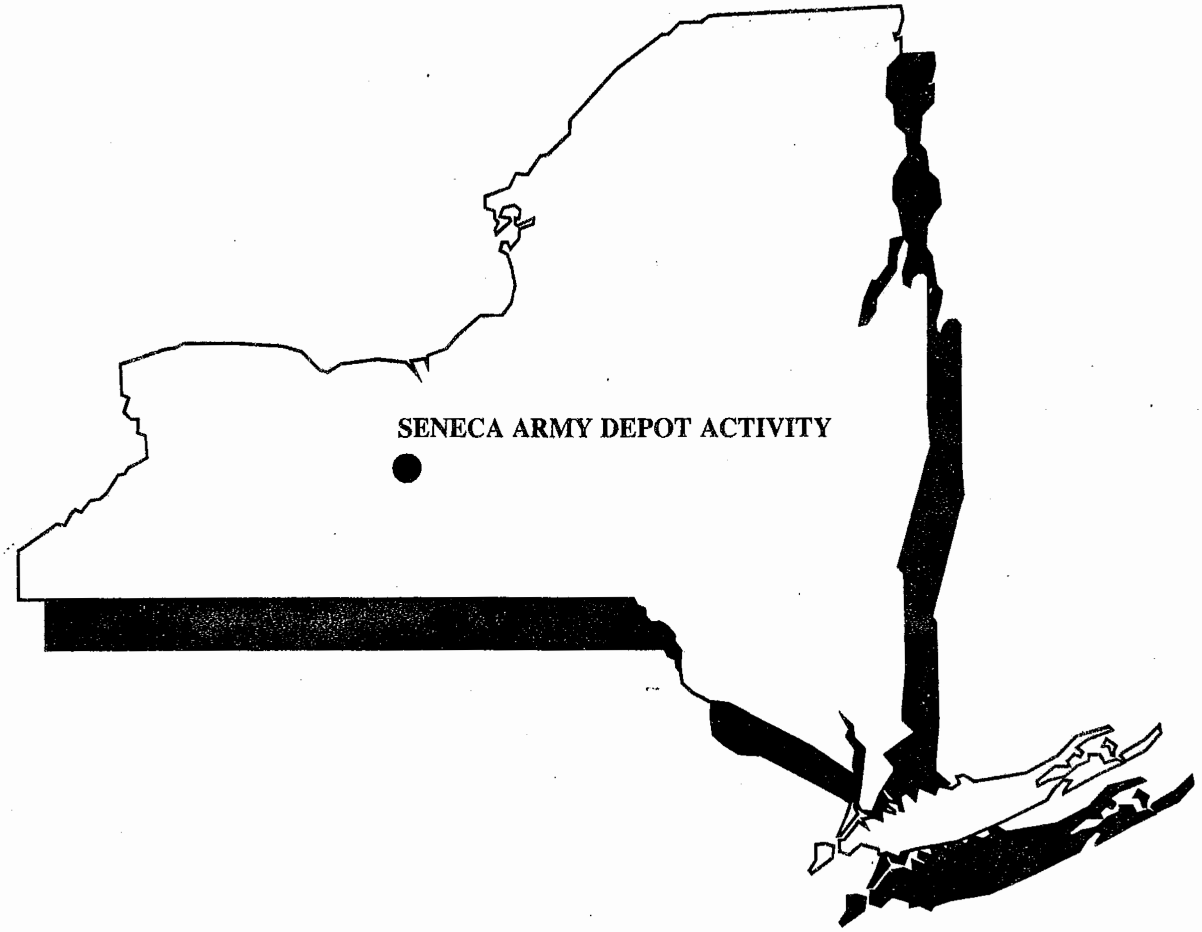
U.S. ARMY ENGINEER DIVISION
HUNTSVILLE, ALABAMA

00650



FINAL

BIOVENTING TREATABILITY STUDY WORKPLAN FOR THE FIRE TRAINING AND DEMONSTRATION PAD (SEAD-25)

CONTRACT NO. DACA87-95-D0031
TASK ORDER 0012

MARCH 2001

FINAL

BIOVENTING TREATABILITY STUDY WORK PLAN

FOR

THE FIRE TRAINING AND DEMONSTRATION PAD (SEAD-25)

SENECA ARMY DEPOT ACTIVITY, ROMULUS, NEW YORK

Prepared for:

United States Army Corps of Engineers
Huntsville, Alabama

and

Seneca Army Depot Activity
Romulus, New York

March 2001

Prepared by:

Parsons Engineering-Science, Inc.
Canton, Massachusetts

CONTENTS

Section	Title	Page
1.0	Introduction	1
2.0	Site Description	3
	2.1 Site Location and History	3
	2.2 Site Geology	3
	2.3 Constituents of Concern	3
3.0	Pilot Test Activities	3
	3.1 General Layout of Pilot Test Components	4
	3.2 Installation of Vent Wells and Monitoring Points	4
	3.2.1 Installation of Vent Wells	4
	3.2.2 Installation of Vapor Monitoring Points	4
	3.2.3 Soil Sampling During Installation of Wells and Points	5
	3.2.4 Handling of Investigation Derived Waste	5
	3.3 Initial Soil Gas Sampling	6
	3.4 Installation of Bioventing Equipment for Initial Testing	6
	3.4.1 Blower System Installation and Connection to Vent Wells	6
	3.4.2 Systems Check	7
	3.5 Initial Soil Gas Permeability (Air Injection) Test	7
	3.6 Initial *In Situ* Respiration Test	7
	3.7 Evaluation of Initial Air Injection and In Situ Respiration Tests	8
	3.8 Bioventing System Start-up	8
	3.9 Systems Monthly Monitoring	8
	3.10 Intermediate Soil Gas Sampling (6 months)	9
	3.11 Intermediate In Situ Respiration Test (6 months)	9
	3.12 Final Soil Gas Sampling (12 months)	9

F Procedure for In Situ Respiration Testing and Interpretation of Results

G RI/FS Monitoring Well Completion Diagrams and Soil Boring Logs at SEAD-25

H Blower Specifications for Treatability Study

I Response to Comments

1.0 INTRODUCTION

This workplan presents the scope of the enhanced biological degradation, or "bioventing", *in-situ* pilot test for treatment of fuel-contaminated soils at SEAD-25, located at Seneca Army Depot Activity, Romulus, New York. The pilot test has three primary objectives: 1) to assess the potential for supplying oxygen throughout the contaminated soil interval; 2) to determine the rates at which indigenous microorganisms will degrade fuel when stimulated by oxygen-rich soil gas; and 3) to evaluate the potential for sustaining these rates of biodegradation until fuel contamination in the soil is remediated to concentrations below regulatory standards. If at the end of the pilot test, bioventing proves to be an effective means of remediating the soil at this site, the pilot system may be expanded to biodegrade the remaining contaminated soils.

The above objectives will be met by conducting: 1) soil gas permeability tests; 2) in-situ respiration tests; and 3) soil gas and in-situ respiration tests 6-months and 12-months into the pilot test. Biodegradation rates will be estimated from oxygen utilization rates based on the following stoichiometric relationship, with hexane used as the representative hydrocarbon:

$$C_6H_{14} + 9.5O_2 \quad \rightarrow \quad 6CO_2 + 7H_2O$$

Oxygen utilization rates will be determined by the above tests and calculated as the percent change in oxygen over time. This rate will then be used in the following equation to determine the biodegradation rate:

$$-k_B = \frac{-k_o\, \theta_a\, \rho_{o_2}\, C\, (0.01)}{\rho_k}$$

Where:
k_B = biodegradation rate (mg/kg day)
k_o = oxygen utilization rate (%/day)
θ_a = gas-filled pore space (volumetric content at the vapor phase, m^3 gas/cm^3soil)
ρ_{o_2} = density of oxygen gas (mg/L)
C = mass ratio of hydrocarbons to oxygen required for mineralization (1:3.5)
ρ_k = soil bulk density (g/cm^3)

Using the following assumptions, values for θ_a, ρ_{o_2}, C, and ρ_k can be calculated. Tables are available in Appendix F to help refine these assumptions based on specific site soils.

- Gas-filled porosity (θ_a) of 0.25.
- Soil bulk density (ρ_k) of 1.4 g/cm3
- Oxygen density (ρ_{o_2})of 1,330 mg/L (varies with temperature, altitude, and atmospheric pressure)
- C, hydrocarbon-to-oxygen ratio of 1/3.5 (0.29) from the above equation for hexane.

Based on the above assumptions the resulting equation is:

$$k_B = -(k_o)(0.25)(1330)(1/3.5)(0.01)/1.4 = -0.68k_o \text{ (Hinchee et. al., 1996)}$$

This treatability pilot test will be conducted in two phases. The initial phase of the project will consist of constructing vent wells and vapor monitoring points, and conducting an *in-situ* respiration test and an air permeability test. This initial testing is expected to take approximately 2 weeks. During the second phase, the pilot-scale bioventing system will be started and monitored over a 1-year period.

The SEAD-25 treatability study will be composed of the following tasks, which are further discussed in the workplan:

1. Install vent wells and vapor monitoring points at locations of highest contamination, and one vent well in background location, based on existing site characterization data;
2. Perform initial soil sampling to determine physical/chemical characteristics and to determine whether soil nutrient condition is adequate for biodegradation;
3. Install bioventing equipment;
4. Perform systems check to ensure that gauges and monitoring equipment are functioning properly;
5. Perform initial soil gas sampling. Resulting data will be compared to soil gas data collected 6-months and 12-months into the pilot test to determine the reduction in BTEX and total volatile hydrocarbon (TVH) levels;
6. Perform initial air injection test to determine an estimate of the soil's permeability to fluid flow and to determine the extent of the subsurface that can be oxygenated using one air injection well;
7. Perform initial in-situ respiration test to provide rapid field measurement of oxygen utilization rates and, therefore, in-situ biodegradation rates for use in design of the full scale bioventing system;
8. Start-up bioventing system, assuming air injection and in-situ respiration tests support stimulated biodegradation;
9. Perform monthly monitoring to ensure that all equipment is functioning properly;
10. Perform soil gas sampling and in-situ respiration tests at 6 and 12 months to determine reduction in BTEX and TVH and to monitor long-term performance of bioventing system;
11. Perform final soil sampling at 12 months to determine the results of the year-long pilot test;
12. Demobilize from the site.

The contaminated soils at SEAD-25 comprise an area of 6000 ft^2 and extend six feet deep. The above equations and site specific parameters indicate that the biodegradation rate is estimated to be 0.11mg/kg-day. Based on stoichiometry and an assumed 1% oxygen utilization rate, it is estimated that approximately 350 lbs. of oxygen will be required to degrade all the existing hydrocarbons and should be applied at an air flow rate of approximately 10 scfm. These estimates will be further refined based on the initial air injection and in-situ respiration tests.

Additional background information on the development and recent success of the bioventing technology is found in the document entitled *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing* (Hinchee et. al., 1992) and *Bioventing Principles and Practice* (USEPA, 1995). These protocol documents will also serve as the primary references for pilot test well design and the detailed procedures to be used during the test.

2.0 SITE DESCRIPTION

2.1 Site Location and History

SEAD-25 is located in the east central portion of SEDA at the intersection of Administration Avenue and Ordnance Drive. It is composed mostly of undeveloped land with a centrally located, and slightly raised, crushed shale pad, which is accessible via a crushed shale roadway (Figure 1). The areas immediately surrounding the site are mostly undeveloped, however, developed portions of land (e.g., administration and maintenance buildings, etc.) are located nearby.

2.2 Site Geology

The stratigraphy at the Fire Training and Demonstration pad consists of 1 to 2 feet of crushed shale fill at the ground surface, 5 to 6 feet of till, both of which lie above Devonian shale (i.e., bedrock); the upper 2 to 4 feet of the shale is weathered. Geologic cross-sections from the RI indicate that the pad occurs on a local, natural high in the shale topography. The depth to groundwater at the site varies seasonably, but generally occurs at depths of between 2 to 6 feet below ground surface at this site.

2.3 Constituents of Concern

Various mixtures of petroleum hydrocarbon fuels are the constituents of concern at this site. The pad was used for fire training demonstrations from the late 1960s to the late 1980s. The soil beneath the pad has been impacted by petroleum hydrocarbons. The most significant impacts were in the western portions of the pad. The maximum BTEX concentrations in soil in the southwestern portion of the pad were 151,500 μg/Kg, detected in soil boring SB25-5. Conversely, BTEX was not detected in the northeastern portion of the pad, in soil boring SB25-1. Figures 2 and 3 detail the distribution of BTEX in the SEAD-25 soils and the results of the soil gas investigations performed at the site, respectively.

3.0 PILOT TEST ACTIVITIES

The purpose of this section is to describe the work that will be performed by Parsons ES at the SEAD-25 site. The numbers and locations of bioventing wells and monitoring points, and the blower system to be installed, is based on data collected during the remedial investigation. The activities to be undertaken during this treatability study include siting and construction of two air injection vent wells and seven vapor monitoring points, performance of an *in-situ* respiration test and an air permeability test, and installation of a bioventing pilot test system for extended testing. Soil and soil gas sampling procedures are also discussed in this section. No groundwater treatment or dewatering will take place during the pilot tests. Pilot test activities will be confined to unsaturated soils. Existing monitoring wells will not be used as primary air injection wells but they will be used to continue monitoring groundwater levels. Monitoring wells MW25-2 and MW25-3will also be used as vapor monitoring points or to measure the composition of background soil gas. When not in use, however, these monitoring wells will be sealed.

3.1 General Layout of Pilot Test Components

A general description of criteria for siting a vent well and monitoring points is included in the protocol document (Hinchee et. al., 1992). Figure 1 indicates the proposed locations of the vent wells and monitoring points at the SEAD-25 site. Soils in the central and southwestern portions of the Fire Training and Demonstration Pad are expected to be oxygen depleted (<2%) due to relatively high hydrocarbon levels and increased biological activity. Vent wells will serve as a means of getting supplemental oxygen into the ground so as to stimulate biodegradation.

Due to the generally fine-grained composition of the soils at this site, the potential radius of venting influence around each vent well is expected to be approximately 30 to 35 feet.

At the Fire Training Pad, one vent well (VW1) will be installed in the most contaminated area. Also, six monitoring points (MP1, MP2, MP3, MP4, MP5 and MP6) will be located within a 50-foot radius of the proposed vent well (Figure 1). If possible, existing wells MW25-2 and MW25-3 will also be used as vapor monitoring points during the treatability study.

In addition, at a background (control) location, another vent well (VW2) will be installed. One monitoring point will be installed at a distance of 5 feet from the vent well (Figure 1); this location is a control point and it will be used to monitor background respiration. If possible, existing well MW25-6 will also be used as background (or control) vapor monitoring point during the treatability study.

3.2 Installation of Vent Wells and Monitoring Points

3.2.1 Installation of Venting Wells

Two vent wells will be installed at the SEAD-25 site, one at the crushed shale pad and another in a background, or control, location. Vent wells will be designed for low groundwater level conditions to maximize the depth to which air may be delivered. If the groundwater level rises above the entire vent well screen during the one-year study, the system may be shut off temporarily until water levels drop below the top of the vent screen and delivery of air into the soils can resume. The wells will be constructed of 2-inch inside-diameter (ID) Schedule 40 polyvinyl chloride (PVC) casing, with an interval of 0.01-inch slotted screen set at approximately 2.5 to5.5 feet below the ground surface. One vent well VW1 will be installed in the area where the highest concentration of volatile organic compounds was found in soil during the Remedial Investigation. The other well VW2, will be installed in a background location to evaluate the background respiration conditions at the SEAD-25 site. Installation details and a diagram for the vent wells are included in Appendix B. The vent well specifications at the SEAD-25 site may be modified during construction, based on field conditions.

3.2.2 Installation of Vapor Monitoring Points

Vapor monitoring points will be installed around each of the vent wells. At the crushed shale pad, a total of six monitoring points will be installed around VW1. Three of these points (MP1, MP2, and MP3,) will be installed southwest of the vent well, along the direction of the volatile organic plume that emanates from the pad. Another point (MP4) will be installed to the northeast of the vent well, VW1. Points MP5 and MP6 will be installed to the northwest and northeast, respectively, of VW1. The distances for these points from vent well VW1, shown on Figure 1, are:

MP1	5 ft

MP2, MP4, MP5, MP6	15 ft
MP3	30 ft

At the background location, one vapor monitoring point (MP7) will be installed. This point will be installed 5 feet to the southwest of vent well VW2. This point is required to measure background levels of oxygen and carbon dioxide and to determine if natural carbon sources are contributing to oxygen uptake during the *in-situ* respiration test.

Installation details and a diagram for the vapor monitoring points are included in Appendix B. Due to seasonal high groundwater levels and shallow bedrock, only one monitoring zone will be installed into the monitoring points. However, if groundwater is unusually low, and there is adequate space to accommodate two monitoring zones (at least 5 feet between the ground surface and the water level encountered), two monitoring zones will be constructed.

Soil gas oxygen and carbon dioxide concentrations will be monitored with vapor probes installed at each monitoring point location. Soil temperature will be monitored using thermocouples installed at both depth intervals. Vapor probes will be constructed of a 6-inch-long section of Geoprobe® stainless steel well screen implant and anchor point, with a 0.25-inch inner diameter Teflon tube riser. Each vapor probe will be placed within a 1-foot layer of No. 3 Silica Sand. If two monitoring zones are installed, the annular space between these two intervals will be sealed with bentonite to isolate each monitoring zone.

3.2.3 Soil Sampling during Installation of Wells and Points

Soil sampling will be conducted only near the area where contamination was found (i.e., the crushed shale pad); no soil sampling will be conducted in the background (control) location.

One soil sample will be collected from the vent well VW1. In addition, one soil sample will be collected from each of the four borings used to install the monitoring points (MP1, MP2, MP3, and MP4). Sampling procedures will follow those outlined in Appendix A. Each sample will be collected from the most contaminated interval of each boring. A total hydrocarbon vapor analyzer will be used during drilling to screen split-spoon samples for intervals of high fuel contamination. Soil samples will be analyzed for the parameters indicated in Table 1.

Samples will be collected using a split-spoon sampler. Soil samples will be collected and handled as specified in Table 1. This table also contains the sample container requirements. Soil samples will be labeled following the nomenclature specified in the Generic Installation RI/FS Work Plan, wrapped in plastic, and placed in a cooler for shipment. A chain-of-custody form will be filled out, and the cooler will be shipped to Severn Trent Laboratories, Inc. (formerly Intertek Testing Services) in Burlington, Vermont for analysis.

Note: At the end of the Bioventing Treatability Study, additional soil samples will be collected from locations immediately adjacent to those described above.

3.2.4 Handling of Investigation Derived Waste

Drill cuttings will be collected in U.S. Department of Transportation (DOT) approved containers. The containers will be labeled and staged on pallets at the site. Drill cuttings will be analyzed, handled, and disposed of in accordance with the current procedures for ongoing remedial investigations at SEDA. This bioventing pilot test project is expected to generate approximately six 55-gallon drums of drill cuttings.

Drilling equipment will be cleaned at the decontamination pad located near the baseball backstop, which is north of the pad. Wastewater generated during the decontamination of drilling equipment will be drummed and labeled according to the standard requirements set in the SEAD-25 Remedial Investigation Workplan. Drums will be stored in the holding area adjacent to the decontamination pad, and disposed of in accordance with the current procedures for ongoing remedial investigations at SEDA.

3.3 Initial Soil Gas Sampling

Before the bioventing pilot test system has been turned on, initial soil gas samples will be collected from the vent well VW1 and all six of the vapor monitoring points near the crushed shale pad (MP1 through MP6) and from two existing monitoring wells: MW25-2 and MW25-3. These samples will be collected in syringes and analyzed for total volatile organics using a portable gas chromatograph. The procedures for analyzing the soil gas samples are presented in Appendix C.

In addition, confirmatory samples will be collected in SUMMA canisters from vent well VW1 and four vapor monitoring points (MP1, MP2, MP3, and MP4) near the crushed shale pad at SEAD-25. These samples will be collected in accordance with the procedures in Appendix D. The samples will be analyzed for the parameters listed in Table 2. These soil gas samples will be used to determine the reduction in BTEX and total volatile hydrocarbons (TVH), and to detect migration of these vapors from the source areas, by a comparison to the samples that will be collected during the 1-year test.

Soil gas sample canisters will be placed in a small cooler and packed with foam pellets to prevent excessive movement during shipment. Samples will not be sent on ice to prevent possible condensation of hydrocarbons. A chain-of-custody form will be filled out, and the cooler will be shipped to the laboratory for analysis.

Note: Soil gas samples will be collected from these same locations immediately prior to the 6 month and 12 month *in-situ* respiration tests.

3.4 Installation of Bioventing Equipment for Initial Testing

3.4.1 Blower System Installation and Connection to Vent Wells

Air injection rates of 5 to 20 standard cubic feet per minute (scfm) are anticipated for initial soil gas permeability testing. Figure 4 is a schematic of a typical air injection system used for pilot testing. The maximum power requirement that is anticipated for the pilot test is 230-volt, single-phase, 30-amp service. The specifications of blowers which are recommended for use in this test are presented in Appendix H. These blowers were recommended based on the low flows and medium to high pressures which may be required of the soils at SEAD-25. It is anticipated that the extended test blower will have a flow rate in the range of 10 scfm per vent well and will not exceed 3 horsepower. For the Bioventing Treatability Study, the blower will be manifolded to the vent wells and will be housed in a small, prefabricated "shed" to provide protection from the weather.

A breaker box with 230-volt/single-phase/50-amp power, one 230-volt receptacle, and two 115-volt receptacles should be located as near as possible to the proposed vent well locations (Figure 1). A licensed electrician subcontracted to Parsons ES will perform the connections to existing power source and assist in wiring the blower to line power. Power may be brought to the site from overhead power lines located either in the western portion of SEAD-25 or on the east side of Administration Avenue.

3.4.2 Systems Check

Upon completion of the bioventing system installation, Parsons ES will conduct a 10-to 15-minute, preliminary system check to ensure proper operation of gauges and vapor monitoring equipment, and to measure the initial pressure response and air flow rates. After the systems check, air will be introduced gradually into the soils via VW1 and VW2 to "condition" the soils to allow the air into pore spaces and prevent "blowout" of the vent well seals.

3.5 Initial Soil Gas Permeability (Air Injection) Test

The objective of the soil gas permeability test is to determine the extent of the subsurface that can be oxygenated using one air injection vent well. Specifically, the test will be used to determine and estimate the soil's permeability to fluid flow (k) and the radius of influence (R_I) of venting wells. Appendix E of this work plan provides the procedures to conduct the air injection test.

Permeability testing will commence after systems checks have been performed and monitoring point pressures return to zero. Air will be injected into vent well VW1 and VW2 and pressure response will be measured at each monitoring point with differential pressure gages to determine the region influenced by the unit. Oxygen will also be monitored in the monitoring points to ascertain whether oxygen levels in the soil increase as the result of air injection. One air permeability test lasting 8 to 12 hours will be performed at the site.

3.6 Initial *In-Situ* Respiration Test

The in-situ respiration test was developed to provide a rapid field measurement of in-situ biodegradation rates. The objective of the *in-situ* respiration test is to determine the rate at which soil bacteria degrade petroleum hydrocarbons. Appendix F of this work plan provides the procedures to conduct the in-situ respiration test. Section 5.7 of the protocol document describes the procedures to be used for the *in-situ* tests (Hinchee et al., 1992). Respiration tests will be performed at each vent well (VW1 and VW2) and several vapor monitoring points where bacterial degradation of hydrocarbons is indicated by low oxygen levels (<2%) and elevated carbon dioxide concentrations in the soil gas. The selection of these monitoring points will be done after field measurements of O_2 and CO_2 have been completed. If none of the monitoring points have O_2 levels below 2%, monitoring points with O_2 levels less than 5% will be selected for respiration testing. In either case, a minimum of three monitoring points will be selected for respiration testing. Air will be injected into VW1 and VW2, and O_2 and CO_2 levels will be monitored in the monitoring points selected. A 20-hour period of air injection using a 1-scfm air pump will be done to oxygenate local contaminated soils. At the end of the 20-hour air injection period, the air supply will be shut off, and oxygen and carbon dioxide levels will be monitored until oxygen levels drop down to 5% in the monitoring points or after 5 days of monitoring.

A helium tracer will be mixed into the injected air and monitored for the duration of the respiration test to determine whether oxygen loss is due to bacterial degradation or to other effects such as system leaks or short circuits to the surface.

3.7 Evaluation of Initial Air Injection and In-situ Respiration Testing

After the initial air injection and in-situ respiration tests have been completed, Parsons ES will evaluate the results to determine if bioventing is likely to be a viable remedial mechanism at SEAD-25. For the air injection test, if either the soil gas permeability or the radius of influence is high (greater than 0.01 darcy or a R_i greater that the screened interval of the vent well), it is likely that bioventing may be feasible at the site. A low soil gas permeability or radius of influence (less than 0.01 darcy or a R_i less than the screened interval of the vent well) may indicate that bioventing is not feasible. For the in-situ respiration test, oxygen utilization rates greater than 1 percent/day above background oxygen utilization rates are a good indicator that bioventing may be feasible at the site. If oxygen utilization rates are less than 1percent/day, yet significant contamination is present, other factors may be involved in limiting biodegradation. The identification of these factors may be determined by soil sampling. If no other variables can be identified as limiting biodegradation, alternative technologies may have to be employed for site remediation. Additional information on the interpretation of the air injection and in-situ respiration tests are included in Appendices E and F of this work plan.

3.8 Bioventing System Start-up

Once the initial air injection and in-situ respiration tests have been conducted and evaluated, the bioventing system will be started for the extended pilot test bioventing. The system will be in operation for 1 year, and at 6 months and 12 months Parsons ES personnel will conduct an *in-situ* respiration test to monitor the long-term performance of this bioventing system. Weekly system checks will be performed by SEDA personnel. If required, major maintenance of the blower units will be performed by Parsons ES personnel. Detailed blower system information and maintenance schedules will be included in the operation and maintenance information provided to SEDA. More detailed information regarding the test procedures can be found in the protocol document.

3.9 System Monthly Monitoring

Monthly system checks will be performed by Parsons ES personnel. This check will consist of a survey of the equipment to ensure that it is operating properly and that there has been no damage to the blower, vent wells or monitoring points. All of the systems gauges will be read and recorded (e.g., the flow through the blower, pressure in the lines, etc.). Adjustments to the system will be made accordingly. Monthly system checks will also include water level readings in existing monitoring wells. If water level measurements indicate that monitoring points will be submerged (i.e. during seasonally high groundwater levels) when performance testing is scheduled (e.g. soil samples, respiration tests, etc.), the data collection schedule will be modified. Data collection will be conducted either earlier or later than planned in this work plan to avoid such conditions. Any changes to the sampling schedule will be documented. In addition, the monthly monitoring will be supplemented by weekly system checks by SEDA personnel. If required, Parsons ES personnel will perform major maintenance of the blower unit. Detailed blower system information and maintenance schedules will be included in the operation and maintenance information provided to SEDA.

3.10 Intermediate Soil Gas Sampling (6 Months)

Intermediate soil gas samples will be collected from the vent well VW1 and all six of the vapor monitoring points near the crushed shale pad (MP1 through MP6). These samples will be collected in syringes and analyzed for total volatile organics using a portable gas chromatograph. The procedures for analyzing the soil gas samples are presented in Appendix C.

In addition, five confirmatory samples will be collected in SUMMA canisters from vent well VW1 and four vapor monitoring points (MP1, MP2, MP3, and MP4,) near the crushed shale pad at SEAD-25. These samples will be collected in accordance with the procedures in Appendix D. The samples will be analyzed for the parameters listed in Table 2. These soil gas samples will be used to determine the reduction in BTEX and total volatile hydrocarbons (TVH), and to detect migration of these vapors from the source areas, by comparison with the samples collected initially and during the 1-year test.

Soil gas sample canisters will be placed in a small cooler and packed with foam pellets to prevent possible excessive movement during shipment. Samples will not be sent on ice to prevent possible condensation of hydrocarbons. A chain-of-custody form will be filled out, and the cooler will be shipped to the laboratory for analysis.

3.11 Intermediate In-situ Respiration Test (6 Months)

Intermediate (at 6 months) respiration tests will be performed at each vent well (VW1 and VW2) and the same vapor monitoring points that were measured for the initial in-situ respiration test. Air will be injected into the vent wells and O_2 and CO_2 levels will be monitored in the monitoring points. A 20-hour period of air injection using a 1-scfm air pump will be used to oxygenate local contaminated soils. At the end of the 20-hour air injection period, the air supply will be shut off, and oxygen and carbon dioxide levels will be monitored until oxygen level is 5% or after 5 days of monitoring.

3.12 Final Soil Gas Sampling (12 Months)

Final soil gas samples will be collected from the vent well VW1 and all six of the vapor monitoring points near the crushed shale pad (MP1 through MP6). These samples will be collected in syringes and analyzed for total volatile organics using a portable gas chromatograph. The procedures for analyzing the soil gas samples are presented in Appendix C.

In addition, five confirmatory samples will be collected in SUMMA canisters from vent well VW1 and four vapor monitoring points (MP1, MP2, MP3, and MP4,) near the crushed shale pad at SEAD-25. These samples will be collected in accordance with the procedures in Appendix D. The samples will be analyzed for the parameters listed in Table 2. These soil gas samples will be used determine the reduction in BTEX and total volatile hydrocarbons (TVH), and to detect migration of these vapors from the source areas, by comparison to the samples collected initially and during the 6-month test.

Soil gas sample canisters will be placed in a small cooler and packed with foam pellets to prevent possible excessive movement during shipment. Samples will not be sent on ice to prevent possible condensation of hydrocarbons. A chain-of-custody form will be filled out, and the cooler will be shipped to the laboratory for analysis.

3.13 Final In-situ Respiration Test (12 Months)

Final (at 12 months) respiration tests will be performed at each vent well (VW1 and VW2) and the same vapor monitoring points that were measured for the initial and intermediate in-situ respiration test. Air will be injected into the vent wells and O_2 and CO_2 levels will be monitored in the monitoring points. A 20-hour period of air injection using a 1-scfm air pump will be used to oxygenate local contaminated soils. At the end of the 20-hour air injection period, the air supply will be shut off, and oxygen and carbon dioxide levels will be monitored until oxygen level is 5% or after 5 days of monitoring. .

3.14 Final Soil Sampling (12 Months)

Final soil samples will be collected from borings located 2 feet away from the initial soil boring (vent well or monitoring point) location (Table 1). The samples will be collected from the same depth as the previous samples collected during the installation of the vent well and vapor monitoring points. The samples will be analyzed for the parameters noted in Table 1.

The results of the two sets of analyses will be compared.

3.15 Bioventing System Shut-down and Evaluation of Results

After one year of operation, Parsons ES will evaluate the results of the Bioventing Treatability Study.

4.0 PROJECT SCHEDULE

The anticipated schedule for this Bioventing Treatability Study is shown on Figure 3.

If water level measurements indicate that monitoring points will be submerged (i.e. during seasonally high groundwater levels) when performance testing is scheduled (e.g. soil samples, respiration tests, etc.), the data collection schedule will be modified. Data collection will be conducted either earlier or later than planned in this work plan to avoid such conditions. Any changes to the sampling schedule will be documented.

5.0 POINTS OF CONTACT

Mr. Michael Duchesneau	Parsons Engineering Science	30 Dan Road Canton, MA 02021-2809	Ph: (781) 401-2492 Fx: (781) 401 2043
Mr. Steve Absolom SOISE-BEC BRAC Env. Coordinator	Seneca Army Depot Activity	Building 123 Romulus, NY 14541	Ph: (607) 869-1450 Fx: (607) 869-1362

Mr. Kevin Healy Engineering Support Center	U.S. Army Corps of Engineers Huntsville Division	2480 University Avenue Huntsville, AL 35816-1822	Ph: (205) 895-1627 Fx: (205) 895-1602

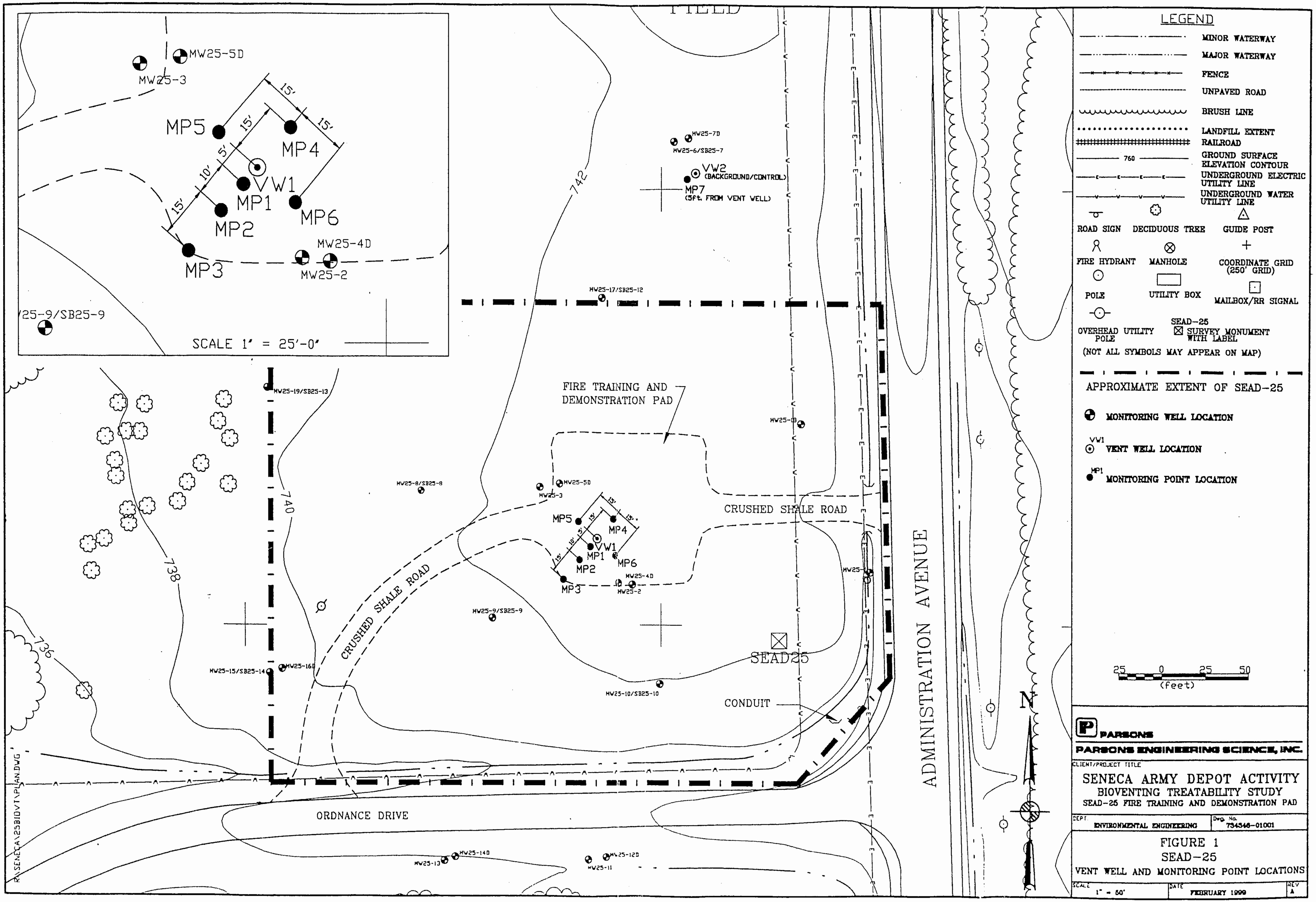
6.0 REFERENCES

Leeson, A. and Hinchee, R.E., 1996. *Principles and Practices of Bioventing Volume I: Bioventing Principles and Volume II: Bioventing Design*, Battelle Memorial Institute, Columbus, OH.

Parsons Engineering Science, Inc., 1992. *Field Sampling Plan.*

Parsons Engineering Science, Inc., May 1998. *Remedial Investigation Report at the Fire Training and Demonstration Pad (SEAD-25) and the Fire Training Pit and Area (SEAD-26).*

United States Environmental Protection Agency (USEPA), September 1995. *Bioventing Principles and Practice*. EPA/540/R-95/543a. Office of Research and Development, Washington, DC.



PARSONS

PARSONS ENGINEERING SCIENCE, INC.

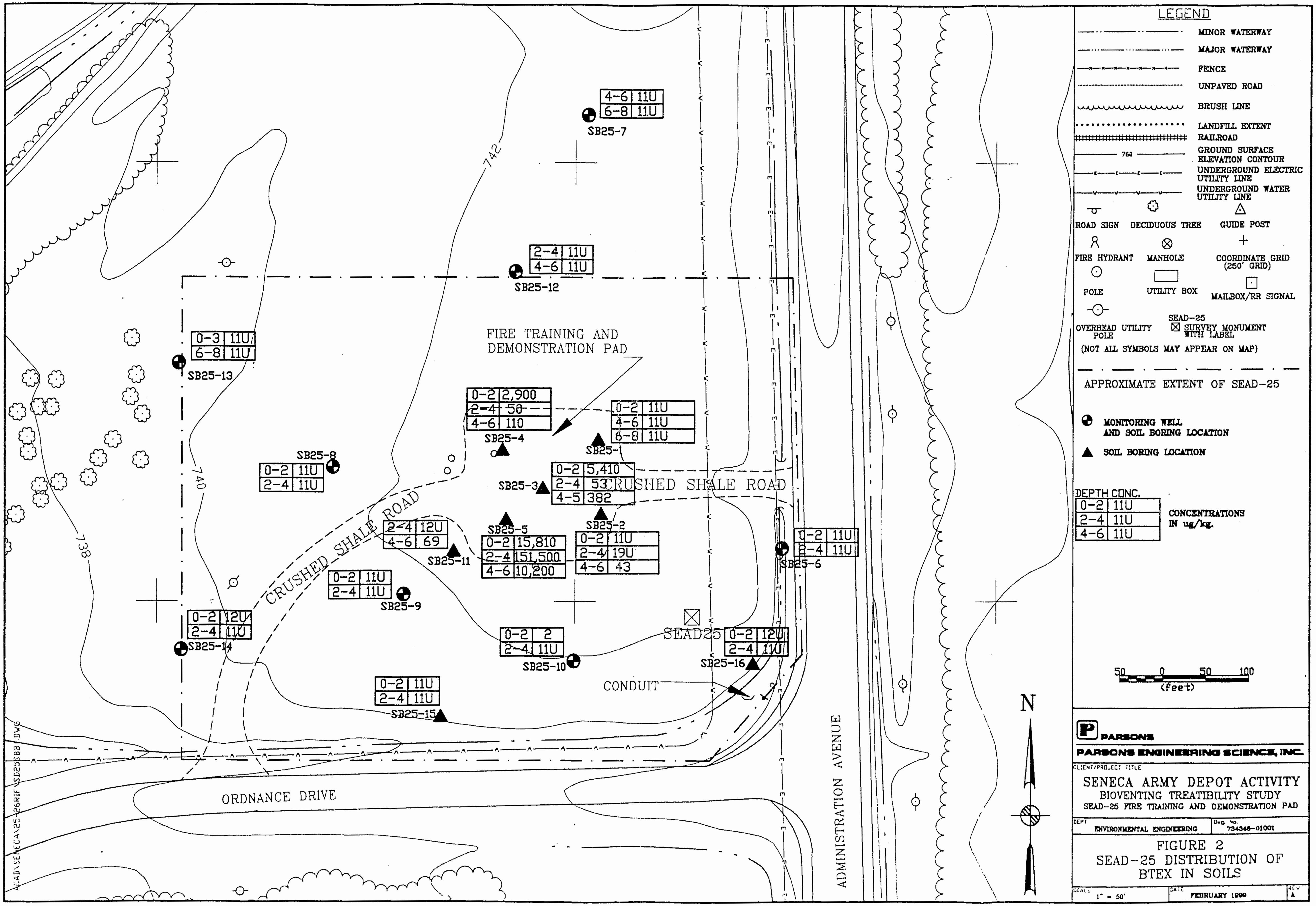
CLIENT/PROJECT TITLE

SENECA ARMY DEPOT ACTIVITY
BIOVENTING TREATABILITY STUDY
SEAD-25 FIRE TRAINING AND DEMONSTRATION PAD

DEPT.	Dwg. No.
ENVIRONMENTAL ENGINEERING	734346-01001

FIGURE 1
SEAD-25
VENT WELL AND MONITORING POINT LOCATIONS

SCALE	DATE	REV
1" = 60'	FEBRUARY 1999	A



PARSONS

PARSONS ENGINEERING SCIENCE, INC.

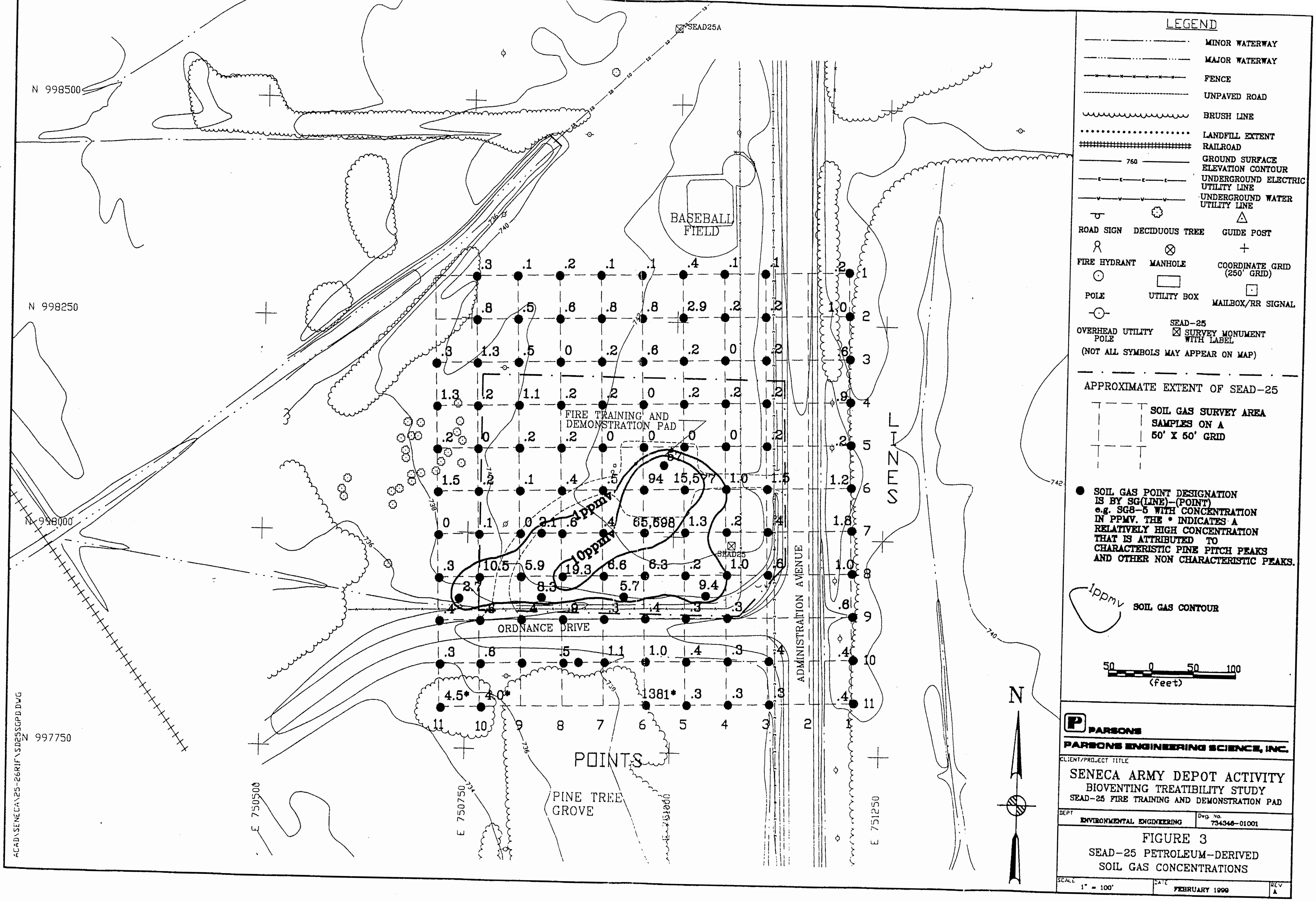
CLIENT/PROJECT TITLE

SENECA ARMY DEPOT ACTIVITY
BIOVENTING TREATIBILITY STUDY
SEAD-25 FIRE TRAINING AND DEMONSTRATION PAD

DEPT ENVIRONMENTAL ENGINEERING
Dwg. No. 734346-01001

FIGURE 2
SEAD-25 DISTRIBUTION OF
BTEX IN SOILS

SCALE 1" = 50'
DATE FEBRUARY 1999
REV A



PARSONS

PARSONS ENGINEERING SCIENCE, INC.

CLIENT/PROJECT TITLE

SENECA ARMY DEPOT ACTIVITY
BIOVENTING TREATIBILITY STUDY
SEAD-25 FIRE TRAINING AND DEMONSTRATION PAD

DEPT	Dwg. No.
ENVIRONMENTAL ENGINEERING	734346-01001

FIGURE 3
SEAD-25 PETROLEUM-DERIVED
SOIL GAS CONCENTRATIONS

SCALE	DATE	REV
1" = 100'	FEBRUARY 1999	A

Table 1

Soil Sampling Requirements
Bioventing Treatability Study Work Plan for SEAD-25
Seneca Army Depot Activity

Location ID	Depth (ft bls)	Analytical Parameters										Notes/Comments
		Volatiles (TCL) (NYSDEC CLP)	pH (EPA 9045C)	Grain Size Analysis (ASTM 422-63)	Phosphorous (EPA 365.2)	Total Kjeldahl Nitrogen - TKN (351.3)	Ammonia-N (350.2)	Nitrate-N (353.2)	Moisture Content (ASTM D2216)	Total Iron (EPA 6010)	Alkalinity (EPA 310)	
Pre-Test: Initial Samples Collected During Installation of Vent Well and Monitoring Points												
VW1	Collect at depth in vadose zone with highest VOC screen using OVM	1	1	1	1	1	1	1	1	1	1	2-4 ft based on soil results from SB25-5*
MP1	Collect at depth in vadose zone with highest VOC screen using OVM	1	1	1	1	1	1	1	1	1	1	2-4 ft based on soil results from SB25-5*
MP2	Collect at depth in vadose zone with highest VOC screen using OVM	1	1	1	1	1	1	1	1	1	1	2-4 ft based on soil results from SB25-5*
MP3	Collect at depth in vadose zone with highest VOC screen using OVM	1	1	1	1	1	1	1	1	1	1	2-4 ft based on soil results from SB25-5*
MP4	Collect at depth in vadose zone with highest VOC screen using OVM	1	1	1	1	1	1	1	1	1	1	4-6 ft based on soil results from SB25-11*
QA/QC	Collect one trip blank and one duplicate sample	2	0	0	0	0	0	0	0	0	0	QA/QC
Post-Test: Final Samples Collected after One Year of Operation of Bioventing System												
VW1A	same depth as sample collected during initial sampling	1	1	1	1	1	1	1	1	1	1	2 feet cross-gradient of VW-1
MP1A	same depth as sample collected during initial sampling	1	1	1	1	1	1	1	1	1	1	2 feet cross-gradient of MP1
MP2A	same depth as sample collected during initial sampling	1	1	1	1	1	1	1	1	1	1	2 feet cross-gradient of MP2
MP3A	same depth as sample collected during initial sampling	1	1	1	1	1	1	1	1	1	1	2 feet cross-gradient of MP3
MP4A	same depth as sample collected during initial sampling	1	1	1	1	1	1	1	1	1	1	2 feet cross-gradient of MP4
QA/QCA	Collect one trip blank and one duplicate sample	2	0	0	0	0	0	0	0	0	0	QA/QC
	Sample Container and Size	125 ml clear glass	500 ml amber glass *	500 ml amber glass	500 ml amber glass *	500 ml amber glass *	500 ml amber glass *	500 ml amber glass *	500 ml amber glass *	500 ml amber glass *	500 ml amber glass *	
	No. of Containers	1	1*	1	1*	1*	1*	1*	1*	1*	1*	
	Preservative	4 deg. C	4 deg. C	4 deg. C	4 deg. C	4 deg. C	4 deg. C	4 deg. C	4 deg. C	4 deg. C	4 deg. C	

Notes:

1) VW = Vent Well
2) MP = Monitoring Point
3) * All parameters may be taken from 1 500 ml amber glass container.

Table 2

Air Sampling Requirements
Bioventing Treatability Study Work Plan for SEAD-25
Seneca Army Depot Activity

	Initial (Pre Respiration Test)									6th Month (Pre Respiration Test)									12th Month (Pre Respiration Test)								
Location ID	Analytical Parameters									Analytical Parameters									Analytical Parameters								
	VOCs		CO_2		CO	N_2	O_2		CH_4	VOCs		CO_2		CO	N_2	O_2		CH_4	VOCs		CO_2		CO	N_2	O_2		CH_4
	Portable Gas Chromato-graph in Field	GC/MS Full Scan (EPA Method TO-14) in Lab	Field	Lab (ASTM 1946)	Lab (ASTM 1946)	Lab (ASTM 1946)	Field	Lab (ASTM 1946)	Lab (ASTM 1946)	Portable Gas Chromato-graph in Field	GC/MS Full Scan (EPA Method TO-14) in Lab	Field	Lab (ASTM 1946)	Lab (ASTM 1946)	Lab (ASTM 1946)	Field	Lab (ASTM 1946)	Lab (ASTM 1946)	Portable Gas Chromato-graph in Field	GC/MS Full Scan (EPA Method TO-14) in Lab	Field	Lab (ASTM 1946)	Lab (ASTM 1946)	Lab (ASTM 1946)	Field	Lab (ASTM 1946)	Lab (ASTM 1946)
VW1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MP1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MP2	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MP3	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MP4	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1	1
MP5	1	0	1	0	0	0	1	0	0	1	0	1	0	0	0	1	0	0	1	0	1	0	0	0	1	0	0
MP6	1	0	1	0	0	0	1	0	0	1	0	1	0	0	0	1	0	0	1	0	1	0	0	0	1	0	0
MW25-2	1	0	1	0	0	0	1	0	0	1	0	1	0	0	0	1	0	0	1	0	1	0	0	0	1	0	0
MW25-3	1	0	1	0	0	0	1	0	0	1	0	1	0	0	0	1	0	0	1	0	1	0	0	0	1	0	0
VW2	0	0	1		0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0
MP7	0	0	1		0	0	1	0	0	0	0	1	0	0	0	1	0	0	0	0	1	0	0	0	1	0	0
QA/QC *	0	2	0	1	1	1	0	1	2	0	2	0	1	1	1	0	1	2	0	2	0	1	1	1	0	1	2

Notes:

1) Lab to supply 6L Summa Cannister - cleaned and batch certified; and Flow Controler - precleaned and set.

2) QA/QC samples include one trip blank for organic analyses only and one duplicate (1 set of QA/QC samples for each sample collection event.)

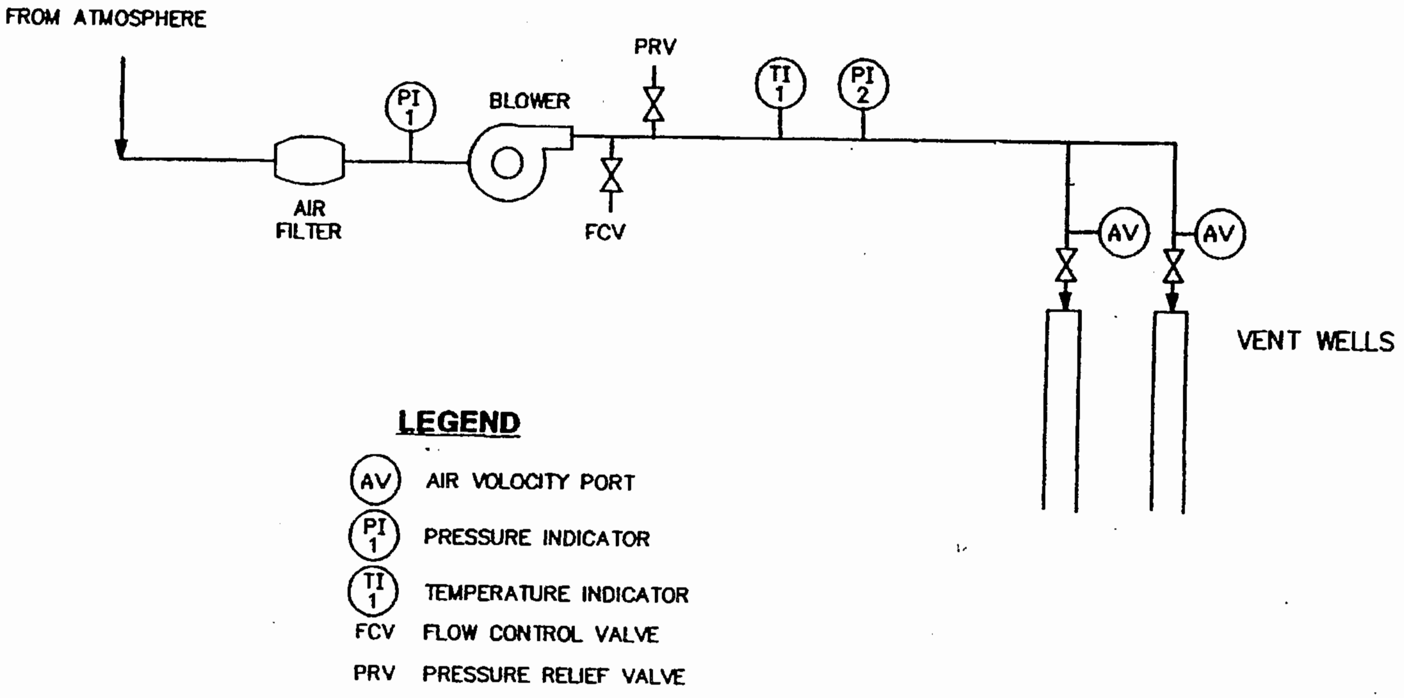
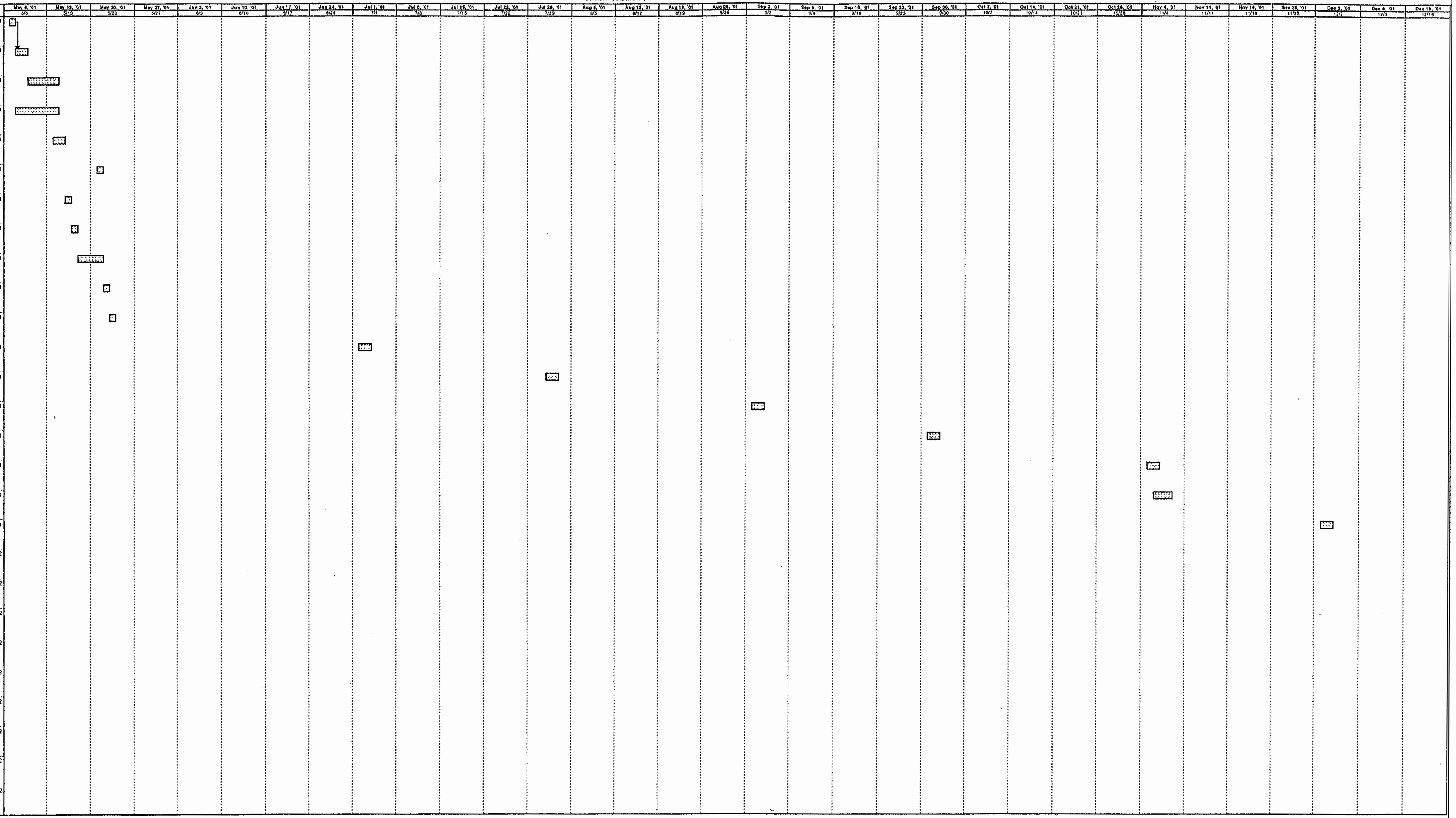


Figure 4. Proposed Blower System Instrumentation Diagram for Air Injection

H:eng/seneca/s25biovt/workplan/blower.cdr

Figure 5. Proposed Schedule for Bioventing Treatability Study
SEAD-25 Bioventing Treatability Study
Seneca Army Depot Activity

ID	O	Task Name	Duration	Start
1		Mobilization	1 day	Mon 5/7/01
2		Installation of Vent Wells (VW1 and VW2)	2 days	Tue 5/8/01
3		Installation of Monitoring Points (MP1, MP2, MP3, MP4, MP5, MP6, MP7)	3 days	Thu 5/10/01
4		Initial Soil Sampling (Performed During Installation of Wells and Points)	5 days	Tue 5/8/01
5		Installation of Bioventing Equipment for Initial Testing (Blower, Protective Shed, and Assoc. Piping/Gages)	2 days	Mon 5/14/01
6		Initial Soil Gas Sampling	1 day	Mon 5/21/01
7		Systems Check	1 day	Wed 5/16/01
8		Initial Soil Gas Permeability (Air Injection) Testing	1 day	Thu 5/17/01
9		Initial In-Situ Respiration Testing	2 days	Fri 5/18/01
10		Evaluation of Air Injection and In-Situ Respiration Testing	1 day	Tue 5/22/01
11		Bioventing Pilot Test System Start-up and Depart Site	1 day	Wed 5/23/01
12		2nd Month Systems Monitoring	2 days	Mon 7/2/01
13		3rd Month Systems Monitoring	2 days	Wed 8/1/01
14		4th Month Systems Monitoring	2 days	Mon 9/3/01
15		5th Month Systems Monitoring and Sampling	2 days	Mon 10/1/01
16		Intermediate (6th month) Systems Monitoring and Sampling	2 days	Mon 11/5/01
17		Intermediate (6 month) In-Situ Respiration Testing	3 days	Tue 11/6/01
18		7th Month Systems Monitoring	2 days	Mon 12/3/01
19		8th Month Systems Monitoring	2 days	Wed 1/2/02
20		9th Month Systems Monitoring	2 days	Mon 2/4/02
21		10th Month Systems Monitoring	2 days	Mon 3/4/02
22		11th Month Systems Monitoring	2 days	Mon 4/1/02
23		Final (12 Month) Systems Monitoring and Sampling	2 days	Wed 5/1/02
24		Final (12 Month) In-situ Respiration Testing	3 days	Fri 5/3/02
25		Final (12 Month) Drilling and Soil Sampling	3 days	Wed 5/8/02
26		Pilot Test Bioventing System Shut-down and Evaluation of Results in the Office (Soil Gas, In-Situ Respiration, Soil Analytical Data)	30 days	Mon 5/13/02
27		Submission of Treatability Study Report to regulatory agencies	1 day	Thu 8/1/02



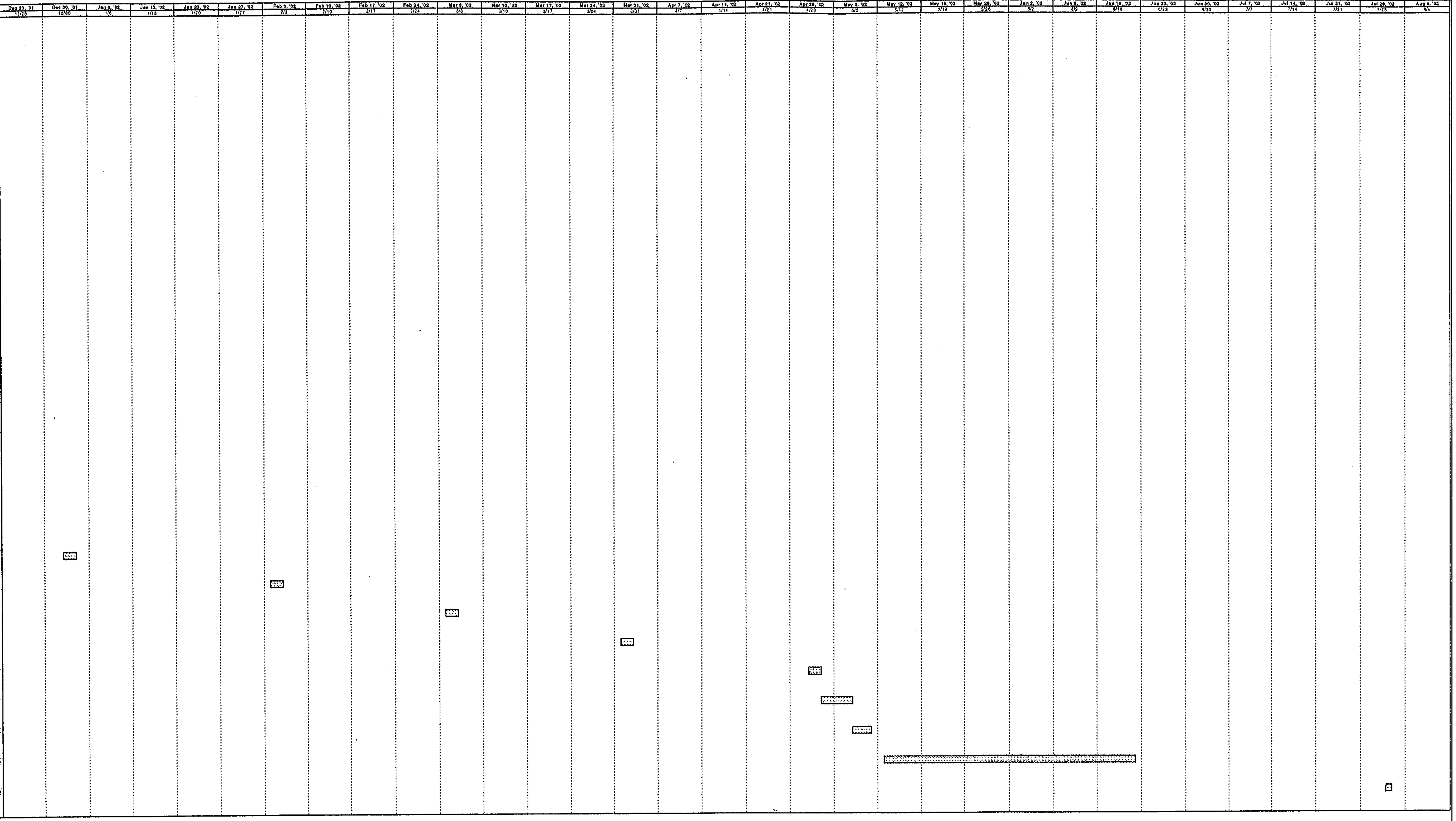
Project: REVSCHDL2
Date: Mon 2/26/01

Task ▨ Progress ■ Milestone ◆ Summary ■ Rolled Up Task ▨ Rolled Up Milestone ◇ Rolled Up Progress ■ External Tasks ▨ Project Summary ▨ Split . . . . Rolled Up Split . . . .

REVSCHDL2.MPP

Figure 5. Proposed Schedule for Bioventing Treatability Study
SEAD-25 Bioventing Treatability Study
Seneca Army Depot Activity

ID	Task Name	Duration	Start
1	Mobilization	1 day	Mon 5/7/01
2	Installation of Vent Wells (VW1 and VW2)	2 days	Tue 5/8/01
3	Installation of Monitoring Points (MP1, MP2, MP3, MP4, MP5, MP6, MP7)	3 days	Thu 5/10/01
4	Initial Soil Sampling (Performed During Installation of Wells and Points)	5 days	Tue 5/8/01
5	Installation of Bioventing Equipment for Initial Testing (Blower, Protective Shed, and Assoc. Piping/Gages)	2 days	Mon 5/14/01
6	Initial Soil Gas Sampling	1 day	Mon 5/21/01
7	Systems Check	1 day	Wed 5/16/01
8	Initial Soil Gas Permeability (Air Injection) Testing	1 day	Thu 5/17/01
9	Initial In-Situ Respiration Testing	2 days	Fri 5/18/01
10	Evaluation of Air Injection and In-Situ Respiration Testing	1 day	Tue 5/22/01
11	Bioventing Pilot Test System Start-up and Depart Site	1 day	Wed 5/23/01
12	2nd Month Systems Monitoring	2 days	Mon 7/2/01
13	3rd Month Systems Monitoring	2 days	Wed 8/1/01
14	4th Month Systems Monitoring	2 days	Mon 9/3/01
15	5th Month Systems Monitoring and Sampling	2 days	Mon 10/1/01
16	Intermediate (6th month) Systems Monitoring and Sampling	2 days	Mon 11/5/01
17	Intermediate (6 month) In-Situ Respiration Testing	3 days	Tue 11/6/01
18	7th Month Systems Monitoring	2 days	Mon 12/3/01
19	8th Month Systems Monitoring	2 days	Wed 1/2/02
20	9th Month Systems Monitoring	2 days	Mon 2/4/02
21	10th Month Systems Monitoring	2 days	Mon 3/4/02
22	11th Month Systems Monitoring	2 days	Mon 4/1/02
23	Final (12 Month) Systems Monitoring and Sampling	2 days	Wed 5/1/02
24	Final (12 Month) In-Situ Respiration Testing	3 days	Fri 5/3/02
25	Final (12 Month) Drilling and Soil Sampling	3 days	Wed 5/8/02
26	Pilot Test Bioventing System Shut-down and Evaluation of Results in the Office (Soil Gas, In-Situ Respiration, Soil Analytical Data)	30 days	Mon 5/13/02
27	Submission of Treatability Study Report to regulatory agencies	1 day	Thu 8/1/02



Project: REVSCHDL2
Date: Mon 2/26/01

Task ▨ Progress ■ Milestone ◆ Summary ▬ Rolled Up Task ▨ Rolled Up Milestone ◇ Rolled Up Progress ■ External Tasks ▨ Project Summary ▬ Split .... Rolled Up Split ....

REVSCHDL2.MPP

APPENDIX A

Procedure For Soil Borings and Soil Sample Collection

1. Scope/Purpose

This procedure describes the soil boring techniques, and soil sample collection methods for the Bioventing Pilot Study. It also discusses decontamination procedures for sampling equipment.

2. Equipment Decontamination

Soil samples will be collected with split-spoon samplers during soil-boring operation. Regardless of how samples are collected, all equipment will be decontaminated prior to and after collection of each sample.

All equipment used during the collection, preparation, preservation, and storage of environmental samples must be cleaned prior to their use and after each subsequent use. Frequently, sampling equipment must be cleaned between successive uses in the field to prevent cross contamination. When field cleaning is needed, it is essential that it be conducted diligently, to ensure that all parts of the field equipment that come in contact with the sample are properly decontaminated.

Supplies needed for cleaning or decontamination are dependent upon the materials and equipment to be cleaned. When small items require cleaning in the field, several small buckets and small containers of reagents or wash liquids are adequate. However, when major items, such as large pumps, require decontamination, it may be necessary to transport large wash basins and larger volumes of washing solutions. The following is a general equipment list for field decontamination operations.

1. Detergent, such as Alconox;

2. Potable water;

3. Demonstrated analyte free water;

4. Methanol;

5. Hexane and/or other suitable solvents to remove petroleum products;

6. Storage vessels to transport large volumes of water to the site;

7. Buckets for washing and rinsing equipment;

8. Paper towels, clean rags or chemwipes to remove excessive soil or petroleum products before the equipment is decontaminated;

9. Ultrapure $HN0_3$; and

10. Plastic squeeze bottles for rinsing equipment;

The following procedure will be used to decontaminate the sampling equipment (e.g., split spoons, syringes, bowls, scoops, bailers, soil gas sampling rods and points):

Wipe with rag, towel or chemwipes, or steam clean to remove excess soils or debris;

2. Wash and scrub with low phosphate detergent;
3. Tap water rinse;
4. Rinse with 10% $HN0_3$, ultrapure, on stainless steel equipment;
5. Tap water rinse;
6. Rinse with high-purity methanol followed by hexane rinse;
7. Rinse well with demonstrated analyte free water;
8. Air dry; and
9. Use equipment immediately or wrap in clean aluminum foil or Teflon film for temporary storage.

When it is necessary to use split spoon sampling devices which are composed of carbon steel instead of stainless steel, the nitric acid rinse may be lowered to a concentration of 1% instead of 10% so as to reduce the possibility of leaching metals from the spoon itself.

Rinse water level tapes with tap water, followed by demonstrated analyte-free water. Place in a polyethylene bag to prevent contamination during storage or transit.

Drilling equipment, such as augers, mud tubs, downhole hammers and drill rods, and backhoe buckets will be steam cleaned before use at each location and at the end of the job before going off-site.

3. Soil Sample Collection

3.1 Boring Techniques

Hollow stem augers (4.25 inch I.D.) will be used to drill each boring. Soil samples will be collected continuously during the boring using a standard three-inch diameter, two-foot long carbon steel split spoon barrel. The borings will be advanced to the appropriate depth to install either vent wells or monitoring points, or to collect soil samples. Note that "refusal" represents the depth of the "competent" bedrock. Penetration through the till and upper few feet of the weathered shale can be easily documented by split spoon sampling and the augering rate. However, the determination at auger "refusal" in competent shale will be somewhat subjective as the hollow stem augers can generally penetrate through the shale although at a very slow rate. For the purposes of these studies, auger "refusal" in "competent" shale will be defined as the depth (after penetrating the weathered shale) when augering becomes significantly more difficult and auger advancement is slow.

All borings will be logged using a standardized boring log form (Figure A-1). Soil samples will be classified according to the Unified Soil Classification System (USCS). In addition, a lithologic description will be provided according to the Burmiester system. Each boring log will record:

1. Boring identification and location;
2. Type of and manufacturer's name of drilling equipment;
3. Type and size of sampling and drilling equipment;
4. Starting and ending dates of drilling;
5. Length and depth of each sampled interval;
6. Length of each recovered sample;
7. Depth of all stratigraphic changes;
8. Lithologic description according to the Burmiester system and soil classification using standard USCS nomenclature;
9. Depth at which groundwater is first encountered;
10. Depths and rates of any water losses;
11. Depth to static water level;
12. Depths at which drilling problems occur and how the problems are solved;
13. Total boring depth;
14. Reason for terminating borehole;
15. Surface elevation; and
16. VOC readings of split spoon samples.

If the boring is not being completed as a vent well or monitoring point, after the boring is completed, it will be filled to the ground surface with lean grout containing at least 3 % bentonite powder by volume. The cement/bentonite grout seal will be placed from the bottom of the boring to approximately 3 feet below the land surface by pouring the mixture into the hole. The grout

The following procedure will be used to decontaminate the sampling equipment (e.g., split spoons, syringes, bowls, scoops, bailers, soil gas sampling rods and points):

Wipe with rag, towel or chemwipes, or steam clean to remove excess soils or debris;

2. Wash and scrub with low phosphate detergent;
3. Tap water rinse;
4. Rinse with 10% $HN0_3$, ultrapure, on stainless steel equipment;
5. Tap water rinse;
6. Rinse with high-purity methanol followed by hexane rinse;
7. Rinse well with demonstrated analyte free water;
8. Air dry; and
9. Use equipment immediately or wrap in clean aluminum foil or Teflon film for temporary storage.

When it is necessary to use split spoon sampling devices which are composed of carbon steel instead of stainless steel, the nitric acid rinse may be lowered to a concentration of 1% instead of 10% so as to reduce the possibility of leaching metals from the spoon itself.

Rinse water level tapes with tap water, followed by demonstrated analyte-free water. Place in a polyethylene bag to prevent contamination during storage or transit.

Drilling equipment, such as augers, mud tubs, downhole hammers and drill rods, and backhoe buckets will be steam cleaned before use at each location and at the end of the job before going off-site.

3. Soil Sample Collection

3.1 Boring Techniques

Hollow stem augers (4.25 inch I.D.) will be used to drill each boring. Soil samples will be collected continuously during the boring using a standard three-inch diameter, two-foot long carbon steel split spoon barrel. The borings will be advanced to the appropriate depth to install either vent wells or monitoring points, or to collect soil samples. Note that "refusal" represents the depth of the "competent" bedrock. Penetration through the till and upper few feet of the weathered shale can be easily documented by split spoon sampling and the augering rate. However, the determination at auger "refusal" in competent shale will be somewhat subjective as the hollow stem augers can generally penetrate through the shale although at a very slow rate. For the

PAGE 1 OF

OVERBURDEN BORING REPORT

ENGINEERING-SCIENCE, INC. | **CLIENT:** | **BORING NO.:**

PROJECT :

LOCATION :

JOB NO. :

EST. GROUND ELEV.:

START DATE:

FINISH DATE:

CONTRACTOR:

DRILLER:

INSPECTOR:

CHECKED BY:

CHECK DATE:

DRILLING SUMMARY:

DRILLING	HOLE	DEPTH	SAMPLER		HAMMER	
METHOD	DIA.	INT.	SIZE	TYPE	TYPE	WT/FALL

DRILLING ACRONYMS:

HSA	HOLLOW-STEM AUGERS	HMR	HAMMER	SS	SPLIT SPOON
DW	DRIVE-AND-WASH	SHR	SAFETY HAMMER	CS	CONTINUOUS SAMPLING
MRSLC	MUD-ROTARY SOIL-CORING	HHR	HYDRAULIC HAMMER	5I	5 FT INTERVAL SAMPLING
CA	CASING ADVANCER	DHR	DOWN-HOLE HAMMER	NS	NO SAMPLING
SPC	SPIN CASING	WL	WIRE-LINE	ST	SHELBY TUBE
				3S	3 INCH SPLIT SPOON

MONITORING EQUPMENT SUMMARY

INSTRUMENT	DETECTOR	RANGE	BACKGROUND			CALIBRATION		
TYPE	TYPE/ENERGY		READING	TIME	DATE	TIME	DATE	WEATHER

MONITORING ACRONYMS

PID	PHOTO - IONIZATION DETECTOR	BGD	BACKGROUND	DGRT	DRAEGER TUBES
FID	FLAME - IONIZATION DETECTOR	CPM	COUNTS PER MINUTE	PPB	PARTS PER BILLION
GMD	GEIGER MUELLER DETECTOR	PPM	PARTS PER MILLION	MDL	METHOD DETECTION LIMIT
SCT	SCINTILLATION DETECTOR	RAD	RADIATION		

QA/QC:

QA/QC SAMPLES COLLECTED: YES or NO

Duplicate Sample Number:

MRD Sample Number:

QA/QC Rinsate Sample Number:

INVESTIGATION DERIVED WASTE:

AMOUNT OF SOIL DRUMMED:

DRUM NUMBER:

H:\ENG\SENECA\APPEND.A\OBBORP1.WK3

A-1

FIGURE ~~A-2~~

purposes of these studies, auger "refusal" in "competent" shale will be defined as the depth (after penetrating the weathered shale) when augering becomes significantly more difficult and auger advancement is slow.

All borings will be logged using a standardized boring log form (Figure A-1). Soil samples will be classified according to the Unified Soil Classification System (USCS). In addition, a lithologic description will be provided according to the Burmiester system. Each boring log will record:

1. Boring identification and location;
2. Type of and manufacturer's name of drilling equipment;
3. Type and size of sampling and drilling equipment;
4. Starting and ending dates of drilling;
5. Length and depth of each sampled interval;
6. Length of each recovered sample;
7. Depth of all stratigraphic changes;
8. Lithologic description according to the Burmiester system and soil classification using standard USCS nomenclature;
9. Depth at which groundwater is first encountered;
10. Depths and rates of any water losses;
11. Depth to static water level;
12. Depths at which drilling problems occur and how the problems are solved;
13. Total boring depth;
14. Reason for terminating borehole;
15. Surface elevation; and
16. VOC readings of split spoon samples.

If the boring is not being completed as a vent well or monitoring point, after the boring is completed, it will be filled to the ground surface with lean grout containing at least 3 % bentonite powder by volume. The cement/bentonite grout seal will be placed from the bottom of the boring to approximately 3 feet below the land surface by pouring the mixture into the hole. The grout

PAGE 2 OF

OVERBURDEN BORING REPORT

ENGINEERING-SCIENCE, INC. | **CLIENT:** | **BORING #:**

MONITORING			
INSTRUMENT	INTERVAL	BGD	TIME

COMMENTS:

DRILLER: ______________

INSPECTOR: ______________

DATE:

DEPTH (FT)	SAMPLING			SAMPLE				SAMPLE DESCRIPTION	USCS CLASS	STRATUM CLASS
	BLOWS PER 6 INCHES	PENETRATION RANGE (FEET)	RECOVERY RANGE (FEET)	DEPTH INT (FEET)	NO.	VOC	RAD SCRN	(As per Burmeister: color, grain size, MAJOR COMPONENT, Minor Components with amount modifiers and grain-size, density, stratification, wetness, etc.)		
5										
10										
15										
20										

FIGURE A-~~2~~ 1 (cont.)

PAGE OF

OVERBURDEN BORING REPORT

ENGINEERING-SCIENCE, INC.

CLIENT:

BORING #:

MONITORING			
INSTRUMENT	INTERVAL	BGD	TIME

COMMENTS:

DRILLER

INSPECTOR

DATE

DEPTH (FT)	SAMPLING			SAMPLE				SAMPLE DESCRIPTION	USCS CLASS	STRATUM CLASS
	BLOWS PER 6 INCHES	PENETRATION RANGE (FEET)	RECOVERY RANGE (FEET)	DEPTH INT (FEET)	NO.	VOC	RAD SCRN	(As per Burmeister: color, grain size, MAJOR COMPONENT, Minor Components with amount modifiers and grain-size, density, stratification, wetness, etc.)		

FIGURE A-2 (cont.)

mixture will consist of Portland cement (ASTM C 150-86) and water in the proportion of not more than 7.0 to 8.0 gallons (gal) of clean water per bag of cement [1 cubic foot (ft') or 94 pounds (lb)]. Additionally, 3 percent by weight of bentonite powder will be added to help reduce shrinkage of the grout mixture. The grout will be allowed to set a minimum of 48 hours. If the borehole is greater than 15 feet and groundwater is present in the borehole, the grout will be pumped through a tremie pipe to the bottom of the boring. Grout will be pumped in until undiluted grout discharges from the bore hole at the ground surface. A bentonite backfill consisting of bentonite pellets will be placed from the top of the cement/bentonite grout seal to the ground surface and allowed to hydrate.

3.2 Soil Sampling Methods

Soil samples will be collected continuously during the boring using a standard three-inch diameter, two-foot long carbon steel split spoon barrel. Soil samples will be screened for volatile organic compounds using a FID or OVM. One of the samples from each boring will be selected for chemical analysis. The sample that exhibits elevated FID readings will be the sample to be analyzed. Each of these samples will be submitted for chemical testing for parameters identified in the main body of the text of this work plan. Samples to be analyzed for volatile organic compounds will be collected first in the appropriate sample containers; these soil samples will not be homogenized or composited during the sampling process.

The remaining soil from the spoon will be mixed (homogenized) in a decontaminated stainless steel bowl with a decontaminated stainless steel utensil and placed in appropriate sample containers. If the soil is to be transferred to other containers, scoop the sample directly into the sample container. If organic analyses are to be performed, the scoop should be stainless steel. In addition to the samples collected from the borings, quality control samples will also be taken. These include a trip blank and a duplicate for VOC analysis.

New gloves will be used to collect each sample.

3.3 Other Sampling Information

Soil samples will be stored in appropriate containers as indicated in the site test plan or as directed by the analytical laboratory. For sample containers and size requirements, refer to the main body of this work plan.

Sample labeling and logging, and shipment will be performed in accordance with the procedures outlined in the Generic Installation RI/FS Work Plan.

APPENDIX B

Procedure For Installation of Vent Well and Monitoring Points

1. Scope/Purpose

This procedure describes methods to be used to install Vent Wells and Monitoring Points for the Bioventing Pilot Study, as well as decontamination procedures for the well equipment. The drilling subcontractor will perform the following tasks:

1. Install Venting Wells; and

2. Install Vapor Monitoring Points.

The methods and means for performing these tasks are described below.

2. Decontamination of Equipment and Materials

Every appropriate precaution must be taken during drilling and construction of monitoring wells to avoid introducing contamination into the borehole. All equipment to be placed into the boring will be decontaminated before use at the site and between boreholes using EPA Region II and NYSDEC protocols. Equipment must be steam-cleaned between holes and only non-chlorinated potable water may be used during drilling operations, unless otherwise approved by the NYSDEC. The manufacturers of PVC pipe immediately wrap the pipe in plastic bags after it comes off the extrusion line to protect the pipe from any contamination during storage and transport. Companies who prepare the pipe for use in well construction typically slot the pipe, dust it, wash it with a mild Alconox solution, and also wrap it in plastic to protect if from contamination during storage and transport. The PVC pipe will be steam cleaned prior to installation in the borehole.

3. Installation of Venting Wells

Two (2) venting wells will be installed at SEAD-25 in the locations shown in the main body of the text of this work plan. The construction of the wells shall be as shown in Figure B-1. The installation of each vent well will begin after the boring has been completed. Once installation has begun, no breaks in the installation process will be made until the well has been grouted and the drill casing removed.

Vent wells will be installed using hollow-stem augers. Figure B-1 shows the well details. Vent wells shall extend to the top of the competent shale. Water table variations, site stratigraphy, expected contaminant flow will also be considered in determining the screen length and position. Previous well logs and current field work suggest these wells will not be more than six feet deep with well screens lengths of four feet or less. Soil split spoon samples will be collected continuously as the auger penetrates the formation. Soil samples will be collected as described in Appendix A. The vent wells will be constructed of new 2-inch National Sanitation Foundation (NSF) or ASTM-approved schedule 40 PVC wire wrapped screens as required by NYSDEC with threaded, flush joints that contain a rubber gasket. No solvents or glues, or other adhesives will be used to connect the PVC casing. A silt sump "point" will be placed at the bottom of each well. The PVC shall extend one foot above the ground surface.

A 0.010-inch slot size used with a No. 3 Silica Sand filter pack shall be used. The filter pack will be placed by pouring sand from the surface into the annular space between the well screen and the hollow stem auger. The sand pack will extend 6 inches above the top of the screen.

Bentonite chips (about 18 inches thick) will be used to seal the well and will be poured within the annular space and hydrated. Then the remaining annular space will be completely filled with a lean cement grout containing at least 3% by weight bentonite to cement. The grout mixture will be placed in the annular space by pouring it from the surface.

A cement collar will surround the well.

4. Installation of Vapor Monitoring Points

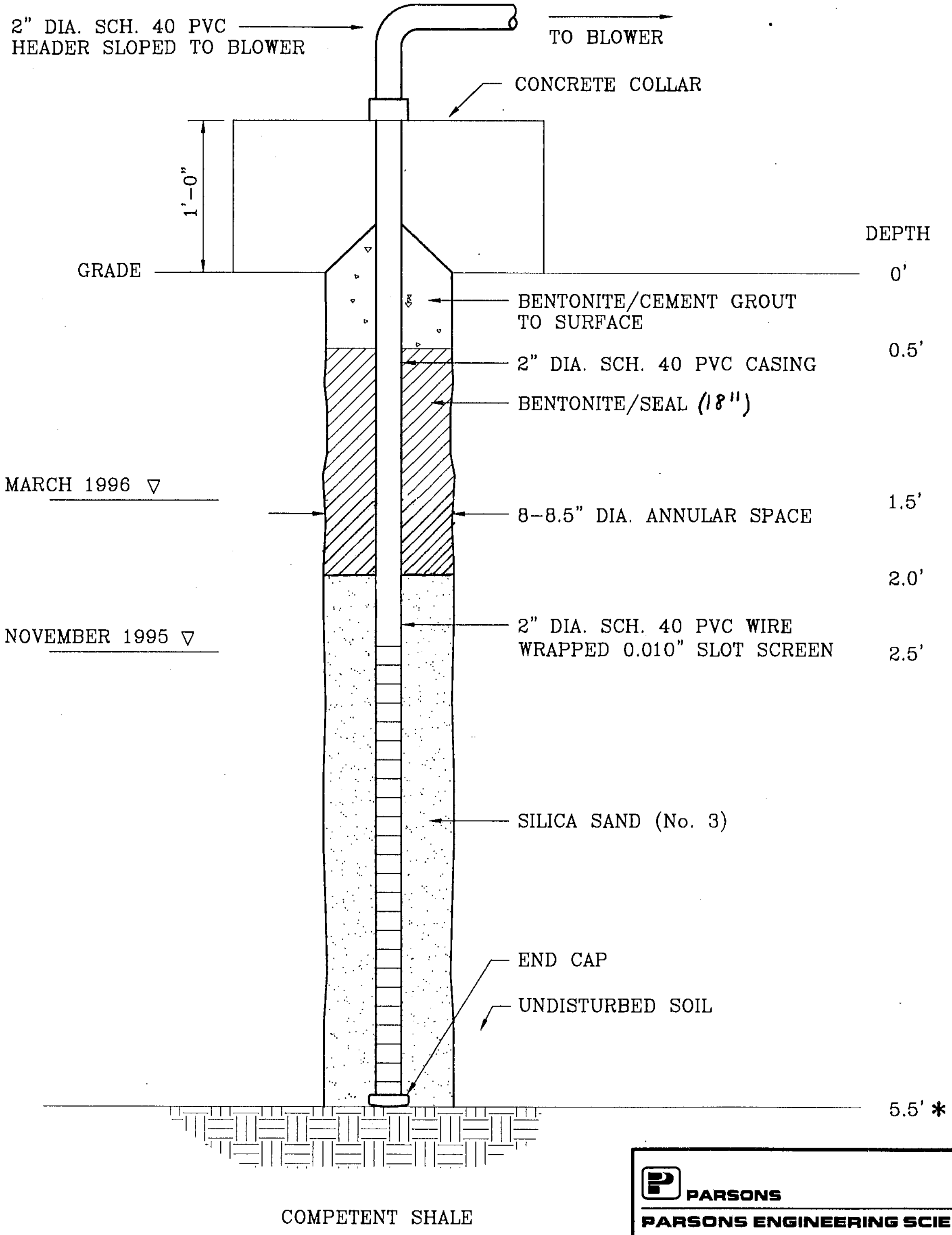
The installation of each vapor monitoring point will begin after the boring has been completed. Once installation has begun, no breaks in the installation process will be made until the well has been grouted and the drill casing removed.

Vapor monitoring point locations will be installed using hollow-stem augers. Soil split-spoon samples will be collected continuously as the auger penetrates the formation. Soil samples will be collected as described in Appendix A. Figure B-2 shows the general construction of these monitoring points. Borings used for the installation of monitoring points will be drilled to bedrock. If groundwater is unusually low, and there is adequate space to accommodate two monitoring zones (at least 5 feet between the ground surface and the water level encountered), two monitoring zones will be constructed as described in Appendix B. If such space is not encountered, a 3 foot long section of lean grout containing 3% bentonite by volume will be placed in the borehole. Above that, one monitoring zone approximately 1.5 feet below the ground surface to 2.5 feet below ground surface will be installed. The seal will extend 1.5 feet below ground surface. See Figure B-2 for monitoring point construction details when only one monitoring zone is constructed.Each monitoring point will consist of a 1-inch diameter, six-inch long Geoprobe® stainless steel screen. These monitoring points will be located in a one foot zone of No. 3 silica sand. The sand pack will be placed by pouring sand from the surface into the annular space between the well screen and the hollow stem auger. A riser comprised of 0.25-inch inner diameter Teflon tubing will connect the screened monitoring point to the top of the borehole at the ground surface. Metal tags and quick couples will be provided and installed by Parsons field scientists.

In addition, a thermocouple will be provided by Parsons field scientists to be installed into the sand zone (or both sand zones) of each monitoring point.

A layer of bentonite chips, approximately 1 foot thick, will be used to seal each sand pack (as shown in Figure B-2) and will be poured within the annular space and hydrated. The bentonite will be placed in approximately 6-inch thick layers, then hydrated with potable water to assure complete saturation and hydration of the bentonite before placement of subsequent layers. Approximately, the upper 6 inches of the monitoring point location will be filled with gravel for the box drainage.

A watertight, cast iron well box will be installed at each of the seven vapor monitoring point locations. The space between the roadway box and the borehole will be filled with neat cement to the ground surface.



NOTE:

*APPROXIMATE DEPTH TO AUGER REFUSAL IN COMPETENT SHALE AT VW1.

R:\SENECA\BRIES\SD25-26\VENTWELL.DWG

PARSONS

PARSONS ENGINEERING SCIENCE, INC.

CLIENT/PROJECT TITLE

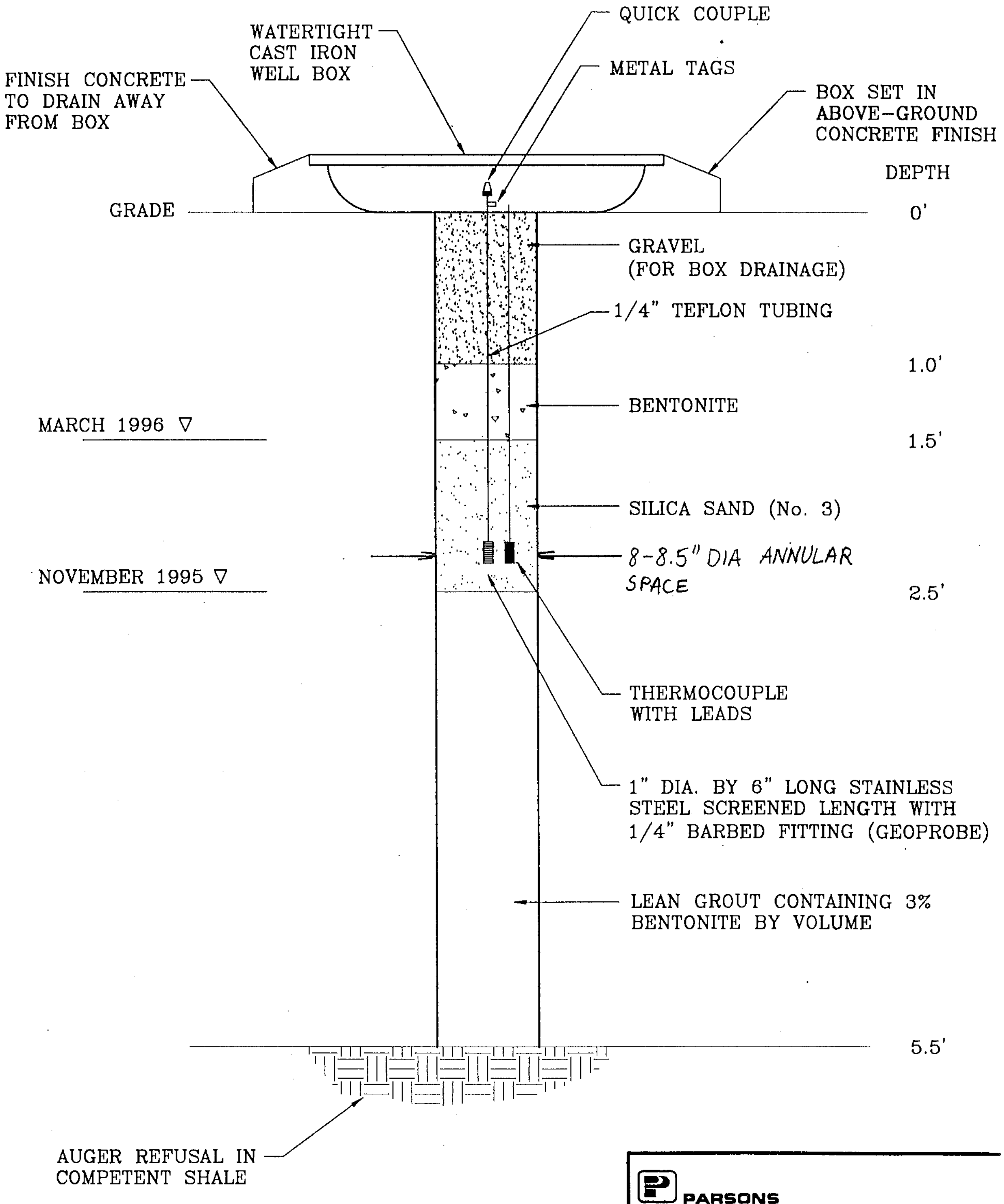
SENECA ARMY DEPOT ACTIVITY

BIOVENTING TREATABILITY STUDY WORKPLAN FOR
FINE TRAINING AND DEMONSTRATION PAD (SEAD-25)

DEPT.	Dwg. No.
ENVIRINMENTAL ENGINEERING	734346-01001

FIGURE B-1
VENT WELL CONSTRUCTION DETAIL

SCALE	DATE	REV
NOT TO SCALE	AUGUST 1999	▲



PARSONS

PARSONS ENGINEERING SCIENCE,

CLIENT/PROJECT TITLE
SENECA ARMY DEPOT ACTIV
BIOVENTING TREATABILITY STUDY WORKPLAN
FINE TRAINING AND DEMONSTRATION PAD (SEA

DEPT. ENVIRINMENTAL ENGINEERING
Dwg. No. 734346-01001

FIGURE B-2
MONITORING POINTS
CONSTRUCTION DETAIL

SCALE NOT TO SCALE
DATE AUGUST 1999

R:\SENECA\BIEFS\SD25-26\MPOINTS.DWG

APPENDIX C

Procedure For

Soil Gas Sampling and Analysis

1. Scope/Purpose

This section describes procedures for conducting a soil gas survey. Soil gas surveys will be performed to evaluate the total volatile organic compounds at the vent wells and vapor monitoring points. The soil gas sampling will be performed during three (3) events: (1) prior to the bioventing system start up, (2) prior to the 6-month in situ respiration test, and (3) prior to the 12-month in situ respiration test. A decrease in soil gas concentrations of hydrocarbons over time will be an indication that bioventing is enhancing biodegradation of these compounds. This data in conjunction with confirmatory sampling and other design parameters measured during the study will be used to assess the effectiveness of bioventing as a remedial alternative at SEAD-25.

2. Explanation of Method

The soil gas sampling will be performed during three (3) events: (1) prior to the bioventing system start up, (2) prior to the 6-month in situ respiration test, and (3) prior to the 12-month in situ respiration test. Soil gas sampling will be performed while the bioventing system is shut down. For the 6-month and 12-month tests, the system will be shut off overnight prior to conducting the soil gas sampling.

The method involves extracting a small representative sample of soil gas through an in-line sampling port and analyzing the gas for the presence of volatile contaminants. The presence of contaminants in the soil gas provides a strong indication that there is a source of volatile organics either in the soil near the well or in the groundwater below the well. The soil gas analysis is performed in the field with a portable gas chromatograph so that sample loss does not occur due to shipment off-site. The analytical results are available immediately and can be used to help evaluate the performance of the bioventing system.

The soil gas evaluation program involves three essential elements. These are:

1. Soil Gas Sampling
2. Analytical Support
3. Data Interpretation

3. Soil Gas Sampling

1. The vent well is fitted with a coupling containing both a blower shut off valve and an in-line sampling port. The vapor monitoring points and monitoring wells MW25-2 and MW25-3 will also be fitted with an in-line sampling port. Teflon tape will be used on the threads connecting the coupling to the well to prevent infiltration of surface gases into the sampling port.

2. An air sampling pump will be used to create a slight negative pressure to ensure that the gases flowing through the sampling train are representative of soil gases. Samples of soil gas are collected prior to contact with the pump.

3. The effluent gas from the air sampling pump will be monitored with a hand held vapor monitor, such as the HNU PI101. The gas sample will be collected immediately if the effluent monitoring indicates an increase in the concentration of volatiles. Gas samples will be collected to coincide, as much as possible, with the highest concentration of gas found to be present. If no increase in the concentration of soil gas is determined by the effluent monitoring then purging will be

performed. The volume of the sampling train will be calculated to determine the length of time required for purging. The flow rate of the pump will be between 1 and 3 L/min. After purging, a soil gas sample is collected through a septum port using a gas-tight gas sampling syringe.

4. The sample is then injected into the portable gas chromatograph for analysis.

5. Soil gas sampling data is to be recorded on Figure C-1, Soil Gas Sample Location Data.

Page 1 of

SOIL GAS SAMPLE LOCATION DATA

ENGINEERING-SCIENCE	CLIENT:	DATE:

PROJECT : LOCATION:	INSPECTOR: CONTRACTOR: TYPE OF RIG:

WEATHER/FIELD CONDITIONS (record major changes)				MONITORING	
TIME	TEMP	PRECIP.	GROUND SURFACE CONDITIONS	INSTRUMENT	DETECTOR

SAMPLE LOCATION:	
BLOWS PER 6 INCHES	OVM MAXIMUM:
	TIME OF OVM MAXIMUM:
DEPTH OF PENETROMETER POINT (ft):	TIME OF SOIL GAS SAMPLE:
DEPTH TO BOTTOM OF ROD (FT)	FLOW RATE (ml/min).
TIME START EVACUATION PUMP	VOLUME OF GAS REMOVED AT SAMPLE TIME (ml):
TIME STOP EVACUATION PUMP	SYRINGE NUMBER:

COMMENTS:

IS GROUNDWATER PRESENT IN THE SAMPLING PIPE? YES NO

SAMPLE LOCATION:	
BLOWS PER 6 INCHES	OVM MAXIMUM:
	TIME OF OVM MAXIMUM
DEPTH OF PENETROMETER POINT (ft)	TIME OF SOIL GAS SAMPLE:
DEPTH TO BOTTOM OF ROD (FT)	FLOW RATE (ml/min):
TIME START EVACUATION PUMP	VOLUME OF GAS REMOVED AT SAMPLE TIME (ml):
TIME STOP EVACUATION PUMP	SYRINGE NUMBER

COMMENTS:

IS GROUNDWATER PRESENT IN THE SAMPLING PIPE? YES NO

SAMPLE LOCATION:	
BLOWS PER 6 INCHES	OVM MAXIMUM.
	TIME OF OVM MAXIMUM:
DEPTH OF PENETROMETER POINT (ft)	TIME OF SOIL GAS SAMPLE.
DEPTH TO BOTTOM OF ROD (FT)	FLOW RATE (ml/min):
TIME START EVACUATION PUMP	VOLUME OF GAS REMOVED AT SAMPLE TIME (ml):
TIME STOP EVACUATION PUMP.	SYRINGE NUMBER

COMMENTS:

IS GROUNDWATER PRESENT IN THE SAMPLING PIPE?. YES NO

H:\ENG\SENECA\GENERIC\APPEND.A\SGFORM.WK3

FIGURE C-1

Page of

SOIL GAS SAMPLE LOCATION DATA

SAMPLE LOCATION:	
BLOWS PER 6 INCHES	OVM MAXIMUM
	TIME OF OVM MAXIMUM
DEPTH OF PENETROMETER POINT (ft)	TIME OF SOIL GAS SAMPLE:
DEPTH TO BOTTOM OF ROD (FT):	FLOW RATE (ml/min):
TIME START EVACUATION PUMP	VOLUME OF GAS REMOVED AT SAMPLE TIME (ml):
TIME STOP EVACUATION PUMP	SYRINGE NUMBER:

COMMENTS:

IS GROUNDWATER PRESENT IN THE SAMPLING PIPE? YES NO

SAMPLE LOCATION:	
BLOWS PER 6 INCHES.	OVM MAXIMUM.
	TIME OF OVM MAXIMUM
DEPTH OF PENETROMETER POINT (ft).	TIME OF SOIL GAS SAMPLE:
DEPTH TO BOTTOM OF ROD (FT)	FLOW RATE (ml/min)
TIME START EVACUATION PUMP	VOLUME OF GAS REMOVED AT SAMPLE TIME (ml)
TIME STOP EVACUATION PUMP	SYRINGE NUMBER

COMMENTS:

IS GROUNDWATER PRESENT IN THE SAMPLING PIPE? YES NO

SAMPLE LOCATION:	
BLOWS PER 6 INCHES	OVM MAXIMUM
	TIME OF OVM MAXIMUM
DEPTH OF PENETROMETER POINT (ft)	TIME OF SOIL GAS SAMPLE
DEPTH TO BOTTOM OF ROD (FT)	FLOW RATE (ml/min)
TIME START EVACUATION PUMP	VOLUME OF GAS REMOVED AT SAMPLE TIME (ml):
TIME STOP EVACUATION PUMP	SYRINGE NUMBER

COMMENTS:

IS GROUNDWATER PRESENT IN THE SAMPLING PIPE? YES NO

SAMPLE LOCATION:	
BLOWS PER 6 INCHES	OVM MAXIMUM
	TIME OF OVM MAXIMUM
DEPTH OF PENETROMETER POINT (ft)	TIME OF SOIL GAS SAMPLE
DEPTH TO BOTTOM OF ROD (FT):	FLOW RATE (ml/min):
TIME START EVACUATION PUMP	VOLUME OF GAS REMOVED AT SAMPLE TIME (ml)
TIME STOP EVACUATION PUMP	SYRINGE NUMBER

COMMENTS:

IS GROUNDWATER PRESENT IN THE SAMPLING PIPE? YES NO

H:\ENG\SENECA\GENERIC\APPEND.A\SGFORM.WK3

FIGURE C-1

4. Analytical Support

Soil gas samples are analyzed in the field using a portable gas chromatograph to facilitate real time data acquisition. A simplified explanation of the analytical procedure is provided in the following paragraphs.

The gas chromatograph instrument separates compounds in a chromatographic column (selected on a site-specific basis) and detects and quantifies the compounds using a detector.

After a sample is introduced to the chromatograph, it is carried by a carrier gas through the column. Different compounds pass through the column at different rates, resulting in a characteristic "retention time" for each compound. By comparison with standards, this retention time can be used to identify compounds. The detector responds to the presence of compounds by producing an electric current. The magnitude of this current can be used, when compared to standards, to determine concentrations of compounds present in the sample.

The analytical system to be utilized for this program is the portable Photovac 10SPlus gas chromatograph. This instrument is equipped with a heated capillary column and an on-board peak integrator. The detector for this instrument is the Photoionization Detector (PID). The PID is ideal for detecting volatile organic compounds which contain aromatic rings and unsaturated double bonds.

Quantitative analysis of soil gas requires quantitative gas standards. Gas standards will be prepared by a gas standard vendor such as Scott Specialty Gas or Canaan Scientific Products, Inc. The gas standard mixture will include benzene, toluen, ethylbenzene, and xylene at a concentration of approximately 100 ppmv each. This standard will be certified by the standard manufacturer and a certificate of analysis will accompany the gas standard. All field calibration standards will be prepared from this certified gas standard. Dilutions will be made from this standard by injecting a known volume of calibration gas into a clean glass sampling bulb of known volume.

Since the intent of the soil gas program is to indicate the presence of elevated concentrations of volatile organic compounds, soil gas results will be expressed as total volatile organic compounds as toluene. If retention time matches between the soil gas sample and the calibrated gas standard are within ± 1 sec. then individual compounds detected in the soil gas will be reported. However, since the soil gas program is a screening program determination of individual organic compounds is not critical to the detection and delineation of likely source areas.

A detailed description of the analytical procedures is as follows:

Calibration Procedures and Frequency

The analytical instrument will be calibrated each day prior to the analysis of a sample.

Gas Standards

Gas standards will be prepared from certified pre-calibrated compressed gas cylinders. Compressed gas standards offer advantages in time savings and ease of use. However, they are limited to only those compounds within the cylinder. The VOC concentrations will be traceable to National Bureau of Standards (NBS) standards.

The calibration procedure is as follows:

1. A two stage pressure regulator is attached to the cylinder for gas removal.

2. A clean, labeled, glass gas sampling bulb (approx. 125 ml), with a teflon connection is placed over the second stage effluent port. The teflon stopcocks at both ends are opened.

3. The diaphragm of the regulator is turned counterclockwise until the pressure in the diaphragm is unnoticeable by the hand.

4. The cylinder valve is opened. The first stage pressure will indicate the current cylinder pressure.

5. The second stage pressure is increased to 2 psig by turning the regulator valve clockwise.

6. Gas should be heard passing through the bulb as the second stage pressure is increased. The bulb is allowed to purge for approximately 10 seconds. The teflon stopcock furthest from the regulator is closed, then, the stopcock closest to the regulator is closed. The gas is now captured within the glass bulb at the delivery pressure of the regulator.

7. Using a gas-tight, designated syringe, an appropriate volume of captured gas will be removed from the bulb through the silicone septum and injected into the clean sampling bulb.

8. The Response Factor (RF) for each analyte is obtained as the ratio of the gas concentration injected and the area under the peak produced by that injection. This integration is performed electronically by the on-board electronic integrator.

9. Response factors will be obtained for each analyte listed in the gas standard.

10. For constant volume injections, the RF represents the concentration of analyte per unit area of instrument response. It is obtained by injecting a known concentration of analyte into the instrument and dividing the concentration by the area of the peak observed on the chromatogram. The analyte concentration in an unknown soil gas sample is determined by injecting an equal volume of gas into the gas chromatograph. The peak area obtained from the unknown sample is multiplied by the RF to determine the actual concentration of the analyte injected.

    The RF allows conversion of peak areas into concentrations for the contaminants of interest. The RF used is changed if the standard response varies 50%. If the standard injections vary by more than 50% the standard injections are repeated. If the mean of the two standard injections represents greater then 50% difference than a third standard is injected and a new RF is calculated from the three standard injections. A new data sheet is started with the new RFs and calibration data.

$$\% \; Difference = \frac{A\ area - B\ area}{A\ area}$$

Where: A = mean peak area of standard injection from first calibration
B = peak area of subsequent standard injection

The low peak standards will be made fresh daily.

A two point calibration curve will be performed daily, one point will be approximately 0.5 ppmv and the second point will be at approximately 5 ppmv. Dilutions of the calibrated gas standard will be performed using gas-tight syringes and injecting appropriate volumes into clean gas-tight gas sampling bulbs of known volume.

11. Syringe blanks will be performed for each syringe to be used prior to analysis. Syringes will be cleaned with Alconox or equivalent detergent and brush daily. They will be baked out in an oven at a minimum temperature of 60°C. for a minimum of 1 hour prior to use.

12. System blanks are ambient air drawn through a probe not installed in the ground and through the complete sampling apparatus. This air is analyzed by the same procedure as a soil gas sample. One system blank will be run at the start of each day from the batch of probes to be used.

13. A duplicate field sample will be taken after every 20 sample locations or at a minimum of one per day.

14. Field notebooks will be kept detailing the sample identification and amount of sample injected.

    The following system parameters will also be noted:

    a) Gas flows for the ultra pure air
    b) Tank pressures for the ultra pure air
    c) Integrator parameters
        1) Gain and baseline offset
    d) Column
        1) type
        2) length and diameter
        3) packing material
        4) temperature
    e) Operator
    f) Date and time

    If any system parameters change, the chromatograms are labeled with the changes noted.

15. Sample Documentation - The field notebooks will allow for full traceability of results. The response factors used and how they were calculated will be noted. The sample number, time, amount injected and the peak are noted.

The actual chromatogram can be traced from this information. The sample concentration is calculated using the RF, amount injected and peak area for the component of interest.

5. Data Interpretation

Data interpretation is an important element of the soil gas analysis. The acquired vapor phase concentrations are evaluated to determine the relationship between soil gas and source soils.

When examining chromatographs and comparing peak heights, several factors must be considered. Retention times (used to identify compounds) will vary with operating temperature and carrier gas flow rate. The detector responds to mass, not necessarily the concentration of the gas. Consequently, the sample volume injected into the chromatograph is important when interpreting output. "Gain", the degree of electronic amplification of the signal from the detector, must also be considered. If concentrations and volumes of two samples are equal, peak height will be higher in the one analyzed using a higher gain. Typically, large sample volumes and, if necessary, high gains are used to detect very low concentrations.

Typically, the soil gas survey is used to provide screening data, identifying areas where compounds are present and the total volatile organic concentration. This is primarily accomplished by expressing the concentrations of compounds as the benzene equivalents. Various volumes and concentrations of benzene gas reference standards are injected under similar operating conditions as those for the unknown samples. Quantification of VOCs in the samples is accomplished by comparing the area of the compound peaks on the sample chromatogram with the area of the benzene reference standard peak. This is most often accomplished by the instrument integrator, however, it can be accomplished manually.

The soil gas data will be tabulated by relating each location to a specific concentration of total volatile organic compound, expressed as benzene equivalents. Additionally, individual volatile organic peaks will be quantified, such as benzene, providing a reasonable retention time match can be obtained, ± 1 sec. This data will also be presented on a site map with each sampling location assigned a specific soil gas concentration. Soil gas isocontours will then be interpreted from the obtained data, thereby identifying approximate boundaries for likely source areas.

APPENDIX D

Procedure For
Soil Gas Sampling using SUMMA® Canisters

1. Scope/Purpose

This section describes procedures for conducting a soil gas survey using SUMMA® canisters. Soil gas surveys will be performed to evaluate the total volatile organic compounds at the vent wells and vapor monitoring points. The soil gas survey using SUMMA® canisters will be performed several times throughout the pilot test to confirm the results of the field soil gas screenings and to give insight as to whether the bioventing system is performing effectively.

2. Explanation of Method

This method involves extracting a representative sample of soil gas using a 1-liter (for high level samples; 1-L canisters will be used for initial testing) or 6-liter (for trace level samples) evacuated stainless steel SUMMA® canister and shipping the sample to an analytical laboratory for analysis by EPA Method TO-14. The presence of contaminants in the soil gas provides a strong indication that there is a source of volatile organics either in the soil near the well or in the groundwater below the well. The soil gas analysis is performed at a laboratory in order to confirm the results of the field soil gas screenings.

3. Soil Gas Sampling Procedure

Required Equipment:

- Evacuated SUMMA® canisters
- 2-7 micron filter
- 1/2 open end wrench
- 9/16 open end wrench
- hose barb adapter to adapt the threaded fitting on the canister to 3/16-inch
- Tygon® tubing
- Tedlar® bags.

Assembly of Sampling Hardware:

1. Remove the brass cap from the canister.
2. Connect the filter to the canister. Tighten the filter to the canister using the 9/16-inch wrench.
3. Connect the hose barb to the filter.
4. Connect the well head or the Tedlar® bag to the hose barb using 3/16-inch Tygon® tubing (using as short a connector as possible).

The above steps complete the assembly. Sampling will commence when the valve on the canister (green handle) is opened. Because the canisters are evacuated, when they are opened, the sample is collected almost instantaneously. Temperature and pressure do not need to be recorded because the samples are brought to a standard pressure and temperature in the lab. One sample in twenty (5%) should be a field duplicate.

In silt and clay soils the soil gas sample will first be collected in a new 2-liter Tedlar® bag (for 1-liter canister) using a vacuum chamber (egg) connected to the vapor well. The Tedlar® bag will then be connected to the evacuated canister using a 6-inch section of clean Tygon® tubing. The gas is transferred from the Tedlar® bag by first opening the Tedlar® bag valve and then opening the valve on the evacuated canister. The sample will transfer rapidly.

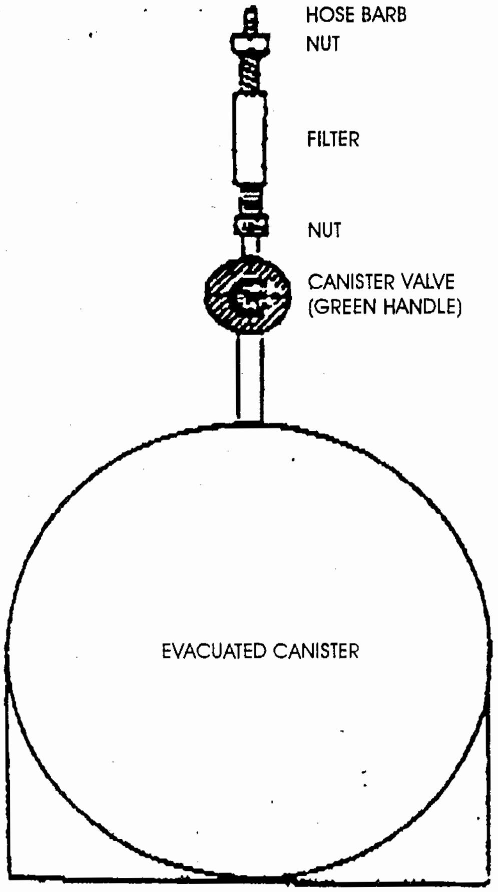
In sandy soils, the evacuated canister can be connected directly to a purged vapor monitoring point and the canister valve opened to draw a soil gas sample from the well.

When the sample transfer is complete, perform the following steps:

1. Close the valve (green handle) on the canister. It is not necessary to over-tighten the valve upon closing. Seal valve with a piece of tape to prevent reopening.
2. Remove the filter.
3. Replace the brass cap.
4. Fill out the sample tracking tag.
5. Return to laboratory for analysis.

Soil gas sample canisters will be placed in a small cooler and packed with foam pellets to prevent excessive movement during shipment. Samples will not be sent on ice to prevent possible condensation of hydrocarbons.

FIGURE D-1. Hardware Assembly for Soil Gas Sampling using SUMMA Canister



APPENDIX E

Procedure For
Soil Gas Permeability (Air Injection) Testing and Interpretation of Results

1. Scope/Purpose

This section describes procedures for conducting a soil gas permeability test.

2.1 Field Instrumentation and Measurement

2.1.1 Oxygen and Carbon Dioxide

Gaseous concentrations of carbon dioxide and oxygen will be analyzed using a GasTech model 3252OX carbon dioxide/oxygen analyzer or equivalent. The battery charge level will be checked to ensure proper operation. The air filters will be checked and, if necessary, cleaned or replaced before the experiment is started. The instrument will be turned on and equilibrated for at least 30 minutes before conducting calibration or obtaining measurements. The sampling pump of the instrument will be checked to ensure that it is functioning. Low flow of the sampling pump can indicate that the battery level is low or that some fines are trapped in the pump or tubing.

Meters will be calibrated each day prior to use against purchased carbon dioxide and oxygen calibration standards. These standards will be selected to be in the concentration range of the soil gas to be sampled. The carbon dioxide calibration will be performed against atmospheric carbon dioxide (0.05 %) and a 5 % standard. The oxygen will be calibrated using atmospheric oxygen (20.9 %) and against a 5 % and 0 % standard. Standard gases will be purchased from a specialty gas supplier. To calibrate the instrument with standard gases, a Tedlar™ bag (capacity approx. 1 L) is filled with the standard gas, and the valve on the bag is closed. The inlet nozzle of the instrument is connected to the Tedlar™ bag, and the valve on the bag is opened. The instrument is then calibrated against the standard gas according to the manufacturer's instructions. Next, the inlet nozzle of the instrument is disconnected from the Tedlar™ bag and the valve on the bag is shut off. The instrument will be rechecked against atmospheric concentration. If recalibration is required, the above steps will be repeated.

2.1.2 Hydrocarbon Concentrations

Petroleum hydrocarbon concentrations will be analyzed using a GasTech Trace-Techtor™ hydrocarbon analyzer (or equivalent) with range settings of 100 ppm, 1,000 ppm, and 10,000 ppm. The analyzer will be calibrated against two hexane calibration gases (500 ppm and 4,400 ppm). The Trace-Techtor™ has a dilution fitting that can be used to calibrate the instrument in the low concentration range.

Calibration of the GasTech Trace-Techtor™ is similar to the GasTech Model 32402X, except that a mylar bag is used instead of a Tedlar™ bag. The oxygen concentration must be above 10 % for the Trace-Techtor™ analyzer to be accurate. When the oxygen drops below 10 %, a dilution fitting must be added to provide adequate oxygen for analysis.

Hydrocarbon concentrations can also be determined with a flame ionization detector (FID), which can detect low (below 100 ppm) concentrations. A photoionization detector (PID) is *not* acceptable.

2.1.3 Pressure Vacuum Monitoring

Changes in soil gas pressure during the air permeability test will be measured at monitoring points using Magnehelic™ or equivalent gauges. Tygon™ or equivalent tubing will be used to connect the pressure/vacuum gauge to the quick-disconnect on the top of each monitoring point. Similar gauges will be positioned before and after the blower unit to measure pressure at the blower and at the head of the venting well. Pressure gauges are available in a variety of pressure ranges, and the same gauge can be used to measure either positive or negative (vacuum) pressure by simply switching inlet ports. Gauges are sealed and calibrated at the factory and will be re-zeroed before each test. The following pressure ranges (in inches H_20) will typically be available for this field test: 0-1", 0-5", 0-10", 0-20", 0-50", 0-100", and 0-200".

Air pressure during injection for the in situ respiration test will be measured with a pressure gauge having a minimum range of 0 to 30 psig.

2.1.4 Airflow Measurement

During the air permeability test, an accurate estimate of flow (Q) entering or exiting the vent well is required to determine k and R_I. Several airflow measuring devices are acceptable for this test procedure.

Pitot tubes or orifice plates combined with an inclined manometer or differential pressure gauge are acceptable for measuring flow velocities of 1,000 ft/min or greater (approx. 20 scfm in a 2-inch pipe). For lower flow rates, a large rotameter will provide a more accurate measurement. If an inclined manometer is used, the manometer must be re-zeroed before and after the test to account for thermal expansion/contraction of the water. Devices to measure static and dynamic pressure must also be installed in straight pipe sections according to manufacturer's specifications. All flow rates will be corrected to standard temperature and ambient pressure (altitude) conditions.

3. Soil Gas Permeability (Air Injection) Test Procedures

This section describes the field procedures that will be used to gather data to determine k and to estimate R_I.

Before the soil gas permeability test is initiated, the site will be examined for any wells (or other structures) that will not be used in the test but may serve as vertical conduits for gas flow. These will be sealed using pressure caps to prevent short-circuiting and to ensure the validity of the soil gas permeability test.

3.1 System Check

Before proceeding with this test, soil gas samples will be collected from the vent well, the background well, and all monitoring points and analyzed for oxygen, carbon dioxide, and volatile hydrocarbons.

After the blower system has been connected to the vent well and the power has been hooked up, a brief system check will be performed to ensure proper operation of the blower and the pressure and airflow gauges and to measure an initial pressure response at each monitoring point. This test is essential to ensure that the proper range of Magnehelic™ gauges are available for each monitoring point at the onset of the soil gas permeability (air injection) test. Generally, a 10- to 15-minute period of air extraction or injection will be sufficient to predict the magnitude of the pressure response, and the ability of the blower to influence the test volume.

3.2 Soil Gas Permeability (Air Injection) Test

After the system check, and when all monitoring point pressures have returned to zero, air will be introduced gradually into the soil matrix to condition the soil, allowing air to flow through it and prevent blow-out of the vent well seals. To begin, the bleed valve will be opened completely and the blower will be turned on. The bleed valve will then be closed slowly, gradually introducing air into the soil matrix. Air may be introduced into the matrix this way for as long as 24 hours before target flow rates are reached. Once target flow rates are reached, the system will be turned off. Once monitoring point pressures return to zero, the soil gas permeability test will begin. Two people will be required during the initial hour of this test - one to read the Magnehelic™ gauges and the other to record pressure (P') versus time on the data sheet. This will improve the consistency in reading the gauges and will reduce confusion. Typically, the following test sequence will be followed:

1. Connect the Magnehelic gauges to the top of each monitoring point with the stopcock opened. Return the gauges to zero.

2. Turn the blower unit on, and record the starting time to the nearest second.

3. At 1-minute intervals, record the pressure at each monitoring point beginning at $t = 60$ s.

4. After 10 minutes, extend the interval to 2 minutes. Return to the blower unit and record the pressure reading at the well head, the temperature readings, and the flow rate from the vent well.

5. After 20 minutes, measure P' at each monitoring point in 3-minute intervals. Continue to record all blower data at 3-minute intervals during the first hour of the test.

6. Continue to record monitoring point pressure data at 3-minute intervals until the 3-minute change in P' is less than 0. 1 in. of H_20. At this time, a 5- to 20-minute interval can be used. Review data to ensure accurate data were collected during the first 20 minutes. If the quality of these data is in question, turn off the blower, allow all monitoring points to return to zero pressure, and restart the test.

7. Begin to measure pressure at any groundwater monitoring points that have been converted to monitoring points. Record all readings, including zero readings and the time of the measurement. Record all blower data at 30 minute intervals.

8. Once the interval of pressure data collection has increased, collect soil gas samples from monitoring points and the blower exhaust (if extraction system), and analyze for oxygen, carbon dioxide, and hydrocarbons. Continue to gather pressure data for 4 to 8 hours. The test will normally be continued until the outermost monitoring point with a pressure reading does not increase by more than 10 % over a 1-hour interval.

9. Calculate the values of k and R_I with the data from the completed test; the HyperVentilate™ computer program is recommended for this calculation.

3.3 Post-Permeability Test Off Gas Monitoring

Immediately after the permeability test is completed, soil gas samples will be collected from the vent well, the background well, and all monitoring points, and analyzed for oxygen, carbon dioxide, and hydrocarbons. If the oxygen concentration in the vent well has increased by 5 % or more, oxygen and carbon dioxide will be monitored in the vent well in a manner similar to that described for the monitoring points in the in situ respiration test. (Initial monitoring may be less frequent.) The monitoring will provide additional in situ respiration data for the site.

4. Quality Control

- Descriptions and dates of all of the above activities will be documented in study records.
- Soil analysis information will be included in the study records. Photographs should be taken periodically and retained with the study records.
- Records will be kept as indicated in this procedure and will be reviewed periodically by the study/task leader.

Interpretation of Results of Soil Gas Air Permeability (Air Injection) Test

[from Principals and Practices of Bioventing, Vol. II: Bioventing Design

by Leeson and Hinchee, 1996]

1.5 Soil Gas Permeability and Radius of Influence

In situ respiration rates may be used to calculate the required air flowrate to satisfy oxygen demand at a given site[2]. However, it is necessary also to determine the distance air can physically be moved. An estimate of the soil's permeability to fluid flow (k) and the radius of influence (R_I) of venting wells are both important elements of a full-scale bioventing design. On-site testing provides the most accurate estimate of the soil gas permeability. On-site testing also can be used to determine the radius of influence that can be achieved for a given well configuration and flowrate. These data are used in full-scale system design, to space venting wells, to size blower equipment, and to ensure that the entire site receives a supply of oxygen-rich air to sustain in situ biodegradation.

---

[1] Calculated from a different field site. Refer to Example 3-2, Volume I for a description of the calculation of the activation energy.

[2] Refer to Section 2.2 for a presentation of the calculation of required air flowrates.

Soil gas permeability, or intrinsic permeability, can be defined as a soil's capacity for fluid flow, and varies according to grain size, soil uniformity, porosity, and moisture content. The value of k is a physical property of the soil; k does not change with different extraction/injection rates or different pressure levels.

Soil gas permeability is generally expressed in the units cm^2 or darcy (1 darcy = 1×10^{-8} cm^2). Like hydraulic conductivity, soil gas permeability may vary by more than an order of magnitude at one site because of soil variability. Table 1-12 illustrates the range of typical k values to be expected with different uniform soil types. Actual soils will contain a mixture of grain sizes, which generally will increase the observed darcy values based on pilot testing.

Table 1-12. Soil Gas Permeability Values (Johnson et al., 1990)

Soil Type	k in Darcy
Coarse sand	100 to 1,000
Medium sand	1 to 100
Fine sand	0.1 to 1.0
Silts/clay	<0.1

Several field methods have been developed for determining soil gas permeability (Sellers and Fan, 1991). The most commonly applied field test method probably is the modified field drawdown method developed by Paul Johnson at Arizona State University and former associates at the Shell Development Company. This method involves the injection or extraction of air at a constant rate from a single venting well while measuring the pressure/vacuum changes over time at several monitoring points in the soil away from the venting well[1].

The field drawdown method is based on Darcy's law and equations for steady-state radial flow to or from a vent well. A full mathematical development of this method and supporting calculations are provided by Johnson et al. (1990). The HyperVentilate™ computer program was produced by

---

[1] Refer to Appendix B for recommended specifications and manufacturers for the soil gas permeability testing equipment.

Johnson for use in storing field data and computing soil gas permeability. This or other commercially available programs can be used to speed the calculation and data presentation process.

Two solution methods may be used to calculate soil gas permeability, as described in Johnson et al. (1990). The first solution is based on carefully measuring the dynamic response of the soil to a constant injection or extraction rate. The second solution for soil gas permeability is based on steady-state conditions and the measurement or estimation of the radius of influence at steady state. Whenever possible, field data should be collected to support both solution methods because one or both of the solution methods may be appropriate, depending on site-specific conditions. An example procedure for conducting a soil gas permeability test is provided in Appendix C.

1.5.1 Radius of Influence Determination Based on Pressure Measurements

At a bioventing site, the radius of influence is defined as the maximum distance from the air extraction or injection well where a sufficient supply of oxygen for microbial respiration can be delivered. We will call the radius of influence measured by increased oxygen the "oxygen radius of influence". In practice, we frequently estimate this radius by measuring a pressure radius of influence. A description of how that is done will follow.

The oxygen and pressure radii of influence are a function of soil properties, but also are dependent on the configuration of the venting well and extraction or injection flowrates, and are altered by soil stratification. The oxygen radius of influence also depends on microbial oxygen utilization rates. At sites with shallow contamination, the oxygen and pressure radius of influence also may be increased by impermeable surface barriers such as asphalt or concrete. These paved surfaces may or may not act as vapor barriers. Without a tight seal to the native soil surface[1], the pavement will not significantly impact soil gas flow.

At a bioventing site, the oxygen radius of influence is the true radius of influence; however, for design purposes, we frequently use the pressure radius of influence. The pressure radius of influence is the maximum distance from a vent well where vacuum (in extraction mode) or pressure (in injection mode) can be measured. In practice, we usually use 0.1 inches of water as the cut off pressure. In highly permeable soils, 0.01 inches of water is a better cut off, if it can be reliably

---

[1] It is the authors' experience that at most sites, this seal does not occur.

measured. There is a connection between the pressure radius of influence and the oxygen radius of influence; however, there are many variables which are not fully understood. In practice, it has been our experience that when our design procedures are followed, that the oxygen radius of influence is larger than the measured pressure radius of influence, making the pressure radius of influence a reasonably conservative, rapid method for estimating the true radius of influence. The oxygen radius of influence may be determined directly by measuring the distance from the vent well at which a change in oxygen concentration can be detected. However, it may take several days to weeks for equilibrium to be reached and an accurate oxygen radius of influence to be measured. In addition, oxygen utilization rates may change, increasing or reducing the oxygen radius of influence. Therefore, if possible, it is best to measure the oxygen radius of influence at times of peak microbial activity. Alternatively, the pressure radius of influence may be determined very quickly, generally within 2 to 4 hours. Therefore, the pressure radius of influence typically is used to design bioventing systems.

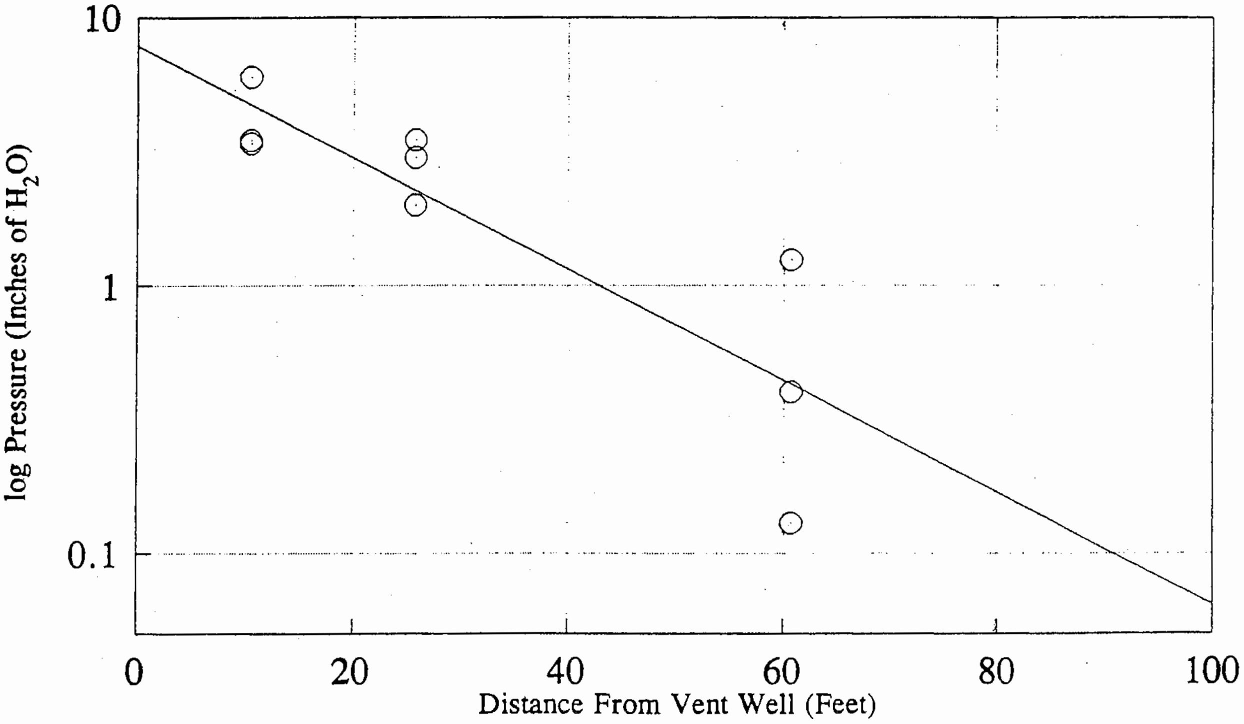
The pressure radius of influence should be determined at three different flowrates, with a 1- to 2-hour test per flowrate during the permeability test. Determining the radius of influence at different flowrates will allow for more accurate blower sizing[1]. Recommended flowrates for the permeability test are 0.5, 1.5, and 3 cfm (14, 42, 85 L/min) per ft (0.3 m) of well screen.

The pressure radius of influence may be estimated by determining pressure change versus distance from the vent well. The log of the pressure is plotted versus the distance from the vent well. The radius of influence is that distance at which the curve intersects a pressure of 0.1"H_2O (25 Pa). This value was determined empirically from Bioventing Initiative sites. Example 1-10 illustrates calculating the radius of influence in this manner.

Example 1-10. Calculation of the Radius of Influence Based on Pressure Measurements: Soil gas permeability results from the Saddle Tank Farm Site at Galena AFS, Alaska are shown in Figure 1-11 with the log of the steady-state pressure response at each monitoring point plotted versus the distance from the vent well. The radius of influence is taken to be the intersection of the resulting slope of the curve at a pressure of 0.1"H_2O (25 Pa). Therefore, in this instance, the pressure radius of influence would be estimated at 92 ft (28 m).

---

[1] Refer to Section 2.4 for a discussion of blower sizing.



c:\plot50\manual\GA1Rad.sp5

Figure 1-11. Determination of Radius of Influence at the Saddle Tank Farm, Galena AFS, Alaska

When using pressure radius of influence, it should be remembered that the estimated radius of influence actually is an estimate of the radius in which measurable soil gas pressures are affected and does not always equate to gas flow. In highly permeable gravel, for example, significant gas flow can occur well beyond the measurable radius of influence. On the other hand, in a low-permeability clay, a small pressure gradient may not result in significant gas flow.

1.5.2 Interpretation of Soil Gas Permeability Testing Results

The technology of bioventing has not advanced far enough to provide firm quantitative criteria for determining the applicability of bioventing based solely on values of soil permeability or the radius of influence. In general, the soil permeability must be sufficiently high to allow movement of oxygen in a reasonable time frame (1 to 10 days) from either the vent well, in the case of injection, or the atmosphere or uncontaminated soils, in the case of extraction. If such a flowrate cannot be achieved, oxygen cannot be supplied at a rate to match its demand. Closer vent well spacing or high injection/extraction rates may be required. If either the soil gas permeability or the radius of influence is high ($>$0.01 darcy or a R_I greater than the screened interval of the vent well), this is a good indicator that bioventing may be feasible at the site and it is appropriate to proceed to soil sampling and full-scale design. If either the soil gas permeability or the radius of influence is low ($<$0.01 darcy or a R_I less than the screened interval of the vent well), bioventing may not be feasible. In this situation, it is necessary to evaluate the cost effectiveness of bioventing over other alternative technologies for site remediation. The cost of installing a bioventing system at a low-permeability site will be driven primarily by the need to install more vent wells, use a blower with a higher delivery pressure, or install horizontal wells.

APPENDIX F

Procedure For In-Situ Respiration Testing and Interpretation of Results

1. Scope/Purpose

This section describes procedures for conducting an in-situ respiration test.

2.1 Field Instrumentation and Measurement

2.1.1 Oxygen and Carbon Dioxide

Gaseous concentrations of carbon dioxide and oxygen will be analyzed using a GasTech™ model 3252OX carbon dioxide/oxygen analyzer or equivalent. The battery charge level will be checked to ensure proper operation. The air filters will be checked and, if necessary, cleaned or replaced before the experiment is started. The instrument will be turned on and equilibrated for at least 30 minutes before conducting calibration or obtaining measurements. The sampling pump of the instrument will be checked to ensure that it is functioning. Low flow of the sampling pump can indicate that the battery level is low or that some fines are trapped in the pump or tubing.

Before use each day, meters will be calibrated against purchased carbon dioxide and oxygen calibration standards. These standards will be selected to be in the concentration range of the soil gas to be sampled. The carbon dioxide calibration will be performed against atmospheric carbon dioxide (0.05%) and a 5% standard. The oxygen will be calibrated using atmospheric oxygen (20.9%) and against a 5 % and 0 % standard. Standard gases will be purchased from a specialty gas supplier. To calibrate the instrument with standard gases, a Tedlar™ bag (capacity approx. 1 L) is filled with the standard gas, and the valve on the bag is closed. The inlet nozzle of the instrument is connected to the ppm Tedlar™ bag, and the valve on the bag is opened. The instrument is then calibrated against the standard gas according to the manufacturer's instructions. Next, the inlet nozzle of the instrument is disconnected from the Tedlar™ bag, and the valve on the bag is shut off. The instrument will be rechecked against atmospheric concentration. If recalibration is required, the above steps will be repeated.

2.1.2 Hydrocarbon Concentration

Petroleum hydrocarbon concentrations will be analyzed using a GasTech Trace-Techtor™ hydrocarbon analyzer (or equivalent) with range settings of 100 ppm, 1,000 ppm, and 10,000 ppm. The analyzer will be calibrated against two hexane calibration gases (500 ppm and 4,400 ppm). The Trace-Techtor™ has a dilution fitting that can be used to calibrate the instrument in the low-each concentration range.

Calibration of the GasTech Trace-Techtor™ is similar to the GasTech Model 32402X, except that a mylar bag is used instead of a Tedlar™ bag. The oxygen concentration must be above 10 % for the Trace-Techtor™ analyzer to be accurate. When the oxygen drops below 10 %, a dilution fitting must be added to provide adequate oxygen for analysis.

Hydrocarbon concentrations can be determined also with a flame ionization detector (FID), which can detect low (below 100 ppm) concentrations. A photoionization detector (PID) is *not* acceptable.

2.1.3 Helium Monitoring

Helium in the soil gas will be measured with a Marks Helium Detector Model 9821 or equivalent with a minimum sensitivity of 100 ppm (0.01 %). Calibration of the helium detector follows the same basic procedure described for oxygen calibration, except that the setup for calibration is different. Helium standards used are 100 ppm (0.01 *%),* 5,000 ppm (0.5%), and 10,000 ppm

2.1.4 Temperature Monitoring

In-situ soil temperature will be monitored using Omega Type J or K thermocouples (or equivalent). The thermocouples will be connected to an Omega OM-400 Thermocouple Thermometer (or equivalent). Each thermocouple will be calibrated against "ice water" and "boiling water" by the contractor before field installation.

2.1.5 Airflow Measurement

Before respiration tests are initiated at individual monitoring points, air will be pumped into each monitoring point using a small air compressor as described in Section 5.7 of the protocol document. Airflow rates of 1 to 1.5 cfm will be used, and flow will be measured using a Cole-Parmer Variable Area Flowmeter No. N03291-4 (or equivalent). Helium will be introduced into the injected air at a 1 % concentration. A helium flow rate of approximately 0.01 to 0.015 cfm (0.6 to 1.0 cfh) will be required to achieve this concentration. A Cole-Parmer Model L-03291-00 flowmeter or equivalent will be used to measure the flow rate of the helium feed stream.

2.2 In-situ Respiration Test Procedures

The in-situ respiration test should be conducted using at least four screened intervals of the monitoring points and a background well. The results from this test will determine if in-situ microbial activity is occurring and if it is oxygen-limited.

2.2.1 Test Implementation

Air with 1 to 2% helium will be injected into the vent wells. Following injection, the change of oxygen, carbon dioxide, total hydrocarbon, and helium in the soil gas will be measured over time. Helium will be used as an inert tracer gas to assess the extent of diffusion of soil gases within the aerated zone. A rate of helium loss that is less than the rate of oxygen loss would indicate that the oxygen loss is due to microbial degradation. A rate of helium loss that is greater than the rate of oxygen loss would indicate that the oxygen loss is due to system leakage or diffusion. If the background well is screened over an interval greater than 10 ft, the required air injection rate may be too high to allow helium injection. The background monitoring point will be used to monitor natural degradation of organic matter in the soil.

Oxygen, carbon dioxide, and total hydrocarbon levels will be measured at the monitoring points before air injection. Normally, air will be injected into the ground for at least 20 hours at rates ranging from 1.0 to 1.7 cfm (60 to 100 cfh). The blowers used will be diaphragm compressors Model 4Z024 from Grainger (or equivalent) with a nominal capacity of 1.7 cfm (100 cfh) at 10 psi. The helium used as a tracer will be 99% or greater purity, which is available from most welding supply stores. The flow rate of helium will be adjusted to 0.6 to 1.0 cfh to obtain about 1 % in the final air mixture which will be injected into the contaminated area. Helium in the soil gas will be measured with a Marks Helium Detector Model 9821 (or equivalent) with a minimum sensitivity of 0.01 %.

After air and helium injection is completed, the soil gas will be measured for oxygen, carbon dioxide, helium, and total hydrocarbon. Soil gas will be extracted from the contaminated area with a soil gas sampling pump system. Typically, measurement of the soil gas will be conducted at 2, 4, 6, and 8 hours and then every 4 to 12 hours, depending on the rate at which the oxygen is utilized. If oxygen uptake is rapid, more frequent monitoring will be required. If it is slower, less frequent readings will be acceptable.

At shallow monitoring points, there is a risk of pulling in atmospheric air in the process of purging and sampling. Excessive purging and sampling may result in erroneous readings. There is no benefit in over sampling, and when sampling shallow points, care will be taken to minimize the volume of air extraction. In these cases, a low-flow extraction pump of about 0.03 to 0.07 cfm (2.0 to 4.0 cfh) will be used. Field judgment will be required at each site in determining the sampling frequency.

The in-situ respiration test will be terminated when the oxygen level is about 5 %, or after 5 days of sampling. The temperature of the soil before air injection and after the in-situ respiration test will be recorded.

2.2.2 Data Interpretation

Data from the in-situ respiration tests will be summarized, and their oxygen utilization rates computed. Details on data interpretation are presented later in this appendix.

3. Quality Control

- Descriptions and dates of all of the above activities will be documented in study records.
- Soil analysis information will be included in the study records. Photographs will be taken periodically and retained with the study records.
- Records will be kept as indicated in this procedure and will be periodically reviewed by the study/task leader.

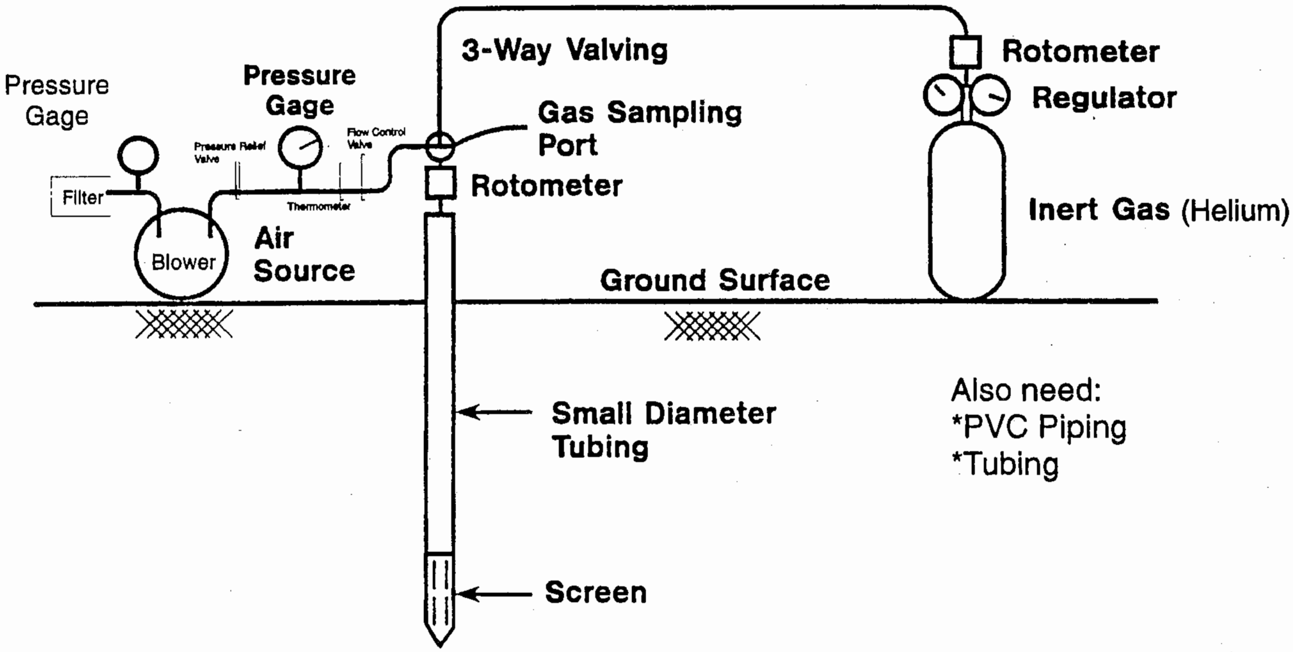


Figure F-1. In Situ Respiration Test Apparatus

Interpretation of Results of In-situ Respiration Test

[from Principals and Practices of Bioventing, Vol. II: Bioventing Design

by Leeson and Hinchee, 1996]

1.4 In Situ Respiration Testing

The in situ respiration test was developed to provide rapid field measurement of in situ biodegradation rates. This information is needed to determine the potential applicability of bioventing at a contaminated site and to provide information for a full-scale bioventing system design. This section describes the test as developed by Hinchee and Ong (1992). This respiration test has been used at each of the Bioventing Initiative sites and at numerous other sites throughout the United States. The in situ respiration test described in this document is essentially the same as the described by Hinchee and Ong (1992), with minor modifications.

1.4.1 In Situ Respiration Test Procedures

The in situ respiration test is conducted by placing narrowly screened soil gas monitoring points into the unsaturated zone of contaminated soils and venting these soils for a given period of time with air containing an inert tracer gas (typically helium). The apparatus for the respiration test is illustrated in Figure 1-6[1]. An example procedure for conducting an in situ respiration test is provided in Appendix C.

As part of the Bioventing Initiative, respiration rates in uncontaminated areas of similar geology to the contaminated test site were evaluated. Given the results, it was evident that measurement of background respiration rates was not necessary since there was little significant respiration. Instead, it is recommended that oxygen and carbon dioxide be measured in an uncontaminated location of similar geology, and, if there is significant oxygen depletion, only then should a background in situ respiration test be conducted since there may be significant background respiration.

In a typical experiment, a cluster of three to four soil gas probes are placed in the contaminated soil of the test location. These soil gas probes must be located in the center of contaminated areas where low soil gas oxygen concentrations and high TPH concentrations have been measured. If the monitoring points are not located in contaminated areas, the in situ respiration test

---

[1] Refer to Appendix B for recommended specifications and manufacturers for the in situ respiration testing equipment.

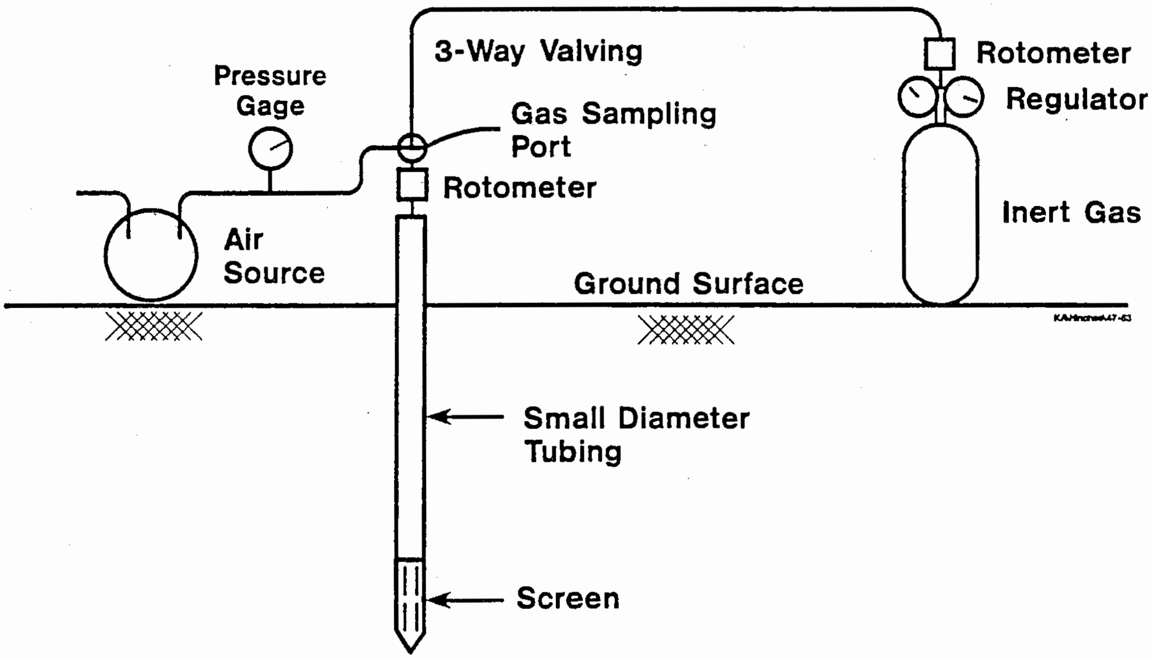


Figure 1-6. In Situ Respiration Test Apparatus

will not produce meaningful results. Additional detail on monitoring point location and construction is provided in Section 2.6.

Measurements of carbon dioxide and oxygen concentrations in the soil gas are taken prior to air and inert gas injection. A 1 to 3% concentration of inert gas is added to the injection air, which is injected for approximately 24 hours at flowrates ranging from 1.0 to 1.7 cfm (28 to 48 L/min). The air provides oxygen to the soil, and the inert gas measurements provide data on the diffusion of oxygen from the ground surface and the surrounding soil and to ensure that the soil gas sampling system does not leak. The background control location is placed in similar soils in an uncontaminated area to monitor natural background respiration rates.

After air and inert gas injection are turned off, oxygen, carbon dioxide, and inert gas concentrations are monitored over time. Before a reading is taken, the probe is purged for a few minutes until the carbon dioxide and oxygen readings are constant. Initial readings are taken every 2 hours and then progressively over 4- to 8-hour intervals. If oxygen uptake is rapid, more frequent monitoring may be required. If it is slower, less frequent readings may be acceptable. The experiment usually is terminated when the soil gas oxygen concentration is approximately 5%.

As discussed in Section 1.2, at shallow monitoring points there is a risk of pulling in atmospheric air in the process of purging and sampling. Excessive purging and sampling may result in erroneous readings. There is no benefit in oversampling and, when sampling shallow points, care must be taken to minimize the volume of air extraction. In these cases, a low-flow extraction pump of about 0.03 to 0.07 cfm (0.85 to 2.0 L/min) should be used.

1.4.2 Interpretation of In Situ Respiration Test Results

Oxygen utilization rates are determined from data obtained during the in situ respiration test. The rates are calculated as the zero order relationship between percent oxygen and time. Typically, a rapid linear decrease in oxygen is observed, followed by a lag period once oxygen concentrations drop below approximately 5%. To calculate oxygen utilization rates, only the first linear portion of the data is used because this represents oxygen utilization when oxygen is not limiting, as is the case during active bioventing.

To estimate hydrocarbon biodegradation rates from the oxygen utilization rates, a stoichiometric relationship for the oxidation of the contaminant is used. For hydrocarbons, hexane is used as the representative hydrocarbon. If a site is contaminated with compounds other then petroleum hydrocarbons, a suitable compound should be used to determine stoichiometry. The stoichiometric relationship used to determine petroleum degradation rates is:

$$C_6H_{14} + 9.5O_2 \rightarrow 6CO_2 + 7H_2O \tag{1-1}$$

Based on the utilization rates (% oxygen per day), the biodegradation rate in terms of mg hexane-equivalent per kg of soil per day is estimated using Equation (1-2).

$$k_B = \frac{-\frac{k_o}{100}\,\theta_a\,\frac{1L}{1{,}000\ cm^3}\,\rho_{O_2}\,C}{\rho_k\left(\frac{1\ kg}{1{,}000\ g}\right)} = \frac{-k_o\,\theta_a\,\rho_{O_2}\,C\,(0.01)}{\rho_k} \tag{1-2}$$

where: k_B = biodegradation rate (mg/kg-day)

k_o = oxygen utilization rate (%/day)

θ_a = gas-filled pore space (volumetric content at the vapor phase, m^3 gas/cm^3 soil)

ρ_{O2} = density of oxygen (mg/L)

C = mass ratio of hydrocarbons to oxygen required for mineralization (1/3.5)

ρ_k = soil bulk density (g/cm^3)

These terms may be derived through either direct measurement or estimation. The oxygen utilization rate, k_o is directly measured in the in situ respiration test. The ratio of hydrocarbons to oxygen required for mineralization, C, can be calculated based on stoichiometry (see Equation (1-1) for hexane) but generally will fall between 0.29 and 0.33. This neglects any conversion to biomass, which probably is small and difficult, if not impossible, to measure. The density of oxygen may be obtained from a handbook for a given temperature and pressure or calculated from the ideal gas law. Table 1-6 provides some useful oxygen density information. The bulk density of soil is difficult to

Table 1-6. Oxygen Density Versus Temperature

Temperature (°C)	Temperature(°F)	Density (mg/L)[1]	Density (lb/ft^3)[1]
-33	-27.4	1,627[2]	0.10[2]
-3	26.6	1,446[3]	0.090[3]
0	32	1,429[3]	0.089[3]
5	41	1,403[3]	0.088[3]
10	50	1,378[3]	0.086[3]
15	59	1,354[3]	0.084[3]
20	68	1,331[3]	0.083[3]
27	80.6	1,301[2]	0.082[2]
30	86	1,287[3]	0.080[3]
35	95	1,266[3]	0.079[3]
40	104	1,246[3]	0.078[3]
57	134.6	1,182[2]	0.074[2]
87	188.6	1,083[2]	0.067[2]
127	260.0	975[2]	0.061[2]

[1] Oxygen density at standard pressure.

[2] Density values from Braker and Mossmon, 1980.

[3] Density calculated using the second virial coefficient to the equation of state for oxygen gas:

$$P = \frac{RT}{V}\left[1 + \frac{B(T)}{V}\right]$$

where P = pressure (atm), R = gas constant, V = molar volume, and B = second virial coefficient. The temperature dependence of B was calculated from:

$$B(T) = \sum_{i=1}^{n} A_i \left[\frac{T_0}{T} - 1\right]^{i-1}$$

The constants A^i were obtained from Lide and Kehianian (1994).

accurately measure due to the difficulty of collecting an undisturbed sample; however, it may be reasonably estimated from the literature. Table 1-7 lists useful literature values for bulk density.

The gas-filled porosity, θ_a, is the single parameter in Equation (1-2) with the most variability. Theoretically, it can be related to the total porosity, soil bulk density, and moisture content. A doubling of the air-filled porosity results in a doubling of the estimated hydrocarbon degradation rate. Gas-filled porosity may be as high as 0.5 to 0.6 in some very dry clays, but saturated soil is zero. To collect soil gas samples, the gas-filled porosity must be sufficient to allow gas flow. Therefore, it is not possible to conduct an in situ respiration test at very low gas-filled porosity. At most bioventing sites, θ_a ranges from 0.1 to 0.4. Soil in a core or split-spoon sample will be compressed, thereby reducing θ_a. It can be estimated as follows:

$$\theta_a = \theta - \theta_W \tag{1-3}$$

where: θ = total porosity (cm^3/cm^3)

θ_W = water-filled porosity (cm^3/cm^3)

The total void volume may be estimated as:

$$\theta = 1 - \frac{\rho_k}{\rho_T} \tag{1-4}$$

where: ρ_k = soil bulk density (g dry soil/cm^3) (from Table 1-7)

ρ_T = soil mineral density (g/cm^3), estimated at 2.65

The water-filled void volume then can be calculated as:

$$\theta_W = M \frac{\rho_k}{\rho_T} \tag{1-4}$$

where: M = soil moisture (g moisture/g soil)

Table 1-7. Bulk Density of Various Soils[1]

Soil Description	Porosity	Soil Bulk Density, ρ_k (dry g/cm^3)
Uniform sand, loose	0.46	1.43
Uniform sand, dense	0.34	1.75
Mixed-grain sand, loose	0.40	1.59
Mixed-grain sand, dense	0.30	1.86
Windblown silt (loess)	0.50	1.36
Glacial till, very mixed-grained	0.20	2.12
Soft glacial clay	0.55	1.22
Stiff glacial clay	0.37	1.70
Soft slightly organic clay	0.66	0.93
Soft very organic clay	0.75	0.68
Soft montmorillonitic clay (calcium bentonite)	0.84	0.43

[1] From Peck et al. (1962).

Because the water-filled porosity (θ_W) is a difficult parameter to estimate accurately, it frequently is assumed to be 0.2 or 0.3.

Using several assumptions, values for θ_a, ρ_{O2}, C, and ρ_k can be calculated and substituted into Equation (1-2). Assumptions used for these calculations are:

- Gas filled porosity (θ_a) of 0.25
- Soil bulk density (ρ_k) of 1.4 g/cm
- Oxygen density (ρ_{O2}) of 1,330 mg/L
- C, hydrocarbon-to-oxygen ratio of 0.29 from Equation (1-1) for hexane.

The resulting equation is:

$$k_B = \frac{-(k_o)\ (0.25)\ (1{,}330)\ (0.29)\ (0.01)}{1.4} = -\ 0.68\ k_o \qquad (1\text{-}5)$$

The biodegradation rates measured by the in situ respiration test appear to be representative of those for a full-scale bioventing system. Miller (1990) conducted a 9-month bioventing pilot project at Tyndall AFB at the same time Hinchee et al. (1991b) were conducting an in situ respiration test. The oxygen utilization rates (Miller, 1990) measured from nearby active treatment areas were virtually identical to those measured in the in situ respiration test. Oxygen utilization rates greater than 1.0%/day are a good indicator that bioventing may be feasible at the site and that it is appropriate to proceed to soil gas permeability testing. If oxygen utilization rates are less than 1.0%/day, yet significant contamination is present, other factors may be involved in limiting biodegradation. In this case, other process variables as discussed in Section 3.3 should be considered as limiting biodegradation. Identifying these other process variables may require additional soil sampling and analysis. If none of these other process variables can be identified as potentially limiting microbial degradation, alternative technologies may have to be employed for site remediation.

Example 1-6. Results From An In Situ Respiration Test Conducted at Keesler AFB: At the site described in Example 1-1, an in situ respiration test was conducted. After the soil gas survey, three-level monitoring points were installed at each of the soil gas survey point locations, because these areas were highly contaminated and were oxygen-limited. Initial soil gas readings were taken at each of the monitoring points and are shown in Table 1-8. Since all locations were oxygen limited, it was decided to inject air at the deepest level of each of the monitoring points (K1-MPA-7.0′, K1-MPB-7.0′, K1-MPC-7.0′, and K1-MPD-7′1″).

Table 1-9 contains data collected at each monitoring point during the in situ respiration test. The oxygen utilization rate is determined as the slope of the % oxygen versus time curve. Only data beginning with that taken at t=0 that appear linear with time were used to calculated the slope. A zero-order respiration rate as seen in these data is typical of most sites (Figure 1-7). Calculated oxygen utilization rates and corresponding biodegradation rates for these data are shown in Table 1-10.

Results of this test indicate that this site is an excellent candidate for bioventing.

Example 1-6 illustrates the calculation of oxygen utilization data that is linear with time. However, in some instances, this relationship will not be linear and only selected data should be used to calculate the oxygen utilization rate. Example 1-7 illustrates calculation of the oxygen utilization rate from nonlinear data.

Example 1-7. Calculation of Oxygen Utilization Rates From Nonlinear Data: Table 1-11 contains sample data from the Solid Waste Management Unit (SWMU) 66, Keesler AFB. The oxygen utilization rate is determined as the slope of % oxygen versus time curve. Only data beginning with that taken at t=0 that appear linear with time should be used to calculate the slope. A fairly rapid change in oxygen levels was observed at Keesler AFB (Figure 1-8). In this case, the oxygen utilization rate was obtained from the initial linear portion of the respiration curve, which included data from t=0 to t=30.5 hr. As shown, after this point, oxygen concentrations dropped below 5%, and were limiting. The calculated oxygen utilization rate was 11%/day.

The helium data collected at a site will provide insight into whether observed oxygen utilization rates are due to microbial utilization or to other effects such as leakage or diffusion. As a rough estimate, diffusion of gas molecules is inversely proportional to the square root of the molecular weight of the gas. Based on the molecular weights of 4 and 32 g/mole for helium and oxygen, respectively, helium diffuses about 2.8 times faster than oxygen. Thus, although helium is a conservative tracer, its concentration should decrease with time. As a general rule of thumb, one should consider any in situ respiration test in which the rate of helium loss is less than the oxygen loss rate to be an acceptable test. If the helium loss rate is greater than the oxygen loss rate, disregard the test from that monitoring point. We do not use the helium loss rate to correct the oxygen utilization rate.

Table 1-8. Initial Soil Gas Readings at Monitoring Points at AOC A, Keesler AFB, Mississippi

Monitoring Point	Depth (ft)	Oxygen (%)	Carbon Dioxide (%)	TPH (ppmv)
K1-MPA	3.0	0.1	16	>100,000
	5.0	0.4	15	>100,000
	7.0	0.6	15	>100,000
K1-MPB	2.5	0.5	15	>100,000
	4.0	0.5	15	>100,000
	7.0	0.8	15	>100,000
K1-MPC	3.0	0.4	14	28,000
	5.0	0.1	15	30,000
	7.0	0.5	15	29,000
K1-MPD	3.0	0.6	14	45,000
	5.0	0.5	15	54,000
	7′1″	0.5	15	58,000
Background		16.8	4.6	140

Table 1-9. Raw Data From an In Situ Respiration Test at AOC A, Keesler AFB, Mississippi

Time (hr)	K1-MPA-5.0′			K1-MPA-7.0′		
	O_2 (%)	CO_2 (%)	He (%)	O_2(%)	CO_2(%)	He(%)
0	20.7	0	1.4	20.5	0	1.4
5	20.6	0	1.6	20.6	0	1.4
10	20.1	0.1	1.4	20.3	0.1	1.4
25	19.0	0	1.75	20.1	0	1.6
37	17.8	0	1.4	19.5	0	1.4
50	16.9	0.6	1.4	18.7	0.2	1.25
75	15.2	1.2	1.6	17.3	1.2	1.6
99	14.0	2.0	1.4	16.3	1.2	1.4
Time (hr)	K1-MPB-5.0′			K1-MPC-7.0′		
0	20.6	0	1.6	20.8	0	1.3
5	20.2	0	1.8	20.5	0.2	1.5
10	19.4	0	14	20.2	0.2	1.4
25	16.9	0	1.6	19.5	0	1.3
37	14.8	0	1.4	18.1	0.6	1.2
50	12.9	1.0	1.4	16.9	1.5	1.2
75	9.9	2.6	1.2	13.9	3.0	1.0
99	8.0	3.0	1.2	11.0	4.0	1.0

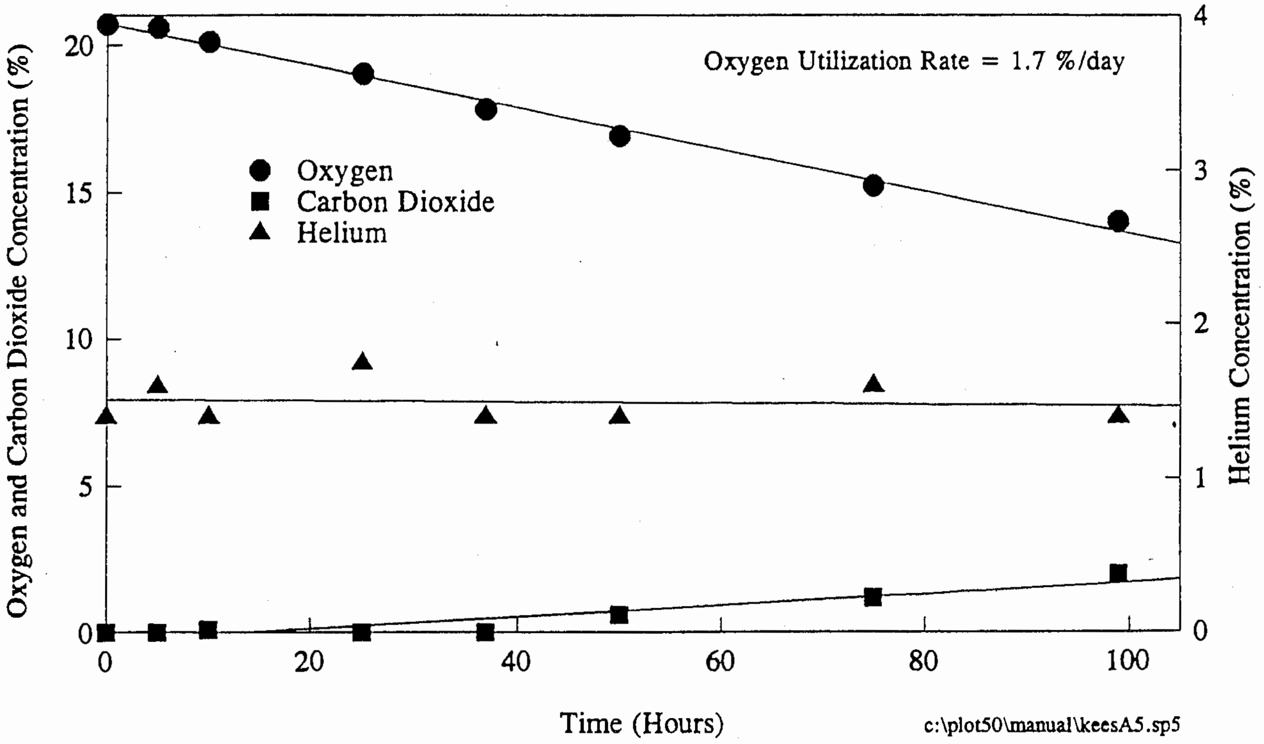


Figure 1-7. **In Situ Respiration Test Results with Linear Oxygen Concentration Versus Time at AOC A, Keesler AFB, Mississippi**

Table 1-10. Oxygen Utilization and Carbon Dioxide Production Rates During the In Situ Respiration Test at AOC A, Keesler AFB, Mississippi

Sample Name	Oxygen Utilization Rate (%/hour)	Estimated Biodegradation Rate (mg/kg-day)
K1-MPA-5.0′	0.071	1.16
K1-MPA-7.0′	0.045	0.73
K1-MPB-5.0′	0.13	2.12
K1-MPC-7.0	0.099	1.62
Background	0.012	0.20

Table 1-11. Raw Data From an In Situ Respiration Test at SWMU 66, Keesler AFB, Mississippi

Time (Hours)	Oxygen (%)	Carbon Dioxide (%)	Helium (%)
0	20.5	0	1.6
6.3	18.1	.05	1.6
9.3	16.5	1.0	1.6
15	14	2.2	1.8
22	11	3.2	1.5
31	6.8	5.0	1.5
48	3.7	5.1	1.5
57	2.9	5.1	1.5

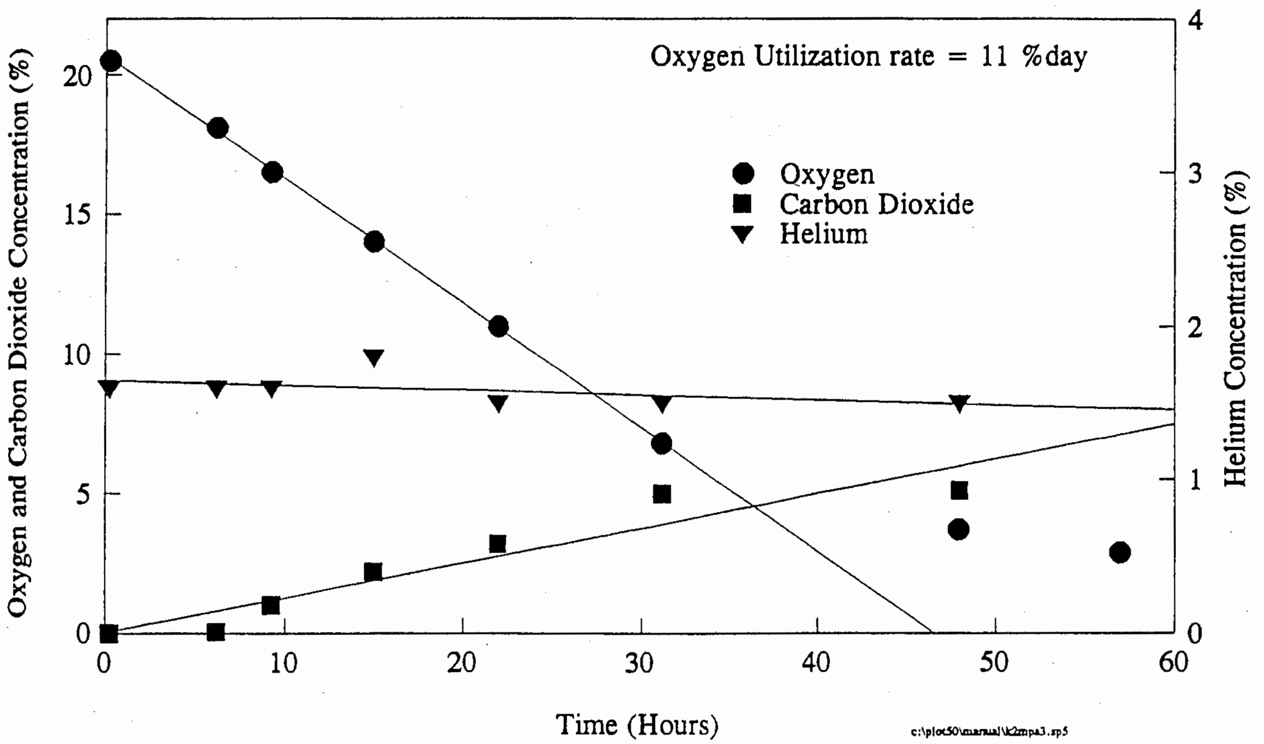


Figure 1-8. In Situ Respiration Test Results with Nonlinear Oxygen Concentration Versus Time at SWMU 66, Keesler AFB, Mississippi

Example 1-8. Evaluation of Helium Loss During an In Situ Respiration Test: Figures 1-9 and 1-10 show helium data for two test wells. The helium concentration at monitoring point S1 (Figure 1-9) at Tinker AFB started at 1.5% and after 108 hours had dropped to 1.1%, i.e., a fractional loss of ~0.25; and, therefore, an acceptable point. In contrast, for Kenai K3 (Figure 1-10), the change in helium was rapid (a fractional drop of about 0.8 in 7 hours), indicating that there was possible short circuiting at this monitoring point. This suggested that the data from this monitoring point were unreliable, and the data were not used in calculating degradation rates.

1.4.3 Factors Affecting Observed In Situ Biodegradation Rates

Because in situ biodegradation rates are measured indirectly through measurements of soil gas oxygen and carbon dioxide concentrations, abiotic processes that affect oxygen and carbon dioxide concentration will affect measured biodegradation rates. The factors that may most influence soil gas oxygen and carbon dioxide concentrations are soil pH, soil alkalinity, and iron content. In addition, any environmental parameter that may affect microbial activity also may affect observed oxygen utilization rates. Soil temperature often is a significant factor at bioventing sites.

At several sites, oxygen utilization has proven to be a more useful measure of biodegradation rates than carbon dioxide production. The biodegradation rate in mg of hexane-equivalent/kg of soil per day based on carbon dioxide production usually is less than can be accounted for by the oxygen disappearance. At virtually all sites studied as part of the Bioventing Initiative, oxygen utilization rates have been higher than carbon dioxide production rates. However, a study conducted at Tyndall AFB site was an exception. That site had low-alkalinity soils and low-pH quartz sands, and carbon dioxide production actually resulted in a slightly higher estimate of biodegradation (Miller, 1990).

In the case of the higher pH and higher alkalinity soils at Fallon NAS and Eielson AFB, little or no gaseous carbon dioxide production was measured (Hinchee et al., 1991a; Leeson et al., 1995). This is possibly due to the formation of carbonates from the gaseous evolution of carbon dioxide produced by biodegradation at these sites. A similar phenomenon was encountered by van Eyk and Vreeken (1988) in their attempt to use carbon dioxide evolution to quantify biodegradation associated with soil venting.

Iron is a nutrient required for microbial growth, but the iron also may react with oxygen to form iron oxides. Theoretically, if a significant amount of iron oxidation were to occur, the observed oxygen utilization rate would reflect both iron oxidation and microbial activity. Therefore, calculated biodegradation rates would be an overestimate of actual biodegradation rates. However, in data collected from the Bioventing Initiative study, iron concentrations have varied greatly, ranging from less than 100 mg/kg to greater than 100,000 mg/kg, with no apparent impact on oxygen utilization rates. Iron impact on oxygen utilization rates has been observed at only one site, the Marine Base at Kaneohe, Hawaii, where soil iron concentrations are in the 100,000 mg/kg range.

It is important to consider whether the respiration rate was measured at the time of year when microbial activity rates were at their maximum (summer) or if it was measured when activity was low (winter). Investigations at a number of sites have shown that microbial rates can vary by as much as an order of magnitude between peak periods. For design of oxygen delivery systems, respiration rates should be measured during the peak season, typically late summer.

If oxygen utilization rates were determined during periods of low activity, it will be necessary to adjust the rates to the maximum level before making size calculations. The van't Hoff-Arrhenius equation can be used to predict oxygen utilization rates given an initial rate and temperature[1]. The activation energy, E_a must either be known for the site or calculated by using E_a found at another site, recognizing that the temperature-adjusted rate is only a rough estimate. The following example illustrates a typical adjustment.

Example 1-9. Temperature Adjustment of Oxygen Utilization Rate: The oxygen utilization rate was measured in January at a site in Cheyenne, Wyoming. The rate was determined to be 0.75%/day (0.031%/hr). The temperature in the soil was measured at 4°C. Previous temperature measurements at the site have indicated that soil temperatures in August average approximately 24°C, i.e., 20°C higher than the temperature measured during January. The temperature adjustment to the rate for sizing calculations is as follows:

Using the van't Hoff-Arrhenius equation (Metcalf & Eddy, 1979):

$$\frac{dk}{dT} = \frac{E_a}{RT^2} \tag{9}$$

Integration of this equation between the limits T_1 (277°K) and T_2 (297°K) gives:

---

[1] Refer to Volume I for a discussion of the effect of temperature on microbial activity.

$$\ln \frac{k_T}{k_o} = \frac{E_a\,(T_2 - T_1)}{RT_1T_2}$$

where: k_T = temperature-corrected oxygen utilization rate (% O_2/day)
k_o = baseline reaction rate = 0.75%/day
E_a = activation energy[1] = 13.4 kcal/mole
R = gas constant = 1.987 cal/°K-mole
T_1 = absolute temperature for k_o = 277°K
T_2 = absolute temperature for k_T = 297°K

$$k_T = \left(0.75\,\frac{\%}{\text{day}}\right) e^{\left[\frac{(13{,}400\,\text{cal/mole})(297^\circ\text{K} - 277^\circ\text{K})}{\left(1.987\frac{\text{cal}}{^\circ\text{K mole}}\right)(297^\circ\text{K})(277^\circ\text{K})}\right]}$$

$$k_T = 3.9\,\frac{\%}{\text{day}}$$

As can be seen from this calculation, the site would require approximately 5 times greater oxygen delivery rate in the summer.

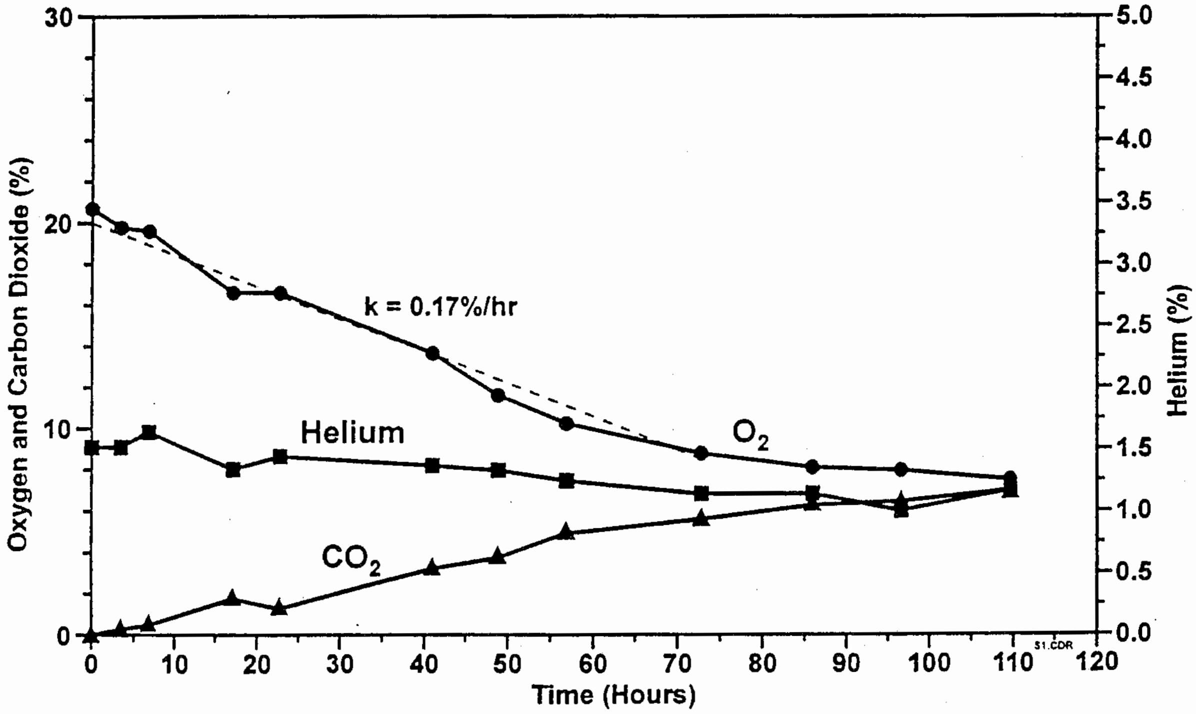


Figure 1-9. In Situ Respiration Test Results With Acceptable Data Based on the Helium Concentration for Monitoring Point S1, Tinker AFB, Oklahoma

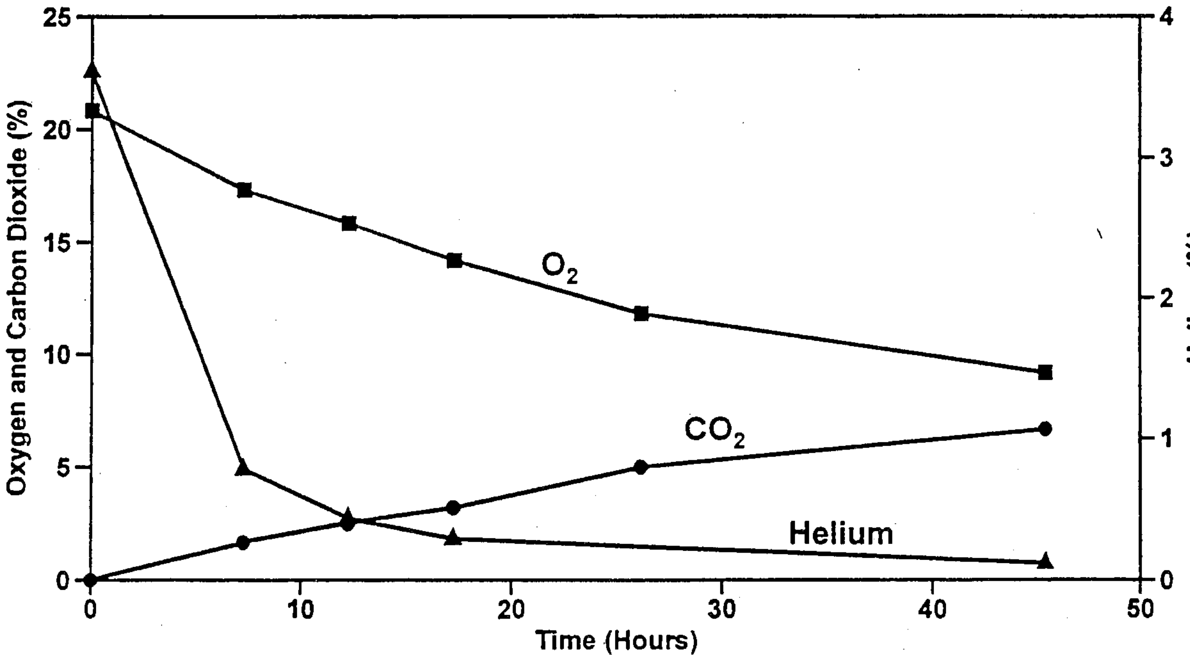


Figure 1-10. In Situ Respiration Test Results With Unacceptable Data Based on the Helium Concentration for Monitoring Point K3, Kenai, Alaska

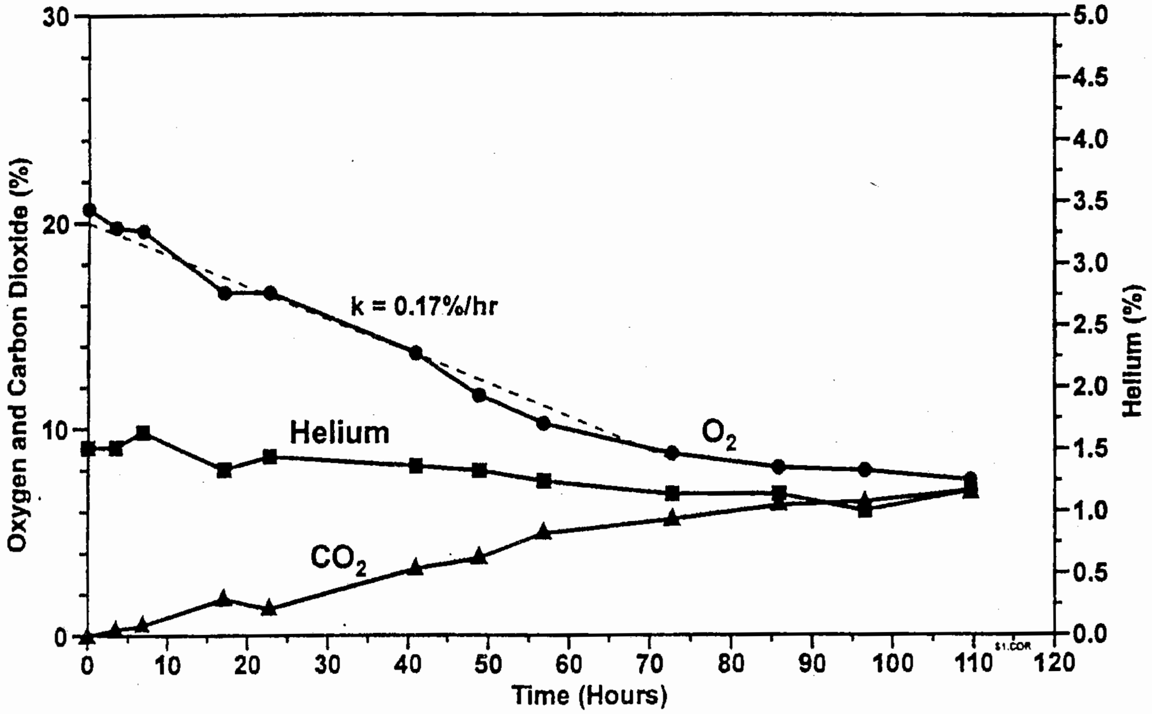


Figure D-2. In situ Respiration Test Results with Acceptable Data Based on Helium Concentration for Monitoring Point (after Leeson and Hinchee, 1996).

APPENDIX G

RI/FS Monitoring Well Completion Diagrams at SEAD-25

LOG OF BORING NO. SB25-1

PROJECT: SEAD-25 & SEAD-26 RI/FS
PROJECT LOCATION: Seneca Army Depot Activity, Romulus, NY 14541
ASSOCIATED UNIT/AREA: SEAD-25
PROJECT NO: 728059
DATE STARTED: 12/03/93
DATE COMPLETED: 12/03/93
DRILLING CONTRACTOR: Empire Soils Investigation, Inc.
DRILLING METHOD: Hollow Stem Auger
SAMPLING METHOD: 3 inch Split Spoons

DEPTH TO WATER (ft): NA
BORING LOCATION (N/E): 998092.6 751014.3
REFERENCE COORDINATE SYSTEM: NY STATE PLANAR
GROUND SURFACE ELEVATION (ft): 743.5
DATUM: NGVD 83
INSPECTOR: B.Harvey, M.Burns
CHECKED BY: P.Feschbach-Merineу

This log is part of a report prepared by Parsons Engineering-Science, Inc. for the named project and should be read together with the report for complete interpretation. This summary applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations.

Sample Number	Blow Counts (# Blows per 6")	Sample Advance	Sample Recovery	VOC Screen-PID (ppm)	Rad Screen (cps)	Depth (ft.)	USCS CLASS	DESCRIPTION	Depth	Macro	Macro Lithology
SB25 -1.1	8 10 10 16	2.00	1.0	0	NA	1.0	GM	Dark brown to black fine gravel-sized SHALE fragments, little fine Sand, wet, petroleum odor.	0.00 1.00	FL	
							ML	Grayish brown SILT and CLAY, little fine to medium gravel-sized Shale, trace very fine Sand, moist, no odor.		TL	
SB25 -1.2	6 12 14 20	2.00	1.2	0	NA						
SB25 -1.3	27 45 60 60	2.00	1.9	0	NA						
SB25 -1.4	45 95 100/.1	1.10	1.1	0	NA	6.5			6.50		
								Dark gray highly fissile SHALE, some interstitial brown Silt, Clay, and very fine Sand, dry, no odor.		WS	
								SPLIT SPOON REFUSAL AT 7.1 FEET.	7.10		
								Dark gray to black SHALE, dry, no odor.		CS	

NOTES:

PARSONS
ENGINEERING-SCIENCE, INC.

UNITED STATES ARMY
CORPS OF ENGINEERS
Seneca Army Depot
Romulus, New York

LOG OF BORING SB25-1

Sheet 1 of 1

LOG OF BORING NO. SB25-2

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
ASSOCIATED UNIT/AREA: **SEAD-25**
PROJECT NO: **728059**
DATE STARTED: **12/03/93**
DATE COMPLETED: **12/03/93**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Hollow Stem Auger**
SAMPLING METHOD: **3 inch Split Spoons**

DEPTH TO WATER (ft): **NA**
BORING LOCATION (N/E): **998050.0 751015.9**
REFERENCE COORDINATE SYSTEM: **NY STATE PLANAR**
GROUND SURFACE ELEVATION (ft): **743.7**
DATUM: **NGVD 83**
INSPECTOR: **E. Schacht**
CHECKED BY: **P.Feschbach-Meriney**

This log is part of a report prepared by Parsons Engineering-Science, Inc. for the named project and should be read together with the report for complete interpretation. This summary applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations.

Sample Number	Blow Counts (# Blows per 6")	Sample Advance	Sample Recovery	VOC Screen-PID (ppm)	Rad Screen (cps)	Depth (ft.)	USCS CLASS	DESCRIPTION	Depth	Macro
SB25 -2.1	10 15 11 10	2.00	1.4	0	NA		GM	Dark brown to black fine gravel-sized SHALE fragments, little fine Sand, moist, no odor.	0.00	FL
SB25 -2.2	10 11 20 22	2.00	1.6	19	NA	2.0	ML	Olive gray SILT and CLAY, little fine to medium gravel-sized Shale, trace very fine Sand, moist, no odor.	2.00	TL
SB25 -2.3	17 34 100/.1	1.10	1.0	125	NA			Grayish brown SILT and CLAY, little fine to medium gravel-sized Shale, trace very fine Sand, moist, petroleum odor.		
						5.0		Dark gray highly fissile SHALE, some interstitial brown Silt, Clay, and very fine Sand, moist, petroleum odor. SPLIT SPOON REFUSAL AT 5.1 FEET.	5.00	WS
								Dark gray to black SHALE.	5.40	CS

Macro Lithology

NOTES:

PARSONS
ENGINEERING-SCIENCE, INC.

UNITED STATES ARMY
CORPS OF ENGINEERS
Seneca Army Depot
Romulus, New York

LOG OF BORING SB25-2

Sheet 1 of 1

Sheet 1 of 1

LOG OF BORING NO. SB25-3

PROJECT: SEAD-25 & SEAD-26 RI/FS
PROJECT LOCATION: Seneca Army Depot Activity, Romulus, NY 14541
ASSOCIATED UNIT/AREA: SEAD-25
PROJECT NO: 728059
DATE STARTED: 12/03/93
DATE COMPLETED: 12/03/93
DRILLING CONTRACTOR: Empire Soils Investigation, Inc.
DRILLING METHOD: Hollow Stem Auger
SAMPLING METHOD: 3 inch Split Spoons

DEPTH TO WATER (ft): NA
BORING LOCATION (N/E): 998064.8 750981.2
REFERENCE COORDINATE SYSTEM: NY STATE PLANAR
GROUND SURFACE ELEVATION (ft): 743.8
DATUM: NGVD 83
INSPECTOR: B. Harvey, M. Burns
CHECKED BY: P.Feschbach-Meriney

This log is part of a report prepared by Parsons Engineering-Science, Inc. for the named project and should be read together with the report for complete interpretation. This summary applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations.

Sample Number	Blow Counts (# Blows per 6")	Sample Advance	Sample Recovery	VOC Screen-PID (ppm)	Rad Screen (cps)	Depth (ft.)	USCS CLASS	DESCRIPTION	Depth	Macro	Macro Lithology
SB25 -3.1	12 14 16 10	2.00	1.6	22	NA	1.3	GM	Dark brown to black fine gravel-sized SHALE fragments, little fine Sand, moist, petroleum odor.	0.00 1.30	FL	
SB25 -3.2	12 14 18 20	2.00	2.0	2.0	NA		ML	Olive gray SILT and CLAY, little fine to medium gravel-sized Shale, trace very fine Sand, moist, petroleum odor.		TL	
SB25 -3.3	6 100/.3	0.80	0.6	1.3	NA	4.5			4.50		
								Dark gray highly fissile SHALE, some interstitial brown Silt, Clay, and very fine Sand, moist, petroleum odor. SPLIT SPOON REFUSAL AT 4.8 FEET.	5.00	WS	
								AUGER REFUSAL AT 5.0 FEET. Dark gray to black SHALE.		CS	

NOTES:

PARSONS
ENGINEERING-SCIENCE, INC.

UNITED STATES ARMY
CORPS OF ENGINEERS
Seneca Army Depot
Romulus, New York

LOG OF BORING SB25-3

Sheet 1 of 1

Sheet 1 of 1

LOG OF BORING NO. SB25-4

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
ASSOCIATED UNIT/AREA: **SEAD-25**
PROJECT NO: **728059**
DATE STARTED: **12/03/93**
DATE COMPLETED: **12/03/93**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Hollow Stem Auger**
SAMPLING METHOD: **3 inch Split Spoons**

DEPTH TO WATER (ft): **NA**
BORING LOCATION (N/E): **998086.8 750956.9**
REFERENCE COORDINATE SYSTEM: **NY STATE PLANAR**
GROUND SURFACE ELEVATION (ft): **743.6**
DATUM: **NGVD 83**
INSPECTOR: **B. Harvey, M. Burns**
CHECKED BY: **P.Feschbach-Meriney**

This log is part of a report prepared by Parsons Engineering-Science, Inc. for the named project and should be read together with the report for complete interpretation. This summary applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations.

Sample Number	Blow Counts (# Blows per 6")	Sample Advance	Sample Recovery	VOC Screen-PID (ppm)	Rad Screen (cps)	Depth (ft.)	USCS CLASS	DESCRIPTION	Depth	Macro	Macro Lithology
SB25 -4.1	12 13 8 7	2.00	1.1	15	NA	1 1.3	GM	Dark brown to black fine gravel-sized SHALE fragments, little fine Sand, moist, petroleum odor.	0.00	FL	
SB25 -4.2	6 60 26 25	2.00	1.9	40	NA	2 3	ML	Olive gray SILT and CLAY, little fine to medium gravel-sized Shale, trace very fine Sand, moist, petroleum odor.	1.30	TL	
SB25 -4.3	45 100/.1	0.60	0.5	1.0	NA	4 4.5					
								Dark gray to black highly fissile SHALE, some interstitial brown Silt, Clay, and very fine Sand, dry, no odor.	4.50	WS	
						5		SPLIT SPOON REFUSAL AT 4.6 FEET.	5.00	CS	
								Dark gray to black SHALE.			

NOTES:

PARSONS
ENGINEERING-SCIENCE, INC.

UNITED STATES ARMY
CORPS OF ENGINEERS
Seneca Army Depot
Romulus, New York

LOG OF BORING SB25-4

Sheet 1 of 1

Sheet 1 of 1

LOG OF BORING NO. SB25-5

PROJECT: SEAD-25 & SEAD-26 RI/FS
PROJECT LOCATION: Seneca Army Depot Activity, Romulus, NY 14541
ASSOCIATED UNIT/AREA: SEAD-25
PROJECT NO: 728059
DATE STARTED: 12/03/93
DATE COMPLETED: 12/03/93
DRILLING CONTRACTOR: Empire Soils Investigation, Inc.
DRILLING METHOD: Hollow Stem Auger
SAMPLING METHOD: 3 inch Split Spoons

DEPTH TO WATER (ft): NA
BORING LOCATION (N/E): 998046.9 750959.2
REFERENCE COORDINATE SYSTEM: NY STATE PLANAR
GROUND SURFACE ELEVATION (ft): 743.6
DATUM: NGVD 83
INSPECTOR: E. Schacht
CHECKED BY: P.Feschbach-Meriney

This log is part of a report prepared by Parsons Engineering-Science, Inc. for the named project and should be read together with the report for complete interpretation. This summary applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations.

Sample Number	Blow Counts (# Blows per 6")	Sample Advance	Sample Recovery	VOC Screen-PID (ppm)	Rad Screen (cps)	Depth (ft.)	USCS CLASS	DESCRIPTION	Depth	Macro
SB25 -5.1	7 18 13 10	2.00	2.0	155	NA	0.5	GM	Dark brown to black fine gravel-sized SHALE fragments, little fine Sand, wet, no odor.	0.00 0.50	FL
						1	ML	Olive gray SILT and CLAY, little fine to medium gravel-sized Shale, trace very fine Sand, wet, petroleum odor.		TL
SB25 -5.2	11 12 17 24	2.00	1.6	649	NA	2 3				
SB25 -5.3	17 52 100/.4	1.40	1.2	213	NA	4 5.0 5			5.00	
								Dark gray highly fissile SHALE, some interstitial brown Silt, Clay, and very fine Sand, moist, petroleum odor.	5.50	WS
								SPLIT SPOON REFUSAL AT 5.4 FEET.		CS
								AUGER REFUSAL AT 5.5 FEET. Dark gray to black SHALE.		

NOTES:

PARSONS
ENGINEERING-SCIENCE, INC.

UNITED STATES ARMY
CORPS OF ENGINEERS
Seneca Army Depot
Romulus, New York

LOG OF BORING SB25-5

Sheet 1 of 1

Sheet 1 of 1

LOG OF BORING NO. SB25-11

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
ASSOCIATED UNIT/AREA: **SEAD-25**
PROJECT NO: **728059**
DATE STARTED: **10/17/95**
DATE COMPLETED: **10/17/95**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Hollow Stem Auger**
SAMPLING METHOD: **3 inch Split Spoons**

DEPTH TO WATER (ft): **5.1**
BORING LOCATION (N/E): **998028.5 750927.4**
REFERENCE COORDINATE SYSTEM: **NY STATE PLANAR**
GROUND SURFACE ELEVATION (ft): **742.5**
DATUM: **NGVD 88**
INSPECTOR: **F. O'Loughlin**
CHECKED BY: **P.Feschbach-Meriney**

This log is part of a report prepared by Parsons Engineering-Science, Inc. for the named project and should be read together with the report for complete interpretation. This summary applies only at the location of this boring and at the time of drilling. Subsurface conditions may differ at other locations.

Sample Number	Blow Counts (# Blows per 6")	Sample Advance	Sample Recovery	VOC Screen-PID (ppm)	Rad Screen (cps)	Depth (ft.)	USCS CLASS	DESCRIPTION	Depth	Macro	Macro Lithology
SB25-11-00 SB25-11-01	2 4 5 5	2.00	1.5	0	NA	1	ML	Grayish brown SILT and CLAY, little fine to medium gravel-sized Shale, trace very fine Sand, moist, no odor.	0.00	TL	
SB25-11-02	5 6 8 11	2.00	1.3	0	NA	2 3					
SB25-11-03	11 27 100/.3	1.30	0.6	26	NA	4		Grayish brown SILT and CLAY, little fine to medium gravel-sized Shale, trace very fine Sand, moist, petroleum odor.			
						5 5.0		Dark gray highly fissile SHALE, some interstitial brown Silt, Clay, and very fine Sand, wet, petroleum odor. SPLIT SPOON REFUSAL AT 5.3 FEET.	5.00	WS	
								Dark gray to black SHALE.	5.60	CS	

NOTES:

PARSONS
ENGINEERING-SCIENCE, INC.

UNITED STATES ARMY
CORPS OF ENGINEERS
Seneca Army Depot
Romulus, New York

LOG OF BORING SB25-11

Sheet 1 of 1

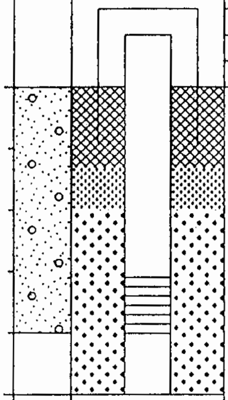
COMPLETION REPORT OF WELL No. MW25-1

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
WELL LOCATION (N/E): **998032.1 751123.1**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Hollow Stem Auger**
WELL INSTALLATION STARTED: **12/03/93**
WELL INSTALLATION COMPLETED: **12/03/93**

GROUND SURFACE ELEVATION: **740.3**
DATUM: **NGVD 88**
GEOLOGIST: **E. Schacht**
CHECKED BY: **P.Feschbach-Meriney**
CONSULTANT:

STRATA

MACRO DESCRIPTION (from boring log)	DEPTH (ft.)
FL	0
WS	5.0
CS	5



DEPTH (ft.)		ELEVATION (ft.)
2.7	TPC	737.6
2.7	TR	737.6
	TC	
0.0	GS	740.3
1.3	TBS	739.0
2.0	TSP	738.3
3.1	TSC	737.2
4.1	BSC	736.2
5.0	POW	735.3

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: **4 inches**
Type: **Square Box Riser**
Interval: **2.98 feet**

RISER
Diameter: **2 inches**
Type: **SCHEDULE 40-PVC**
Interval: **NA**

SCREEN
Diameter: **2 inches**
Type: **SCH 40-PVC, 0.010" slot**
Interval: **1 foot**

SURFACE SEAL
Type: **CEMENT**
Interval: **NA**

GROUT
Type: **CEMENT-BENTONITE**
Interval: **1.3 feet**

SEAL
Type: **BENTONITE**
Interval: **0.7 feet**

SANDPACK
Type: **#1 and #3**
Interval: **3.0 feet**

WELL DEVELOPMENT DATA
Date: **1/8/94**
Method: **Bail & Pump**
Duration: **1 Day**
Rate: **1.5 L/minute**

WATER LEVELS

Date	Time	Depth,TR
1/8/94	1420	5.95 ft
1/8/94	1440	6.20 ft
1/8/94	1500	6.60 ft

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
7.00	4	600	4.44

LEGEND

▨	SURFACE SEAL	●	GRAVEL
▩	GROUT	⁘	SAND
░	SEAL	▥	SILT
⁙	SANDPACK	▨	CLAY
		☒	NO RECOVERY

TPC	TOP OF PROTECTIVE CASING
TR	TOP OF WELL RISER
GS	GROUND SURFACE
TBS	TOP BENTONITE SEAL
TSP	TOP OF SANDPACK
TSC	TOP OF SCREEN
BSC	BOTTOM OF SCREEN
TD	TOTAL DEPTH
POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

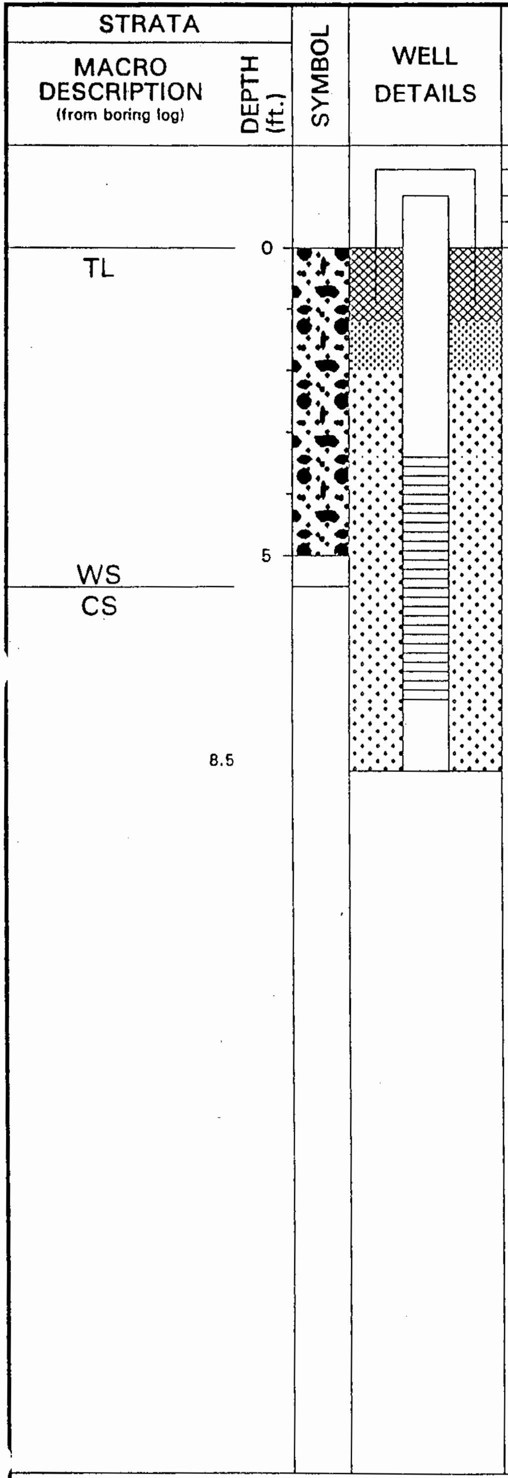
COMPLETION REPORT OF WELL No. MW25-1

Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-2

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
WELL LOCATION (N/E): **998023.1 750973.4**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Hollow Stem Auger**
WELL INSTALLATION STARTED: **11/07/93**
WELL INSTALLATION COMPLETED: **11/07/93**

GROUND SURFACE ELEVATION: **743.8**
DATUM: **NGVD 88**
GEOLOGIST: **E. Schacht**
CHECKED BY: **P.Feschbach-Meriney**
CONSULTANT:



DEPTH (ft.)		ELEVATION (ft.)
2.6	TPC	741.1
2.6	TR	741.1
	TC	
0.0	GS	743.8
1.2	TBS	742.6
2.0	TSP	741.8
3.4	TSC	740.4
7.4	BSC	736.4
8.5	POW	735.3

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: **4 inches**
Type: **Square Box Riser**
Interval: **2.84 feet**

RISER
Diameter: **2 inches**
Type: **SCHEDULE 40-PVC**
Interval: **NA**

SCREEN
Diameter: **2 inches**
Type: **SCH 40-PVC, 0.010" slot**
Interval: **4 feet**

SURFACE SEAL
Type: **CEMENT**
Interval: **NA**

GROUT
Type: **CEMENT-BENTONITE**
Interval: **1.2 feet**

SEAL
Type: **BENTONITE**
Interval: **0.8 feet**

SANDPACK
Type: **#1 and #3**
Interval: **6.5 feet**

WELL DEVELOPMENT DATA
Date: **11/11/93**
Method: **Ball & Pump**
Duration: **11 Days**
Rate: **0.513 L/minute**

WATER LEVELS

Date	Time	Depth,TR
11/11/93	1015	5.12 ft
11/11/93	1430	10.24 ft
11/21/93		4.68 ft
11/22/93	1450	4.74 ft

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
7.19	12	700	1.23

LEGEND

▨	SURFACE SEAL	●	GRAVEL
▩	GROUT	⁘	SAND
░	SEAL	▥	SILT
⁙	SANDPACK	▨	CLAY
		☒	NO RECOVERY

TPC	TOP OF PROTECTIVE CASING
TR	TOP OF WELL RISER
GS	GROUND SURFACE
TBS	TOP BENTONITE SEAL
TSP	TOP OF SANDPACK
TSC	TOP OF SCREEN
BSC	BOTTOM OF SCREEN
TD	TOTAL DEPTH
POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

COMPLETION REPORT OF WELL No. MW25-2

Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-3

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
WELL LOCATION (N/E): **998078.3 750926.3**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Hollow Stem Auger**
WELL INSTALLATION STARTED: **11/07/93**
WELL INSTALLATION COMPLETED: **11/07/93**

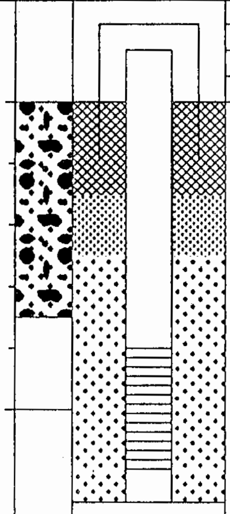
GROUND SURFACE ELEVATION: **743.3**
DATUM: **NGVD 88**
GEOLOGIST: **E. Schacht**
CHECKED BY: **P.Feschbach-Meriney**
CONSULTANT:

STRATA

MACRO DESCRIPTION (from boring log) — DEPTH (ft.)

MACRO DESCRIPTION	DEPTH (ft.)
	0
TL	
WS	
	5
CS	
	6.5

SYMBOL — WELL DETAILS



DEPTH (ft.)		ELEVATION (ft.)
2.6	TPC	740.7
2.5	TR	740.7
	TC	
0.0	GS	743.3
1.5	TBS	741.8
2.5	TSP	740.8
4.0	TSC	739.3
6.0	BSC	737.3
6.5	POW	736.8

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: 4 inches
Type: Square Box Riser
Interval: 2.55 feet

RISER
Diameter: 2 inches
Type: SCHEDULE 40-PVC
Interval: NA

SCREEN
Diameter: 2 inches
Type: SCH 40-PVC, 0.010" slot
Interval: 2 feet

SURFACE SEAL
Type: CEMENT
Interval: NA

GROUT
Type: CEMENT-BENTONITE
Interval: 1.5 feet

SEAL
Type: BENTONITE
Interval: 1.0 feet

SANDPACK
Type: #1 and #3
Interval: 4.0 feet

WELL DEVELOPMENT DATA
Date: 11/9/93
Method: Bail & Pump
Duration: 2 Days
Rate: 1.0 L/minute

WATER LEVELS

	Date	Time	Depth,TR
∇	11/9/93	1345	4.80 ft
▼	11/9/93	1405	9.50 ft
∇	11/11/93	0930	4.90 ft
▼	11/11/93	1045	7.90 ft
∇	11/11/93	1410	7.70 ft
▼			

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
7.42	12.2	500	1.73

LEGEND

▨ SURFACE SEAL
▩ GROUT
▦ SEAL
⁙ SANDPACK
● GRAVEL
⁚ SAND
▥ SILT
▨ CLAY
☒ NO RECOVERY

TPC	TOP OF PROTECTIVE CASING
TR	TOP OF WELL RISER
GS	GROUND SURFACE
TBS	TOP BENTONITE SEAL
TSP	TOP OF SANDPACK
TSC	TOP OF SCREEN
BSC	BOTTOM OF SCREEN
TD	TOTAL DEPTH
POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

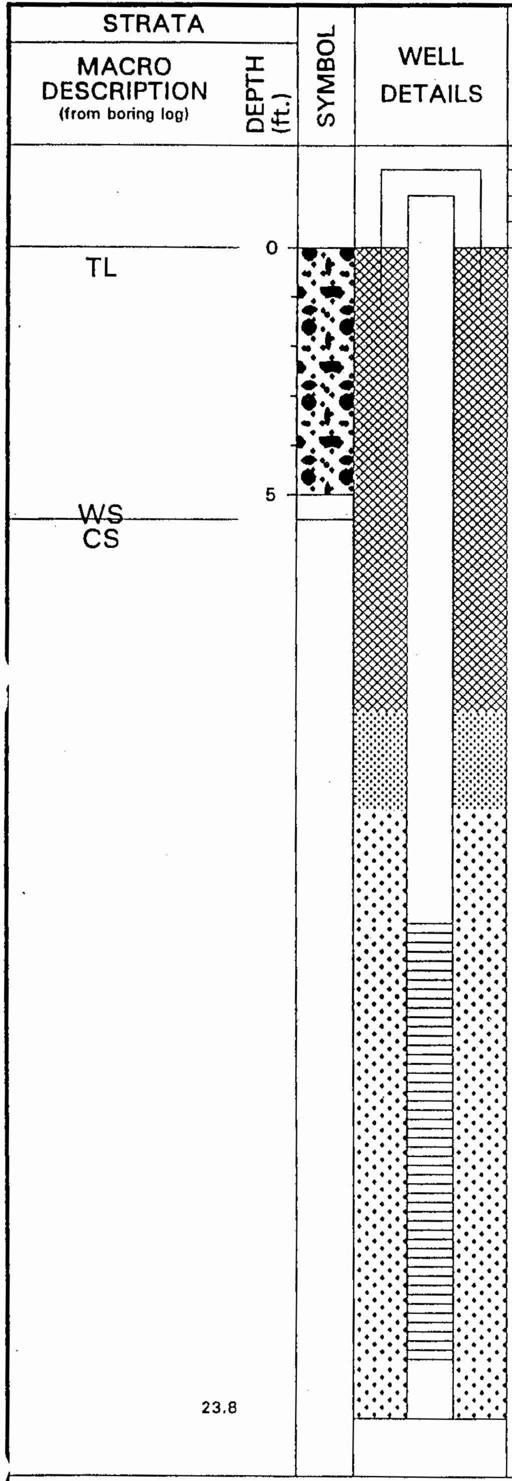
COMPLETION REPORT OF WELL No. MW25-3

Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-4D

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
WELL LOCATION (N/E): **998022.1 750983.2**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Rock Coring**
WELL INSTALLATION STARTED: **10/31/95**
WELL INSTALLATION COMPLETED: **10/31/95**

GROUND SURFACE ELEVATION: **743.8**
DATUM: **NGVD 88**
GEOLOGIST: **F. O'Loughlin**
CHECKED BY: **P.Feschbach-Meriney**
CONSULTANT:



DEPTH (ft.)		ELEVATION (ft.)
1.8	TPC	742.0
1.6	TR	742.2
	TC	
0.0	GS	743.8
9.4	TBS	734.4
11.4	TSP	732.4
13.7	TSC	730.1
22.7	BSC	721.1
23.8	POW	720.0

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: **4 inches**
Type: **Round Box Riser**
Interval: **10.6 feet**

RISER
Diameter: **2 inches**
Type: **SCHEDULE 40-PVC**
Interval: **NA**

SCREEN
Diameter: **1.875 in.**
Type: **WIRE & PVC, 0.010"**
Interval: **9 feet**

SURFACE SEAL
Type: **CEMENT**
Interval: **NA**

GROUT
Type: **CEMENT-BENTONITE**
Interval: **8.4 feet**

SEAL
Type: **BENTONITE**
Interval: **2.0 feet**

SANDPACK
Type: **Morie 0 and #1Q Rock**
Interval: **12.4 feet**

WELL DEVELOPMENT DATA
Date: **11/2/95**
Method: **Surge Block**
Duration: **1 Day**
Rate: **0.936 L/minute**

WATER LEVELS

Date	Time	Depth,TR
11/2/95	1054	7.20 ft

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
7.16	13.8	600	12.1

LEGEND

▨	SURFACE SEAL	●	GRAVEL
▩	GROUT	⁘	SAND
▦	SEAL	▥	SILT
⁘	SANDPACK	▨	CLAY
		☒	NO RECOVERY

TPC	TOP OF PROTECTIVE CASING
TR	TOP OF WELL RISER
GS	GROUND SURFACE
TBS	TOP BENTONITE SEAL
TSP	TOP OF SANDPACK
TSC	TOP OF SCREEN
BSC	BOTTOM OF SCREEN
TD	TOTAL DEPTH
POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

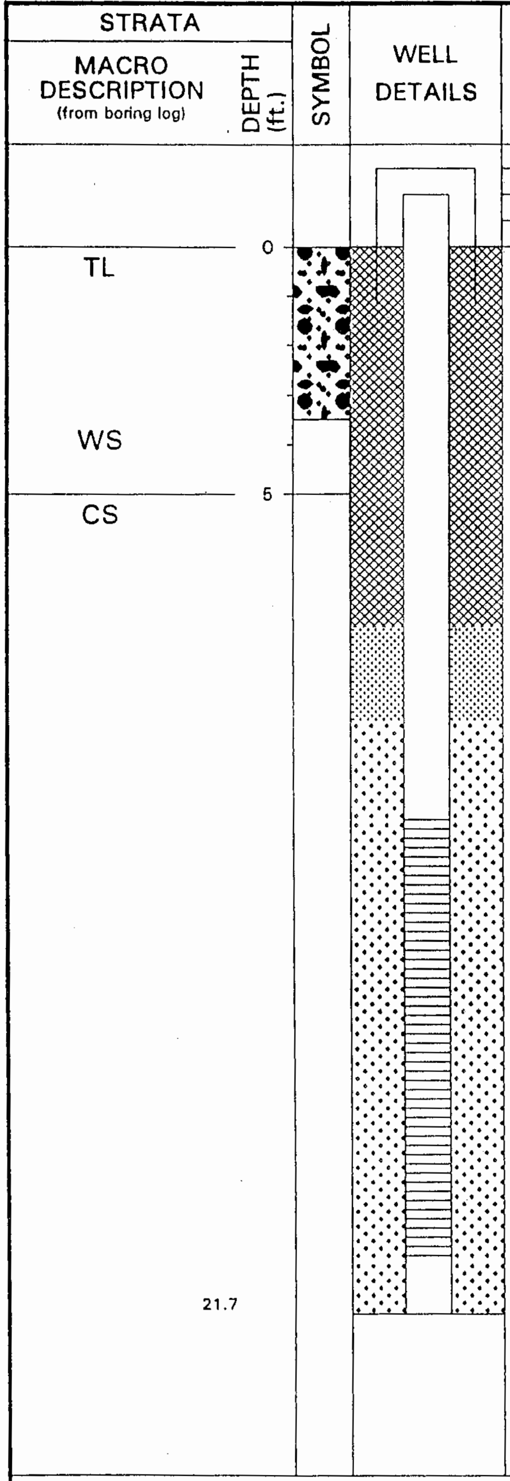
COMPLETION REPORT OF WELL No. MW25-4D

Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-5D

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
WELL LOCATION (N/E): **998080.2 750937.0**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Rock Coring**
WELL INSTALLATION STARTED: **10/30/95**
WELL INSTALLATION COMPLETED: **10/30/95**

GROUND SURFACE ELEVATION: **743.4**
DATUM: **NGVD 88**
GEOLOGIST: **F. O'Loughlin**
CHECKED BY: **P.Feschbach-Merlney**
CONSULTANT:



DEPTH (ft.)		ELEVATION (ft.)
1.8	TPC	741.7
1.6	TR	741.8
	TC	
0.0	GS	743.4
7.7	TBS	735.7
9.6	TSP	733.8
11.6	TSC	731.8
20.6	BSC	722.8
21.7	POW	721.7

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: **4 inches**
Type: **Round Box Riser**
Interval: **8.7 feet**

RISER
Diameter: **2 inches**
Type: **SCHEDULE 40-PVC**
Interval: **13.22 feet**

SCREEN
Diameter: **1.875 in.**
Type: **WIRE & PVC, 0.010" slot**
Interval: **9 feet**

SURFACE SEAL
Type: **CEMENT**
Interval: **NA**

GROUT
Type: **CEMENT-BENTONITE**
Interval: **6.7 feet**

SEAL
Type: **BENTONITE**
Interval: **1.9 feet**

SANDPACK
Type: **Morie 0 and #1Q Rock**
Interval: **12.1 feet**

WELL DEVELOPMENT DATA
Date: **11/1/95**
Method: **Surge Block**
Duration: **2 Days**
Rate: **0.370 L/minute**

WATER LEVELS

	Date	Time	Depth,TR
▽	11/1/95	1505	6.35 ft
▼	11/2/95	0835	6.41 ft

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
6.96	14.8	700	11.0

LEGEND

▨	SURFACE SEAL	●	GRAVEL
▩	GROUT	⁘	SAND
▦	SEAL	▥	SILT
⁘	SANDPACK	▨	CLAY
		☒	NO RECOVERY

TPC	TOP OF PROTECTIVE CASING
TR	TOP OF WELL RISER
GS	GROUND SURFACE
TBS	TOP BENTONITE SEAL
TSP	TOP OF SANDPACK
TSC	TOP OF SCREEN
BSC	BOTTOM OF SCREEN
TD	TOTAL DEPTH
POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

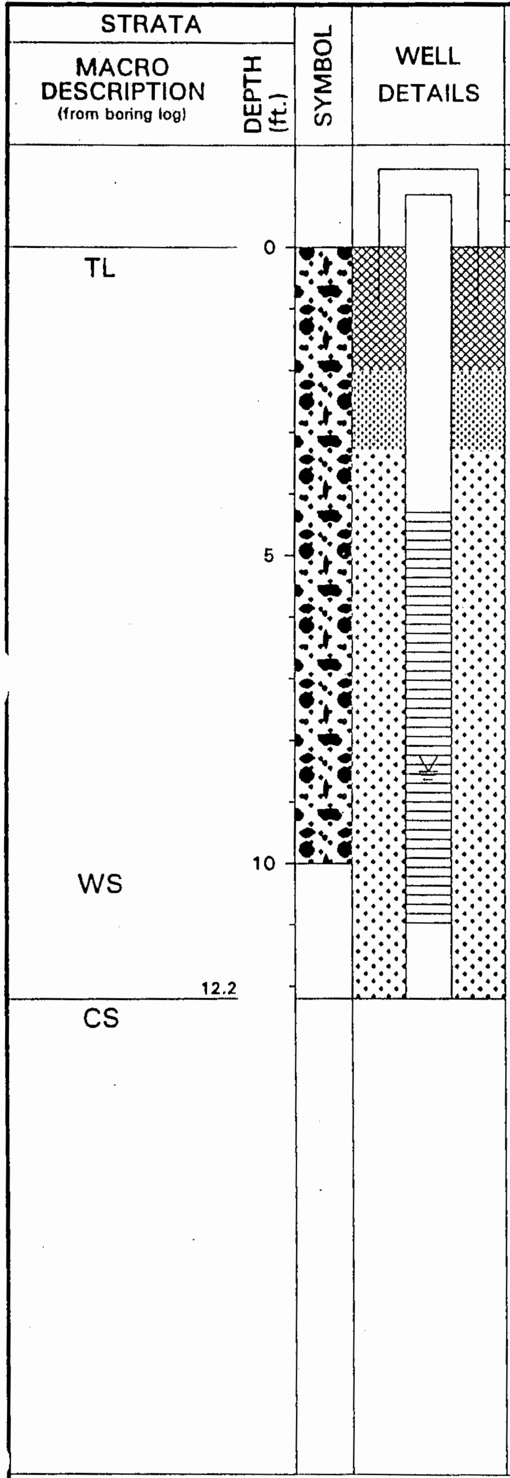
COMPLETION REPORT OF WELL No. MW25-5D

Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-6

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
WELL LOCATION (N/E): **998276.8 751006.2**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Hollow Stem Auger**
WELL INSTALLATION STARTED: **09/25/95**
WELL INSTALLATION COMPLETED: **09/26/95**

GROUND SURFACE ELEVATION: **742.2**
DATUM: **NGVD 88**
GEOLOGIST: **F. O'Loughlin**
CHECKED BY: **P.Feschbach-Meriney**
CONSULTANT:



DEPTH (ft.)		ELEVATION (ft.)
2.3	TPC	739.9
2.2	TR	740.1
	TC	
0.0	GS	742.2
2.0	TBS	740.2
3.3	TSP	738.9
4.3	TSC	737.9
11.1	BSC	731.1
12.2	POW	730.0

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: **4 inches**
Type: **Round Box Riser**
Interval: **4.0 feet**

RISER
Diameter: **2 inches**
Type: **SCHEDULE 40-PVC**
Interval: **6.46 feet**

SCREEN
Diameter: **2 inches**
Type: **SCH 40-PVC, 0.010" slot**
Interval: **6.8 feet**

SURFACE SEAL
Type: **CEMENT**
Interval: **NA**

GROUT
Type: **CEMENT**
Interval: **1.5 feet**

SEAL
Type: **BENTONITE**
Interval: **1.3 feet**

SANDPACK
Type: **Morie 0 and Morie 000**
Interval: **8.9 feet**

WELL DEVELOPMENT DATA
Date: **10/30/95**
Method: **Surge Block**
Duration: **1 Day**
Rate: **0.540 L/minute**

WATER LEVELS

Date	Time	Depth,TR
10/30/95	1125	6.06 ft
10/30/95	1251	6.20 ft
10/30/95	1320	8.24 ft
10/30/95	1341	10.24 ft

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
7.18	15	790	2.85

LEGEND

▨	SURFACE SEAL	●	GRAVEL
▩	GROUT	⁘	SAND
▒	SEAL	▥	SILT
⁘	SANDPACK	▨	CLAY
		☒	NO RECOVERY

TPC	TOP OF PROTECTIVE CASING
TR	TOP OF WELL RISER
GS	GROUND SURFACE
TBS	TOP BENTONITE SEAL
TSP	TOP OF SANDPACK
TSC	TOP OF SCREEN
BSC	BOTTOM OF SCREEN
TD	TOTAL DEPTH
POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

COMPLETION REPORT OF
WELL No. MW25-6

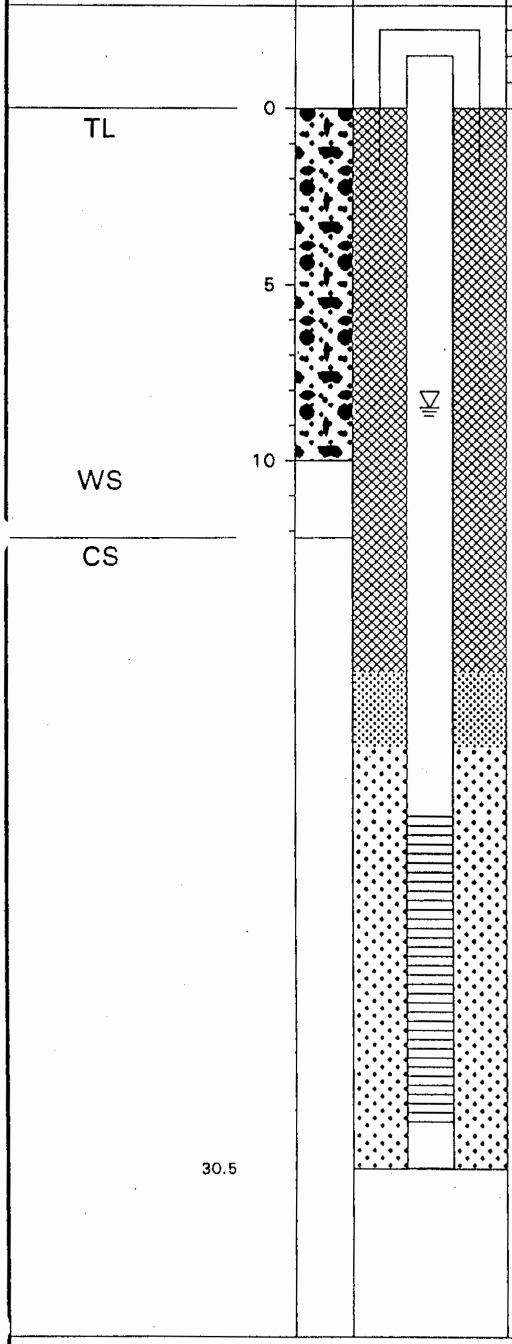
Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-7D

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
WELL LOCATION (N/E): **998277.7 751015.9**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Rock Coring**
WELL INSTALLATION STARTED: **10/24/95**
WELL INSTALLATION COMPLETED: **10/24/95**

GROUND SURFACE ELEVATION: **742.2**
DATUM: **NGVD 88**
GEOLOGIST: **F. O'Loughlin**
CHECKED BY: **P.Feschbach-Meriney**
CONSULTANT:

STRATA — MACRO DESCRIPTION (from boring log) | DEPTH (ft.) | SYMBOL | WELL DETAILS



DEPTH (ft.)		ELEVATION (ft.)
2.1	TPC	740.2
1.8	TR	740.5
	TC	
0.0	GS	742.2
16.0	TBS	726.2
18.1	TSP	724.1
20.1	TSC	722.1
29.1	BSC	713.1
30.2	POW	712.0

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: **4 inches**
Type: **Round Box Riser**
Interval: **17.6 feet**

RISER
Diameter: **2 inches**
Type: **SCHEDULE 40-PVC**
Interval: **21.88 feet**

SCREEN
Diameter: **1.875 in.**
Type: **WIRE & PVC, 0.010" slot**
Interval: **9 feet**

SURFACE SEAL
Type: **CEMENT**
Interval: **1 foot**

GROUT
Type: **CEMENT-BENTONITE**
Interval: **NA**

SEAL
Type: **BENTONITE**
Interval: **2.1 feet**

SANDPACK
Type: **Morie 0 and #1Q Rock**
Interval: **12.4 feet**

WELL DEVELOPMENT DATA
Date: **10/31/95**
Method: **Surge Block**
Duration: **1 Day**
Rate: **0.280 L/minute**

WATER LEVELS

	Date	Time	Depth,TR
▽	10/31/95	0952	5.81 ft
▽			
▽			
▽			
▽			

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
7.32	10.0	700	10.6

LEGEND

▨	SURFACE SEAL	●	GRAVEL
▩	GROUT	⁘	SAND
▦	SEAL	▥	SILT
⁘	SANDPACK	▨	CLAY
		☒	NO RECOVERY

TPC	TOP OF PROTECTIVE CASING
TR	TOP OF WELL RISER
GS	GROUND SURFACE
TBS	TOP BENTONITE SEAL
TSP	TOP OF SANDPACK
TSC	TOP OF SCREEN
BSC	BOTTOM OF SCREEN
TD	TOTAL DEPTH
POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

COMPLETION REPORT OF WELL No. MW25-7D

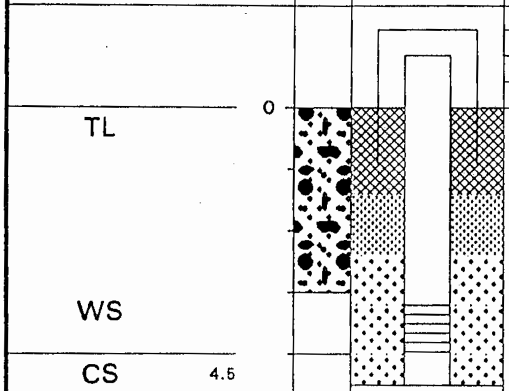
Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-8

PROJECT:	SEAD-25 & SEAD-26 RI/FS
PROJECT LOCATION:	Seneca Army Depot Activity, Romulus, NY 14541
WELL LOCATION (N/E):	998076.8 750856.9
DRILLING CONTRACTOR:	Empire Soils Investigation, Inc.
DRILLING METHOD:	Hollow Stem Auger
WELL INSTALLATION STARTED:	09/26/95
WELL INSTALLATION COMPLETED:	09/26/95

GROUND SURFACE ELEVATION:	741.4
DATUM:	NGVD 88
GEOLOGIST:	F. O'Loughlin
CHECKED BY:	P.Feschbach-Meriney
CONSULTANT:	

STRATA — MACRO DESCRIPTION (from boring log) — DEPTH (ft.) — SYMBOL — WELL DETAILS



DEPTH (ft.)		ELEVATION (ft.)
1.3	TPC	740.1
1.1	TR	740.2
	TC	
0.0	GS	741.4
1.4	TBS	740.0
2.4	TSP	739.0
3.2	TSC	738.2
4.0	BSC	737.4
4.5	POW	736.9

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: 4 inches
Type: Round Box Riser
Interval: 2.50 feet

RISER
Diameter: 2 inches
Type: SCHEDULE 40-PVC
Interval: 4.34 feet

SCREEN
Diameter: 2 inches
Type: SCH 40-PVC, 0.010" slot
Interval: 0.8 feet

SURFACE SEAL
Type: CEMENT
Interval: NA

GROUT
Type: NA
Interval: NA

SEAL
Type: BENTONITE
Interval: 1.0 foot

SANDPACK
Type: Morie 0 and Morie 000
Interval: 2.1 feet

WELL DEVELOPMENT DATA
Date: 10/22/95
Method: Surge Block
Duration: 3 Days
Rate: 0.900 L/minute

WATER LEVELS

Date	Time	Depth,TR
10/20/95	1624	3.32 ft
10/20/95	1700	4.80 ft
10/22/95	1004	1.26 ft
10/22/95	1056	1.32 ft

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
7.35	14.5	350	7.3

LEGEND

▨	SURFACE SEAL	●	GRAVEL
▩	GROUT	⁚	SAND
▒	SEAL	▥	SILT
⁘	SANDPACK	▨	CLAY
		☒	NO RECOVERY

TPC	TOP OF PROTECTIVE CASING
TR	TOP OF WELL RISER
GS	GROUND SURFACE
TBS	TOP BENTONITE SEAL
TSP	TOP OF SANDPACK
TSC	TOP OF SCREEN
BSC	BOTTOM OF SCREEN
TD	TOTAL DEPTH
POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

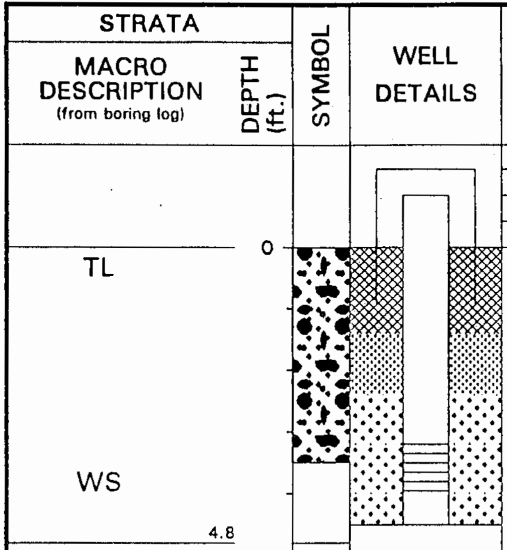
COMPLETION REPORT OF WELL No. MW25-8

Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-9

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
WELL LOCATION (N/E): **998005.3 750898.1**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Hollow Stem Auger**
WELL INSTALLATION STARTED: **09/26/95**
WELL INSTALLATION COMPLETED: **09/26/95**

GROUND SURFACE ELEVATION: **741.3**
DATUM: **NGVD 88**
GEOLOGIST: **F. O'Loughlin**
CHECKED BY: **P.Feschbach-Meriney**
CONSULTANT:



DEPTH (ft.)		ELEVATION (ft.)
1.3	TPC	740.0
1.1	TR	740.2
	TC	
0.0	GS	741.3
1.4	TBS	739.9
2.4	TSP	738.9
3.2	TSC	738.1
4.0	BSC	737.3
4.5	POW	736.8

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: **4 inches**
Type: **Round Box Riser**
Interval: **2.57 feet**

RISER
Diameter: **2 inches**
Type: **SCHEDULE 40-PVC**
Interval: **4.27 feet**

SCREEN
Diameter: **2 inches**
Type: **SCH 40-PVC, 0.010" slot**
Interval: **0.8 feet**

SURFACE SEAL
Type: **CEMENT**
Interval: **NA**

GROUT
Type: **NA**
Interval: **NA**

SEAL
Type: **BENTONITE**
Interval: **1.0 foot**

SANDPACK
Type: **Morie 0 and Morie 000**
Interval: **2.1 feet**

WELL DEVELOPMENT DATA
Date: **10/20/95**
Method: **Surge Block**
Duration: **3 Days**
Rate: **0.320 L/minute**

WATER LEVELS

	Date	Time	Depth,TR
▽	10/20/95	1610	3.10 ft
▼	10/22/95	0948	1.27 ft
▽	10/22/95	1040	2.87 ft
▽	10/22/95	1150	3.50 ft
▽			
▼			

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
7.18	14.0	490	4.44

LEGEND

▨	SURFACE SEAL	●	GRAVEL	TPC	TOP OF PROTECTIVE CASING
▩	GROUT	⁘	SAND	TR	TOP OF WELL RISER
░	SEAL	▥	SILT	GS	GROUND SURFACE
⁘	SANDPACK	▨	CLAY	TBS	TOP BENTONITE SEAL
		☒	NO RECOVERY	TSP	TOP OF SANDPACK
				TSC	TOP OF SCREEN
				BSC	BOTTOM OF SCREEN
				TD	TOTAL DEPTH
				POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

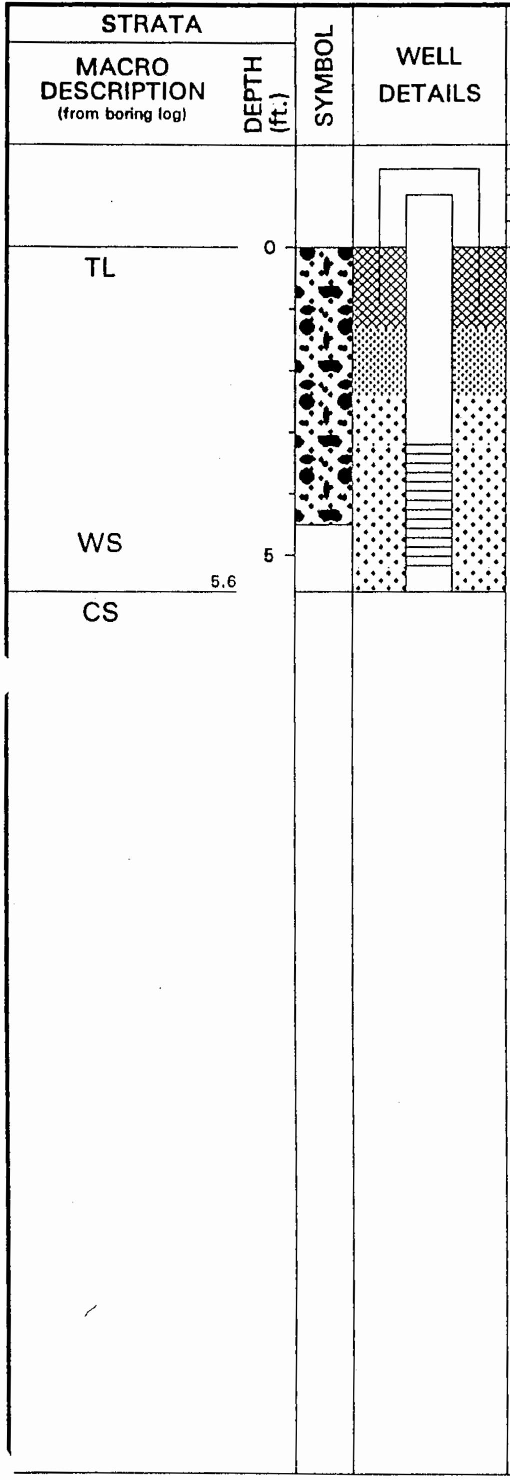
COMPLETION REPORT OF WELL No. MW25-9

Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-10

PROJECT: SEAD-25 & SEAD-26 RI/FS
PROJECT LOCATION: Seneca Army Depot Activity, Romulus, NY 14541
WELL LOCATION (N/E): 997965.0 751000.0
DRILLING CONTRACTOR: Empire Soils Investigation, Inc.
DRILLING METHOD: Hollow Stem Auger
WELL INSTALLATION STARTED: 09/27/95
WELL INSTALLATION COMPLETED: 09/27/95

GROUND SURFACE ELEVATION: 741.8
DATUM: NGVD 88
GEOLOGIST: F. O'Loughlin
CHECKED BY: P.Feschbach-Meriney
CONSULTANT:



DEPTH (ft.)		ELEVATION (ft.)
1.4	TPC	740.4
1.2	TR	740.6
	TC	
0.0	GS	741.8
1.3	TBS	740.5
2.4	TSP	739.4
3.2	TSC	738.6
5.2	BSC	736.6
5.6	POW	736.2

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: 4 inches
Type: Round Box Riser
Interval: 2.29 feet

RISER
Diameter: 2 inches
Type: SCHEDULE 40-PVC
Interval: 4.41 feet

SCREEN
Diameter: 2 inches
Type: SCH 40-PVC, 0.010" slot
Interval: 2.0 feet

SURFACE SEAL
Type: CEMENT
Interval: 0.8 feet

GROUT
Type: NA
Interval: NA

SEAL
Type: BENTONITE
Interval: 1.1 feet

SANDPACK
Type: Morie 0 and Morie 000
Interval: 2.8 feet

WELL DEVELOPMENT DATA
Date: 10/25/95
Method: Surge Block
Duration: 4 Days
Rate: 0.090 L/minute

WATER LEVELS

Date	Time	Depth,TR
10/22/95	1310	1.67 ft
10/22/95	1759	4.30 ft
10/23/95	1643	2.38 ft
10/24/95	1315	2.86 ft

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
7.30	14.9	425	5.46

LEGEND

▨	SURFACE SEAL
▩	GROUT
░	SEAL
⁘	SANDPACK
●	GRAVEL
⁘	SAND
▥	SILT
▨	CLAY
☒	NO RECOVERY

TPC	TOP OF PROTECTIVE CASING
TR	TOP OF WELL RISER
GS	GROUND SURFACE
TBS	TOP BENTONITE SEAL
TSP	TOP OF SANDPACK
TSC	TOP OF SCREEN
BSC	BOTTOM OF SCREEN
TD	TOTAL DEPTH
POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

COMPLETION REPORT OF WELL No. MW25-10

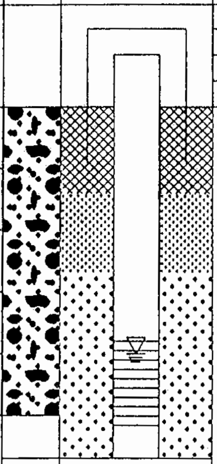
Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-11

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
WELL LOCATION (N/E): **997865.7 750956.7**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Hollow Stem Auger**
WELL INSTALLATION STARTED: **10/11/95**
WELL INSTALLATION COMPLETED: **10/11/95**

GROUND SURFACE ELEVATION: **738.7**
DATUM: **NGVD 88**
GEOLOGIST: **F. O'Loughlin**
CHECKED BY: **P.Feschbach-Meriney**
CONSULTANT:

STRATA MACRO DESCRIPTION (from boring log)	DEPTH (ft.)
TL	0
WS	5 5.7
CS	



DEPTH (ft.)		ELEVATION (ft.)
1.6	TPC	737.1
1.5	TR	737.2
	TC	
0.0	GS	738.7
1.4	TBS	737.3
2.7	TSP	736.0
3.8	TSC	734.9
5.3	BSC	733.4
5.7	POW	733.0

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: **4 inches**
Type: **Round Box Riser**
Interval: **4.53 feet**

RISER
Diameter: **2 inches**
Type: **SCHEDULE 40-PVC**
Interval: **5.35 feet**

SCREEN
Diameter: **2 inches**
Type: **SCH 40-PVC, 0.010" slot**
Interval: **1.5 feet**

SURFACE SEAL
Type: **CEMENT**
Interval: **1.4 feet**

GROUT
Type: **NA**
Interval: **NA**

SEAL
Type: **BENTONITE**
Interval: **1.3 feet**

SANDPACK
Type: **Morie 0 and Morie 000**
Interval: **3.0 feet**

WELL DEVELOPMENT DATA
Date: **10/23/95**
Method: **Surge Block**
Duration: **3 Days**
Rate: **1.020 L/minute**

WATER LEVELS

Date	Time	Depth,TR
10/23/95	1620	4.18 ft
10/24/95	1335	2.92 ft
10/24/95	1650	3.00 ft
10/25/95	0830	3.29 ft

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
7.11	14	920	25.1

LEGEND

▨	SURFACE SEAL	●	GRAVEL
▩	GROUT	⁚	SAND
░	SEAL	▥	SILT
⁘	SANDPACK	▨	CLAY
		☒	NO RECOVERY

TPC	TOP OF PROTECTIVE CASING
TR	TOP OF WELL RISER
GS	GROUND SURFACE
TBS	TOP BENTONITE SEAL
TSP	TOP OF SANDPACK
TSC	TOP OF SCREEN
BSC	BOTTOM OF SCREEN
TD	TOTAL DEPTH
POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

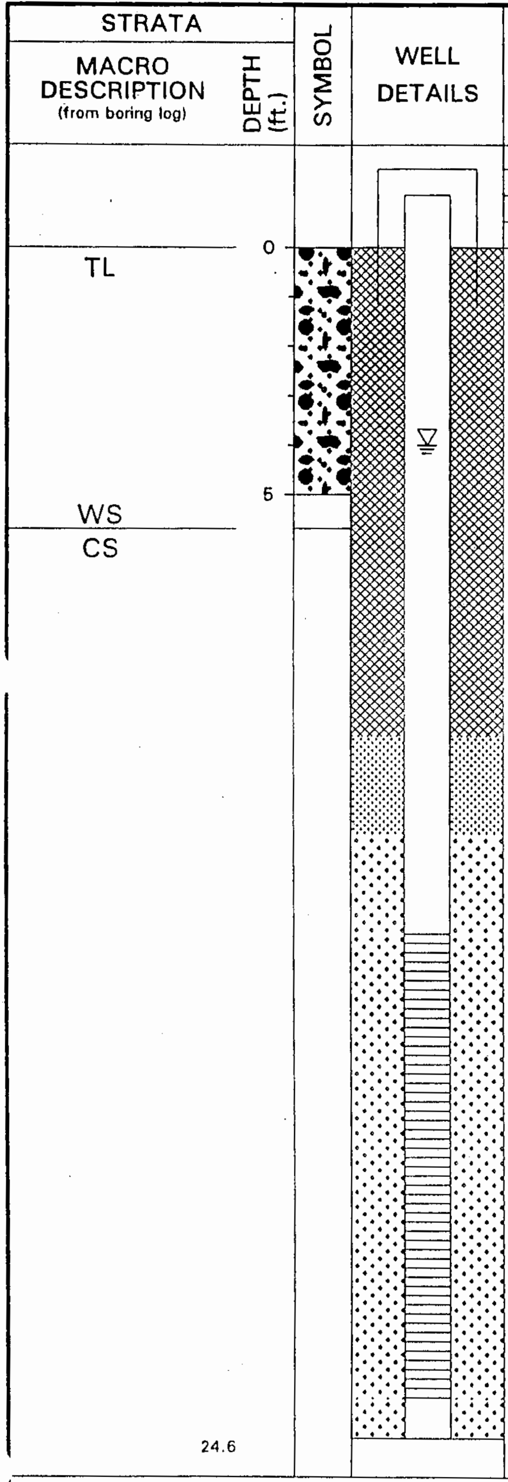
COMPLETION REPORT OF WELL No. MW25-11

Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-12D

PROJECT: SEAD-25 & SEAD-26 RI/FS
PROJECT LOCATION: Seneca Army Depot Activity, Romulus, NY 14541
WELL LOCATION (N/E): 997866.1 750967.3
DRILLING CONTRACTOR: Empire Soils Investigation, Inc.
DRILLING METHOD: Rock Coring
WELL INSTALLATION STARTED: 11/01/95
WELL INSTALLATION COMPLETED: 11/01/95

GROUND SURFACE ELEVATION: 738.9
DATUM: NGVD 88
GEOLOGIST: F. O'Loughlin
CHECKED BY: P.Feschbach-Meriney
CONSULTANT:



DEPTH (ft.)		ELEVATION (ft.)
1.4	TPC	737.5
1.2	TR	737.7
	TC	
0.0	GS	738.9
9.9	TBS	729.0
11.9	TSP	727.0
13.9	TSC	725.0
23.4	BSC	715.5
24.2	POW	714.7

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: 4 inches
Type: Round Box Riser
Interval: 16.18 feet

RISER
Diameter: 2 inches
Type: SCHEDULE 40-PVC
Interval: 15.08 feet

SCREEN
Diameter: 1.875 in
Type: WIRE & PVC, 0.010" slot
Interval: 9.5 feet

SURFACE SEAL
Type: CEMENT
Interval: 1 foot

GROUT
Type: CEMENT-BENTONITE
Interval: NA

SEAL
Type: BENTONITE
Interval: 8.9 feet

SANDPACK
Type: Morie 0 and #1Q Rock
Interval: 12.3 feet

WELL DEVELOPMENT DATA
Date: 11/3/95
Method: Surge Block
Duration: 1 Day
Rate: 1.920 L/minute

WATER LEVELS

	Date	Time	Depth,TR
▽	11/3/95	1245	3.72 ft
▼	11/3/95	1431	7.60 ft
▽	11/3/95	1443	7.80 ft
▽	11/3/95	1456	7.90 ft

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
7.58	11	400	13.3

LEGEND

▨	SURFACE SEAL	●	GRAVEL	TPC	TOP OF PROTECTIVE CASING
▩	GROUT	⁘	SAND	TR	TOP OF WELL RISER
░	SEAL	▥	SILT	GS	GROUND SURFACE
⁘	SANDPACK	▨	CLAY	TBS	TOP BENTONITE SEAL
		☒	NO RECOVERY	TSP	TOP OF SANDPACK
				TSC	TOP OF SCREEN
				BSC	BOTTOM OF SCREEN
				TD	TOTAL DEPTH
				POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

COMPLETION REPORT OF WELL No. MW25-12D

Sheet 1 of 1

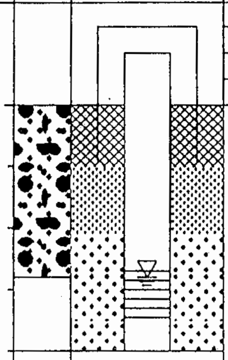
COMPLETION REPORT OF WELL No. MW25-13

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
WELL LOCATION (N/E): **997866.5 750869.7**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Hollow Stem Auger**
WELL INSTALLATION STARTED: **10/11/95**
WELL INSTALLATION COMPLETED: **10/11/95**

GROUND SURFACE ELEVATION: **737.9**
DATUM: **NGVD 88**
GEOLOGIST: **F. O'Loughlin**
CHECKED BY: **P.Feschbach-Meriney**
CONSULTANT:

STRATA

MACRO DESCRIPTION (from boring log)	DEPTH (ft.)
TL	0
WS	
	4.0
CS	



DEPTH (ft.)		ELEVATION (ft.)
1.8	TPC	736.2
1.7	TR	736.3
	TC	
0.0	GS	737.9
1.0	TBS	736.9
2.1	TSP	735.8
2.7	TSC	735.2
3.5	BSC	734.4
4.0	POW	733.9

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: **4 inches**
Type: **Round Box Riser**
Interval: **2.76 feet**

RISER
Diameter: **2 inches**
Type: **SCHEDULE 40-PVC**
Interval: **4.38 feet**

SCREEN
Diameter: **2 inches**
Type: **SCH 40-PVC, 0.010" slot**
Interval: **0.8 feet**

SURFACE SEAL
Type: **CEMENT**
Interval: **1.4 feet**

GROUT
Type: **NA**
Interval: **NA**

SEAL
Type: **BENTONITE**
Interval: **1.1 feet**

SANDPACK
Type: **Morie 0 and Morie 000**
Interval: **1.9 feet**

WELL DEVELOPMENT DATA
Date: **10/25/95**
Method: **Surge Block**
Duration: **9 Days**
Rate: **0.050 L/minute**

WATER LEVELS

	Date	Time	Depth,TR
▽	10/24/95		6.78 ft
▼	10/25/95	1035	4.46 ft
▽	10/25/95	1202	4.69 ft
▽	10/30/95	1040	5.50 ft
▽	10/31/95	1610	5.63 ft
▼	11/2/95	1308	5.73 ft

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
7.10	14.0	1000	9.66

LEGEND

▨	SURFACE SEAL	●	GRAVEL
▩	GROUT	⁘	SAND
▦	SEAL	▥	SILT
⁘	SANDPACK	▨	CLAY
		☒	NO RECOVERY

TPC	TOP OF PROTECTIVE CASING
TR	TOP OF WELL RISER
GS	GROUND SURFACE
TBS	TOP BENTONITE SEAL
TSP	TOP OF SANDPACK
TSC	TOP OF SCREEN
BSC	BOTTOM OF SCREEN
TD	TOTAL DEPTH
POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

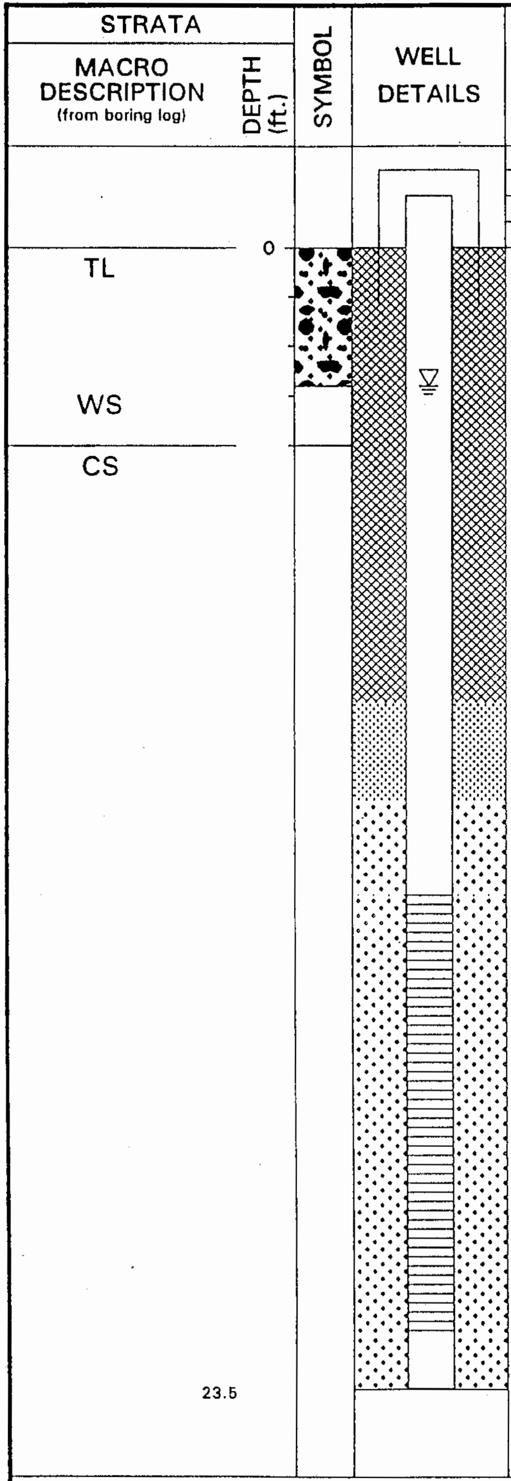
COMPLETION REPORT OF WELL No. MW25-13

Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-14D

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
WELL LOCATION (N/E): **997866.5 750876.2**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Rock Coring**
WELL INSTALLATION STARTED: **10/31/95**
WELL INSTALLATION COMPLETED: **10/31/95**

GROUND SURFACE ELEVATION: **738.2**
DATUM: **NGVD 88**
GEOLOGIST: **F. O'Loughlin**
CHECKED BY: **P.Feschbach-Meriney**
CONSULTANT:



DEPTH (ft.)		ELEVATION (ft.)
1.8	TPC	736.4
1.6	TR	736.6
	TC	
0.0	GS	738.2
9.2	TBS	729.0
11.2	TSP	727.0
13.1	TSC	725.1
22.1	BSC	716.1
23.2	POW	715.0

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: **4 inches**
Type: **Round Box Riser**
Interval: **12.39 feet**

RISER
Diameter: **2 inches**
Type: **SCHEDULE 40-PVC**
Interval: **14.69 feet**

SCREEN
Diameter: **1.875 in**
Type: **WIRE & PVC, 0.010" slot**
Interval: **9 feet**

SURFACE SEAL
Type: **CEMENT**
Interval: **1 foot**

GROUT
Type: **CEMENT-BENTONITE**
Interval: **8.2 feet**

SEAL
Type: **BENTONITE**
Interval: **2.0 feet**

SANDPACK
Type: **Morie 0 and #1Q Rock**
Interval: **12 feet**

WELL DEVELOPMENT DATA
Date: **11/2/95**
Method: **Surge Block**
Duration: **2 Days**
Rate: **0.960 L/minute**

WATER LEVELS

	Date	Time	Depth,TR
⊻	11/2/95	1530	3.90 ft
⊻	11/3/95	1532	6.06 ft
⊻			
⊻			
⊻			
⊻			

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
7.66	11	390	16.9

LEGEND

▨	SURFACE SEAL	●	GRAVEL	TPC	TOP OF PROTECTIVE CASING
▩	GROUT	⁙	SAND	TR	TOP OF WELL RISER
░	SEAL	▥	SILT	GS	GROUND SURFACE
⁘	SANDPACK	▨	CLAY	TBS	TOP BENTONITE SEAL
		☒	NO RECOVERY	TSP	TOP OF SANDPACK
				TSC	TOP OF SCREEN
				BSC	BOTTOM OF SCREEN
				TD	TOTAL DEPTH
				POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

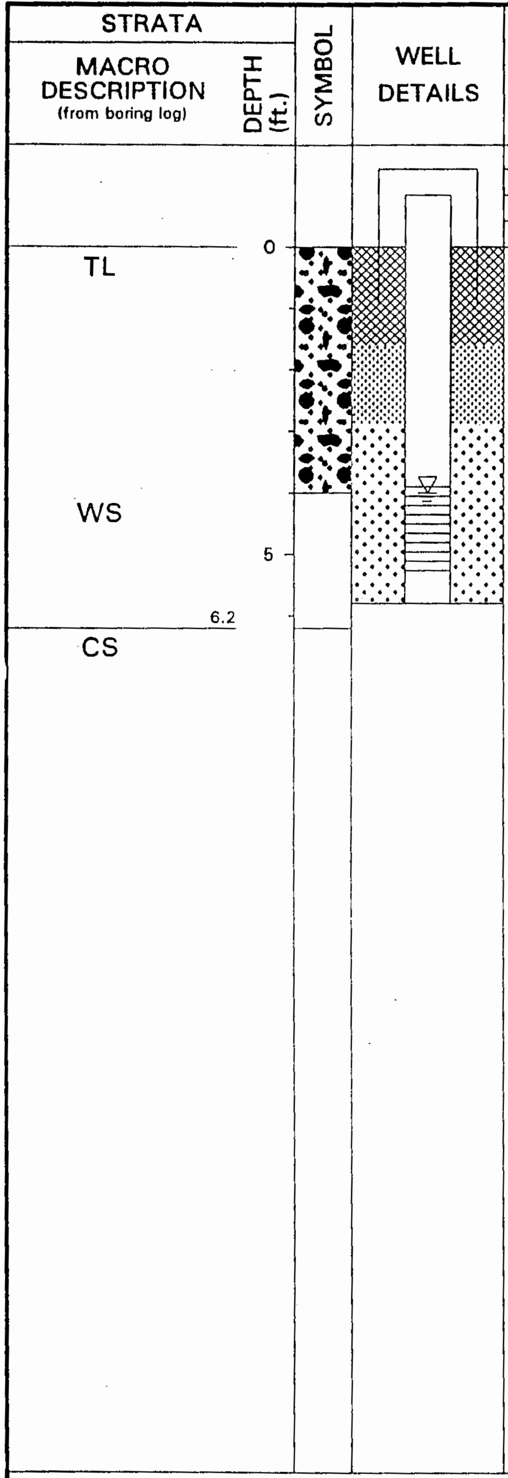
Seneca Army Depot
Romulus, New York

COMPLETION REPORT OF WELL No. MW25-14D
Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-15

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
WELL LOCATION (N/E): **997974.2 750764.4**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Hollow Stem Auger**
WELL INSTALLATION STARTED: **10/10/95**
WELL INSTALLATION COMPLETED: **10/10/95**

GROUND SURFACE ELEVATION: **739.6**
DATUM: **NGVD 88**
GEOLOGIST: **F. O'Loughlin**
CHECKED BY: **P.Feschbach-Meriney**
CONSULTANT:



DEPTH (ft.)		ELEVATION (ft.)
1.6	TPC	738.0
1.4	TR	738.2
	TC	
0.0	GS	739.6
1.6	TBS	738.0
2.9	TSP	736.7
3.9	TSC	735.7
5.4	BSC	734.2
5.8	POW	733.8

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: **4 inches**
Type: **Round Box Riser**
Interval: **3.22 feet**

RISER
Diameter: **2 inches**
Type: **SCHEDULE 40-PVC**
Interval: **5.29 feet**

SCREEN
Diameter: **2 inches**
Type: **SCH 40-PVC, 0.010" slot**
Interval: **1.5 feet**

SURFACE SEAL
Type: **CEMENT**
Interval: **1 foot**

GROUT
Type: **NA**
Interval: **NA**

SEAL
Type: **BENTONITE**
Interval: **1.3 feet**

SANDPACK
Type: **Morie 0 and Morie 000**
Interval: **2.9 feet**

WELL DEVELOPMENT DATA
Date: **10/22/95**
Method: **Surge Block**
Duration: **10 Days**
Rate: **0.050 L/minute**

WATER LEVELS

	Date	Time	Depth,TR
▽	10/24/95	1520	4.57 ft
▼	10/25/95	1300	3.20 ft
▼	10/30/95	1018	4.36 ft
▽	10/31/95	1520	5.00 ft
▽	11/1/95	1007	4.57 ft
▼	11/2/95	1030	4.66 ft

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
6.93	15.0	450	8.38

LEGEND

▨	SURFACE SEAL	●	GRAVEL	TPC	TOP OF PROTECTIVE CASING
▩	GROUT	⁘	SAND	TR	TOP OF WELL RISER
░	SEAL	‖	SILT	GS	GROUND SURFACE
⁘	SANDPACK	▨	CLAY	TBS	TOP BENTONITE SEAL
		☒	NO RECOVERY	TSP	TOP OF SANDPACK
				TSC	TOP OF SCREEN
				BSC	BOTTOM OF SCREEN
				TD	TOTAL DEPTH
				POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

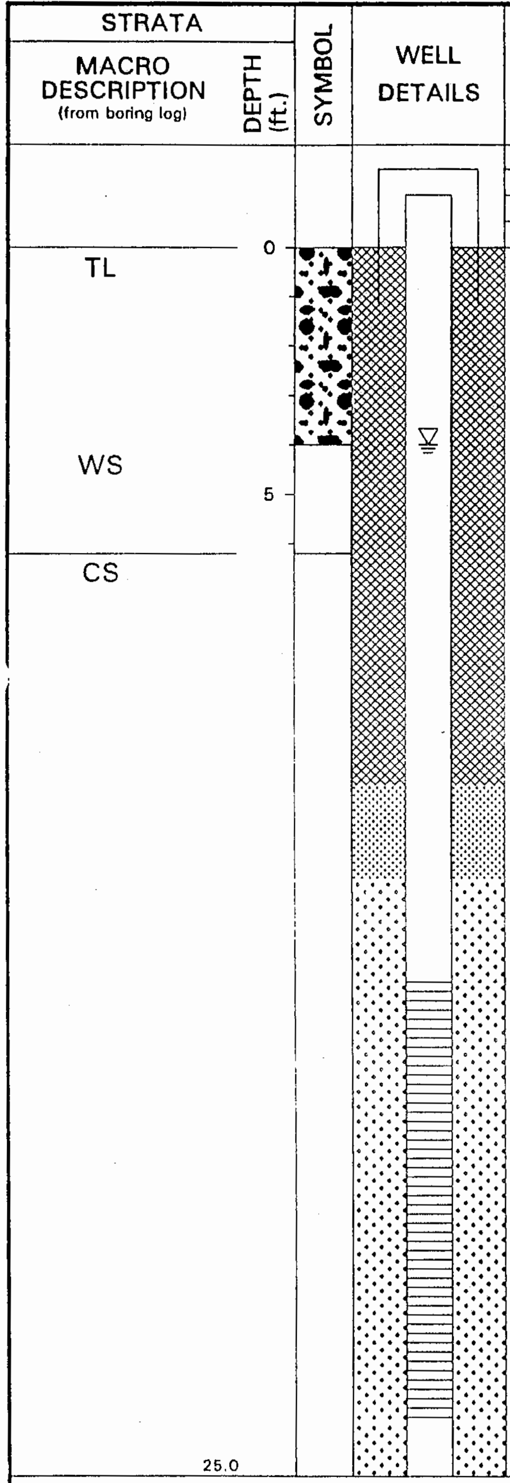
COMPLETION REPORT OF WELL No. MW25-15

Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-16D

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
WELL LOCATION (N/E): **997975.4 750773.2**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Rock Coring**
WELL INSTALLATION STARTED: **10/25/95**
WELL INSTALLATION COMPLETED: **10/25/95**

GROUND SURFACE ELEVATION: **739.8**
DATUM: **NGVD 88**
GEOLOGIST: **F. O'Loughlin**
CHECKED BY: **P.Feschbach-Meriney**
CONSULTANT:



DEPTH (ft.)		ELEVATION (ft.)
1.7	TPC	738.1
1.3	TR	738.4
	TC	
0.0	GS	739.8
10.9	TBS	728.9
12.8	TSP	727.0
14.9	TSC	724.9
23.9	BSC	715.9
25.0	POW	714.8

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: **4 inches**
Type: **Round Box Riser**
Interval: **12.67 feet**

RISER
Diameter: **2 inches**
Type: **SCHEDULE 40-PVC**
Interval: **16.25 feet**

SCREEN
Diameter: **1.875 in**
Type: **WIRE & PVC, 0.010" slot**
Interval: **9 feet**

SURFACE SEAL
Type: **CEMENT**
Interval: **1 foot**

GROUT
Type: **CEMENT-BENTONITE**
Interval: **9.9 feet**

SEAL
Type: **BENTONITE**
Interval: **1.9 feet**

SANDPACK
Type: **Morie 0 and #1Q Rock**
Interval: **12.2 feet**

WELL DEVELOPMENT DATA
Date: **10/30/95**
Method: **Surge Block**
Duration: **1 Day**
Rate: **1.200 L/minute**

WATER LEVELS

	Date	Time	Depth,TR
▽	10/30/95	1130	5.84 ft
▼			
▼			
▼			
▼			

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
6.98	11.9	480	4.64

LEGEND

▨	SURFACE SEAL	●	GRAVEL
▩	GROUT	⁚	SAND
░	SEAL	▥	SILT
⁘	SANDPACK	▨	CLAY
		☒	NO RECOVERY

TPC TOP OF PROTECTIVE CASING
TR TOP OF WELL RISER
GS GROUND SURFACE
TBS TOP BENTONITE SEAL
TSP TOP OF SANDPACK
TSC TOP OF SCREEN
BSC BOTTOM OF SCREEN
TD TOTAL DEPTH
POW POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

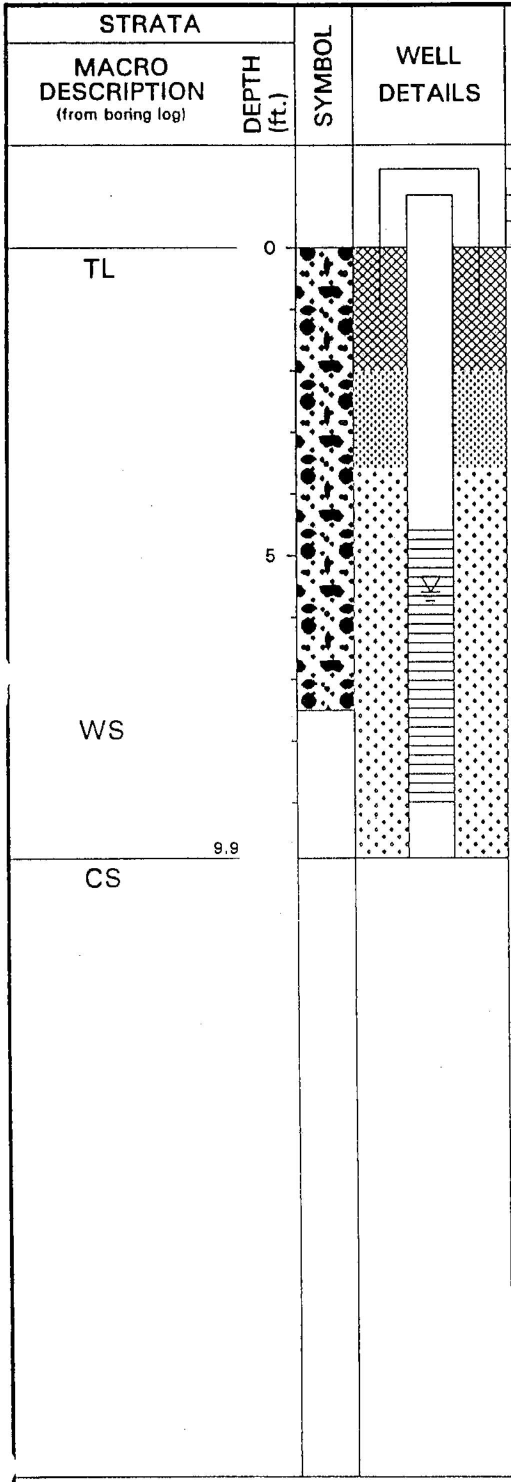
COMPLETION REPORT OF WELL No. MW25-16D

Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-17

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
WELL LOCATION (N/E): **998187.6 750963.0**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Hollow Stem Auger**
WELL INSTALLATION STARTED: **10/16/95**
WELL INSTALLATION COMPLETED: **10/16/95**

GROUND SURFACE ELEVATION: **742.2**
DATUM: **NGVD 88**
GEOLOGIST: **F. O'Loughlin**
CHECKED BY: **P.Feschbach-Meriney**
CONSULTANT:



DEPTH (ft.)		ELEVATION (ft.)
1.7	TPC	740.5
1.7	TR	740.6
	TC	
0.0	GS	742.2
2.0	TBS	740.2
3.6	TSP	738.6
4.6	TSC	737.6
9.1	BSC	733.1
9.9	POW	732.3

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: **4 inches**
Type: **Round Box Riser**
Interval: **5.25 feet**

RISER
Diameter: **2 inches**
Type: **SCHEDULE 40-PVC**
Interval: **6.28 feet**

SCREEN
Diameter: **2 inches**
Type: **SCH 40-PVC, 0.010" slot**
Interval: **4.5 feet**

SURFACE SEAL
Type: **CEMENT**
Interval: **NA**

GROUT
Type: **NA**
Interval: **NA**

SEAL
Type: **BENTONITE**
Interval: **1.6 feet**

SANDPACK
Type: **Morie 0 and #1Q Rock**
Interval: **6.3 feet**

WELL DEVELOPMENT DATA
Date: **10/31/95**
Method: **Surge Block**
Duration: **1 Day**
Rate: **0.780 L/minute**

WATER LEVELS

	Date	Time	Depth,TR
▽	10/31/95	1031	5.70 ft
▼	10/31/95	1415	5.07 ft

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
7.12	13.0	550	4.16

LEGEND

▨	SURFACE SEAL
▩	GROUT
░	SEAL
⁘	SANDPACK
●	GRAVEL
⁚	SAND
▥	SILT
▨	CLAY
☒	NO RECOVERY

TPC	TOP OF PROTECTIVE CASING
TR	TOP OF WELL RISER
GS	GROUND SURFACE
TBS	TOP BENTONITE SEAL
TSP	TOP OF SANDPACK
TSC	TOP OF SCREEN
BSC	BOTTOM OF SCREEN
TD	TOTAL DEPTH
POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

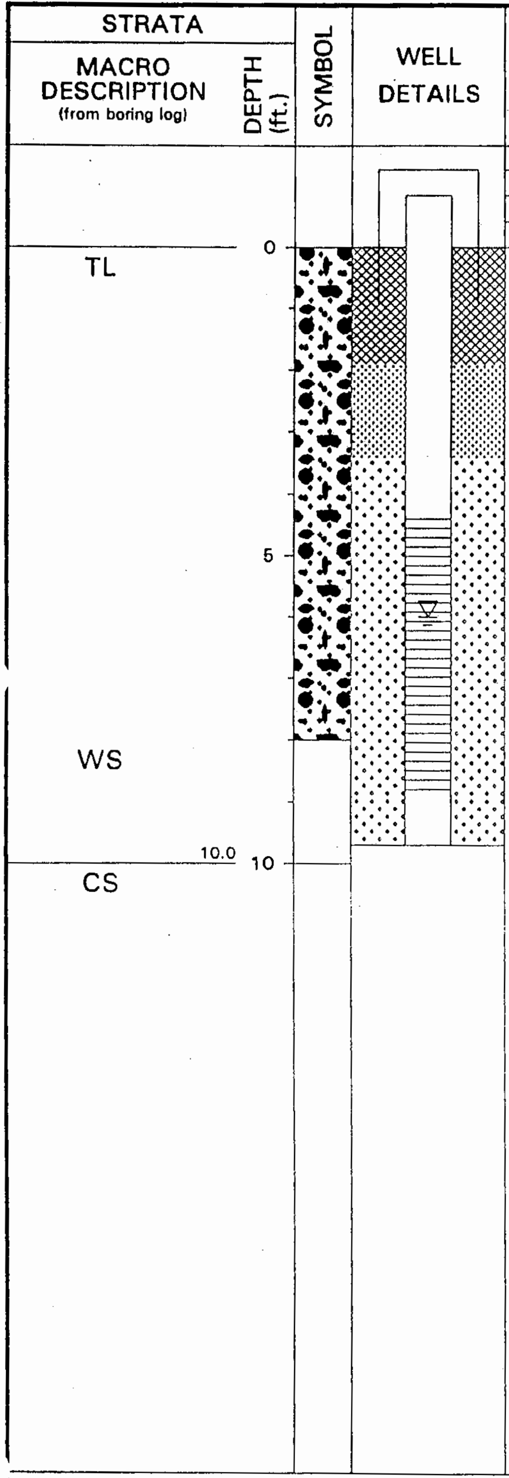
COMPLETION REPORT OF WELL No. MW25-17

Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-18

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
WELL LOCATION (N/E): **998116.3 751082.0**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Hollow Stem Auger**
WELL INSTALLATION STARTED: **10/16/95**
WELL INSTALLATION COMPLETED: **10/16/95**

GROUND SURFACE ELEVATION: **743.1**
DATUM: **NGVD 88**
GEOLOGIST: **F. O'Loughlin**
CHECKED BY: **P.Feschbach-Meriney**
CONSULTANT:



DEPTH (ft.)		ELEVATION (ft.)
1.6	TPC	741.4
1.3	TR	741.7
	TC	
0.0	GS	743.1
1.9	TBS	741.2
3.4	TSP	739.7
4.4	TSC	738.7
8.9	BSC	734.2
9.7	POW	733.4

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER

Diameter: **4 inches**
Type: **Round Box Riser**
Interval: **5.02 feet**

RISER

Diameter: **2 inches**
Type: **SCHEDULE 40-PVC**
Interval: **5.74 feet**

SCREEN

Diameter: **2 inches**
Type: **SCH 40-PVC, 0.010" slot**
Interval: **4.5 feet**

SURFACE SEAL

Type: **CEMENT**
Interval: **NA**

GROUT

Type: **NA**
Interval: **NA**

SEAL

Type: **BENTONITE**
Interval: **1.5 feet**

SANDPACK

Type: **Morie 0 and #1Q Rock**
Interval: **6.3 feet**

WELL DEVELOPMENT DATA

Date: **10/30/95**
Method: **Surge Block**
Duration: **4 Days**
Rate: **0.090 L/minute**

WATER LEVELS

	Date	Time	Depth,TR
▽	10/30/95	1518	5.93 ft
▼	10/31/95	0921	5.98 ft
▽	11/1/95	0900	6.04 ft
▽	11/2/95	0825	5.95 ft
▽			
▼			

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
7.00	14.5	1480	8.57

LEGEND

▨	SURFACE SEAL	●	GRAVEL
▩	GROUT	░	SAND
▒	SEAL	▥	SILT
⁘	SANDPACK	▨	CLAY
		☒	NO RECOVERY

TPC	TOP OF PROTECTIVE CASING
TR	TOP OF WELL RISER
GS	GROUND SURFACE
TBS	TOP BENTONITE SEAL
TSP	TOP OF SANDPACK
TSC	TOP OF SCREEN
BSC	BOTTOM OF SCREEN
TD	TOTAL DEPTH
POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

Seneca Army Depot
Romulus, New York

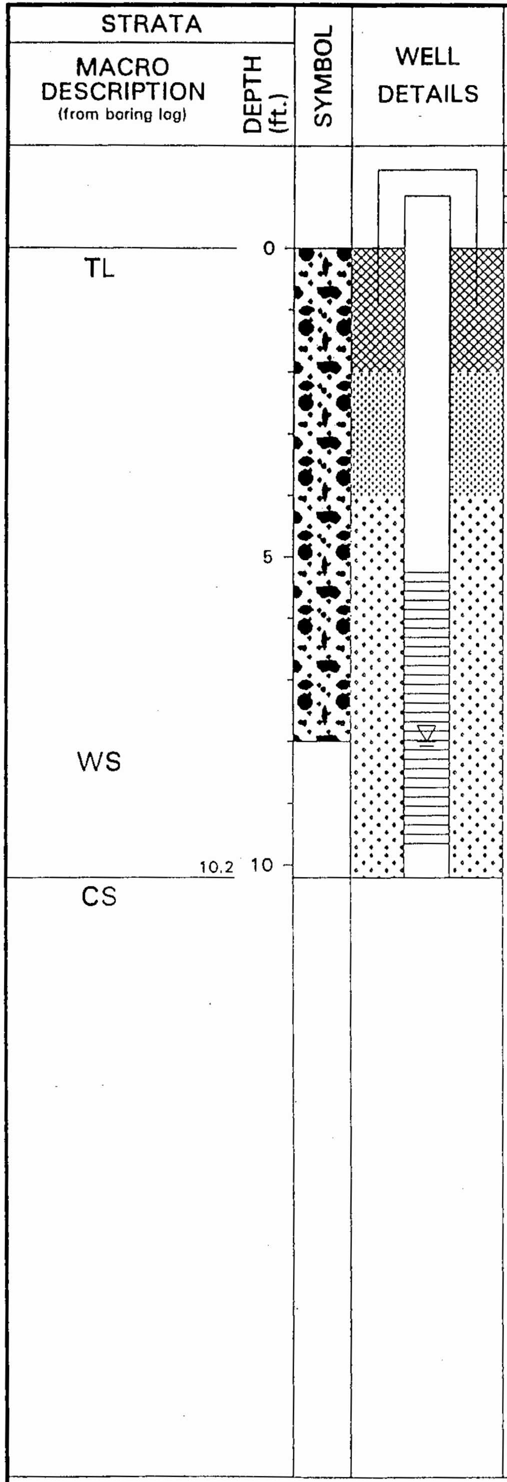
COMPLETION REPORT OF WELL No. MW25-18

Sheet 1 of 1

COMPLETION REPORT OF WELL No. MW25-19

PROJECT: **SEAD-25 & SEAD-26 RI/FS**
PROJECT LOCATION: **Seneca Army Depot Activity, Romulus, NY 14541**
WELL LOCATION (N/E): **998135.0 750762.5**
DRILLING CONTRACTOR: **Empire Soils Investigation, Inc.**
DRILLING METHOD: **Hollow Stem Auger**
WELL INSTALLATION STARTED: **10/07/95**
WELL INSTALLATION COMPLETED: **10/07/95**

GROUND SURFACE ELEVATION: **740.1**
DATUM: **NGVD 88**
GEOLOGIST: **F. O'Loughlin**
CHECKED BY: **P.Feschbach-Meriney**
CONSULTANT:



DEPTH (ft.)		ELEVATION (ft.)
1.9	TPC	738.1
1.9	TR	738.2
	TC	
0.0	GS	740.1
2.0	TBS	738.1
4.0	TSP	736.1
5.3	TSC	734.8
9.8	BSC	730.3
10.2	POW	729.9

WELL CONSTRUCTION DETAILS

PROTECTIVE COVER
Diameter: **4 inches**
Type: **Round Box Riser**
Interval: **3.95 feet**

RISER
Diameter: **2 inches**
Type: **SCHEDULE 40-PVC**
Interval: **7.15 feet**

SCREEN
Diameter: **1.875 in.**
Type: **WIRE & PVC, 0.010" slot**
Interval: **4.5 feet**

SURFACE SEAL
Type: **CEMENT**
Interval: **NA**

GROUT
Type: **NA**
Interval: **NA**

SEAL
Type: **BENTONITE**
Interval: **2.0 feet**

SANDPACK
Type: **Morie 0 and Morie 000**
Interval: **6.2 feet**

WELL DEVELOPMENT DATA
Date: **10/22/95**
Method: **Surge Block**
Duration: **1 Day**
Rate: **0.780 L/minute**

WATER LEVELS

	Date	Time	Depth,TR
▽	10/22/95	1505	2.94 ft
▼			
▽			
▼			
▽			
▼			

Final Measurements:

pH	Temperature (degrees C)	Conductivity (micromhos/cm)	Turbidity (NTU)
6.96	16	550	5.87

LEGEND

▨	SURFACE SEAL	●	GRAVEL	TPC	TOP OF PROTECTIVE CASING
▩	GROUT	⁘	SAND	TR	TOP OF WELL RISER
▒	SEAL	▥	SILT	GS	GROUND SURFACE
⁙	SANDPACK	▨	CLAY	TBS	TOP BENTONITE SEAL
		☒	NO RECOVERY	TSP	TOP OF SANDPACK
				TSC	TOP OF SCREEN
				BSC	BOTTOM OF SCREEN
				TD	TOTAL DEPTH
				POW	POINT OF WELL

PARSONS
ENGINEERING-SCIENCE, INC.

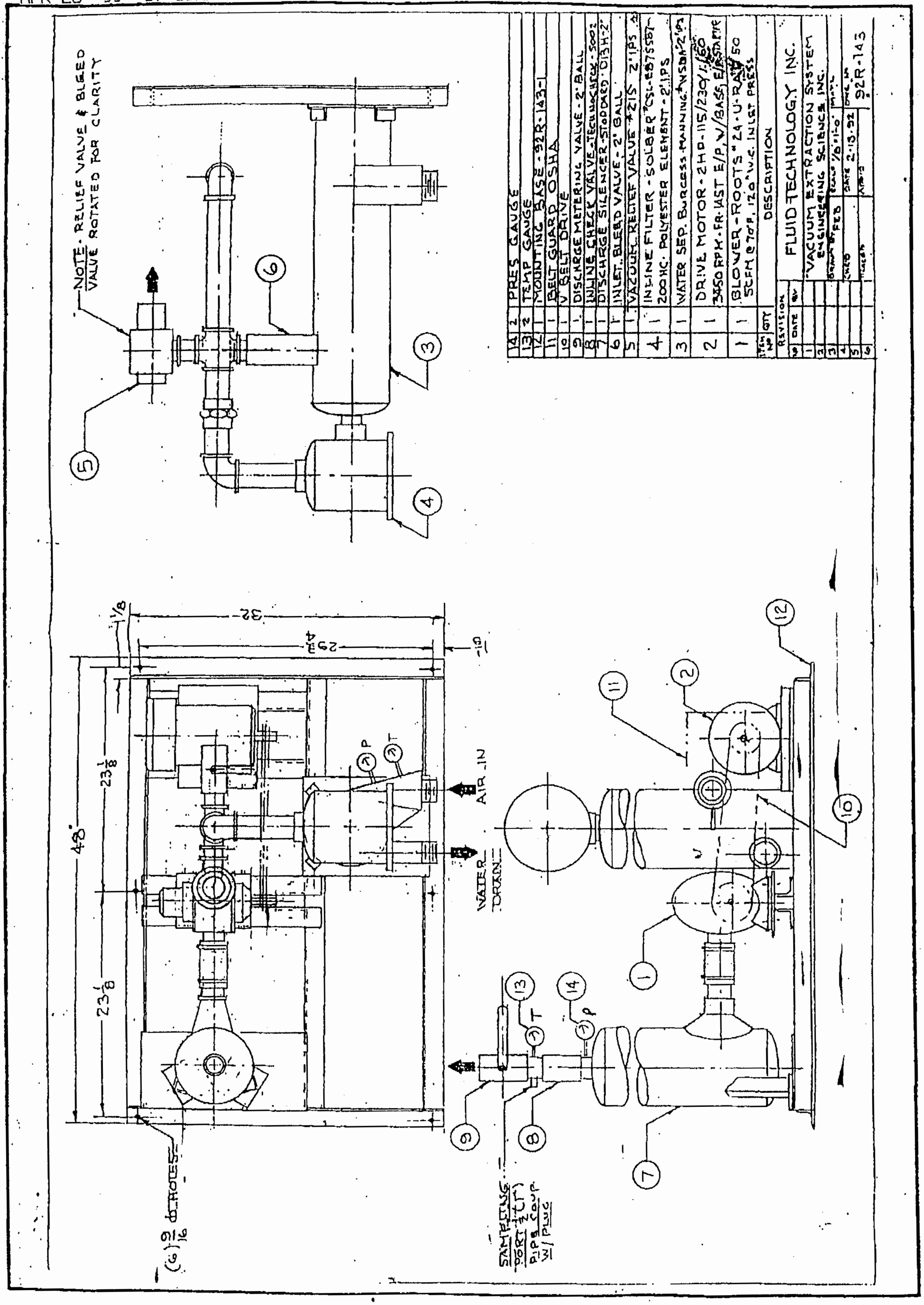
Seneca Army Depot
Romulus, New York

COMPLETION REPORT OF WELL No. MW25-19

Sheet 1 of 1

APPENDIX H

Blower Specifications for Treatability Study



ITEM NO	QTY	DESCRIPTION
14	2	PRES GAUGE
13	2	TEMP GAUGE
12	1	MOUNTING BASE - 92R-143-1
11	1	BELT GUARD OSHA
10	1	V BELT DRIVE
9	1	DISCHARGE METERING VALVE - 2" BALL
8	1	INLINE CHECK VALVE - TECHNOCHECK - 500?
7	1	DISCHARGE SILENCER - STODDARD - D13H-2"
6	1	INLET BLEED VALVE - 2" BALL
5	1	VACUUM RELIEF VALVE #215 2" IPS
4	1	INLINE FILTER - SOLBERG "CSL-857557 - 200HC. POLYESTER ELEMENT - 2" IPS
3	1	WATER SEP. BURGESS-MANNING "VSDA" 2" IPS
2	1	DRIVE MOTOR - 2HP - 115/230/1/60 3450 RPM - FR. 145T E/P, W/BASE, E/STARTER
1	1	BLOWER - ROOTS "24-U-RAI" 50 SCFM @ 7oP, 120" W.C. INLET PRESS

FLUID TECHNOLOGY INC.

"VACUUM EXTRACTION SYSTEM"
ENGINEERING SCIENCE INC.

DRAWN BY FEB
SCALE 1/8"=1'-0"
DATE 2-13-92
DWG NO 92R-143

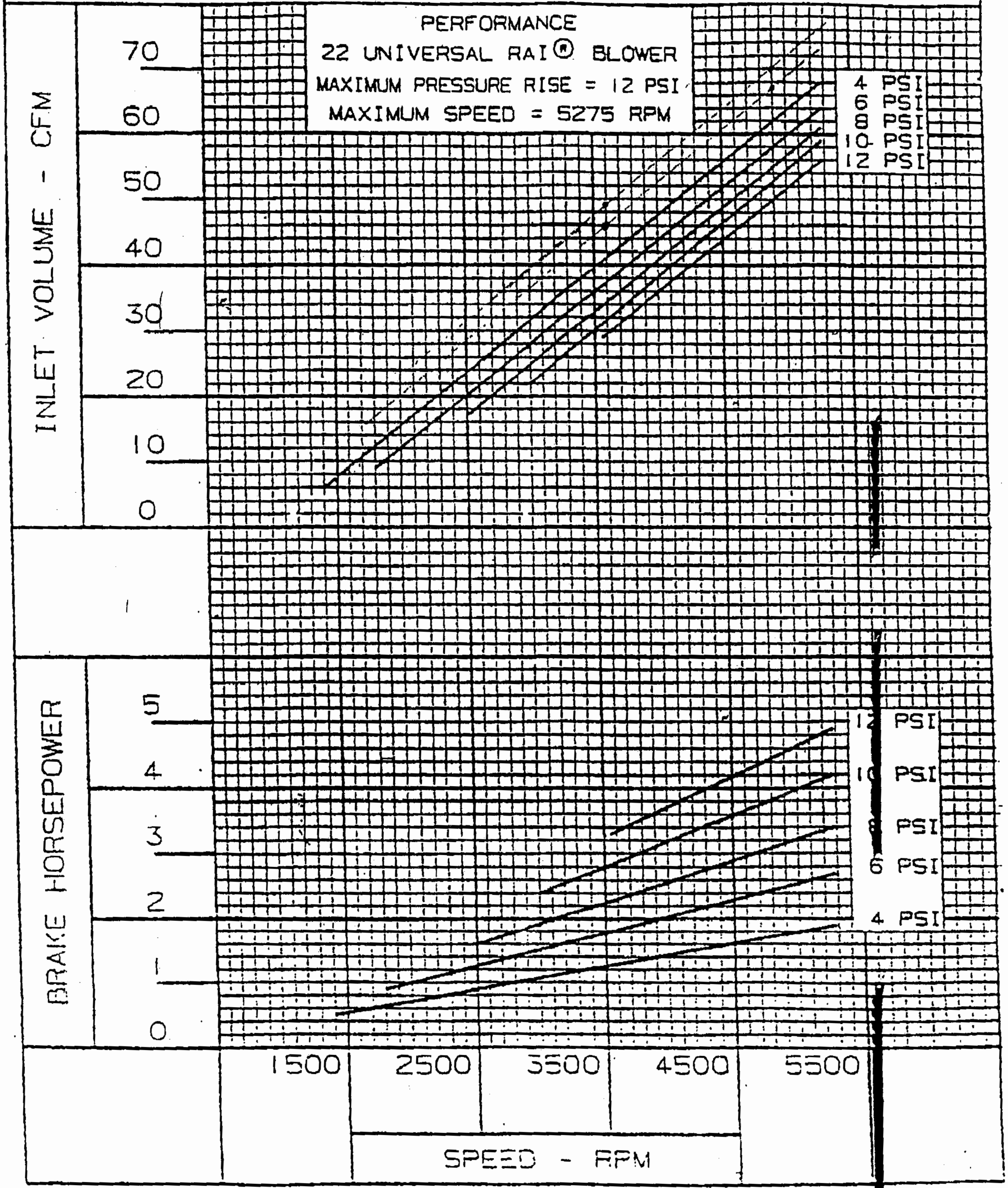
ENGINEERING-SCIENCE

POSITIVE DISPLACEMENT
BLOWER
(OAKLAND OFFICE)

ROOTS DIVISION
DRESSER INDUSTRIES, INC.
CONNERSVILLE, IN. 47331
PRINTED IN U.S.A.

PERFORMANCE BASED ON INLET
AIR AT 14.7 PSIA & 68°F

JUNE 1990



POSITIVE DISPLACEMENT BLOWER

EG&G ROTRON

DR 454
Regenerative Blower

FEATURES

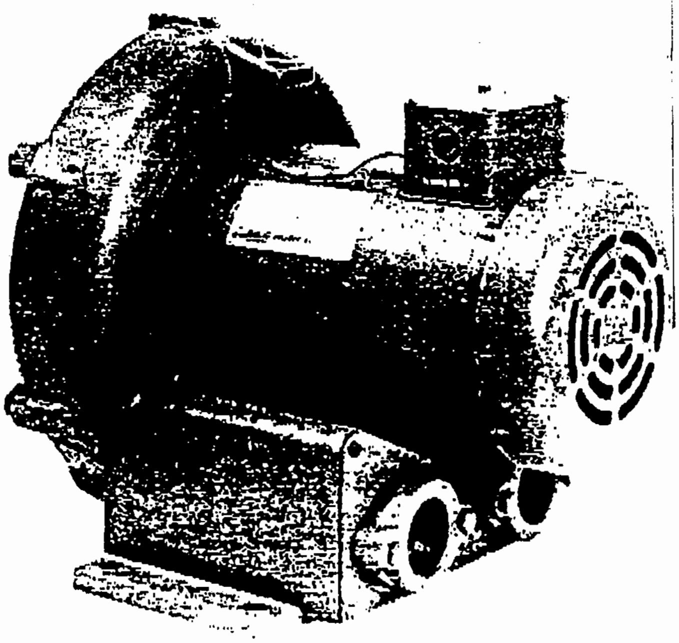
- Manufactured in the USA
- Maximum flow 127 SCFM
- Maximum pressure 65" WG
- Maximum vacuum 4.3" Hg
- 1.5 HP standard
- Blower construction—cast aluminum housing, impeller and cover
- Inlet and outlet internal muffling
- Noise level within OSHA standards
- Weight: 73 lbs. (33 Kg)

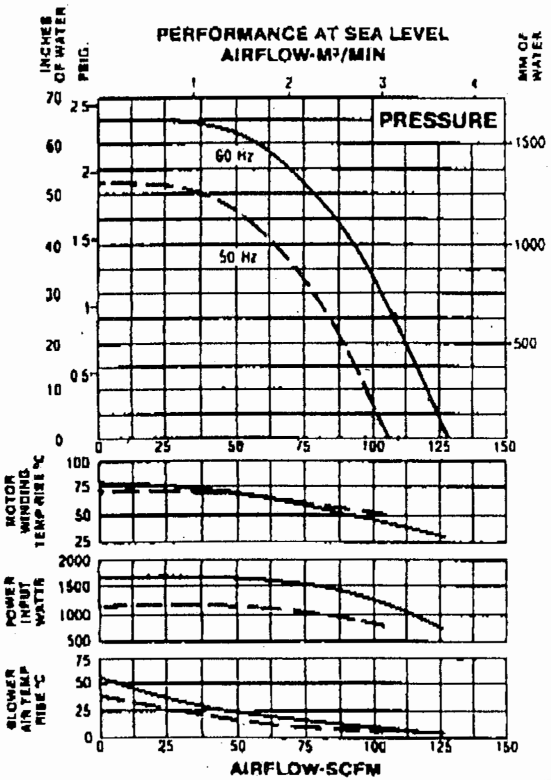
ACCESSORIES

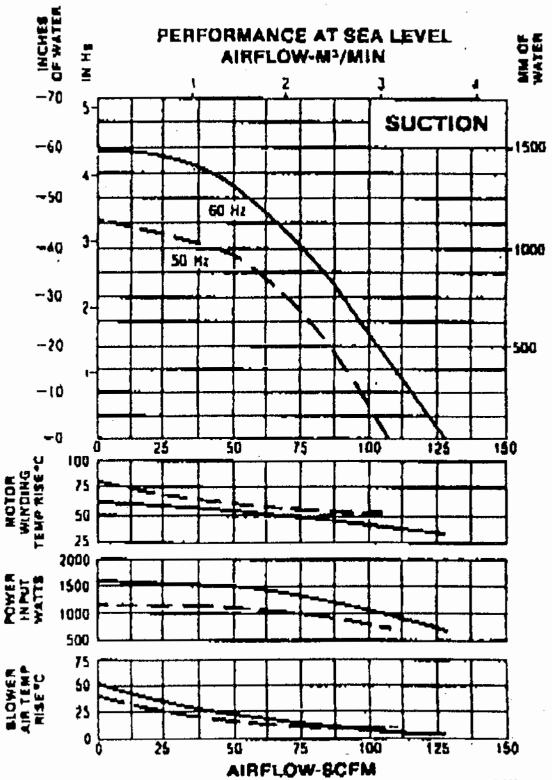
- External mufflers
- Slip-on flanges
- Inlet and/or Inline filters
- For details see Accessories Section

OPTIONS

- Smaller horsepower motors
- 575-volt and XP motors
- Surface treatment or plating
- Single or three phase motors
- Gas tight sealing
- Belt drive (motorless) model; for detail see Remote Drive Section

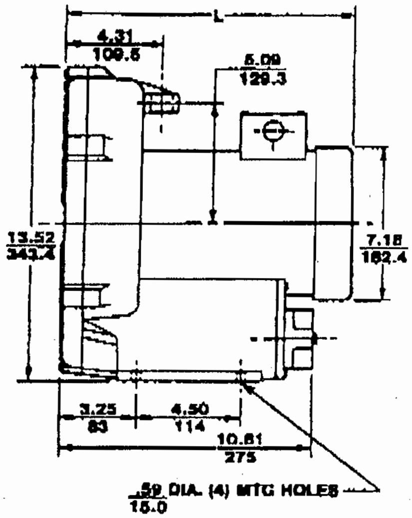


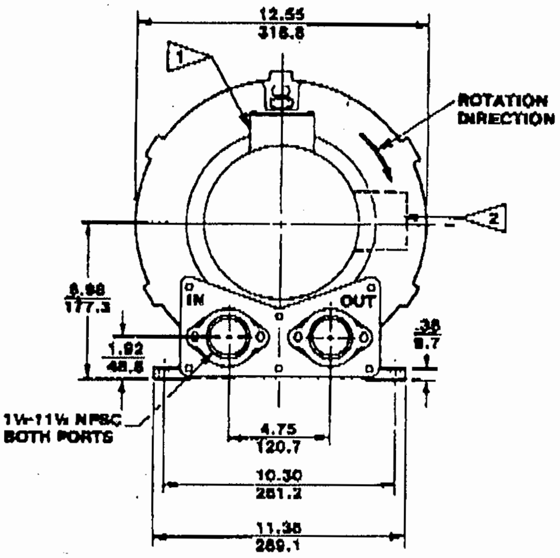




RENTAL FROM ENVIRO EQUIPMENT, INC (704) 588-7970

DR 454
Regenerative Blower





Model	L (IN)	L (MM)
DR454R58	14.59	370.6
DR454W58	17.51	444.8
DR454R72	13.59	345.2
DR454W72	16.63	422.4
DR454R86	13.59	345.2

1 T'BOX CONNECTION .87" DIA. ON TEFC MOTORS, .75 NPT ON XP MOTORS

2 LOCATION OF CAPACITOR ON SINGLE PHASE MOTORS. LOCATION OF TERMINAL BOX ON XP MODELS

DIMENSIONS: $\frac{\text{IN}}{\text{MM}}$

TOLERANCE: .XX ± $\frac{.06}{1.5}$

Specifications Subject To Change Without Notice.

SPECIFICATIONS

MODEL	DR454R58	DR454W58	DR454R72	DR454W72	DR454R86
Part No.	036856	036858	036855	036857	036949
Motor Enclosure Type	TEFC	XP	TEFC	XP	TEFC
Motor Horsepower	1.5	1.5	1.5	1.5	1.5
Voltage[1]	115/230	115/230	230/460	230/460	575
Phase	1	1	3	3	3
Frequency[1] (Hz)	60	60	60	60	60
Insulation Class[2]	F	B	F	B	F
NEMA Rated Motor Amps	17.7/8.85	17.7/8.85	4.5/2.25	4.5/2.25	1.8
Service Factor	1.15	1.0	1.15	1.0	1.15
Locked Rotor Amps	96/48	96/48	32/16	32/16	12.8
Max. Blower Amps	19.0/9.5	19.0/9.5	4.8/2.4	4.8/2.4	2.0
Recommended NEMA Starter Size	1/0	1/0	00/00	00/00	00
Weight (lbs/Kg)	87/39	103/47	73/33	92/42	73/33
Blower Limitations for Continuous Duty (60 Hz/50 Hz)					
Max. Pressure-In. of water	65/52	65/52	65/52	65/52	65
Max. Suction-In. of water	59/45	59/45	59/45	59/45	59
Min. Flow-Pressure-SCFM	0/0	0/0	0/0	0/0	0
Min. Flow-Suction-SCFM	0/0	0/0	0/0	0/0	0

[1] All 3 phase motors are factory tested and certified to operate on 200-230/460 VAC-3 ph-60 Hz and 220-240/380-415 VAC-3 ph-50 Hz. All 1 phase motors are factory tested and certified to operate on 115/230 VAC-1 ph-60 Hz and 220-240 VAC-1 ph-50 Hz.

[2] Maximum operating temperatures: Motor winding temperature (winding rise plus ambient) should not exceed 140°C for Class F insulation or 110°C for Class B insulation. Blower outlet air temperature should not exceed 140°C (air temperature rise plus ambient).

ENVIRO EQUIPMENT ; INC. (704) 588-7970

APPENDIX I

Response to Comments

Response to the Comments from United States Environmental Protection Agency, Region 2

Subject: Draft Bioventing Treatability Study Workplan for the Fire Training and Demonstration Pad (SEAD-25), Seneca Army Depot, Romulus, New York, April 28, 1999

Comments Dated: September 17, 1999

Date of Comment Response: March 1, 2001

Responses to these comments have been delayed while the Army considered other remedial alternatives for SEAD-25/26, including the LTTD. Since this alternative is not longer being considered the Army has decided to proceed with this bioventing treatability study effort.

US EPA Comments:

Comment: This is regarding the above referenced document prepared by Parsons Engineering Science, Inc. (Parsons ES) for SEDA through the U.S. Army Corps of Engineers New York District and Huntsville Division. EPA comments are as follows:

The work plan describes three objectives on page 1.

1. assess the ability to supply oxygen to the test plot
2. determine rates of contaminant removal by indigenous microorganisms
3. evaluate potential for sustaining rates of removal until soil concentrations are below regulatory standards.

With some further clarification, the work plan should be able to meet the first two objectives, assessing oxygen supply and measuring removal rates. It may be possible to meet the third objective for lighter hydrocarbons (such as benzene, toluene, and xylene), but not for the heavier hydrocarbons commonly present in fuel spills. Since chlorinated solvents are also present at the site, meeting objective 3 may take longer than one year and may require additional analytical testing.

Response: The major constituents of concern at SEAD-25 are BTEX compounds. Only in borings SB25-12 and SB25-5 did concentrations of chlorinated compounds exceed NYSDEC TAGM values. Chlorinated compounds don't have a significant contribution to the carcinogenic and noncarcinogenic health effects evaluated in the RI. In the Future Residential scenario, the cancer risk due to presence of chlorinated compounds is 8×10^{-5}, which is within USEPA target ranges of 10^{-4} to 10^{-6}. The child hazard index due to presence of chlorinated compounds is 0.3, which is below USEPA target range of 1.0. Therefore, even if no degradation of chlorinated compounds take place, in 1 year, as long as BTEX is being degraded, health risks will be reduced.

Comment: We noted from excerpts of the RI report that SEAD-25 is a small area, perhaps containing as little as 2200 yd^3. If the soil volume is really this small, the Army might find it less expensive to excavate the area. The excavated material could be sent off site for treatment or perhaps it could be treated on site with contaminated materials from other areas.

Response: Disagree. Excavation and off site disposal was considered as a component of remedial alternative RA25-4, -5 and -6 in the Feasibility Study. The bioventing alternative ranked higher in terms of ARAR compliance, protectiveness, effectiveness and reductions. This alternative was also found to be less expensive than those alternatives incorporating excavation and disposal of soil to an off-site landfill.

Several aspects of the work plan would benefit from revision:

Comment 1: The first step in evaluating bioventing should be a soil gas survey to determine whether or not the vadose zone is oxygen deficient. If the material is well oxygenated, bioventing won't increase biological degradation rates.

Response 1: Agreed. Soil gas samples will be collected prior to startup of bioventing. It is expected that the vadose zone will be oxygen deficient. Based on our experience of over 200 fuel-contaminated sites, it would be very unlikely to have oxygen levels greater than 5% when BTEX levels are as high as 151,500μg/kg (in boring SB25-5.) Therefore, we believe bioventing will increase biological degradation rates.

Comment 2: Presence of chlorinated solvents at the site – On page 2, the work plan mentions that a groundwater plume containing BTEX and chlorinated solvents is present adjacent to the site. The text says bioventing is expected to eliminate the source of the plume and in appendix C, analytes are listed as trichloroethane (TCA), 1,2 dichloroethene, benzene, toluene, and xylene. The text does not discuss issues such as the types and soil concentrations of chlorinated compounds or planned mechanism of removal (co-metabolism, aerobic metabolism, etc.). Since bioventing of chlorinated compounds is somewhat different than treatment of hydrocarbons, these issues should be resolved before the project begins.

Contaminated concentrations for SEAD-25 listed in the RI report indicate that bioventing at a low flow rate should be successful for BTEX compounds and DCE, assuming that oxygen is presently limiting biodegradation. TCA may be degraded because other contaminants are present that can act as co-substrates for co-metabolism. However, co-metabolism isn't certain and a bench study would be useful to evaluate TCA degradation.

Response 2: As discussed above, the major constituents of concern at SEAD-25 are BTEX compounds. Only in borings SB25-12 and SB25-5 did concentrations of chlorinated compounds exceed NYSDEC TAGM values. Chlorinated compounds are not major contributors to risk at SEAD-25. However, reduction of these compounds is desirable and may occur during bioventing of the matrix. The effect of bioventing on the degradation of these compounds will be evaluated in this treatability study. If the study length proves inadequate to determine the effect of bioventing on degradation of chlorinated compounds, then additional study, i.e. bench scale study, or extension of the pilot study, may be warranted.

Comment 3: Use of soil gas measurements to determine contaminant reduction – As described in section 3.3 and Appendix C, section 4, the plan is to calculate removal based on soil gas concentrations. This approach is problematic for two reasons.

A. Since soil serves as a hydrocarbon reservoir, it is conceivable that only one may reduce the contaminant mass in the soil, but not change soil gas concentrations significantly over the relatively short one-year period. In that case, it would appear that bioventing is not working when it may be effective. The problem could be resolved by using soil samples to determine contaminant mass before and after treatment; data for an intermediate time would also be useful. This soil data would be in addition to the soil gas data collection.

B. The description of soil gas measurements is unclear in the Appendix. For example, it is not clear why individual compound data will be incorporated into a TCA equivalents basis, how the various compounds will be counted in the TCA equivalents basis, whether blowers will be on or off when soil gas measurements are taken, and how performance will be calculated. In addition, it seems unusual that the main text discusses hydrocarbons but Appendix C seems to focus on TCA equivalents.

Response 3: **A** Agreed. Soil gas sample results alone will not be used to assess the removal of hydrocarbons from the soil. Soil samples collected before and after the bioventing treatability study will also be used to assess contaminant reduction in the treatment zone. Please refer to Tasks 2 and 11 on Page 2 of the text. Collecting soil data at an intermediate time interval is not currently proposed.

B Appendix C has been changed to reflect that instead of TCA, a gas standard mixture of benzene, toluene, ethylbenzene, and xylene (BTEX), will be used for the calibration gas. The BTEX constituents more closely match the primary constituents of concern at the site. Text has been added to the opening paragraphs of Appendix C to clarify when the soil gas sampling will be performed and how the data will be used to evaluate the system's performance. Soil gas sampling will be performed three times during the study: (1) prior to turning the system on, (2) prior to conducting the 6 month in-situ respiration test and (3) prior to conducting the 12 month in-situ respiration test. During each event the bioventing system will be shut off and allowed to equilibrate overnight prior to conducting the soil gas sampling. A decrease in soil gas concentrations of hydrocarbons over time will be an indicator that degradation of these compounds is being enhanced through use of the bioventing system. Soil gas data alone will not be used, however, to make this determination and confirmatory soil sampling conducted prior to the treatability study and at the end of the study will be evaluated as well.

Comment 4: Air flowrates – The estimated flowrate (around 10 scfm) seems high for the portion of the site to be treated in the treatability test. Bioventing is typically designed to operate at about 1 pore volume/day, but the work plan design should result in 3 to 10 pore volumes/day. A smaller blower with lower air flowrates is strongly advised for addressing the volatile contaminants in a shallow setting.

Response 4: An air flowrate of 10 scfm is an estimate. As stated in Section 1 on the bottom of page 2, "[This estimate] will be further refined based on the initial air injection and in-situ respiration tests." Air will be gradually introduced into the soil matrix at lower flow rates. The blower used for the treatability study may be adjusted such that lower flow rates may be used.

Comment 5: Screening soil samples using a PID or OVM – Section 3.2 of Appendix A discusses using a PID or OVM to screen soil samples for elevated levels of hydrocarbons. This technique is not advised. This technique may identify hot spots, but in bioventing, the more important question is whether the contaminant mass is changing. The suggested technique is to take samples at regular intervals over the cores. If individual samples cannot be analyzed, samples can be composited before analysis. Using this technique, a more representative concentration for the soil mass should be obtained. In addition, if volatile compounds are of concern soil sampling should be conducted in a manner, which minimizes volatilization.

Response 5: Although this technique may identify hot spots initially, analytical data from soil samples taken from these "hot spots" will be compared to data from soil samples collected from the same depth intervals, 2 feet from the initial soil boring, at the end of the study. The analytical data collected will be used to assess the reduction in hydrocarbon reduction.

Soil sampling will be conducted in a manner that minimizes volatilization. As described in Appendix A, Section 3.2, samples collected for VOC analysis will not be homogenized or composited during the sampling process.

Comment 6: Depth of contamination – the highest concentrations are typically found fairly close to the soil surface, often in the 0 to 2-ft. interval. Given this situation it may be prudent to place a gas impermeable cover over these regions since volatilization may be enhanced during bioventing, particularly if the high flowrates described in the work plan are used.

Response 6: It is not anticipated that volatilization will not be enhanced to a degree that warrants a gas impermeable cover. The purpose of this study is to add air to the soil matrix to enhance biodegradation, not strip the volatiles from the soils. Flow rates will be optimized during the initial air injection and in-situ respiration test to meet this objective. PID readings will be taken around the test plot on a monthly basis to determine if volatilization of constituents is occurring. If it is found that such volatilization is occurring, then field adjustments will be made to reduce the air injection rate such that volatilization is no longer occurring.

Comment 7: Estimated Radius of Influence – The work plan does not discuss the assumption supporting the assumed radius of influence of 30 ft. to 35 ft. Since the actual radius of influence may be smaller or larger than 30 feet, the work plan should include a provision for adding monitoring points once site data is available.

Response 7: Monitoring points at the site will be installed at 5 feet, 15 feet and 30 feet from the vent well. Therefore, at the end of the study, the study will indicate if the radius of influence is less than 5 feet, between 5 and 15 feet, between 15 and 30 feet or greater than 30 feet. This information will be sufficient to determine if additional vent wells are required to remediate the site in a timely and cost effective manner.

OTHER COMMENTS:

Comment 1: Section 3.2.2 and Figure 1 – In figure 1, MP5 and MP6 are described as being 15 feet from the venting well, but on page 5, these wells are described as 5 feet from the well. This inconsistency should be resolved.

Response 1: Agreed. MP5 and MP6 are 15 feet away from the vent well. Changes have been made to Section 3.2.2 in the text to reflect this.

Comment 2: Section 3.7 – The text states that an oxygen utilization rate of 1%/day will be used as an indicator of bioventing feasibility. This background rate determined in the uncontaminated well should be subtracted from the rate in the contaminated well when comparing to site utilization rates to this 1%/day threshold. However, the 1%/day level should be considered a guideline rather than a rule.

Response 2: Agreed. We recognize that the oxygen utilization rate of 1%/day is considered a guideline rather than a rule. The text in Section 3.7 has been changed to reflect that the oxygen utilization rate in the contaminated well should be compared to that in the uncontaminated well in assessing the net increase in oxygen utilization rate.

Comment 3: Appendix A – In the decontamination operation, is the hexane rinse necessary? The potential for contamination by incomplete drying seems higher than the potential for cross contamination between samples.

Response 3: Hexane will only be used if water and steam is not effective in cleaning equipment. Contamination by incomplete drying is not likely since hexane is very volatile.

Comment 4: Appendix B – It is good that the test plans to calculate radius of influence based on pressures and oxygen levels. Additional monitoring points may be needed to gather this information.

Response 4: Although a more accurate assessment of the radius of influence may be made with additional monitoring points, six monitoring points is sufficient to determine the technical and economic viability of bioventing at SEAD-25.

Response to Comments from the New York Department of Environmental Conservation

Subject: Bioventing Treatability Study Workplan for the Fire Training and Demonstration Pad (Sead-25), Seneca Army Depot Activity, Romulus, NY, April 28, 1999

Comments: Dated June 28, 1999

Date of Comment Response: March 1, 2001

Responses to these comments have been delayed while the Army considered other remedial alternatives for SEAD-25/26, including the LTTD. Since this alternative is not longer being considered, the Army has decided to proceed with this bioventing treatability study effort.

In addition to the changes made to the document based on the comments below, Parsons ES has also made the following changes in the Final Bioventing Treatability Study Work Plan:

Quality control samples, such as duplicates and trip blanks have been added to Table 1 and Table 2.

Helium injection will only be done during initial respiration test. It is not necessary to inject helium in the 6-month and final respiration test since the initial He monitoring can assess the extent of diffusion of soil gases within the aerated zone.

Comment 1: Section 1.0: The remediation technology chosen to treat the ground water plume is natural attenuation. This is not correct and the statement should be removed.

Response 1: Agreed. This statement is removed. In addition, groundwater monitoring has been removed as part of this treatability study, since the focus of the study is on the treatment of soils.

Comment 2: Section 3.0: States that pilot test activities will be confined to unsaturated soils. A review of Appendix D to the Remedial Investigation (RI) report shows that ground water in the vicinity of the pilot test was approximately 2.5 feet below ground surface, as measured in Monitoring Wells MW25-2 and MW25-3 which bracket the pilot test area. Allowing for a bentonite seal of adequate minimum depth to prevent the venting well from short-circuiting to the ground surface, it is questionable whether an effective bioventing system can be constructed in the short space available between the seal and the saturated zone. A discussion should be added to the plan, which details how pilot test activities will be confined to unsaturated soils, while recognizing that Section 2.2 of the plan states that ground water generally occurs at depths of 2 to 6 feet below ground surface at this site. If the bioventing system is constructed based upon the water table encountered during an unusually dry season, what affect would be expected on the treatability study data and its usability if the water table rises into the constructed bioventing system during the study?

Response 2: The groundwater table at SEAD-25 has been observed to fluctuate between 1.5 and 2.5 feet below ground surface. Vent wells will be designed for low groundwater level conditions to maximize the depth to which air may be delivered at least through part of the year. A discussion is added to the plan in Sections 3.2.1 and 3.2.2 which details how vent wells and monitoring points are designed assuming typical low groundwater conditions. Appendix D of the Remedial Investigation does indicate that the groundwater is 2.5 feet below ground surface. Also, injection of air will force the groundwater level down lower as well, increasing the depth to which air is delivered to the overburden soils. Due to seasonal high groundwater levels, the vent wells and monitoring points may become partially submerged in March and April, which typically have elevated groundwater levels.

The vent wells are designed as follows: seals extend from the top of the ground surface to 2 feet below the surface. The well will be screened from 2.5 feet below ground surface until bedrock (refusal in competent shale) at VW1, which is about 5.5 feet below the surface (refer to updated Figure B-1). Borings used for the installation of monitoring points will be drilled to bedrock. If groundwater is unusually low, and there is adequate space to accommodate two monitoring zones (at least 5 feet between the ground surface and the water level encountered), two monitoring zones will be constructed as described in Appendix B. If such space is not encountered, a 3 feet long section of lean grout containing 3% bentonite by volume will be placed in the borehole. Above that, one monitoring zone approximately 1.5 feet below the ground surface to 2.5 feet below ground surface will be installed. The seal will extend 1.5 feet below ground surface. See Figure B-2 for monitoring point construction details when only one monitoring zone is constructed.

If the groundwater level rises above the entire vent well screen during the one-year study, the system may be shut off temporarily until water levels drop below the vent screen and delivery of air into the soils can resume.

Saturation of biovented soils will result in an increased water content within the soil matrix. This may both enhance and inhibit biodegradation. Moisture is necessary for metabolic activities and solubilization of nutrients. Therefore, increased moisture contents could result in an increased rate of biodegradation. However, increased moisture levels decrease air permeability, which limits the rate of biodegradation.

Respiration tests have been scheduled during months typical of lower water table levels. System checks will be performed regularly, and if conditions require, the schedule may be modified so that data collected to evaluate the performance of the bioventing system (i.e. soil samples, respiration tests, etc.) will not be collected when monitoring points are submerged. Any changes to the sampling schedule will be documented.

Comment 3: Section 3.0: States that "monitoring wells that have a portion of their screened interval above the water table may be used as vapor monitoring points or to measure the composition of background soil gas." The plan should specify which wells are to be used for what purpose, so that the site-specific plan can be reviewed.

Response 3: Agree. The workplan is now more specific about the use of the existing monitoring wells: MW25-2 and MW25-3 will be used to monitor pressure and Table 2 has been revised to indicate that O_2, CO_2 and VOCs data will be collected at these locations. The rest of the monitoring wells at SEAD-25 will only be used to monitor groundwater elevations.

Comment 4: Section 3.4.2 states that a preliminary systems check will be performed for 1-hour. The protocol states on page 47 that a 10 to 15 minute period of air extraction or injection should be sufficient to perform the system check. This 10 to 15 minute time frame is reiterated in Appendix E of the draft work plan. Please reconcile. Will an extended period of operation for systems check cause any data interpretation problems of the following permeability test?

Response 4: The system check entails a 10- to 15-minute period where equipment and gauges will be checked. Air injection will be conducted after this, perhaps over a significantly longer period of time. Air will be introduced gradually into the soil matrix to condition the soil, allowing air to flow through it and prevent blowout of vent well seals. Section 3.4.2 has been updated to reflect this. Systems checks and the initial injection of air into the soil matrix will not cause any data interpretation problems on subsequent permeability tests, since the test will not commence until monitoring point pressures return to zero. This is described in Section 3.2 in Appendix E of the work plan.

Comment 5: Section 3.6 states that oxygen and carbon dioxide levels will be monitored for 48 to 76 hours after the 20-hour air injection period. Appendix F states that this monitoring will be terminated when the oxygen level is 5% of after 5 days of sampling. Please reconcile.

Response 5: Section 3.6 has been modified and now states that oxygen and carbon dioxide monitoring will be terminated when the oxygen level is 5% or after 5 days of sampling.

Comment 6: Section 3.6 states that respiration tests will be performed at each vent well and "several" vapor monitoring points where the oxygen levels are <2%. Please specify which monitoring points are expected to be utilized, and what basis will be utilized to make this selection. Is there a minimum number of locations where respiration tests should be run in order to have sufficient data for the study? What will be done if the planned locations for this test exceed the threshold criteria of 2% oxygen?

Response 6: During drilling of VW1, VW2, and MP1through MP-7, field testing for VOCs, O_2, and CO_2 will be conducted as indicated in Table 2 of the Workplan. Based on the O_2 and CO_2 levels observed, monitoring points will be selected for respiration testing. If O_2 levels in all monitoring points are below 2%, test will be conducted in all of them.
If the oxygen level in all monitoring points exceed the threshold criteria of 2% oxygen, monitoring points used to conduct respiration tests will be selected in the following way:

a. If the oxygen level is greater than 2% but less than or equal to 5% at a monitoring point, the point will be selected for respiration testing. Bioventing protocols recommend that wells having oxygen levels between 2 and 5 percent may be selected for respiration testing.
b. O_2 levels greater than 5% may exist when VOC levels are low, indicating that there is not much fuel hydrocarbon left to biodegrade. This situation is not likely since high levels of BTEX have been detected in the soil during the remedial investigation (e.g. 151,500 μg/Kg in SB25-5).

Based on our experience at over 200 fuel-contaminated sites, it would be very unlikely to have oxygen levels greater than 5%. However, if this should occur and VOC levels are elevated, three vapor monitoring points in which the lowest O_2 levels are measured will be selected for the respiration tests.

Comment 7: Figure 1: Shows that MW25-4D, MW25-2, MW25-5D and MW25-3 are near the anticipated zone of influence of the proposed treatability study. The referenced protocol instructs that any wells, which may serve as vertical conduits for gas flow, should be sealed to prevent short circuiting (page 47).

Response 7: Agreed. Existing monitoring wells will be sealed using pressure caps during the treatability study; thus they will not serve as vertical conduits of gas flow. Section 3 in Appendix E has been modified to reflect this.

Comment 8: Table 1 should include soil sample analysis for semi-volatile organic compounds and Total petroleum Hydrocarbons, as the intent of the study is to analyze the effectiveness of bioventing on the remediation of petroleum releases.

Response 8: Disagree. In the Remedial Investigation Report for SEAD-25 semi-volatile organic compounds were detected in the soil only at low levels and contributed neither to significant cancer risk nor elevated adult and child hazard quotients. Volatile organic compounds are the compounds of concern in the soil at the site. VOCs such as benzene are the most significant drivers of risk in the soil medium. Therefore, the effectiveness of bioventing will be based on the destruction of VOCs. Additionally, because no remediation goals have been established for TPH in soil, such data would not provide the best evaluation of bioventing performance in meeting remediation goals.

Comment 9: Figure 5 should include a task and time for the submission of a Treatability Study report to the regulatory agencies.

Response 9: Agreed. Figure 5 now includes a task and time for the submission of a Treatability Study report to the regulatory agencies.

Comment 10: Appendix B: The width of the hollow-stem augers used for venting well installation should be detailed. We note that the protocol calls for the diameter of the annular space to be at least two times greater than the vent well outside diameter (page 28). Also, we suppose that the word "gloves" in the last paragraph of page B-2 should read "glues."

Response 10: Agreed. Appendix B now includes the width of the hollow-stem augers used for venting well installation. Also, the word "gloves" in the last paragraph of page B-2 now reads "glues."

Comment 11: Figure B-1: This shows the proposed vent well sand pack begins 2-feet below grade beneath a 6-inch bentonite seal. Figure 4-1, page 29, of the protocol indicates that the beginning of the sand pack should be a minimum of 5-feet below grade beneath a 2-feet thick bentonite seal. The minimum depth construction details offered in the protocol are designed to prevent short-circuiting of vent well air to the atmosphere. Even with the reduced length of the proposed system's various components, the vent well is expected to reach 6.5 feet below ground surface. Please reconcile this with expected groundwater levels as obtained from the RI.

Response 11: Please refer to Response to Comment 2. The 5-foot minimum depth requirement of sand pack cannot be met for VW1 since the bedrock at this location is probably no more than 5.5 feet. The vent well screen will begin at 2 feet below grade. Because of the shallow depth, we believe a 1.5-foot seal will be adequate to prevent short-circuiting to the atmosphere. Air will be introduced gradually into the soil matrix to condition the soil, allowing air to flow through it and prevent blowout of vent well seals. This is discussed in Section 3.4.2 of the workplan. The introduction of air into the vent well should depress the groundwater levels in the vicinity of the vent well and increase the unsaturated zone in the vicinity.

Comment 12: Figure B-2: Shows the proposed depth of the various monitoring zones and associated bentonite seals are less than the minimum suggested depths in the protocol. The protocol states that the monitoring zones should be a minimum of 1 to 2 feet thick, and greater for low-permeability soils, which are encountered at SEDA-25, and a minimum 2-feet thick bentonite seal should be constructed between monitoring zones (page 32). Even with the reduced length of the proposed system's various components, the vent well is expected to reach 4-feet below ground surface. Please reconcile this with expected groundwater levels as obtained from the RI.

Response 12: Please see Figure B-2 which has been modified to include more site-specific details such as groundwater elevations and the thicknesses of the seals and monitoring zone. Also, see

Responses to Comments 2 and 11 regarding water table rising and its effect on the treatability study.

General Comment: Water level measurements should be routinely collected for the duration of the pilot test to ensure that any interference of the water table upon the collected data or the performance of the system is recognized.

Response: Agreed. Water level measurements will be incorporated into the monthly system monitoring. The text in Section 3.9 has been revised to reflect this.