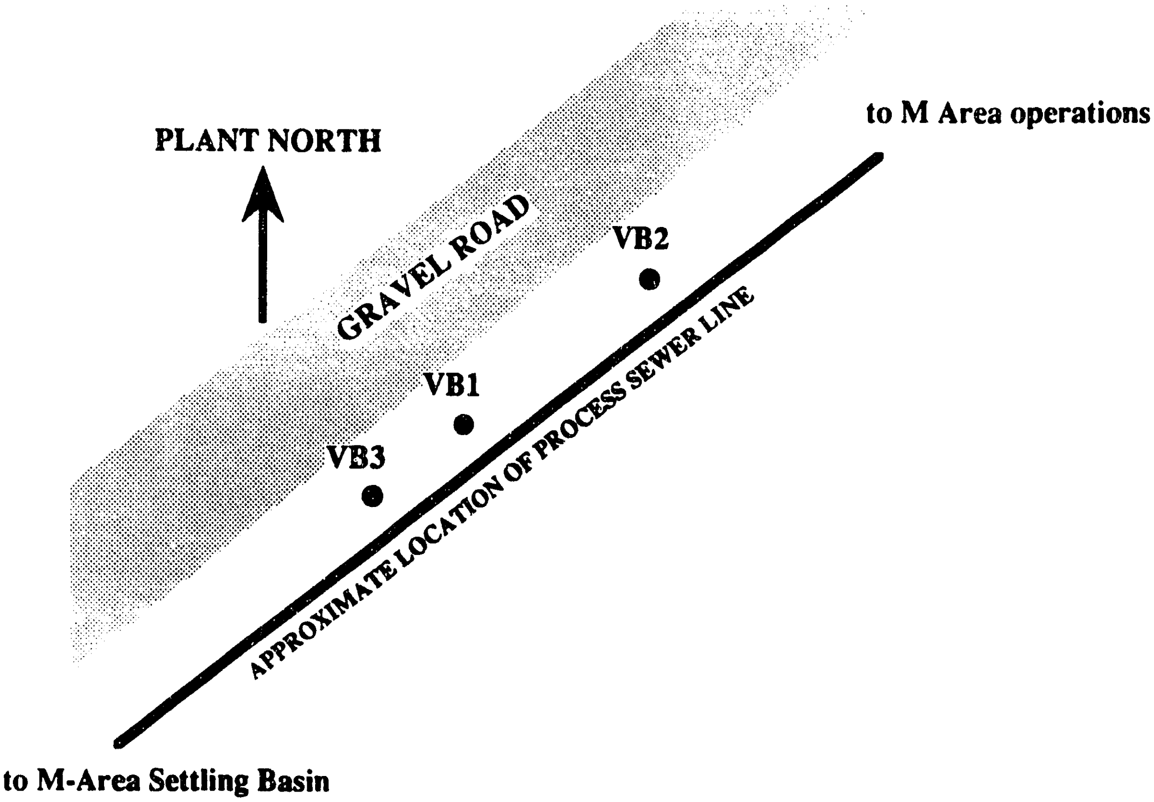


Figure 1. Location of M Area at SRS

M9004007i



Locations and Elevations of Test Wells

---- coordinates ----		elevation (feet above MSL)		Well ID
SRS easting	SRS northing	ground	top of pad	
48827	102848	366.2	366.2	VB 3
48839	102871	366.1	366.1	VB1
48862	102915	na	na	VB2*

* coordinates approximate, well destroyed during sewer line removal before survey completed

Figure 2. Map of Vacuum Extraction Pilot Test Area

M9004007i

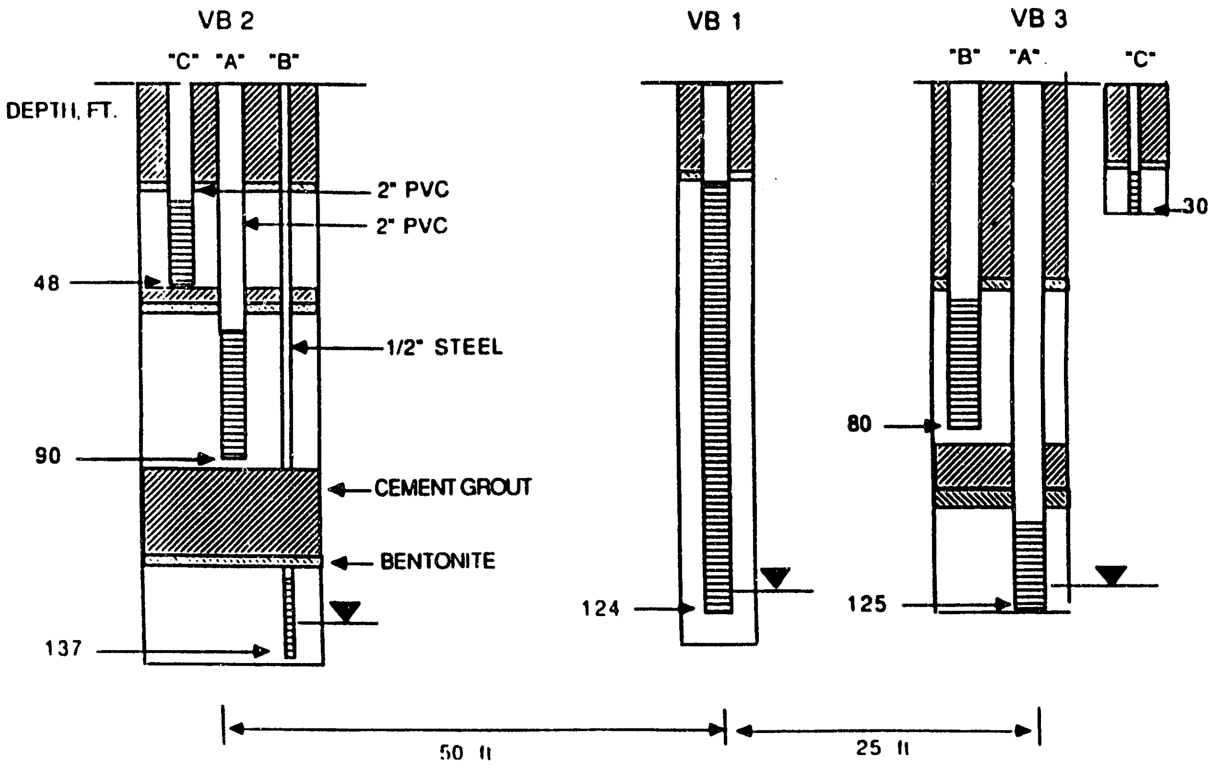


Figure 3. Schematic Diagram of "well' Construction

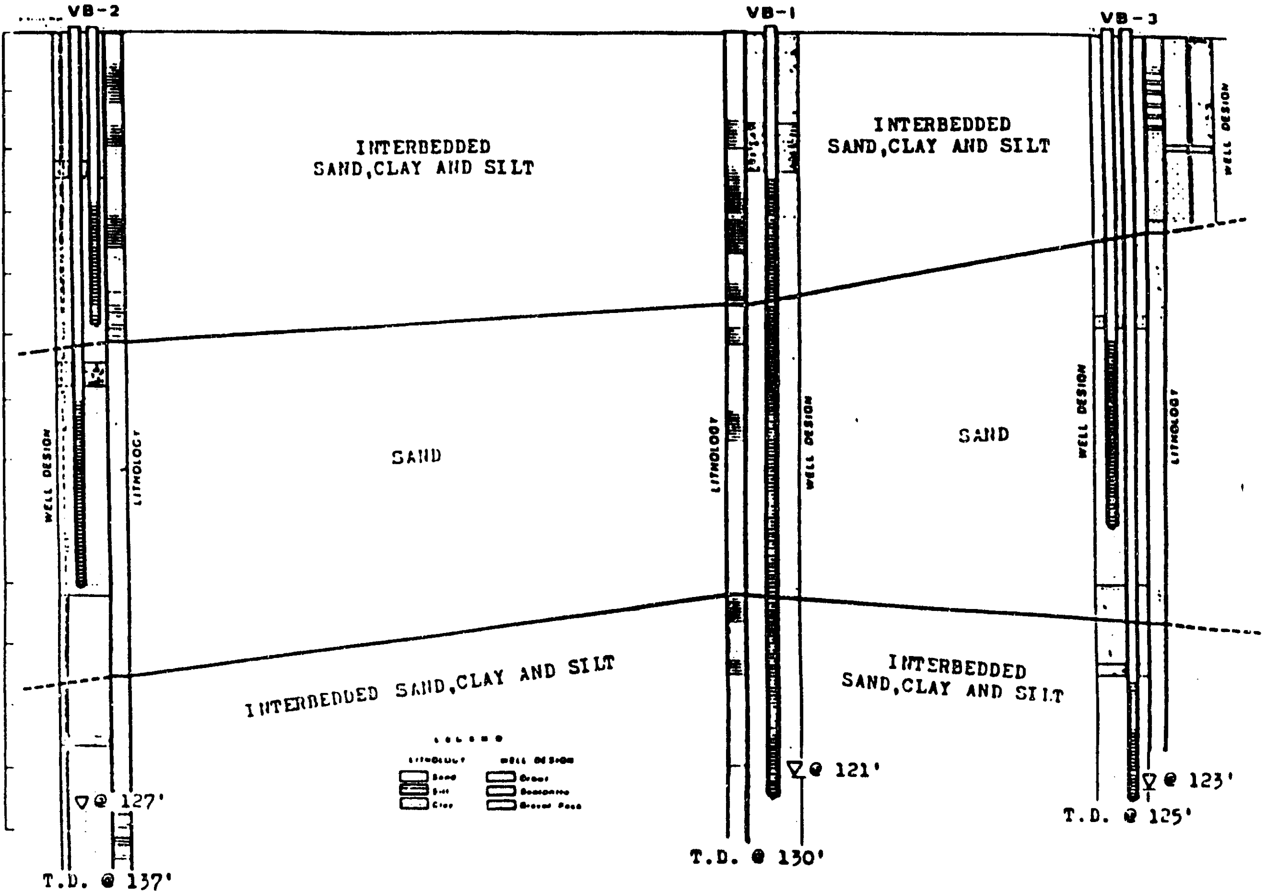


Figure 4. Cross Section Generalized Lithology

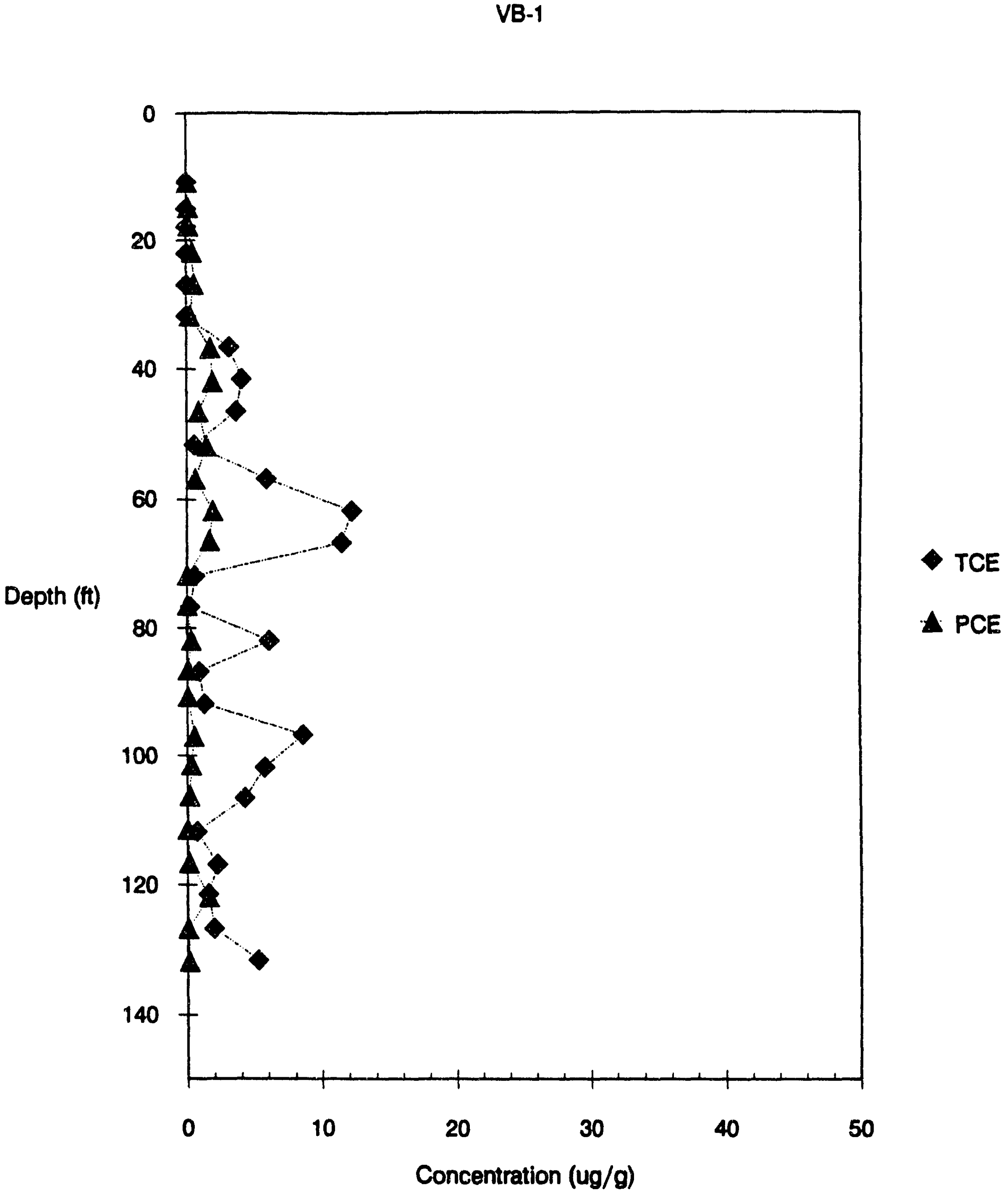


Figure 5. Concentration Profile of VOCs in VB-1

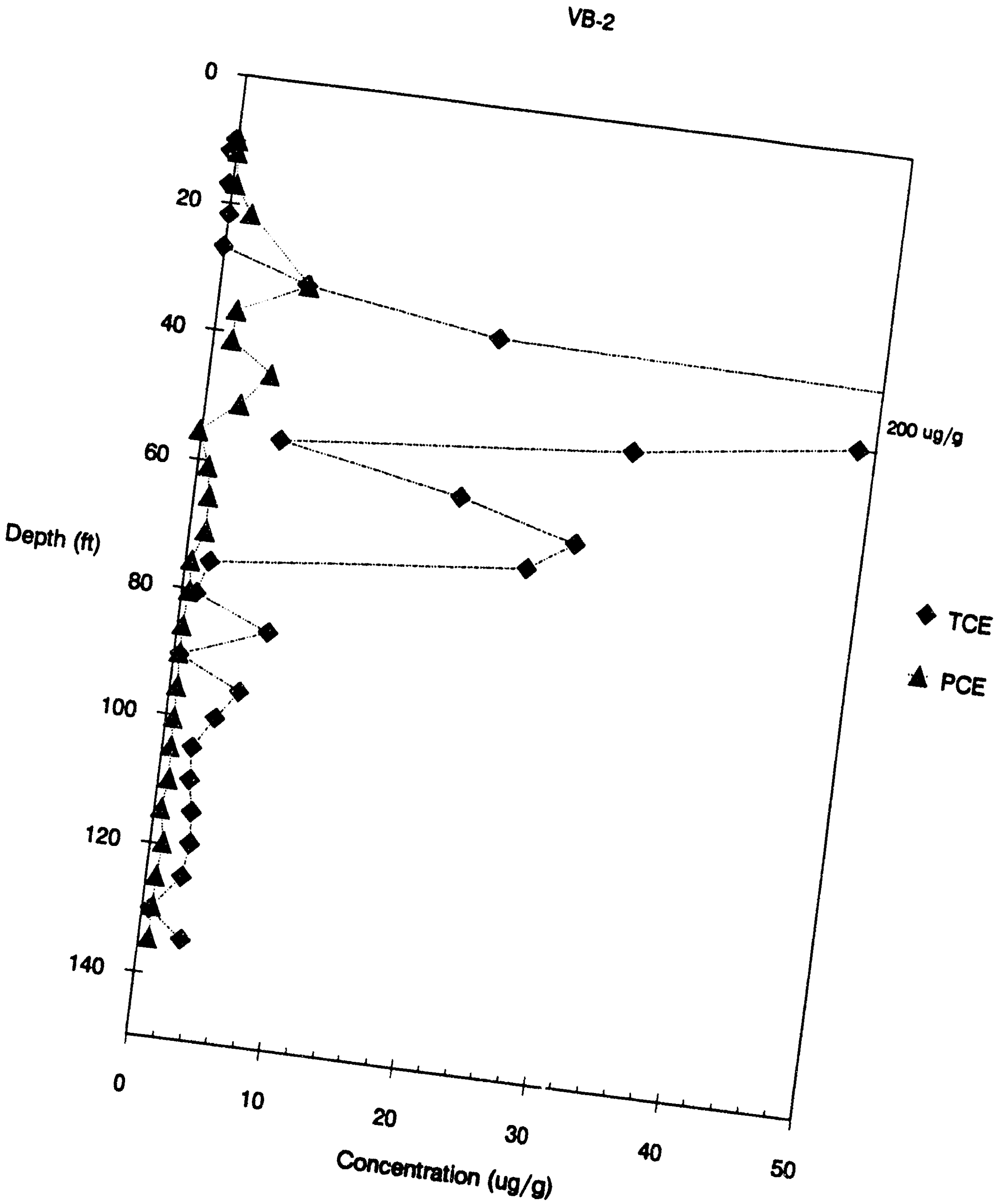


Figure 6. Concentration Profile of VOCs in VB-2

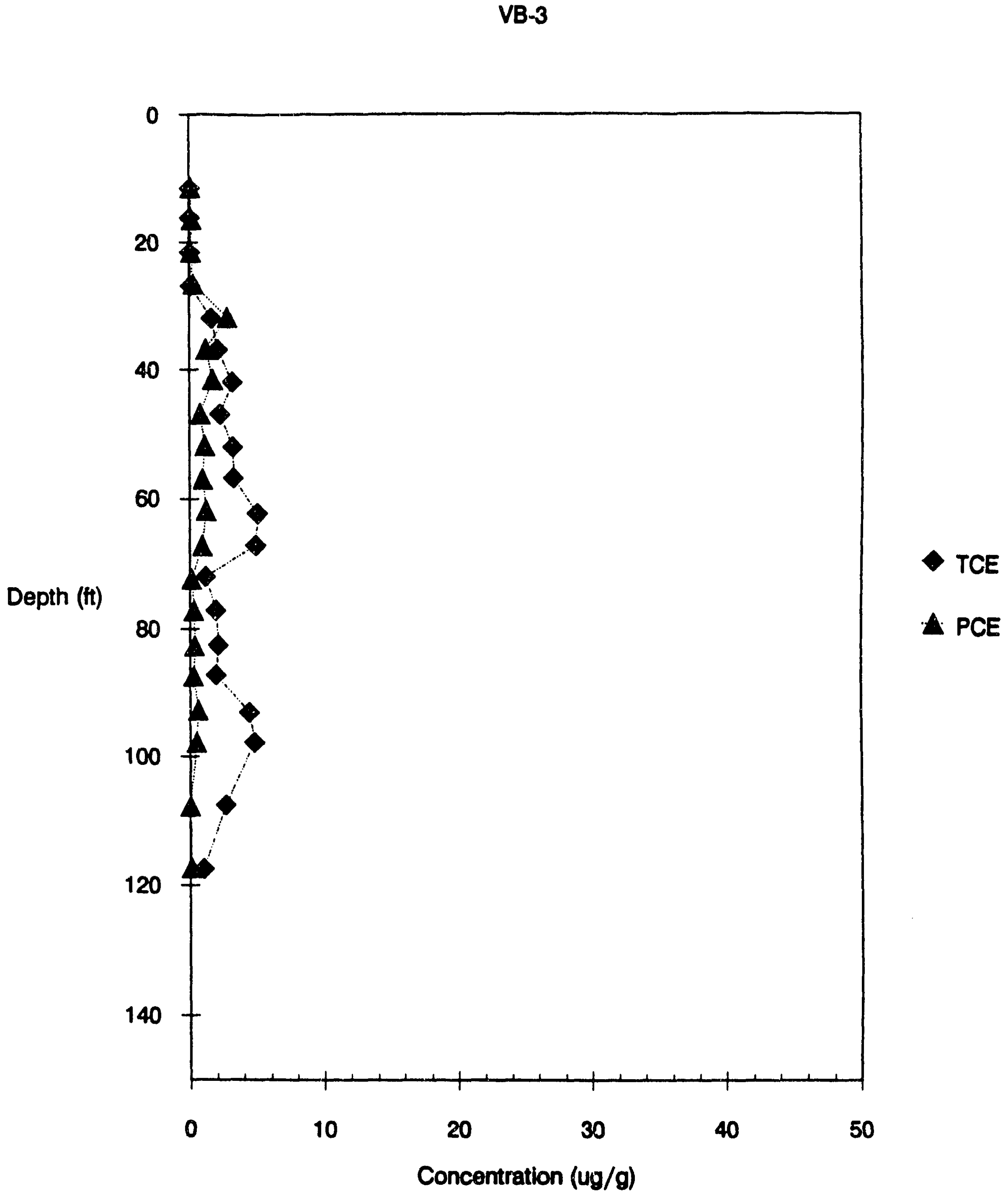


Figure 7. Concentration Profile of VOCs in VB-3

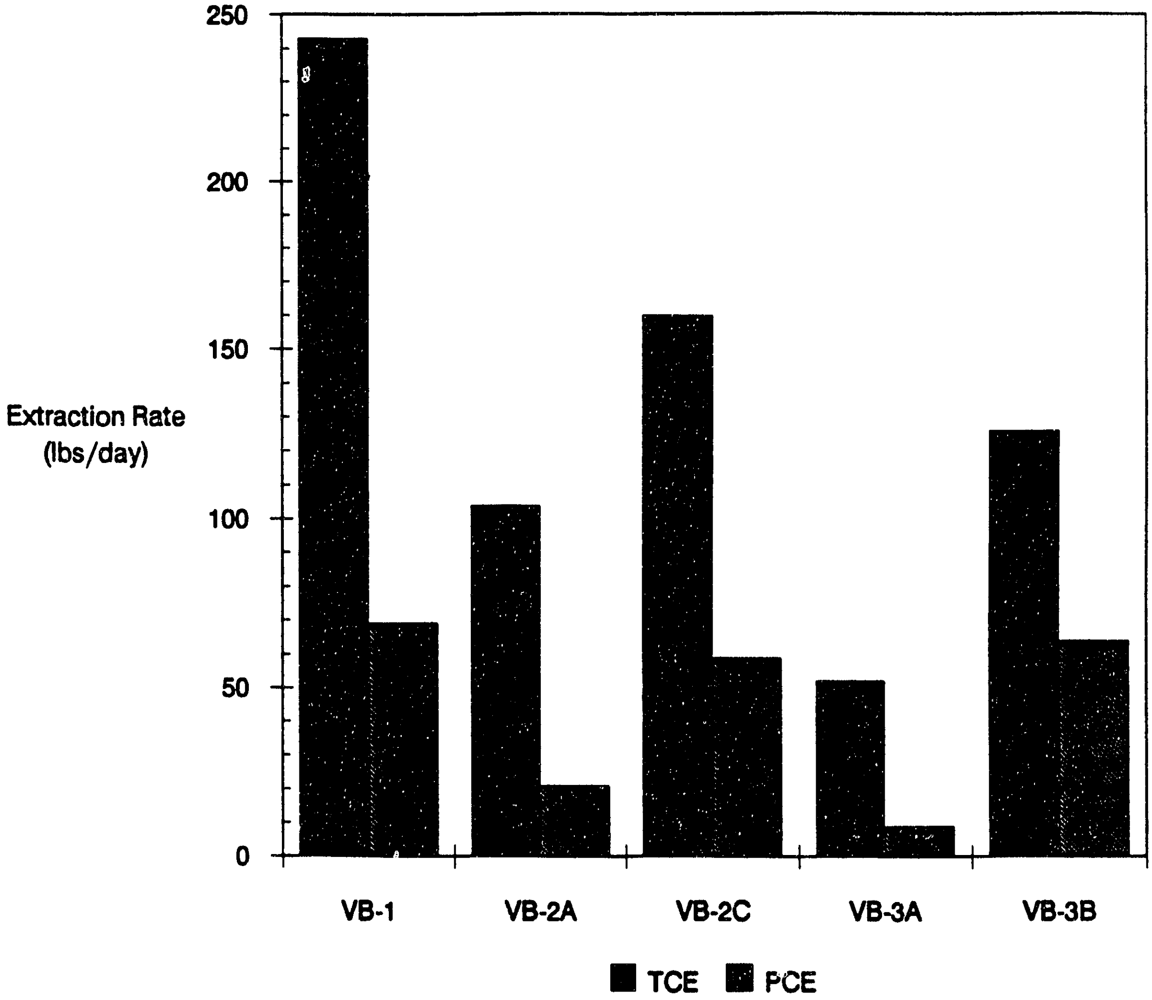


Figure 8. Initial Extraction Rates for all Wells

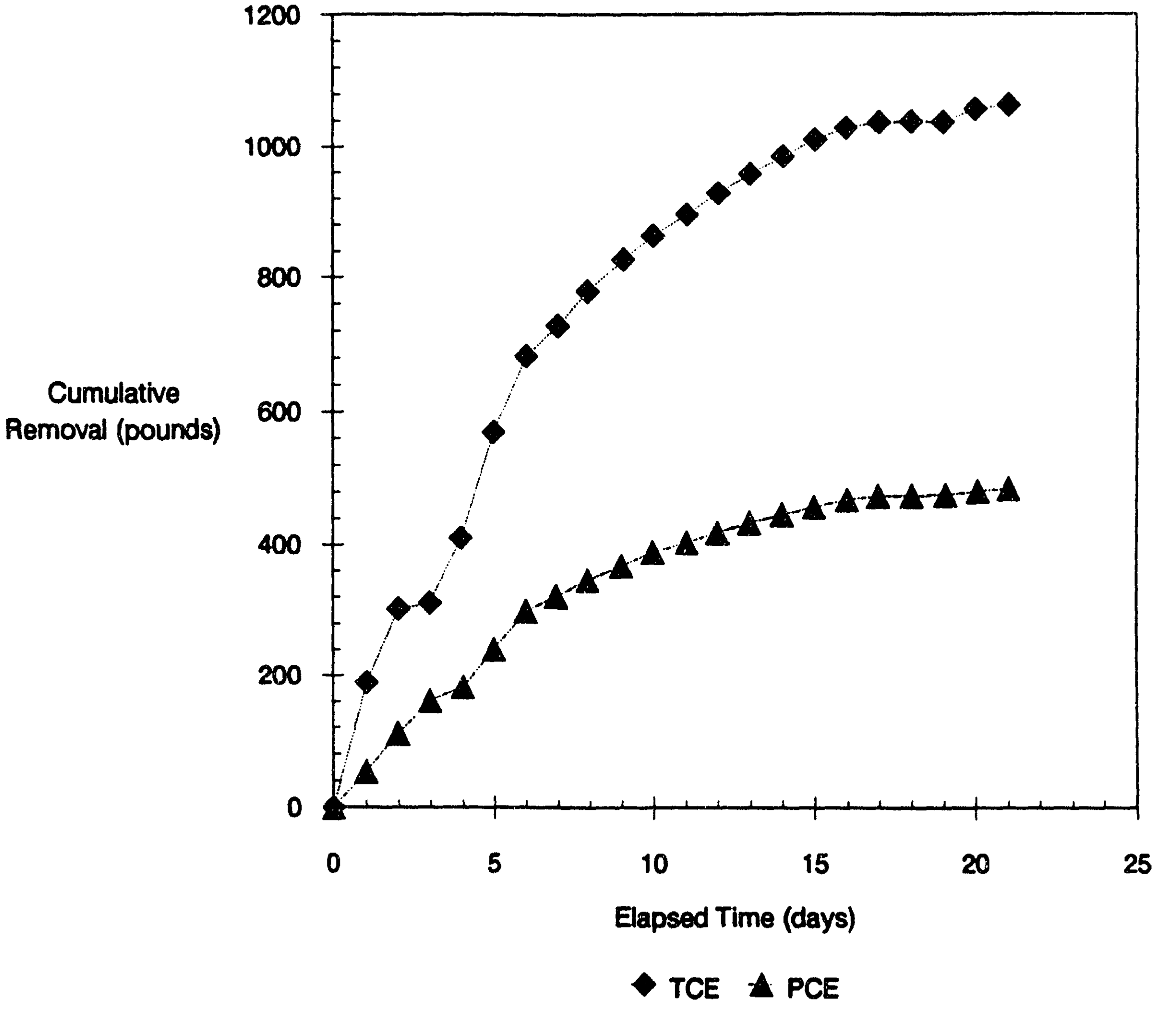


Figure 9. Total VOCs Extracted During Test

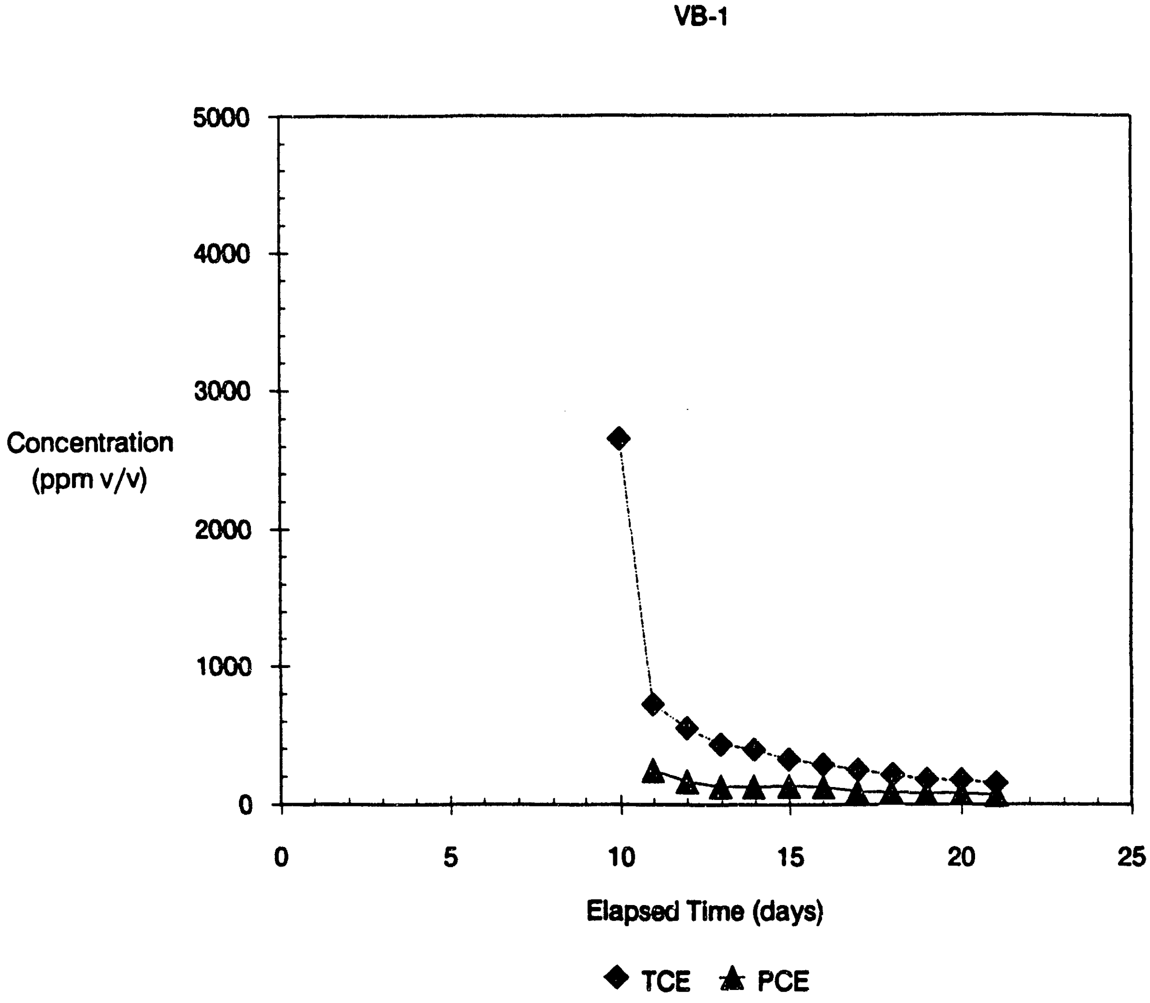


Figure 10. Vapor Concentrations of VOCs in VB-1 During Test

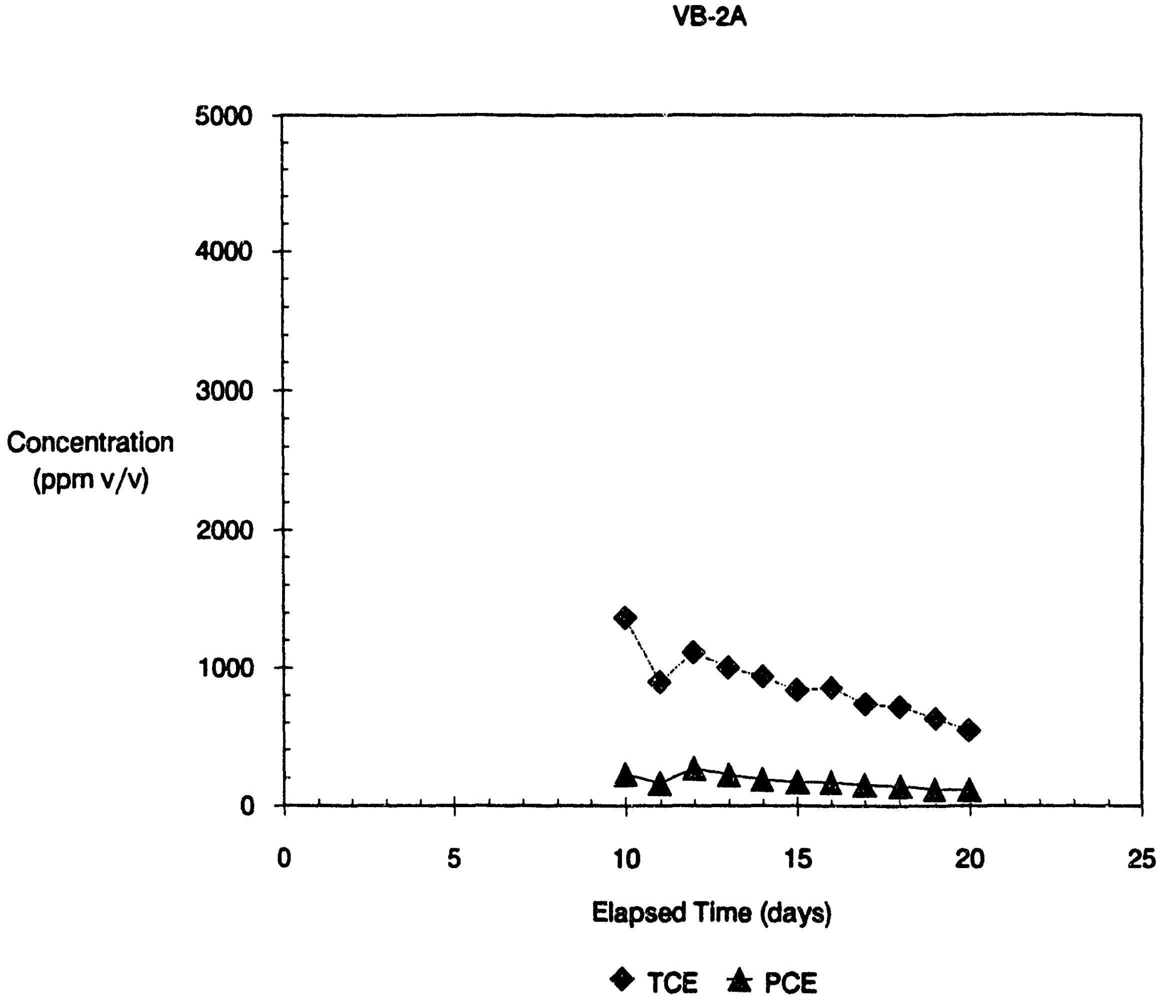


Figure 11. Vapor Concentrations of VOCs in VB-2A During Test

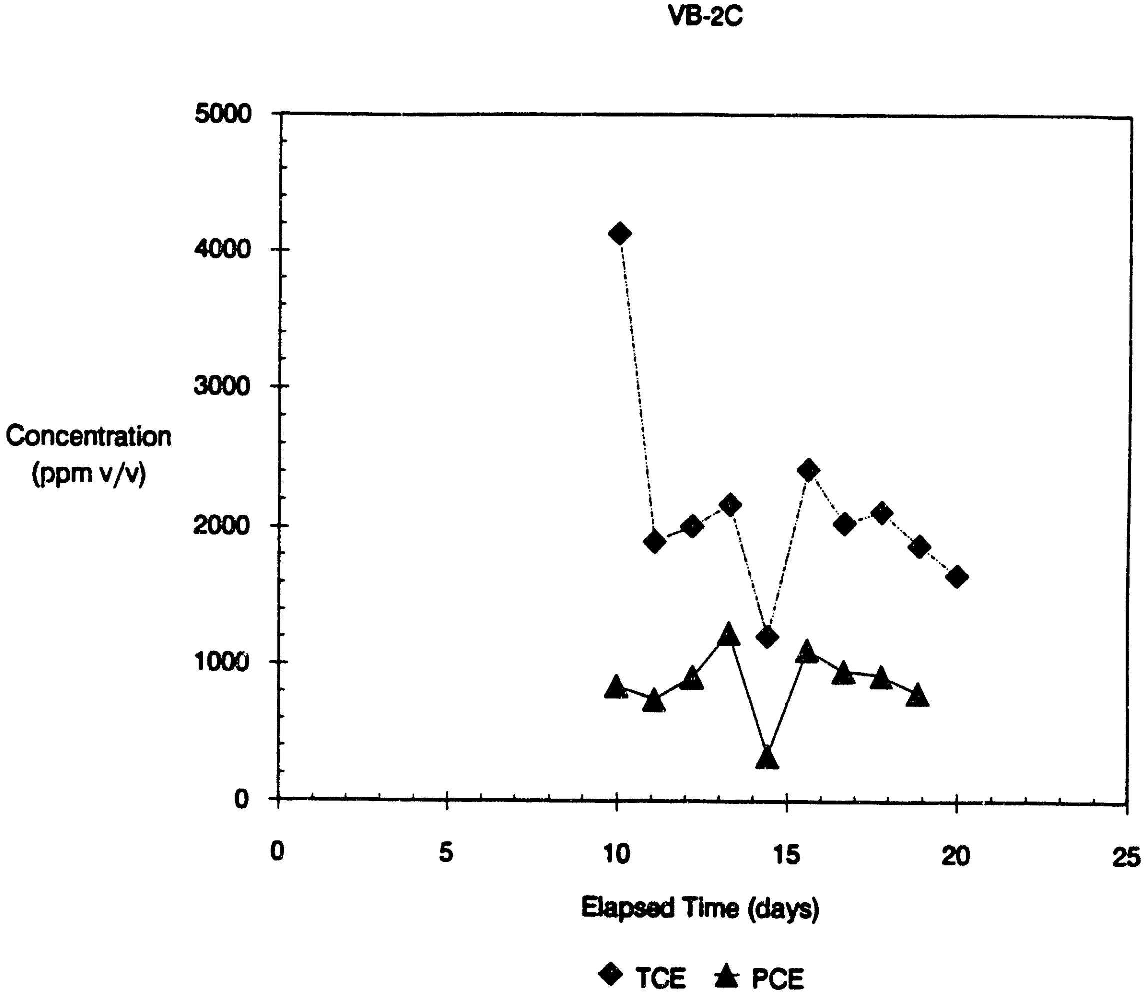


Figure 12. Vapor Concentrations of VOCs in VB-2C During Test

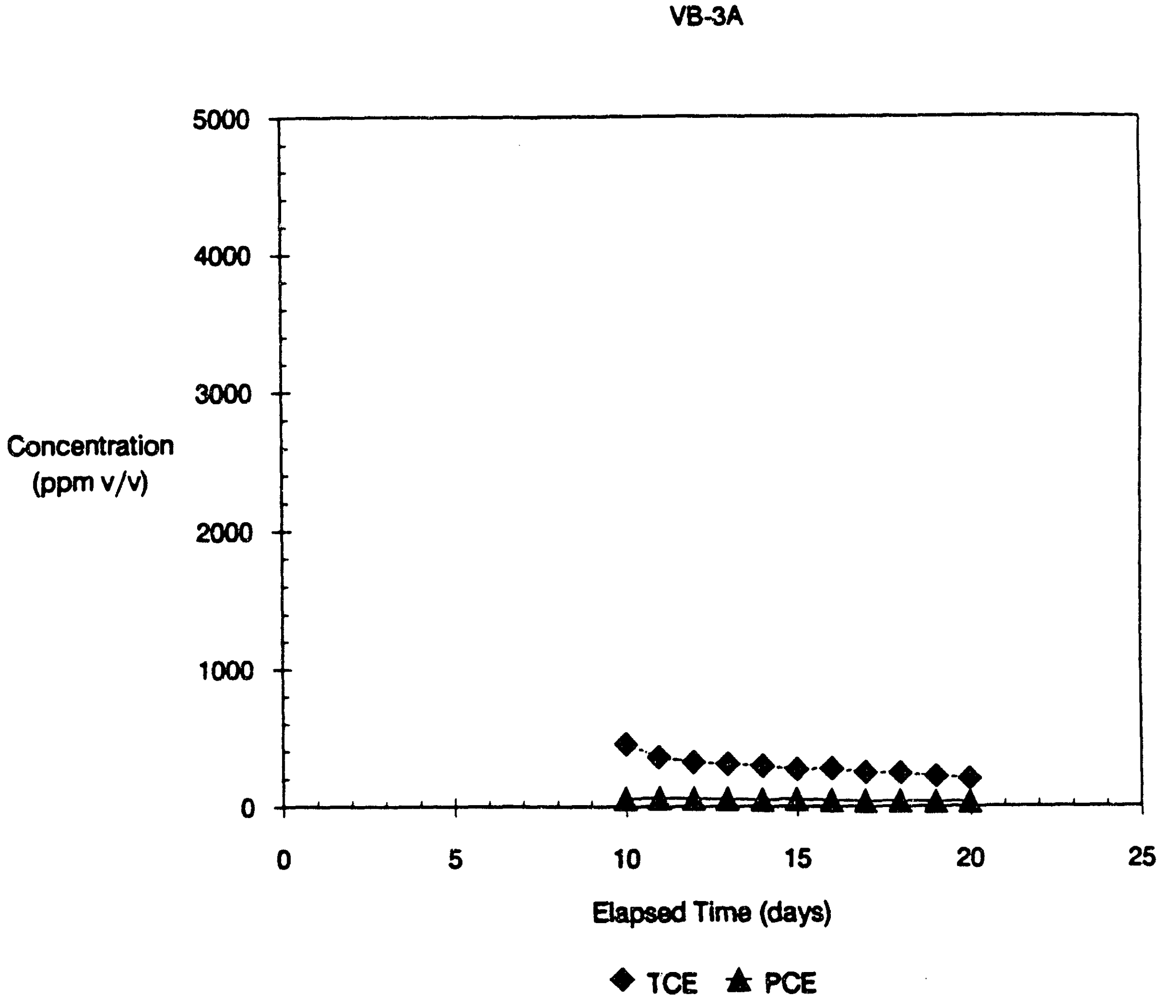


Figure 13. Vapor Concentrations of VOCs in VB-3A During Test

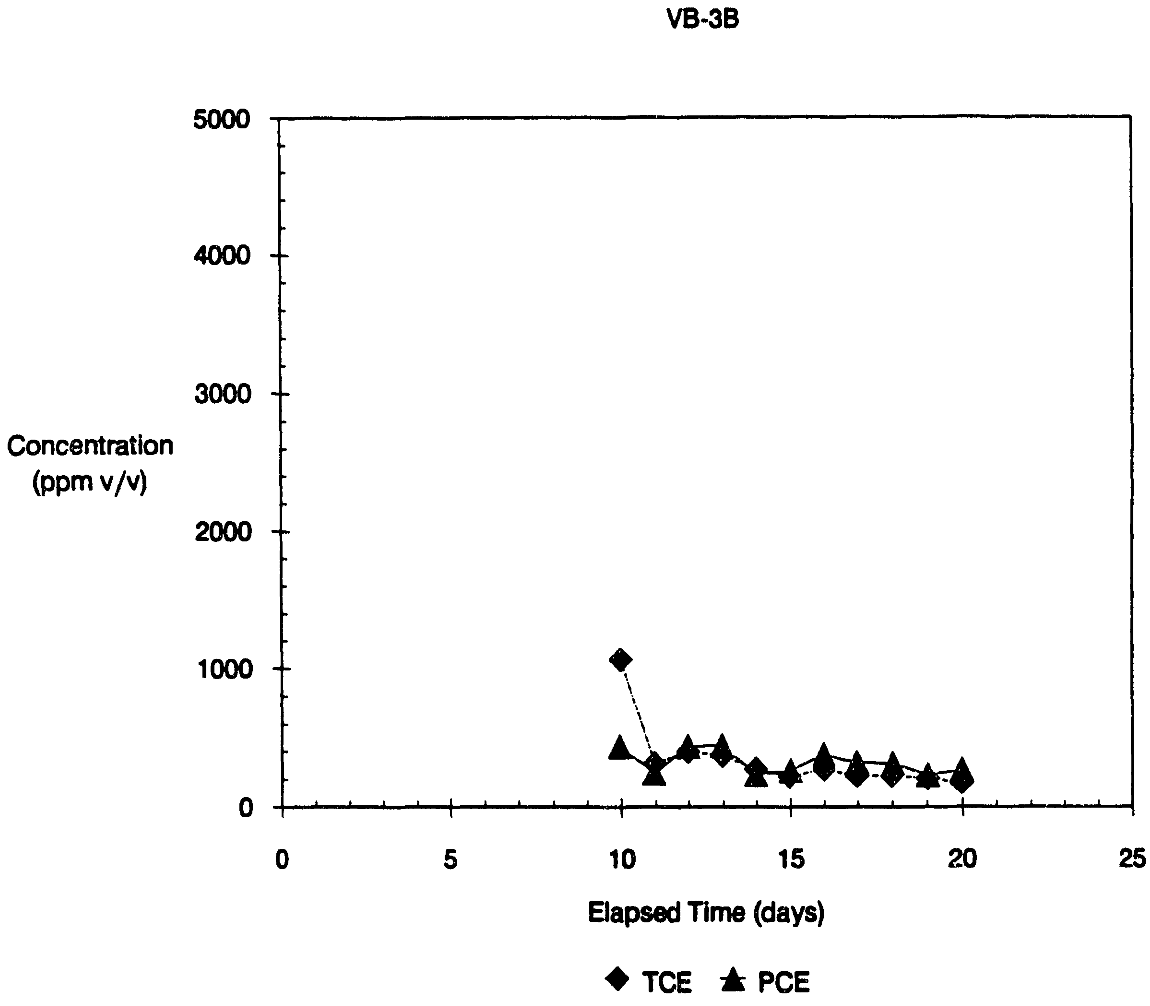
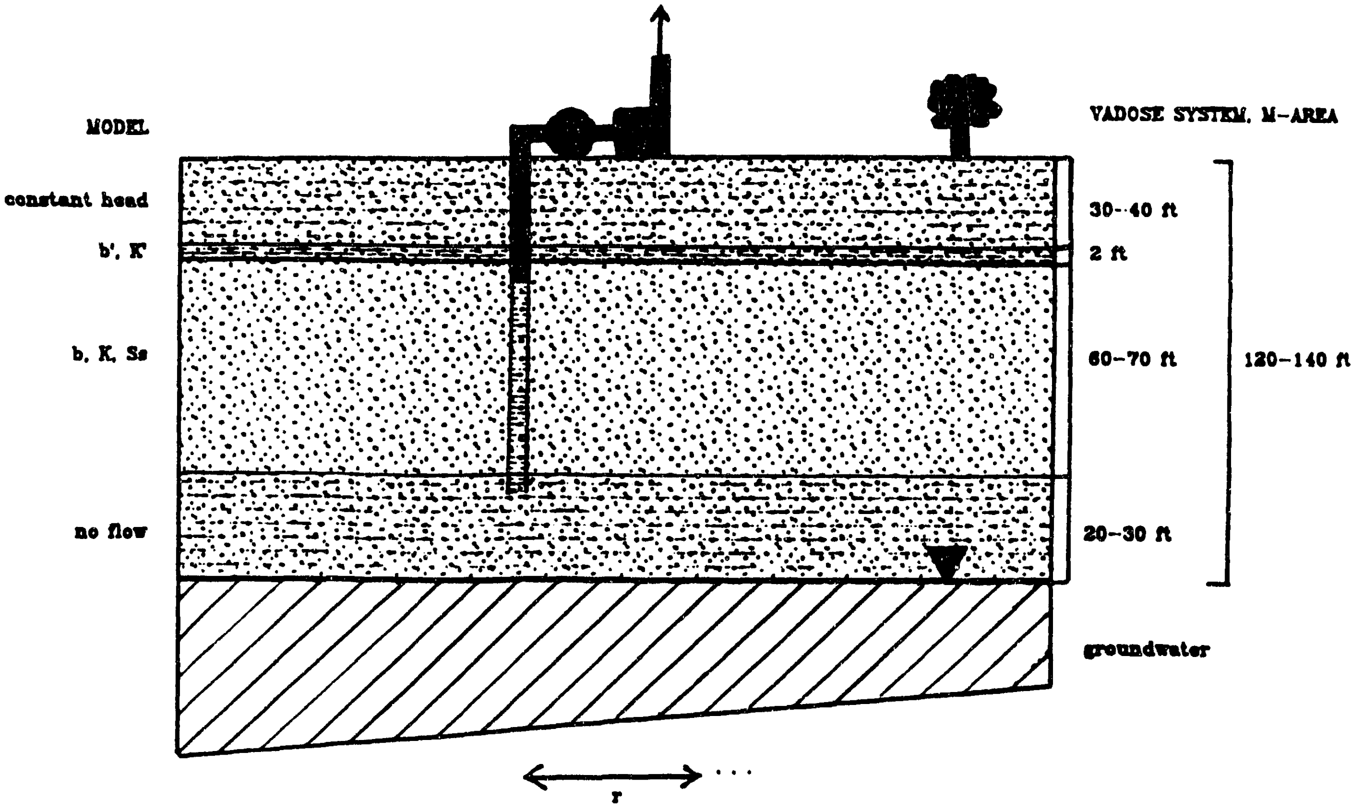


Figure 14. Vapor Concentrations of VOCs in VB-3B During Test



$s_{(r,t)}$ = drawdown at radius r and time t = $(Q/(4\pi Kb))*[W_{(u,r/\lambda)}]$

$u = (r^2 S_s b)/(4Kbt)$

λ = leakage factor = $((b'bK)/K')^{0.5}$

see Bear, 1979

Figure 15. Conceptual Approach Used to Model Test

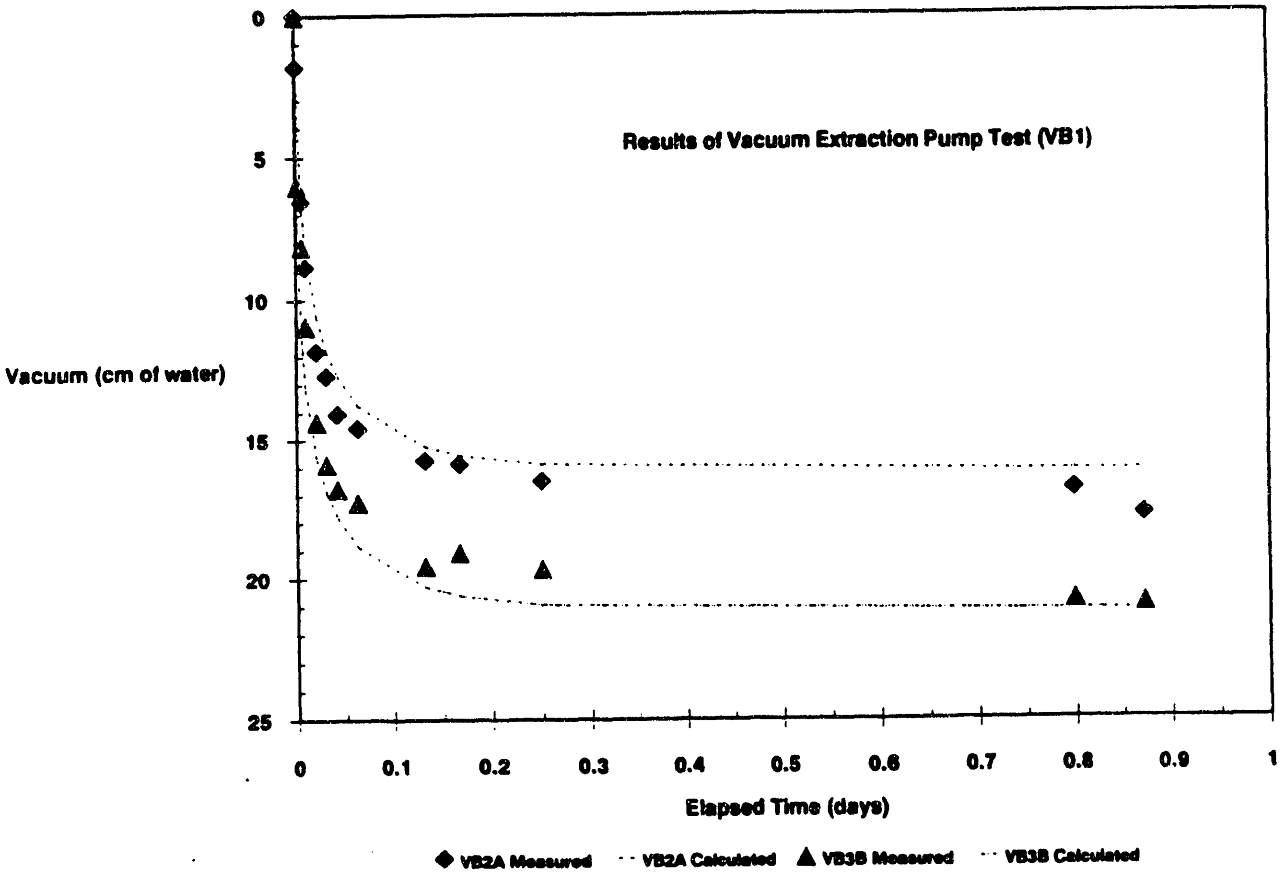


Figure 16. Drawdown Data and Model Predictions for Test

APPENDIX A

SAMPLING AND WELL INSTALLATION PROCEDURES

APPENDIX A

SAMPLING AND WELL INSTALLATION PROCEDURES

Vacuum extraction/monitoring wells were drilled with 6–1/4–in. (outside diameter) hollow stem augers. Soil samples were taken using split–spoon barrel. The augers and the split spoon were steam cleaned in order to remove debris or sediments and to minimize cross–contamination between boreholes. The augers were stored on plastic sheeting to further minimize contamination potential. The split spoon barrels were cleaned between samples with soap and water and clean water rinse.

Soil samples were taken every 5 ft during drilling. The samples were placed in clean glass jars and sealed immediately with teflon–lined lids. Before transferring samples from boreholes, each sample was identified with: Project, Well Name, Sample, Number, Date, Time, and Depth. For quality control, a log with this information was kept by Terra Vac's geologist. Chain of custody records were used to transfer samples from the field to the lab.

Soil samples were analyzed on site by gas chromatography (GC) using a headspace method. Analyses were made with a Photovac 10S50 programmable gas chromatograph. Results of the soil analysis for TCE and PCE are reported on the boring logs in Appendix B.

Based on the subsurface contaminant profile and geologic stratigraphy, well VB–1 was installed as the primary vacuum extraction well. The well was screened from the water table 124 ft deep to a depth of 24 ft. Two–in. PVC screen was installed in the borehole, gravel packed and sealed to the surface with a vacuum tight grout.

Test boring VB–2 was drilled and sampled similar to VB–1. After soil samples were anlayzed and the subsurface contaminant profile was evaluated, VB–2 was completed as a triple monitor/dual extraction well (see Well Logs, Appendix B). Three separate wells were installed in borehole VB–2. The deepest well, VB–2B was used only to monitor subsurface vacuum in the lower stratigraphic unit. This well was constructed of half–inch steel pipe that was slotted in the lower 20 ft and extended from a total depth of 137 ft to the surface. Each section was joined with threaded couplings and teflon tape for a vacuum–tight seal. The screen was gravel packed with silica sand and 2 to 3 ft of bentonite above the screen. A grout seal was placed from the top of the bentonite to a few feet below the next well (VB–2A) that was installed in the same borehole.

Well VB–2A was designed for both monitoring of subsurface vacuum and extraction of solvents from the substrata. This well was constructed similar to VB–1 with a screened zone in the middle stratigraphic unit, from 60 to 90 ft deep. The third well installed in borehole VB–2, well VB–2C, was similarly designed and installed for monitoring and/or vacuum extraction. Well VB–2C was screened from 30 to 50 ft below the ground surface.

Test boring VB–3 was also completed as a triple monitor/dual extraction well. However, well VB–3A was installed for extraction and monitoring in the lower stratigraphic unit with 2–in. PVC wirewrap screen from 123 to 103 ft deep. Next, VB–3B was similarly completed and sealed within the middle soil unit with a screened interval from 80 to 50 ft. Vacuum monitoring well VB–3C was completed with a 1/2 in. steelpipe slotted from 20 to 30 ft deep. Because of a requirement to wait at least 18 hours for the grout to set in VB–3B, it was more convenient to drill a second well one ft away from the original borehole and install VB–3C in that borehole. Refer to well logs (Appendix B) for detailed well construction diagrams.

After the wells were installed, a vapor collection manifold connected each well to the Vacuum Recovery Unit. Each well head was provided with a water manometer and a vacuum gage to monitor subsurface vacuum. A gate valve was installed at each wellhead to control vacuum extraction from individual wells and to isolate stratigraphic units in order to monitor the radius of influence of the vacuum extraction system.

APPENDIX B

WELL LOGS

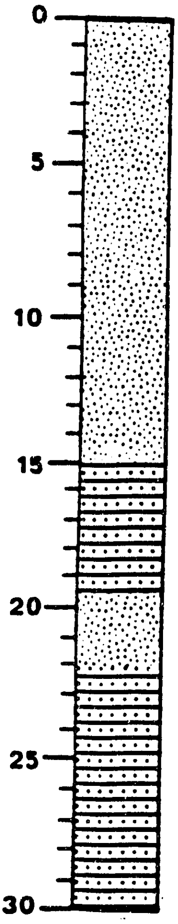
P O BOX 23725
TAMPA, FLORIDA 33623

Page 1 of

WELL LOG

COMPANY E.I. DUPONT ,SAVANNAH RIVER PLANT
WELL NO. VB - 1
Project No. 86-125
Date Completed Jan.27,87
Location "M" Area Pipeline
Geologist Rafael Barba
Sampling Method Split Spoon
Drilling Co. P. S. I.

FT.	L	GEOLOGICAL DESCRIPTION	WELL CONSTRUCTION	N	S



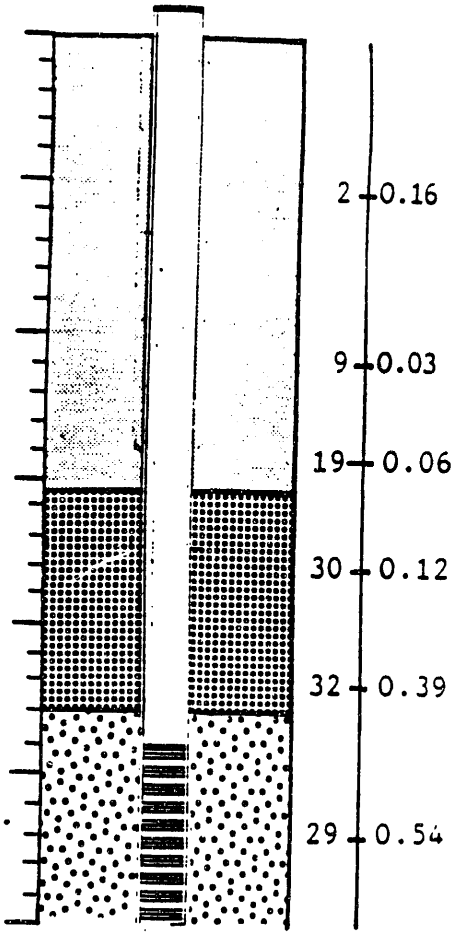
Sand, dark brown with red veins, very loose. Fine to medium grain size. Rock fragments. No odor.

Sand, red. Fine to medium size grain. Very humid and compact. No odor.

Silty sand, red with tan spots. Fine to very fine grain. Lenses of clay, tan in color.

Sand, red. Medium to coarse grains.

Silty sand, red to purple with veins of tan clay. Very fine grain to coarse grain near the clay veins. Dry but compact.



LITHOLOGY

- ▨ **Sand**
- ▤ **Silt**
- ▤ **Clay**

LEGEND

Casing Diameter 2" I.D. (PVC)
Screen Type Tri-Loc Wirewrap
Slot No. .020"
Filter Material Silica Sand
Filter Size No. 10

WELL DESIGN

- ☐ **Grout**
- ▦ **Bentonite**
- ▨ **Gravel Pack**

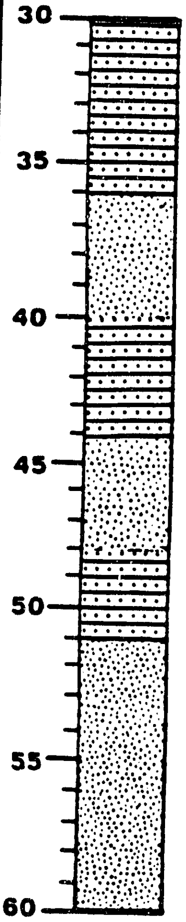
N;Standard Penetration (Blows/Ft.)
S;Soil Concentration (p.p.m.)
∇;Static Water Level
L;Lithology

TERRA VAC
P.O. BOX 23725
TAMPA, FLORIDA 33623

WELL LOG

COMPANY E.I. DUPONT ,SAVANNAH RIVER PLANT
WELL NO. VB - 1
Project No. 86-125
Date Completed Jan.27,87
Location "M" Area Pipeline
Geologist Rafael Barba
Sampling Method Split Spoon
Drilling Co. P. S. I.

FT.	L	GEOLOGICAL DESCRIPTION	WELL CONSTRUCTION	N	S



Siltv sand, red to purple, medium to fine grains with veins of tan clay. Humid. No odor.

Sand, tan to brown. Large grains ranging up to pebble size, very loose and unconsolidated.

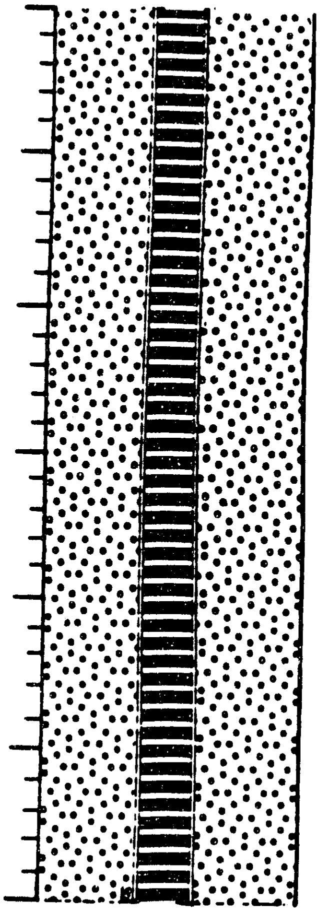
Siltv sand, red to violet. Very fine grain to medium size grain. Humid and plastic.

Sand, tan to light brown. Very coarse grains up to pebble size, unconsolidated.

Siltv sand, red to violet. Medium to fine grains.

Sand, tan to yellow and light brown. Very coarse grains of quartz angular in shape. Unconsolidated.

Sand, layers of colors ranging from tan, yellow, brown to pink-purple. Medium to fine grains.



N	S
15	0.22
13	5.00
5	6.12
13	4.53
19	2.02
28	6.58

LEGEND

LITHOLOGY
░ Sand
▤ Silt
▥ Clay

Casing Diameter 2" I.D. (PVC)
Screen Type Tri-Loc Wirewrap
Slot No. .020"
Filter Material Silica Sand
Filter Size No. 10

WELL DESIGN
☐ Grout
▦ Bentonite
░ Gravel Pack

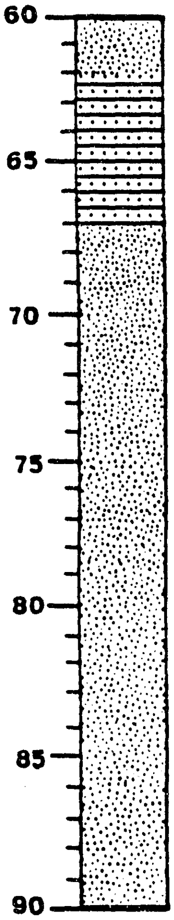
N;Standard Penetration (Blows/Ft.)
S;Soil Concentration (p.p.m.)
∇;Static Water Level
L;Lithology

P.O. BOX 23725
TAMPA, FLORIDA 33623

WELL LOG

COMPANY E.I. DUPONT ,SAVANNAH RIVER PLANT **WELL NO.** VB - 1
Project No. 86-125 **Date Completed** Jan.27,87
Location "M" Area Pipeline **Geologist** Rafael Barba
Sampling Method Split Spoon **Drilling Co.** P. S. I.

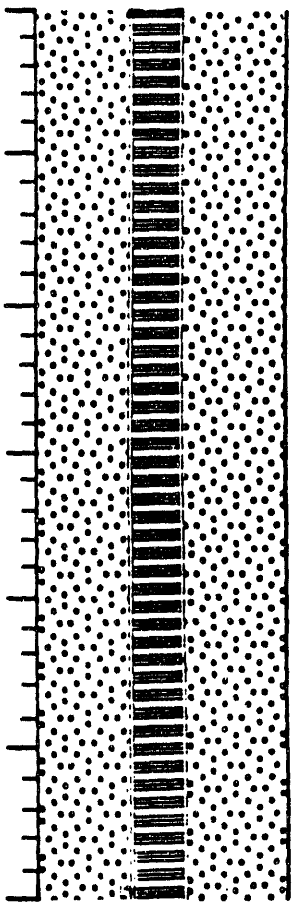
FT. | **L** | **GEOLOGICAL DESCRIPTION** | **WELL CONSTRUCTION** | **N** | **S**



Sand, same as above.

Silt, grading to sand. Gray to violet with lenses of yellow (limonite ?). Very fine grain to fine grain. Very humid.

Sand, tan, yellow, pink and dark brown. Medium to large size grains, angular to rounded, well sorted with high porosity. Unconsolidated. Humid. No odor.



N	S
15	14.33
13	13.20
19	0.62
17	0.21
17	6.47
18	0.89

LEGEND

LITHOLOGY
- Sand
- Silt
- Clay.

Casing Diameter 2" I.D. (PVC)
Screen Type Tri-Loc Wirewrap
Slot No. .020"
Filter Material Silica Sand
Filter Size No. 10

WELL DESIGN
- Grout
- Bentonite
- Gravel Pack

N; Standard Penetration (Blows/Ft.) **S;** Soil Concentration (p.p.m.) **∇;** Static Water Level **L;** Lithology

P.O. BOX 23725
TAMPA, FLORIDA 33623

WELL LOG

COMPANY E.I. DUPONT ,SAVANNAH RIVER PLANT

WELL NO. VB - 1

Project No. 86-125

Date Completed Jan.27,87

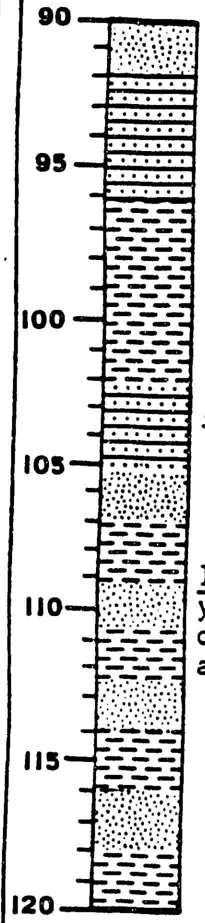
Location "M" Area Pipeline

Geologist Rafael Barba

Sampling Method Split Spoon

Drilling Co. P. S. I.

FT. | **L** | **GEOLOGICAL DESCRIPTION** | **WELL CONSTRUCTION** | **N** | **S**



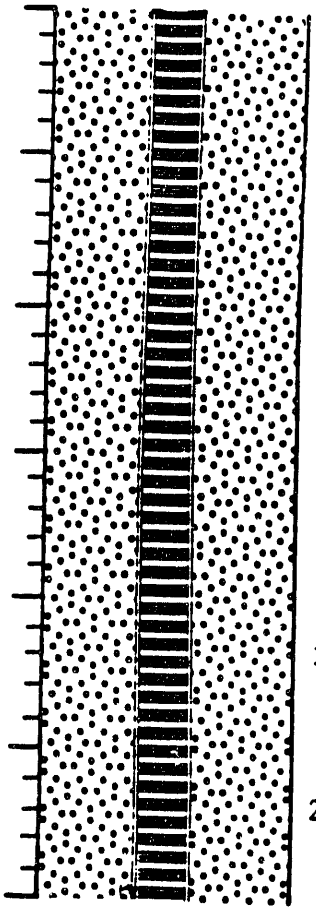
Sand, same as above.

Silty sand, red. Fine to very fine grains.

Clay, yellow-orange to light brown, with lenses of tan grading to pink. Plastic and humid. No odor.

Silty sand, dark yellow to orange. Medium to fine grain, well sorted.

Interbedded lenses of clay and sand, tan to yellow-orange with darker striations on the clays. Sand has medium to fine grain, angular to subangular. Well sorted.



N	S
38	1.27
21	9.10
21	6.06
30	4.43
17	0.65
21	2.19

LITHOLOGY

- ⛆ Sand
- ☰ Silt
- ▤ Clay

LEGEND

Casing Diameter 2" I.D. (PVC)
Screen Type Tri-Loc Wirewrap
Slot No. .020"
Filter Material Silica Sand
Filter Size No. 10

WELL DESIGN

- ☐ Grout
- ▦ Bentonite
- ⛆ Gravel Pack

N;Standard Penetration (Blows/Ft.)   **S;Soil Concentration (p.p.m.)**   **▼;Static Water Level**   **L;Lithology**

TERRA VAC P.O. BOX 23725
TAMPA, FLORIDA 33623

WELL LOG

COMPANY E.I. DUPONT ,SAVANNAH RIVER PLANT

WELL NO. VB - 1

Project No. 86-125

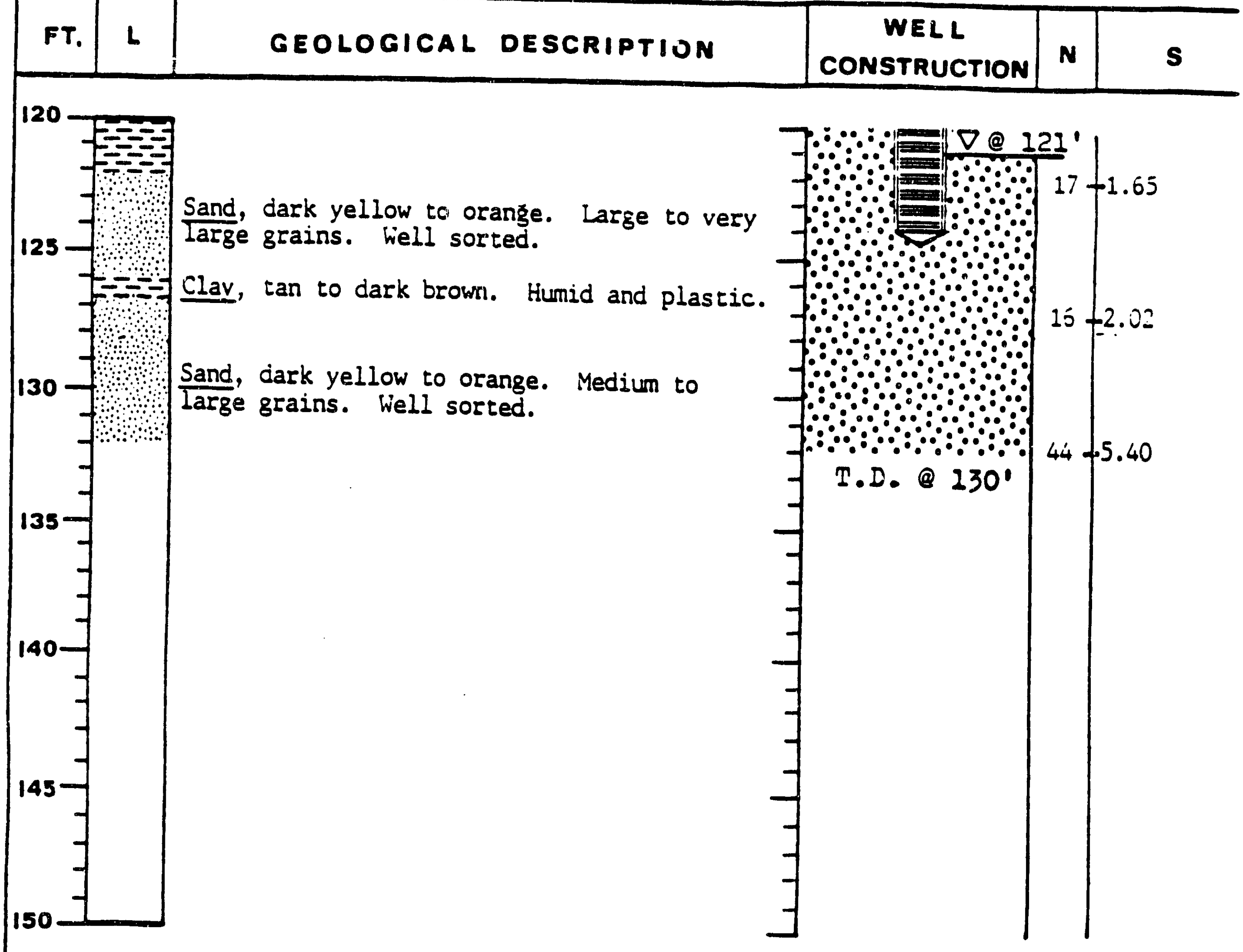
Date Completed Jan.27,87

Location "M" Area Pipeline

Geologist Rafael Barba

Sampling Method Split Spoon

Drilling Co. P. S. I.



Sand, dark yellow to orange. Large to very large grains. Well sorted.

Clay, tan to dark brown. Humid and plastic.

Sand, dark yellow to orange. Medium to large grains. Well sorted.

LEGEND

LITHOLOGY

- ░ Sand
- ▤ Silt
- ▤ Clay

Casing Diameter 2" I.D. (PVC)

Screen Type Tri-Loc Wirewrap

Slot No. .020"

Filter Material Silica Sand

Filter Size No. 10

WELL DESIGN

- ☐ Grout
- ▦ Bentonite
- ░ Gravel Pack

N; Standard Penetration (Blows/Ft.)

S; Soil Concentration (p.p.m.)

▽; Static Water Level

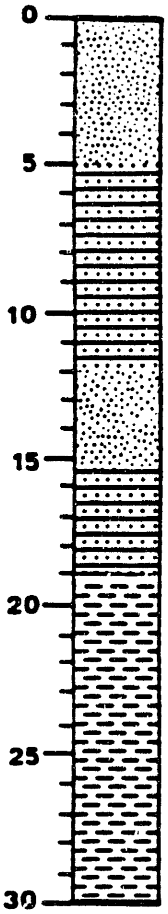
L; Lithology

TERRA VAC
PO BOX 23725
TAMPA, FLORIDA 33623

WELL LOG

COMPANY	E.I. DUPONT ,SAVANNAH RIVER PLANT	**WELL NO.**	VB - 2
Project No.	86-125	**Date Completed**	Jan.29,87
Location	"M" Area Pipeline	**Geologist**	Rafael Barba
Sampling Method	Split Spoon	**Drilling Co.**	P. S. I.

FT. | **L** | **GEOLOGICAL DESCRIPTION** | **WELL CONSTRUCTION** | **N** | **S**



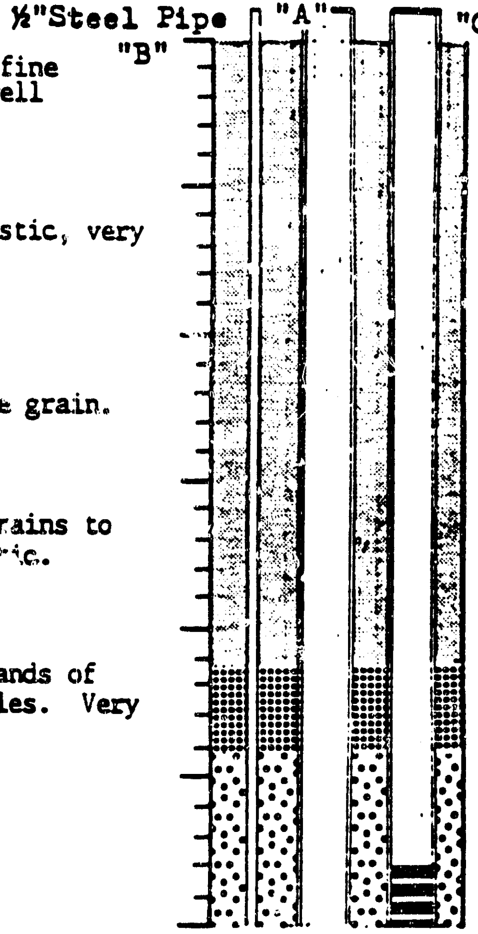
Sand, brown to red. Medium to fine grain, angular to subangular, well sorted.

Silt grading to clay, red. Plastic, very humid. No odor

Sand, dark brown, medium to fine grain. Well sorted.

Silty sand, red. Medium size grains to some large quartz grains. Plastic.

Clay, red to light brown with bands of oxidation and (limonite ?) nodules. Very compact and hard.



N	S
3	0.10
14	0.03
21	0.09
17	0.36
44	1.53
28	1.55

LEGEND

LITHOLOGY

- ▨ Sand
- ▤ Silt
- ▤ Clay

Casing Diameter	2" I.D. (PVC)
Screen Type	Tri-Loc Wirewrap
Slot No.	.020"
Filter Material	Silica Sand
Filter Size	No. 10

WELL DESIGN

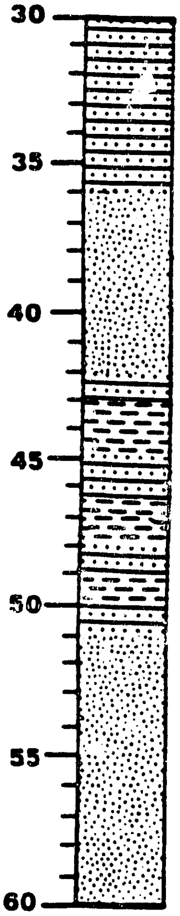
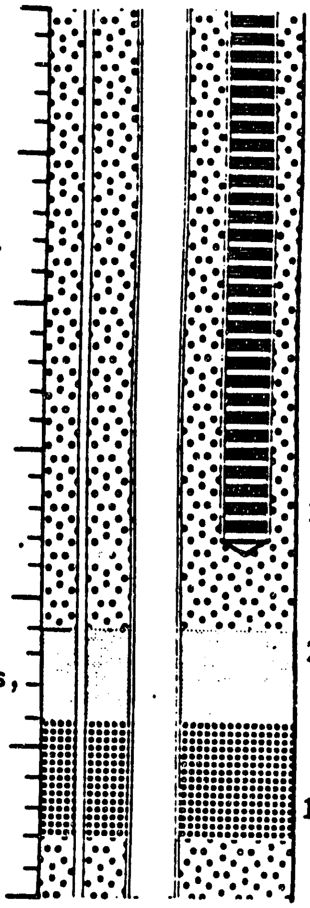
- ☐ Grout
- ▩ Bentonite
- ▨ Gravel Pack

N; Standard Penetration (Blows/Ft.)
S; Soil Concentration (p.p.m.)
∇; Static Water Level
L; Lithology

TAMPA VAC. P.O. BOX 23725 TAMPA, FLORIDA 33623

WELL LOG

COMPANY E.I. DUPONT ,SAVANNAH RIVER PLANT	**WELL NO.** VB - 2
Project No. 86-125	**Date Completed** Jan.29,87
Location "M" Area Pipeline	**Geologist** Rafael Barba
Sampling Method Split Spoon	**Drilling Co.** P. S. I.

FT.	L	GEOLOGICAL DESCRIPTION	WELL CONSTRUCTION	N	S
30		Silty clay, same as above, with small quartz grains interbedded in the clays.		17	12.55
35		Sand, tan to brown with red layers. Medium to large size grains. Well sorted, angular to subrounded. Some quartz pebbles larger than 1" in diameter.		18	23.36
40				15	30.66
45		Clay and silt, interbedded. White, tan, red to dark brown. Very fine grain.		13	203.12
50		Sand, tan, brown to red. Very coarse grains, angular, well sorted, very porous.		22	34.89
55				18	5.74
60					

L E G E N D

LITHOLOGY

- ░ *Sand*
- ▤ *Silt*
- ▥ *Clay*

Casing Diameter 2" I.D. (PVC)
Screen Type Tri-Loc Wirewrap
Slot No. .020"
Filter Material Silica Sand
Filter Size No. 10

WELL DESIGN

- ☐ *Grout*
- ▦ *Bentonite*
- ░ *Gravel Pack*

N;Standard Penetration (Blows/Ft.) *S;Soil Concentration (p.p.m.)* *▽;Static Water Level* *L;Lithology*

PO BOX 23725
TAMPA, FLORIDA 33623

WELL LOG

COMPANY E.I. DUPONT ,SAVANNAH RIVER PLANT

WELL NO. VB - 2

Project No. 86-125

Date Completed Jan.29,87

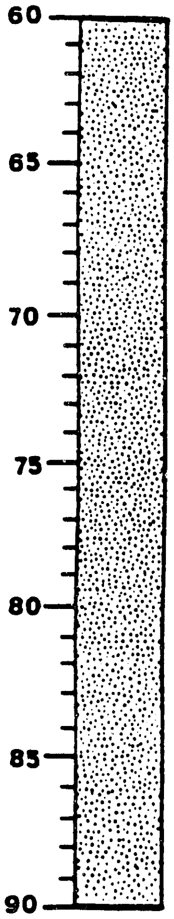
Location "M" Area Pipeline

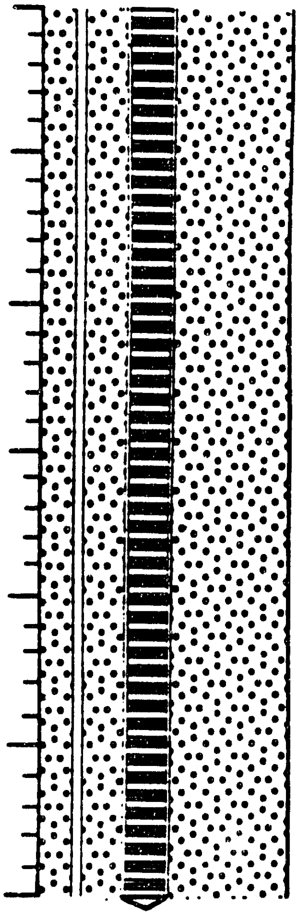
Geologist Rafael Barba

Sampling Method Split Spoon

Drilling Co. P. S. I.

FT.	L	GEOLOGICAL DESCRIPTION	WELL CONSTRUCTION	N	S
60		Sand, tan to dark brown. Very coarse grains (some pebble size), angular, moderated well sorted. Good porosity.		17	21.20
65				18	30.64
70		Sand, medium size grains.		13	26.34
75		Sand, brown, orange, red to violet.		23	1.80
80				27	1.11
85				25	7.71
90					





LEGEND

LITHOLOGY

- Sand
- Silt
- Clay

Casing Diameter 2" I.D. (PVC)
Screen Type Tri-Loc Wirewrap
Slot No. .020"
Filter Material Silica Sand
Filter Size No. 10

WELL DESIGN

- Grout
- Bentonite
- Gravel Pack

N;Standard Penetration (Blows/Ft.)　S;Soil Concentration (p.p.m.)　▽;Static Water Level　L;Lithology

P.O. BOX 23725
TAMPA, FLORIDA 33623

WELL LOG

COMPANY E.I. DUPONT ,SAVANNAH RIVER PLANT

WELL NO. VB - 2

Project No. 86-125

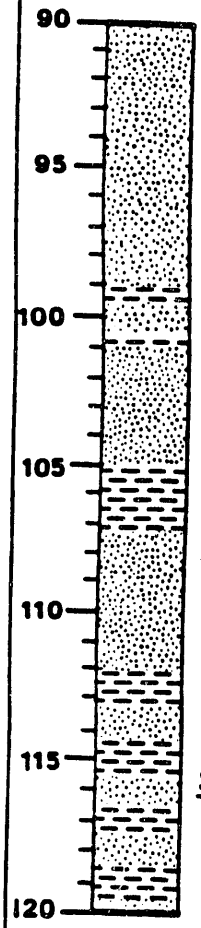
Date Completed Jan.29,87

Location "M" Area Pipeline

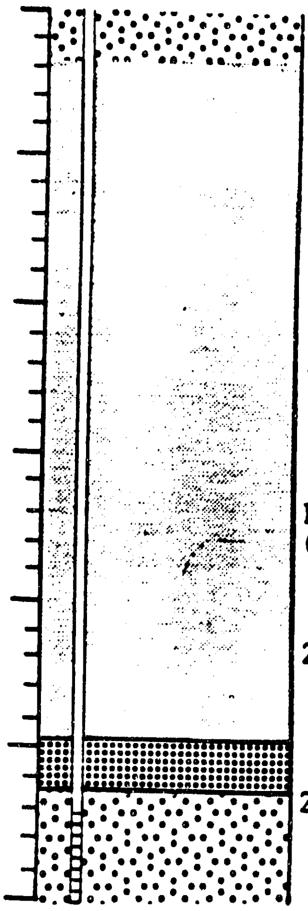
Geologist Rafael Barba

Sampling Method Split Spoon

Drilling Co. P. S. I.



GEOLOGICAL DESCRIPTION	N	S
Sand, same as above.	23	0.55
Sand and clay. Sand same as above. Clay in lenses, orange to red, very humid.	21	6.12
	25	4.03
Sand, brown, orange to red. Medium to coarse grains, angular, well sorted with good porosity.	LC (Lost Count)	2.61
	25	3.17
Sand and clay, same as above.	25	2.82



LEGEND

LITHOLOGY

Sand

Silt

Clay

Casing Diameter 2" I.D. (PVC)

Screen Type Tri-Loc Wirewrap

Slot No. .020"

Filter Material Silica Sand

Filter Size No. 10

WELL DESIGN

Grout

Bentonite

Gravel Pack

N; Standard Penetration (Blows/Ft.)

S; Soil Concentration (p.p.m.)

⊻; Static Water Level

L; Lithology

TERRA VAC

P.O. BOX 23725
TAMPA, FLORIDA 33623

WELL LOG

COMPANY E.I. DUPONT ,SAVANNAH RIVER PLANT

WELL NO. VB - 2

Project No. 86-125

Date Completed Jan.29,87

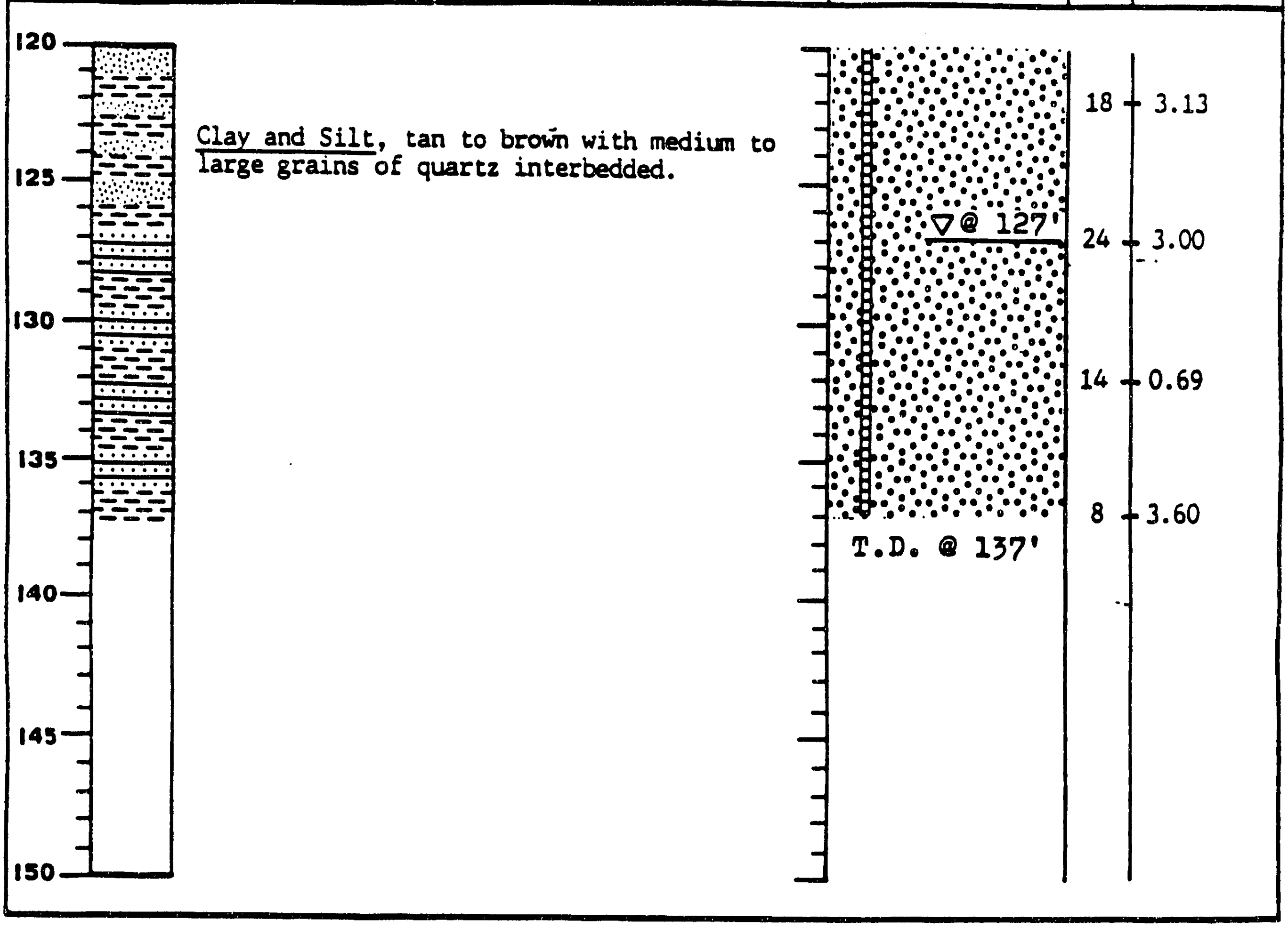
Location "M" Area Pipeline

Geologist Rafael Barba

Sampling Method Split Spoon

Drilling Co. P. S. I.

FT.	L	GEOLOGICAL DESCRIPTION	WELL CONSTRUCTION	N	S



Clay and Silt, tan to brown with medium to large grains of quartz interbedded.

N	S
18	3.13
24	3.00
14	0.69
8	3.60

LEGEND

LITHOLOGY

- ▨ Sand
- ▤ Silt
- ▤ Clay

Casing Diameter 2" I.D. (PVC)

Screen Type Tri-Loc Wirewrap

Slot No. .020"

Filter Material Silica Sand

Filter Size No. 10

WELL DESIGN

- ☐ Grout
- ▦ Bentonite
- ▨ Gravel Pack

N: Standard Penetration (Blows/Ft.)

S: Soil Concentration (p.p.m.)

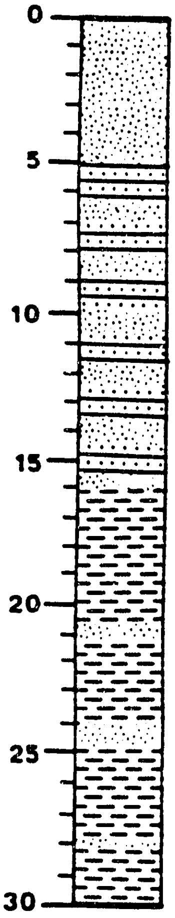
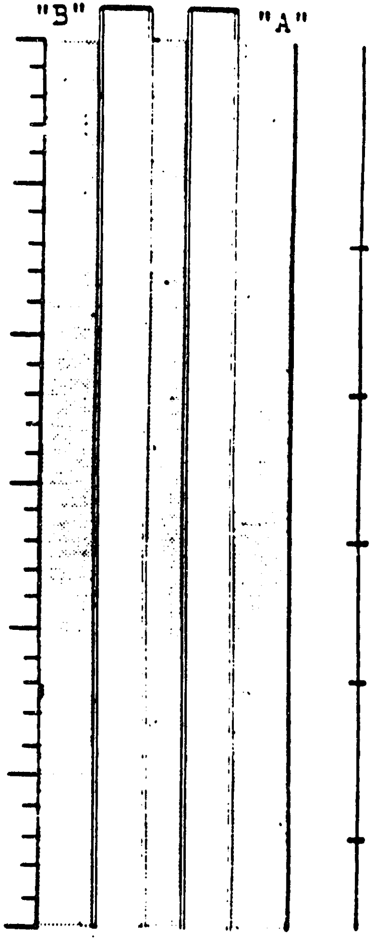
▽: Static Water Level

L: Lithology

TERRA VAC
PO BOX 23725
TAMPA FLORIDA 33623

WELL LOG

COMPANY E.I. DUPONT ,SAVANNAH RIVER PLANT
WELL NO. VB - 3
Project No. 86-125
Date Completed Feb.1,87
Location "M" Area Pipeline
Geologist Rafael Barba
Sampling Method Split Spoon
Drilling Co. P. S. I.

FT.	L	GEOLOGICAL DESCRIPTION	WELL CONSTRUCTION	N	S
		Same as Page 1 of VB-3"C"			

LITHOLOGY

░ Sand
▤ Silt
▭ Clay

LEGEND

Casing Diameter 2" I.D. (PVC)
Screen Type Tri-Loc Wirewrap
Slot No. .020"
Filter Material Silica Sand
Filter Size No. 10

WELL DESIGN

▭ Grout
▦ Bentonite
░ Gravel Pack

N;Standard Penetration (Blows/Ft.)
S;Soil Concentration (p.p.m.)
∇;Static Water Level
L;Lithology

TAMPA VAC
PO BOX 23725
TAMPA FLORIDA 33623

WELL LOG

COMPANY E.I. DUPONT ,SAVANNAH RIVER PLANT

WELL NO. VB - 3

Project No. 86-125

Date Completed Feb.1,87

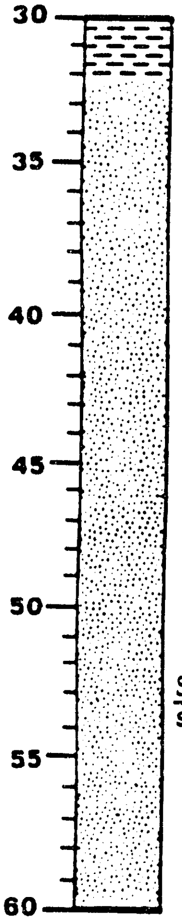
Location "M" Area Pipeline

Geologist Rafael Barba

Sampling Method Split Spoon

Drilling Co. P. S. I.

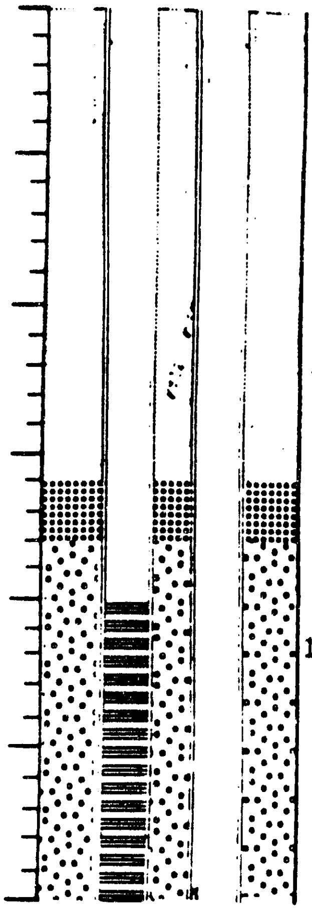
FT.	L	GEOLOGICAL DESCRIPTION	WELL CONSTRUCTION	N	S



Clay, same as above.

Sand, tan, brown to orange. Very large grains, angular, moderate to well sorted. Compact due to clay acting as cement between grains of sand.

Sand, very large grains, almost to pebble size.



N	S
18	4.48
12	3.32
14	4.95
9	3.06
13	4.41
16	4.25

L E G E N D

LITHOLOGY

- ░ Sand
- ▤ Silt
- ▥ Clay

Casing Diameter 2" I.D. (PVC)

Screen Type Tri-Loc Wirewrap

Slot No. .020"

Filter Material Silica Sand

Filter Size No. 10

WELL DESIGN

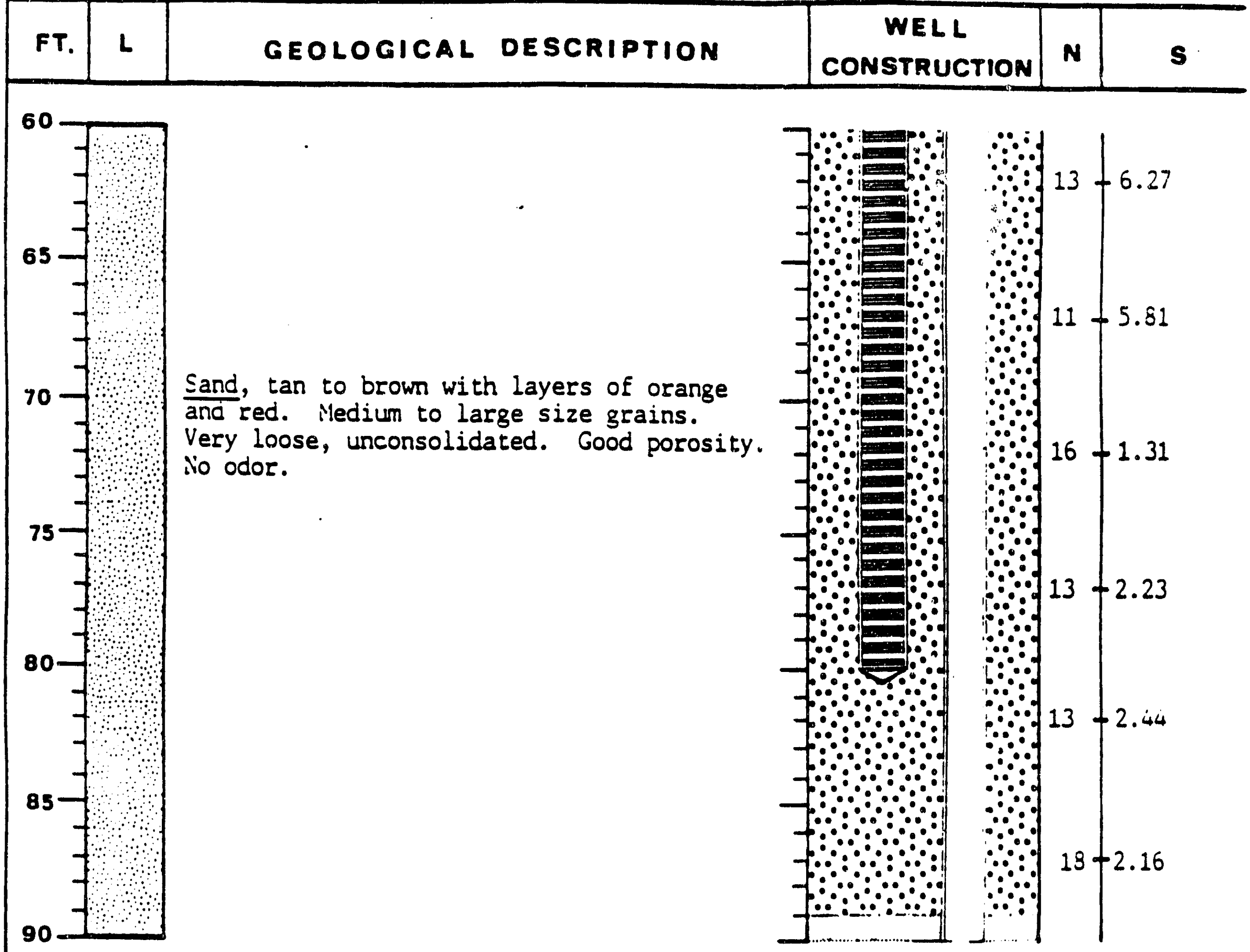
- ☐ Grout
- ▦ Bentonite
- ░ Gravel Pack

N;Standard Penetration (Blows/Ft.)
S;Soil Concentration (p.p.m.)
∇;Static Water Level
L;Lithology

VAC PO BOX 23725
TAMPA FLORIDA 33623

WELL LOG

COMPANY E.I. DUPONT ,SAVANNAH RIVER PLANT
WELL NO. VB - 3
Project No. 86-125
Date Completed Feb.1,87
Location "M" Area Pipeline
Geologist Rafael Barba
Sampling Method Split Spoon
Drilling Co. P. S. I.



Sand, tan to brown with layers of orange and red. Medium to large size grains. Very loose, unconsolidated. Good porosity. No odor.

N	S
13	6.27
11	5.81
16	1.31
13	2.23
13	2.44
18	2.16

LEGEND

LITHOLOGY

░ Sand
☰ Silt
▤ Clay

Casing Diameter 2" I.D. (PVC)
Screen Type Tri-Loc Wirewrap
Slot No. .020"
Filter Material Silica Sand
Filter Size No. 10

WELL DESIGN

☐ Grout
▦ Bentonite
░ Gravel Pack

N; Standard Penetration (Blows/Ft.)
S; Soil Concentration (p.p.m.)
∇; Static Water Level
L; Lithology

PO BOX 23725
TAMPA FLORIDA 33623

WELL LOG

COMPANY E.I. DUPONT ,SAVANNAH RIVER PLANT

WELL NO. VB - 3

Project No. 86-125

Date Completed Feb.1,87

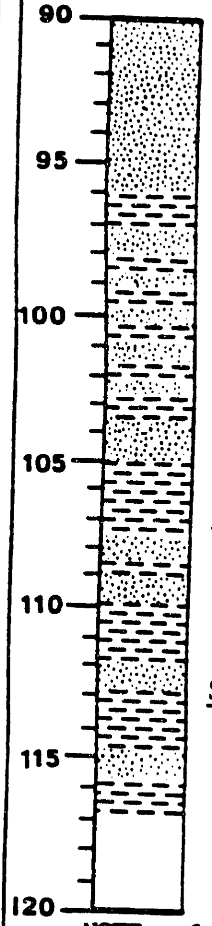
Location "M" Area Pipeline

Geologist Rafael Barba

Sampling Method Split Spoon

Drilling Co. P. S. I.

FT.	L	GEOLOGICAL DESCRIPTION	WELL CONSTRUCTION	N	S

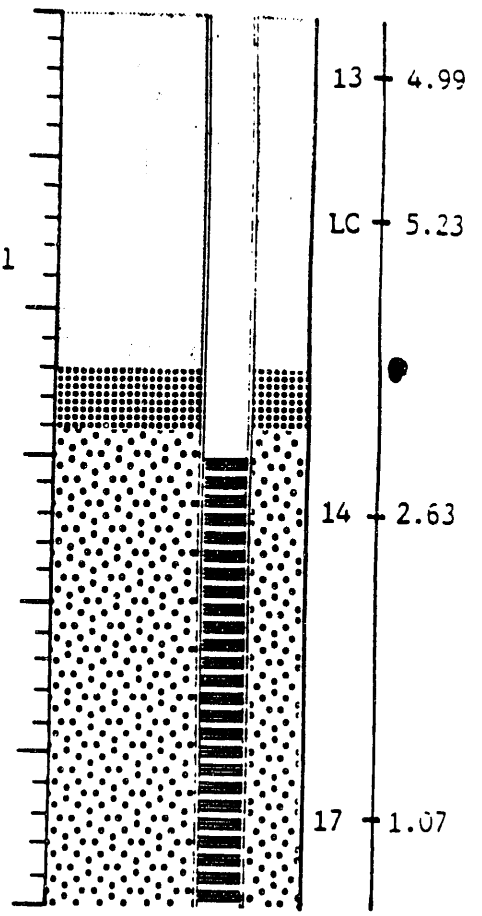


Sand, dark brown. Medium to large size grains. Compact with more clay material between quartz grains.

Sand and clay, dark brown. Medium to small size grains with clay acting as cement reducing the porosity. Compact.

Clay, tan with layers of brown to orange. Very plastic and hard. Slight odor.

Sand and clay, same as above.



NOTE: After 97', sampler were taken every 10' by suggestion of John Pickett.

LITHOLOGY

▨ Sand
▤ Silt
▤ Clay

LEGEND

Casing Diameter 2" I.D. (PVC)
Screen Type Tri-Loc Wirewrap
Slot No. .020"
Filter Material Silica Sand
Filter Size No. 10

WELL DESIGN

☐ Grout
▦ Bentonite
▨ Gravel Pack

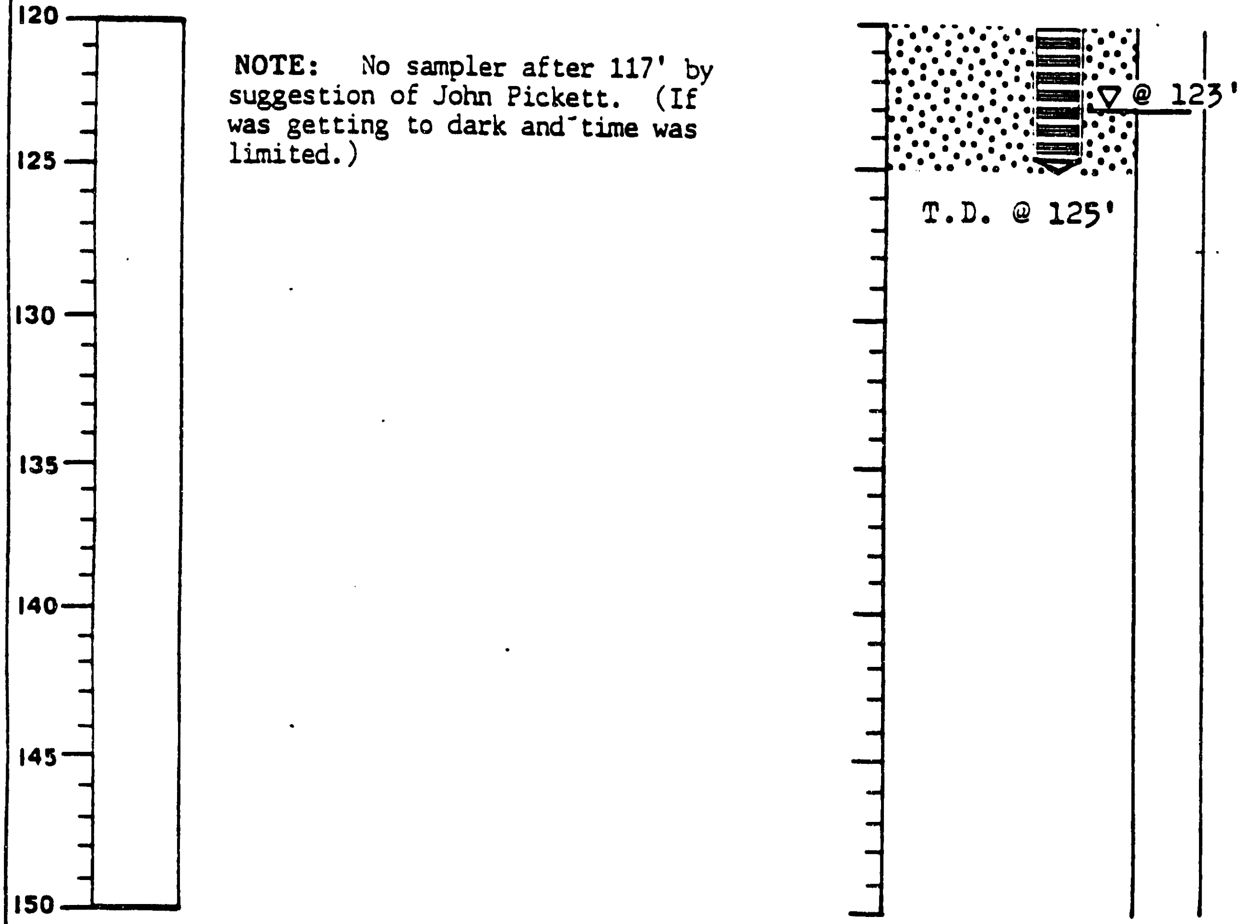
N;Standard Penetration (Blows/Ft.)
S;Soil Concentration (p.p.m.)
∇;Static Water Level
L;Lithology

P.O. BOX 23725
TAMPA, FLORIDA 33623

WELL LOG

COMPANY E.I. DUPONT ,SAVANNAH RIVER PLANT
WELL NO. VB - 3
Project No. 86-125
Date Completed Feb.1,87
Location "M" Area Pipeline
Geologist Rafael Barba
Sampling Method Split Spoon
Drilling Co. P. S. I.

FT.	L	GEOLOGICAL DESCRIPTION	WELL CONSTRUCTION	N	S



NOTE: No sampler after 117' by suggestion of John Pickett. (If was getting to dark and time was limited.)

LEGEND

LITHOLOGY

- ░ Sand
- ▤ Silt
- ▥ Clay

Casing Diameter 2" I.D. (PVC)
Screen Type Tri-Loc Wirewrap
Slot No. .020"
Filter Material Silica Sand
Filter Size No. 10

WELL DESIGN

- ☐ Grout
- ▦ Bentonite
- ░ Gravel Pack

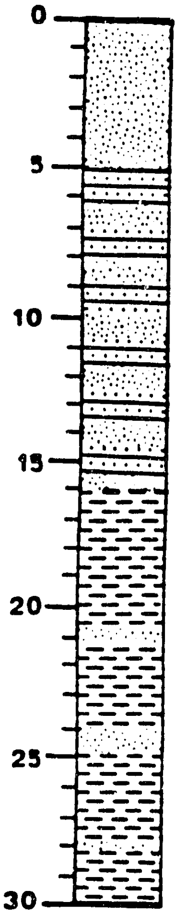
N;Standard Penetration (Blows/Ft.)
S;Soil Concentration (p.p.m.)
▽;Static Water Level
L;Lithology

TERRA VAC
P.O. BOX 23725
TAMPA, FLORIDA 33623

WELL LOG

COMPANY E.I. DUPONT ,SAVANNAH RIVER PLANT
WELL NO. VB-3"C"
Project No. 86-125
Date Completed Feb.1,87
Location "M" Area Pipeline
Geologist Rafael Barba
Sampling Method Split Spoon
Drilling Co. P. S. I.

FT.	L	GEOLOGICAL DESCRIPTION	WELL CONSTRUCTION	N	S

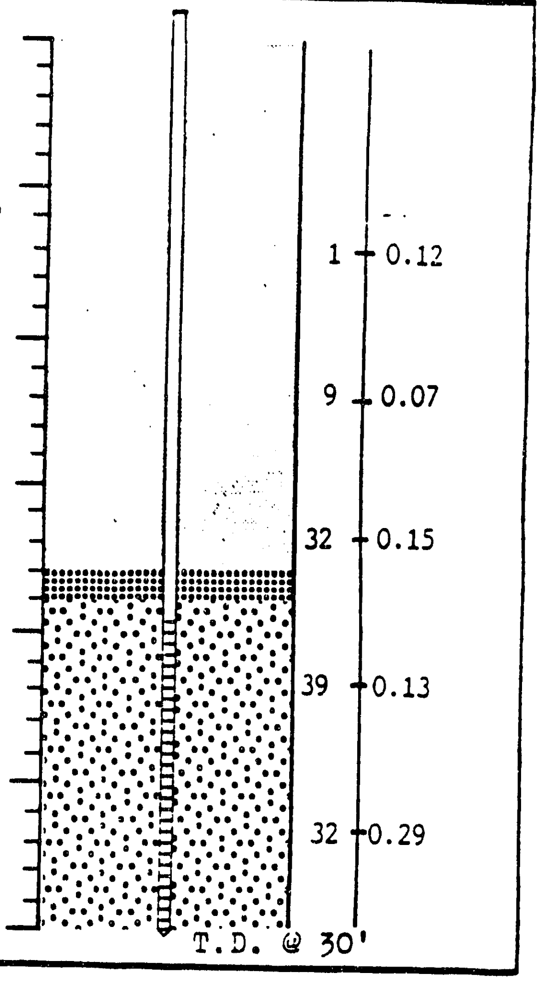


Sand, light to dark brown. Fine to medium size grain.

Silt, red to dark brown. Very fine grains, humid and compact.

Silt and sand, interbedded, red to dark brown. Medium to very fine grains.

Clay, with lenses of sand. Red to dark brown. Very compact with medium size grains of quartz.



LITHOLOGY

░ Sand
☰ Silt
▤ Clay

L E G E N D

Casing Diameter ½" Steel Pipe
Screen Type Tri-Loc Wirewrap
Slot No. .020"
Filter Material Silica Sand
Filter Size No. 10

WELL DESIGN

▭ Grout
▦ Bentonite
░ Gravel Pack

N;Standard Penetration (Blows/Ft.)
S;Soil Concentration (p.p.m.)
∇;Static Water Level
L;Lithology

APPENDIX C

CONCENTRATION DATA FOR VB SEDIMENT SAMPLES

RESULTS OF VB-1 SEDIMENT ANALYSES

Sample Number	Depth (Ft)	TCE (PPM)	PCE (PPM)	Total VOC (PPM)
1/23/87				
VB-1 # 1	5.5	.00	.16	.16
VB-1 # 2	11.0	.00	.03	.03
VB-1 # 3	15.0	.00	.06	.06
VB-1 # 4	18.0	.00	.12	.12
VB-1 # 5	22.0	.00	.39	.39
VB-1 # 6	27.0	.00	.53	.53
VB-1 # 7	32.0	.01	.21	.22
VB-1 # 8	37.0	3.19	1.81	5.00
VB-1 # 9	42.0	4.16	1.97	6.13
VB-1 # 10	47.0	3.68	.85	4.53
1/24/87				
VB-1 # 11	52.0	.53	1.49	2.02
VB-1 # 12	57.0	5.94	.63	6.57
VB-1 # 13	62.0	12.34	1.99	14.33
VB-1 # 14	67.0	11.58	1.60	13.18
VB-1 # 15	72.0	.58	.04	.62
VB-1 # 16	77.0	.20	.01	.21
VB-1 # 17	82.0	6.16	.31	6.47
VB-1 # 18	87.0	.86	.03	.89
VB-1 # 19	92.0	1.23	.05	1.28
VB-1 # 20	97.0	8.59	.51	9.10
VB-1 # 21	102.0	5.76	.30	6.06
VB-1 # 22	107.0	4.29	.15	4.44
VB-1 # 23	112.0	.65	.00	.65
VB-1 # 24	117.0	2.26	.06	2.32
VB-1 # 25	122.0	1.60	1.60	3.20
VB-1 # 26	127.0	1.98	.04	2.02
VB-1 # 27	132.0	5.32	.09	5.41

NOTE: TCE = TRICHLOROETHYLENE
PCE = TETRACHLOROETHYLENE

RESULTS OF VB–2 SEDIMENT ANALYSES

Sample Number	Depth (Ft)	TCE (PPM)	PCE (PPM)	Total VOC (PPM)
1/27/87				
VB–2 # 1	5	.02	.08	.10
VB–2 # 2	10	.01	.02	.03
VB–2 # 3	12	.03	.05	.08
VB–2 # 4	17	.01	.35	.36
VB–2 # 5	22	.01	1.52	1.53
VB–2 # 6	27	.01	1.53	1.54
VB–2 # 7	32	6.79	5.76	12.55
VB–2 # 8	37	22.05	1.31	23.36
VB–2 # 9	42	29.27	1.40	30.67
VB–2 # 10	47	198.29	4.83	203.12
VB–2 # 11	52	32.47	2.42	34.89
VB–2 # 12	57	5.58	.16	5.74
VB–2 # 13	62	20.44	.76	21.20
VB–2 # 14	67	29.47	1.17	30.64
VB–2 # 15	72	25.58	.77	26.35
VB–2 # 16	77	1.79	.01	1.80
VB–2 # 17	82	1.09	.02	1.11
VB–2 # 18	87	7.39	.32	7.71
VB–2 # 19	92	.54	.01	.55
VB–2 # 20	97	5.30	.82	6.12
VB–2 # 21	102	3.70	.33	4.03
VB–2 # 22	107	2.25	.37	2.62
VB–2 # 23	112	2.52	.65	3.17
VB–2 # 24	117	2.74	.08	2.82
VB–2 # 25	122	2.94	.19	3.13
VB–2 # 26	127	2.86	.14	3.00
VB–2 # 27	132	.68	.01	.69
VB–2 # 28	137	3.30	.30	3.60

NOTE: TCE = TRICHLOROETHYLENE
PCE = TETRACHLOROETHYLENE

RESULTS OF VB-3 SEDIMENT ANALYSES

SAMPLE NUMBER	DEPTH (FT)	TCE (PPM)	PCE (PPM)	TOTAL VOC (PPM)
1/27/87				
VB-3 # 1	7	.00	.12	.12
VB-3 # 2	12	.00	.06	.06
VB-3 # 3	17	.01	.14	.15
VB-3 # 4	22	.02	.12	.14
VB-3 # 5	27	.04	.26	.30
VB-3 # 6	32	1.64	2.85	4.49
VB-3 # 7	37	2.11	1.21	3.32
VB-3 # 8	42	3.22	1.73	4.95
VB-3 # 9	47	2.26	.80	3.06
VB-3 # 10	52	3.24	1.16	4.40
VB-3 # 11	57	3.28	.97	4.25
VB-3 # 12	62	5.02	1.25	6.27
VB-3 # 13	67	4.89	.92	5.81
VB-3 # 14	72	1.17	.13	1.30
VB-3 # 15	77	1.94	.29	2.23
VB-3 # 16	82	2.10	.34	2.44
VB-3 # 17	87	1.92	.24	2.16
VB-3 # 18	92	4.40	.59	4.99
VB-3 # 19	97	4.78	.45	5.23
VB-3 # 20	107	2.68	.00	2.68
VB-3 # 21	117	1.02	.05	1.07

NOTE: TCE = TRICHLOROETHYLENE
PCE = TETRACHLOROETHYLENE

APPENDIX D

PRESSURE DATA AND FIELD NOTES FROM TEST PERIOD

VB-1 Pumping Test Results (not corrected for barometric pressure, all values in cm water)

Date	Time	VB-2C	VB-2A	VB-2B	VB-1	VB-3B	VB-3A	VB-3C	barometric pressure	pump vacuum
11-Mar-87	1:30 PM	well VB-1 open, all others closed								
11-Mar-87	1:20 PM	0.32	5.72	6.99	6.35	6.35	6.35	1.91	1041.40	0.00
11-Mar-87	1:30 PM	0.32	5.72	6.99	6.35	6.35	6.35	1.91	1041.15	0.00
11-Mar-87	1:32 PM	0.32	7.30	6.03	172.59	12.07	6.67	1.91	1040.89	172.59
11-Mar-87	1:38 PM	0.32	11.75	6.99	241.63	13.97	6.67	1.91	1040.64	276.15
11-Mar-87	1:45 PM	0.32	13.81	6.99	310.67	16.51	6.99	2.22	1040.38	345.19
11-Mar-87	2:00 PM	0.79	16.51	6.67	310.67	19.69	6.35	2.38	1040.13	345.19
11-Mar-87	2:15 PM	0.95	17.15	6.67	310.67	20.96	6.35	2.38	1039.88	345.19
11-Mar-87	2:30 PM	0.64	18.26	6.51	310.67	21.59	6.35	2.38	1039.62	345.19
11-Mar-87	3:00 PM	1.11	18.26	5.87	310.67	21.59	5.56	2.70	1039.11	345.19
11-Mar-87	4:40 PM	0.32	19.69	5.72	310.67	24.13	6.03	2.22	1039.37	345.19
11-Mar-87	5:30 PM	0.64	20.32	5.72	310.67	24.13	5.72	1.75	1039.88	345.19
11-Mar-87	7:30 PM	0.95	20.96	6.03	310.67	24.77	5.72	0.79	1039.88	345.19
12-Mar-87	8:40 AM	4.13	23.34	7.62	310.67	27.94	7.62	3.18	1041.91	345.19
12-Mar-87	10:25 AM	3.81	23.50	6.99	310.67	27.31	7.30	3.00	1041.15	345.19
12-Mar-87	10:30 AM	well VB-3B open, all others closed								
12-Mar-87	11:15 AM	6.99	19.05	6.99	26.04	310.67	6.99	2.86	1041.40	345.19
12-Mar-87	1:30 PM	5.08	17.78	5.72	24.77	310.67	5.08	1.11	1039.88	345.19
12-Mar-87	3:00 PM	4.45	16.51	4.76	23.50	293.41	4.45	0.64	1039.11	379.70
12-Mar-87	5:30 PM	0.95	24.13	3.81	21.59	293.41	3.49	0.64	1038.35	345.19

VB-1 Pumping Test Results (not corrected for barometric pressure, all values in cm water)

Date	Time	VB-2C	VB-2A	VB-2B	VB-1	VB-3B	VB-3A	VB-3C	barometric pressure	pump vacuum
12-Mar-87	5:31 PM		well VB-1 and VB-3B open, all others closed							
13-Mar-87	8:15 AM	1.91	31.12	5.56	293.41	258.89	5.72	2.22	1039.37	345.19
13-Mar-87	9:00 AM		well VB-3A open, all others closed							
13-Mar-87	11:00 AM	0.64	9.84	21.59	9.53	9.21	310.67	1.91	1038.86	345.19
13-Mar-87	2:30 PM	2.22	3.18	20.64	3.49	3.49	293.41	1.91	1035.30	293.41
14-Mar-87	9:10 AM	0.00	7.62	25.40	5.72	5.72	302.04	1.27	1039.37	336.56
14-Mar-87	10:05 AM		well VB-2A open, all others closed							
14-Mar-87	10:30 AM	5.40	310.67	12.70	13.97	12.07	11.43	1.27	1039.62	345.19
14-Mar-87	12:20 PM	> 30.00	276.15	6.35	15.24	12.70	6.03	0.32	1038.86	310.67
14-Mar-87	4:15 PM	> 30.00	267.52	0.95	13.02	10.16	1.27	3.18	1035.05	302.04
15-Mar-87	9:00 AM	> 30.00	276.15	2.86	16.19	13.34	3.18	0.32	1037.34	336.56
15-Mar-87	9:50 AM		well VB-2C open, all others closed							
15-Mar-87	11:30 AM	284.78	5.72	2.54	5.72	5.72	2.54	0.95	1036.83	na
15-Mar-87	3:02 PM	284.78	1.27	0.95	1.59	1.27	1.27	3.81	1033.78	na
15-Mar-87	5:02 PM	302.04	0.00	1.91	0.32	0.00	1.91	4.13	1033.02	na
16-Mar-87	9:05 AM	302.04	0.95	0.32	1.27	1.27	0.32	2.54	1034.29	na

VB-1 Pumping Test Results (not corrected for barometric pressure, all values in cm water)

Date	Time	VB-2C	VB-2A	VB-2B	VB-1	VB-3B	VB-3A	VB-3C	barometric pressure	pump vacuum
16-Mar-87	10:10 AM		wells VB-1, VB-2A, VB-2C, VB-3A and VB-3B open, all others closed							
16-Mar-87	10:30 AM	189.85	181.22	8.89	189.85	na	163.96	2.86	na	258.89
16-Mar-87	3:15 PM	207.11	181.22	13.34	181.22	na	172.59	4.76	na	310.67
16-Mar-87	5:15 PM	207.11	189.85	13.97	189.85	na	172.59	4.45	na	310.67
17-Mar-87	8:10 AM	214.02	207.11	26.67	207.11	na	189.85	10.80	na	258.89

na = not available

CHART NO. 5-1071-M

PRESSURE IN MILLIBARS

BELFORT INSTRUMENT COMPANY

BALTIMORE MARYLAND, U.S.A.

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March 9, 1987

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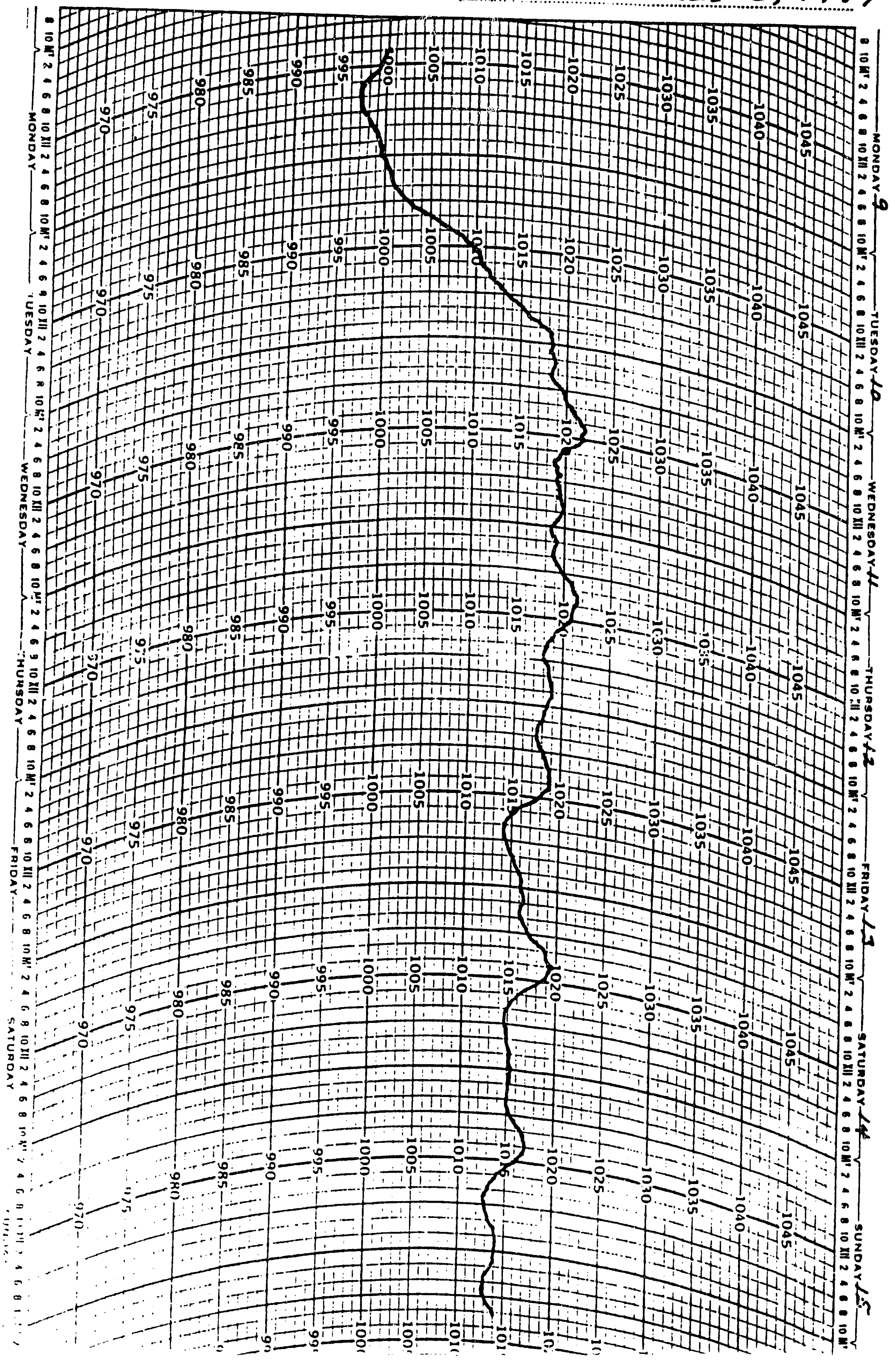

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