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PART I

**Bioventing Pilot Test Work Plan for
IRP Site SS-41
Flightline Fuel Pump House
Charleston AFB, South Carolina**

PART II

**Draft Interim Pilot Test Results Report for
IRP Site SS-41
Former Flightline Fuel Pump House
Charleston AFB, South Carolina**

(Oct 93)

Prepared for

**Air Force Center for Environmental Excellence
Brooks AFB, Texas**

and

**Headquarters 437 Airlift Wing (AMC)
Charleston AFB, South Carolina**

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PART I
BIOVENTING TEST WORK PLAN FOR
IRP SITE SS-41
FLIGHTLINE FUEL PUMP HOUSE
CHARLESTON AFB, SOUTH CAROLINA

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AFB, TEXAS

and

HEADQUARTERS 437 AIRLIFT WING (AMC)
CHARLESTON AFB, SOUTH CAROLINA

October, 1993

Prepared by:
Engineering-Science, Inc.
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Denver, Colorado

CONTENTS

FIGURES

BIOVENTING TEST WORK PLAN FOR
IRP SITE SS-41: FLIGHTLINE FUEL PUMP HOUSE
CHARLESTON AFB, SOUTH CAROLINA

1.0 INTRODUCTION

This site-specific work plan presents the scope of a bioventing pilot test for *in-situ* treatment of fuel-contaminated soils at the flightline fuel pump house, located at Building 93, Charleston Air Force Base, South Carolina. For the purpose of this work plan, this area is designated as IRP Site SS-41. The proposed pilot test has three primary objectives: 1) to assess the potential for supplying oxygen throughout the contaminated soil depth, 2) to determine the rate at which indigenous microorganisms will degrade the fuel when stimulated by oxygen-rich soil gas, and 3) to evaluate the potential for sustaining these rates of biodegradation until fuel contamination is remediated below regulatory standards.

If bioventing proves to be a feasible technology for this site, pilot test data will be used to design a full-scale remediation system and to estimate the time required for remediating soils to regulatory standards. An added benefit expected during pilot testing at Site SS-41 is that a significant amount of the fuel contamination should be biodegraded during the one-year pilot test.

The pilot test system will involve two vertical air injection wells and a blower capable of sustaining a flow rate of at least 30 standard cubic feet per minute (scfm). Each vent well (VW) is expected to produce a radius of influence of approximately 20 to 30 feet, since this test site has a moderately high water table. The design flow rate and actual radius of influence for any one site will depend on soil properties, unsaturated soil thickness, and other factors. Rates of *in-situ* fuel biodegradation can also vary considerably and will be determined for individual soil vapor monitoring points (VMPs) that will be installed around the vent wells.

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." This protocol document is a supplement to the site-specific work plan and it will also serve as the primary reference for pilot test well designs and detailed test objectives and procedures. Unless otherwise noted, test procedures outlined in the protocol document will be used during the pilot test at Site SS-41.

2.0 SITE DESCRIPTION

2.1 Flightline Fuel Pump House: IRP Site SS-41

2.1.1 Site Location and History

Site SS-41 (Building 93) is a metal canopy partially covering the piping manifolds and fuel tanks. These structures are located beside Building 98, which houses the system controls. The fuel pump house system is located on the north side of the AMC Maintenance Apron adjacent to apron access Taxiway #4. A large drainage ditch is located between the facility and Taxiway #4. The fuel pump house is part of the aircraft apron/taxiway fuel distribution system that receives aircraft fuels from bulk storage (via pipelines) on another part of the base and dispenses the fuel to fueling stations around the aircraft apron. Figure 2.1 shows the location of Site SS-41 with respect to the base.

The Building 93 fuel distribution system consists of six 50,000-gallon underground storage tanks (USTs), influent and effluent fuel filters, five oil/water separators, underground pipelines and piping manifolds, fuel pumps, and two small USTs for overflow and waste liquid collection and storage. Base personnel report that JP-4 jet fuel is the primary fuel distributed by this facility. Figure 2.2 shows the fuel distribution system layout at Building 93 and Building 98.

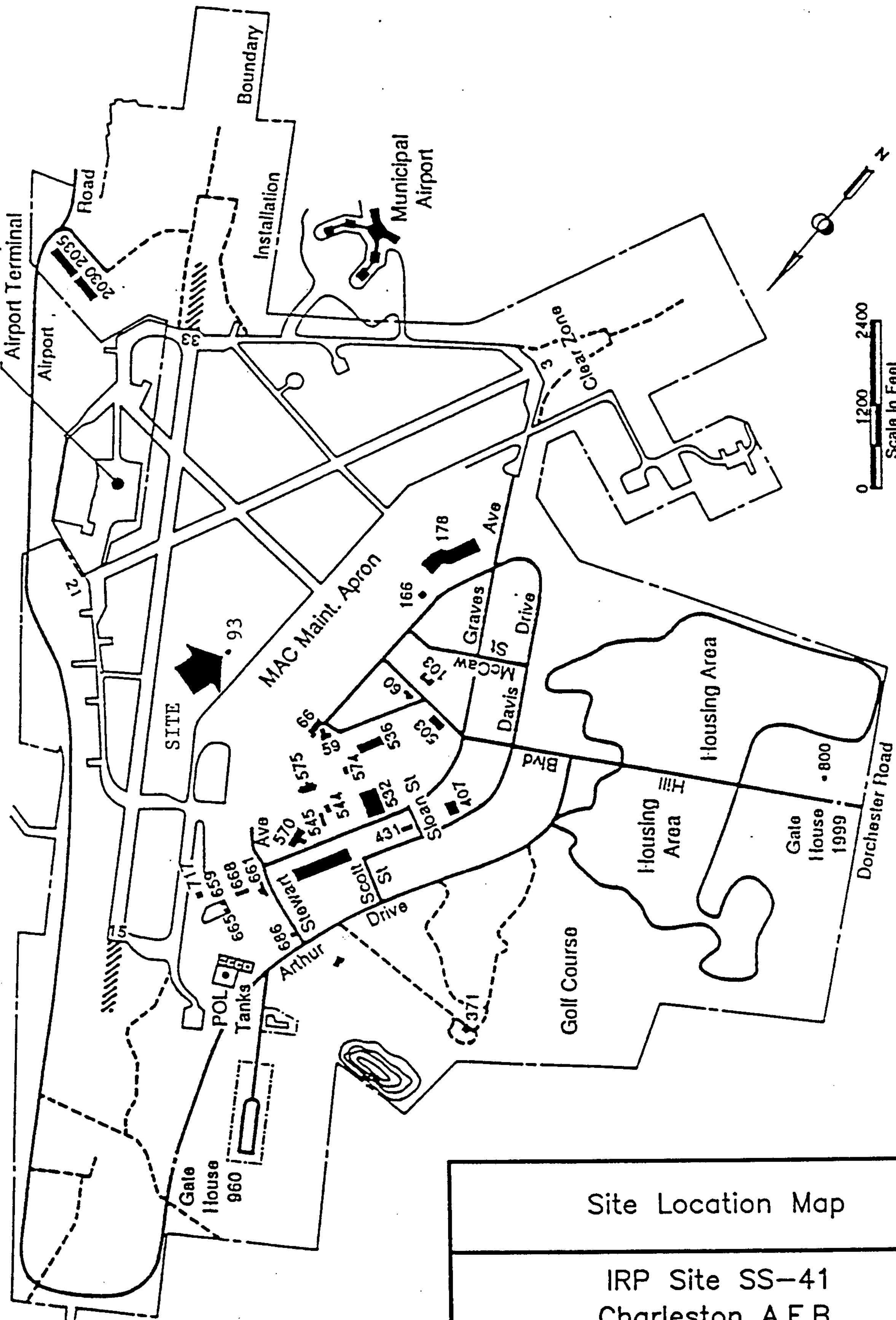
Charleston AFB is currently redesigning and upgrading their hydrant fuel distribution system around the aircraft apron. Part of this renovation project includes demolishing portions of the existing apron taxiway and fuel distribution facilities, including the system located at Site SS-41. The base reports that the fuel distribution system located at Site SS-41 (Building 93) will be demolished by the end of October. Demolition of the facility will include removal of all USTs and ancillary piping, and demolition of above-ground and below-ground structures. A replacement fuel pump house will be built on another part of the base.

2.1.2 Previous Investigations

Limited environmental assessments have been conducted at Site SS-41 to date. Preconstruction geotechnical studies and preliminary environmental sampling were conducted by Westinghouse Environmental and Geotechnical Services, Inc. (Westinghouse) during August and September, 1991. The scope of the Westinghouse study included numerous geotechnical borings along the apron taxiway in the areas planned for demolition and/or renovation. In areas of environmental concern, limited soil sampling and analyses were performed. Soil samples were screened for organic vapors with a photoionization detector (PID) and were laboratory-analyzed for benzene, toluene, ethlybenzene, and xylenes (BTEX) during the Westinghouse study. No groundwater monitoring wells were installed during the investigation. Figure 2.3 shows the locations of the soil boring/sampling points.

During the Westinghouse study, eighteen soil borings were advanced around Site SS-41. Each of the samples were analyzed for BTEX constituents. Fourteen of these sampling points (B-P5 through B-P18) were located around the USTs and fuel filters on the east side of the flightline drainage ditch. The remaining borings (B-P1 through B-P4) were positioned around the delivery pipeline on the west side of the ditch. PID readings, some as high as 3,311 parts per million (ppm), were detected in most of the soil borings. BTEX constituents were also detected in samples collected near the water table from nine of the borings. The greatest total BTEX concentration was 81.8 ppm found in boring B-P14. Westinghouse reported that immiscible, liquid-phase product ("free product") was present in this boring, however, an estimated product thickness was not given. Results of these findings are provided in the Westinghouse report titled *Report of Geotechnical Engineering and Environmental Services, ADAL Apron/Hydrant Fuel System, Charleston Air Force Base* (November, 1991).

Figure 2.1



Source: Versar, 1992

Site Location Map

IRP Site SS-41
Charleston A.F.B.
Charleston, South Carolina

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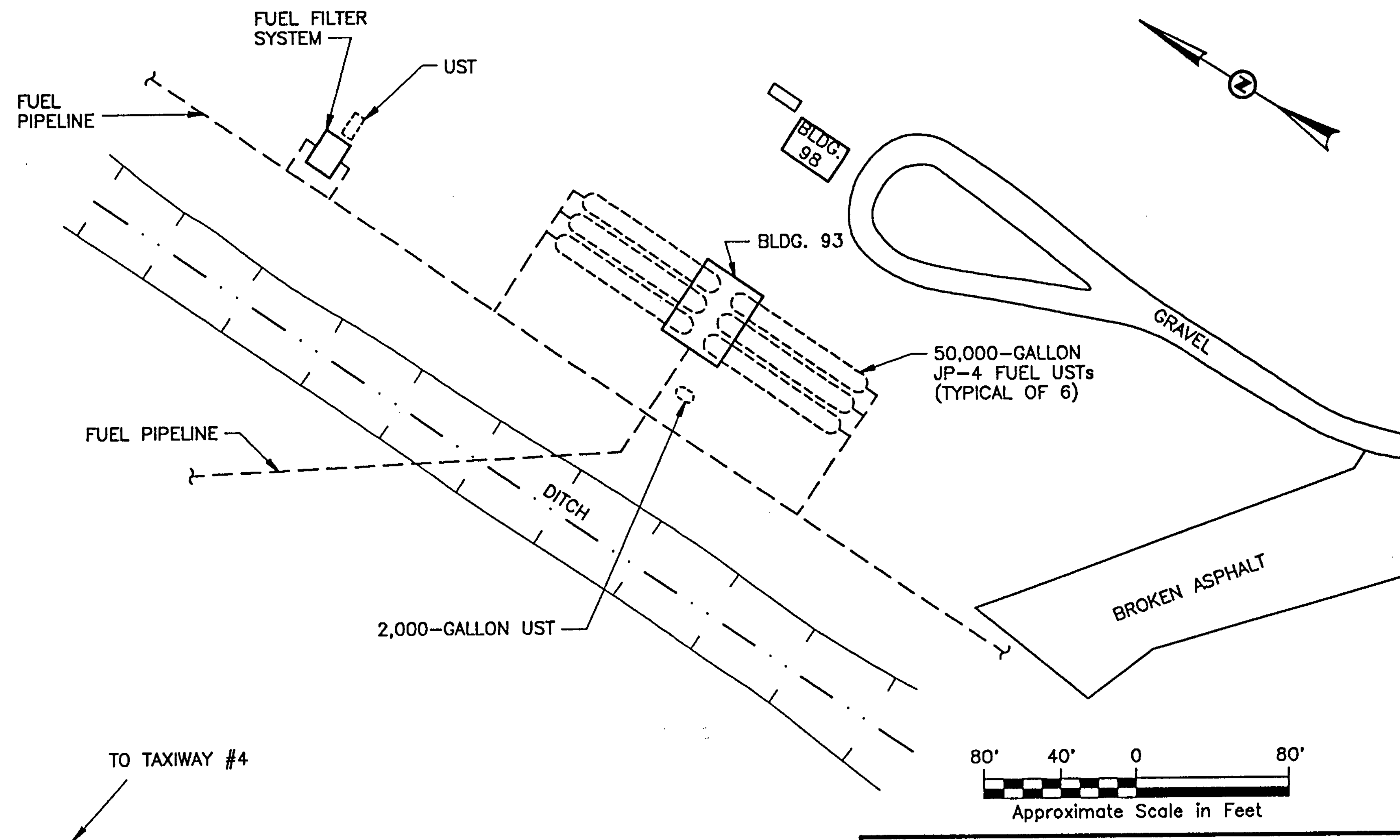

NOTES:

1. All above-grade and below-grade structures and USTs will be removed prior to installing the bioventing system.
2. All facility and appurtenance locations are approximated.
3. Site SS-41 was previously known as Building 93-Flightline Fuel Pump House #3.

Site Plan

IRP Site SS-41
Charleston A.F.B.
Charleston, South Carolina

Figure 2.2

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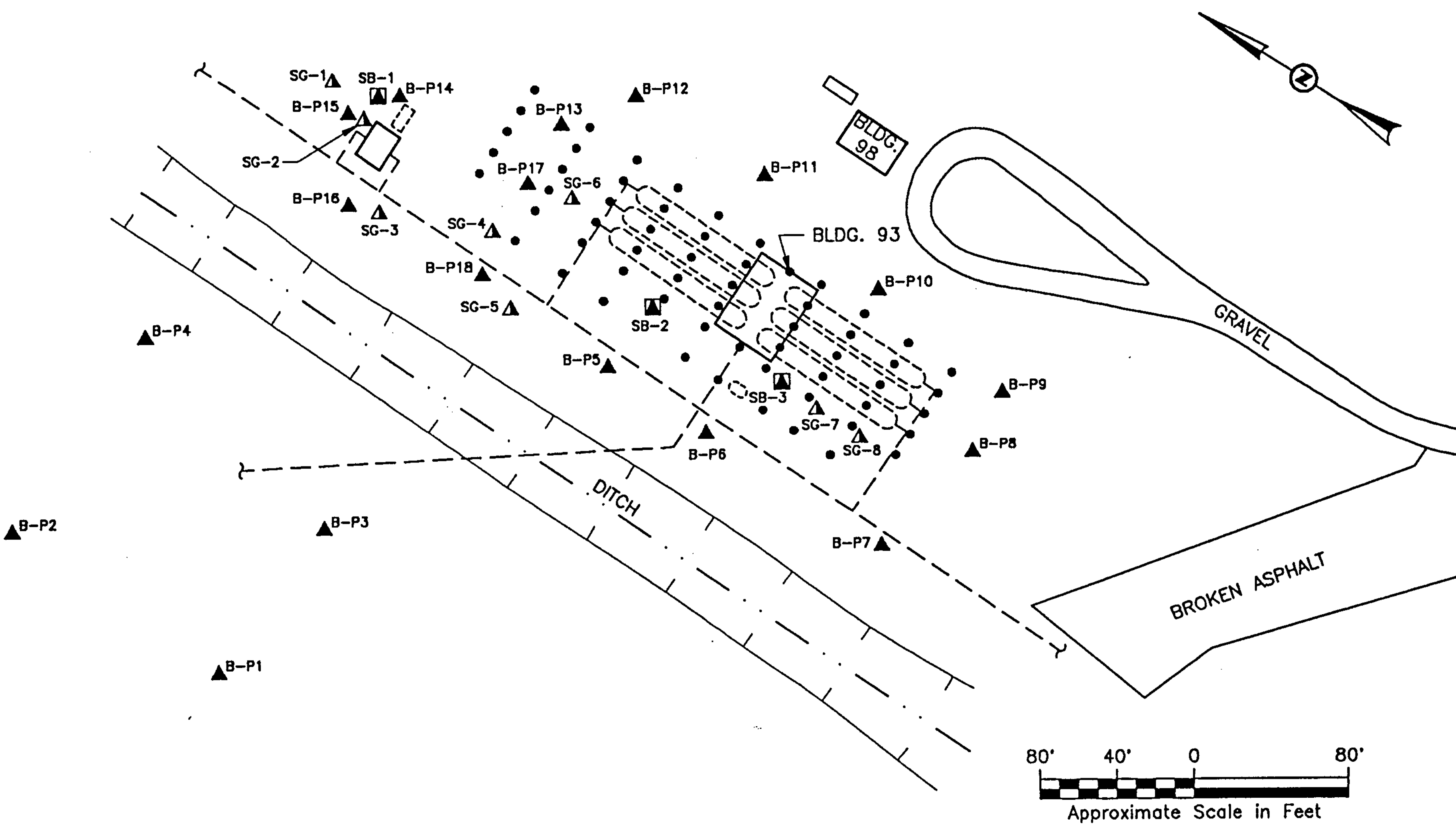

LEGEND

- B-P15 ▲ Westinghouse soil boring.
- SG-1 △ ES soil gas point.
- SB-1 ◪ ES soil boring.
- ● Coastal Engineering soil boring/sampling point.

Soil Boring and Soil Gas Sampling Points

IRP Site SS-41
Charleston A.F.B.
Charleston, South Carolina

Figure 2.3

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ES conducted a preliminary soil gas/soil boring survey at Site SS-41 on February 18-19, 1993 as part of a base-wide search for candidate bioventing study sites. Eight shallow soil gas points and three shallow soil borings were installed to determine soil gas composition, fuel distribution, and lithologic characteristics. One of the soil borings (SB-1) was advanced to the water table adjacent to the boring location (B-P14) where Westinghouse had reported liquid-phase product. The boring installed by ES did not encounter liquid-phase product. Soil borings SB-2 and SB-3 were advanced to the capillary fringe, one on each side of the Building 97 canopy. Soil boring and soil gas test points installed by ES are illustrated in Figure 2.3.

ES accomplished the soil gas survey by using a nondedicated, retractable tip to collect soil gas samples at each test point. Soil gas sampling was attempted at multiple depths (3 feet and 5 feet) for tests points SG-1 through SG-3, but water was drawn into the sampling tubes at the 5-foot depth. The remaining soil gas points were then advanced only to depths of 2.5 to 3.0 feet below ground surface (bgs) to prevent drawing water into the sampling device. Soils in the vicinity of SG-7 and SB-3 were determined to be the most contaminated, having total soil gas hydrocarbon readings greater than 20,000 ppm. Soils in this area were also oxygen depleted (0%) and had elevated carbon dioxide concentrations (10%).

Additional soil sampling was performed by base contractors (Coastal Engineering, Inc.) in September, 1993 prior to and during the UST removals. Soil samples were collected around and beneath the USTs in a grid pattern for total petroleum hydrocarbons (TPH), BTEX, and naphthalene analyses. Detectable soil TPH concentrations ranged from 2.4 milligrams per kilogram (mg/kg) to 1,180 mg/kg. Additional analyses were performed to target jet fuel hydrocarbons using gas chromatograph (GC) analysis. Jet fuel hydrocarbon concentrations ranged from less than 10 mg/kg to 24,000 mg/kg on the samples analyzed by this method. The approximate locations of these soil boring/sampling points are shown in Figure 2.3.

The design of this test work plan is based solely on site data collected to date by Westinghouse, ES, and Coastal Engineering, Inc. Preliminary data suggest that Site SS-41 is a good candidate for bioventing, and the existing data are considered sufficient for designing the bioventing pilot study. Future sampling results and site conditions will be evaluated by ES prior to the bioventing system installation to determine any impact on the bioventing pilot test objectives, design, or procedures. Considerable soil disturbance is expected during the UST removals and demolition activities. Therefore, after the USTs are removed and prior to vent well installation, ES may perform further soil gas sampling to optimize the vent well locations.

2.1.3 Regional and Site Geology

Charleston AFB is located in the Lower Coastal Plain physiographic province of South Carolina. Sediments beneath the base are characterized as a thick sequence of interbedded sands, silts, and clays formed by fluvial and marine processes. These interbedded layers are grouped into regional formations and aquifers based on lithologic and water quality characteristics. Surficial soils around the Base are generally sandy and highly permeable at shallow depths, but may contain zones of clay and organic deposits. The area is marked by low geomorphic relief.

The shallow stratigraphy at Site SS-41 consists of sands, silts, and clays of the Ladson Formation. The upper 10 feet is generally sands and silty sands. Geotechnical borings installed by Westinghouse indicate that this lithologic formation extends to a depth of approximately 43 feet bgs near the AMC maintenance apron. ES soil boring SB-1 encountered an isolated zone of silty clay and clayey sands in the upper 6 feet of the soil profile. This low permeability layer is apparently not continuous across the site, however, as fine to medium sands and silty sands were consistently observed in the other shallow soil borings.

The Ladson Formation forms the surficial, unconfined aquifer in the vicinity of the base. During February, 1993, groundwater was encountered at depths ranging from 6.5 feet bgs in ES soil boring SB-1 to 4.5 feet bgs at soil boring SB-2. The water table is typically highest in this region during the winter months and water levels observed during February, 1993 probably represent seasonal high water table conditions. To support this conclusion, ES documented anonymously-high water levels at another bioventing site on the base during this same month. The Westinghouse report suggested a water table depth of approximately 10 feet bgs during August, 1991. According to base personnel, field observations during one of the UST removals on September 23, 1993 indicated that the water table was greater than 8 feet bgs on that date. Seasonal water table fluctuations of several feet are common in this area and recharge to the surficial aquifer from precipitation events is rapid.

Two 4-inch diameter vertical air injection wells, four multi-depth VMPs, and one temporary background monitoring point will be installed at the test site. No groundwater monitoring wells currently exist at the site for potential use as vapor monitoring points. Because the bioventing technology is applied to unsaturated soils, the thickness of the soil treatment zone is expected to vary on a seasonal basis due to water table fluctuations. The lower portions of the VW screen and some of the deeper VMPs may become submerged during periods of exceptionally high water levels. Preliminary data suggest that the water table at this test site may fluctuate 4 to 5 feet on a seasonal basis.

2.1.4 Site Contaminants

The primary contaminants at Site SS-41 are petroleum hydrocarbons, which have been detected in the soils at depths up to 10 feet bgs. Soil headspace VOCs were detected with a PID in concentrations up to 3,311 ppm and with a total hydrocarbon analyzer at greater than 20,000 ppm. Volatile organic BTEX compounds are confirmed in soils at the test site, and VOCs are potentially found in groundwater as well. Soil TPH concentrations up to 1,180 mg/kg were detected in recent sampling events. Concentrations of jet fuel by GC analysis were detected up to 24,000 mg/kg. The only suspected source of these contaminants is JP-4 jet fuel.

3.0 SITE SPECIFIC ACTIVITIES

This section describes the proposed location of the vent wells (VWs) and vapor monitoring points (VMPs) at Site SS-41. Soil sampling procedures and the blower configuration that will be used to inject air (oxygen) into contaminated soils are also discussed in this section. The two 4-inch air injection wells may be completed several feet into groundwater if the water table is elevated during installation. Vent well design will ensure that a portion of the screen remains above the water table throughout the year. No monitoring wells exist at the site to use as background vapor monitoring points. Because geotechnical boring logs have described organic soil layers on this part of the base, a temporary background VMP will be installed in uncontaminated soils to measure the oxygen demand of non-fuel organics and any abiotic oxygen uptake.

3.1 Bioventing Test Design For Site SS-41

A general description of criteria for siting a central venting well and vapor monitoring points are included in the bioventing protocol document. Figure 3.1 illustrates the proposed locations of the vertical air injection VWs and VMPs at the site. The VWs and VMPs will be located in the most fuel-contaminated and oxygen-deficient soils at the test site. ES anticipates that the pilot test site will be located within, or adjacent to, the UST hold at the pump house. The final locations of these wells may vary slightly from the locations shown in Figure 3.1 based on site conditions encountered during the well installations. Additional soil gas screening will also be performed prior to VW installations to ensure that the test plot is located in oxygen-depleted soils.

Considering the shallow depth of contamination in unsaturated soils at this site (< 5 feet bgs), the soil lithology, and the VW construction required to accommodate shallow water table conditions, the radius of venting influence around a single air injection well is expected not to exceed 30 feet. Further reductions in the estimated radius of influence may be expected during high water table conditions when the unsaturated VW screen interval is decreased. A primary concern at this site is possible short-circuiting of injected air at the ground surface, resulting in a loss of the effective radius of venting influence. Short-circuiting potential is increased as the air injection pressures and/or air flow rates are increased, and as the unsaturated soil column thickness is decreased. For this reason, a multiple VW system (2 vent wells) will be installed. The dual VW system will allow a larger cumulative radius of influence to be maintained with lower injection pressures and air flow rates at the individual VWs.

Three VMPs will be located on 10-foot centers along the axis connecting the two VWs. The fourth VMP will be located perpendicular to this axis (see Figure 3.1). The VWs will be installed 40 feet apart so that their radii of venting influence will overlap near the center VMP. A temporary VMP will be installed in uncontaminated soils using a soil gas probe. The temporary VMP will be utilized to measure background levels of oxygen (O_2) and carbon dioxide (CO_2) and to determine if natural carbon sources (i.e. organic layers) or mineral reactions are contributing to oxygen uptake during the *in-situ* respiration tests. A respiration test will be conducted at the temporary VMP only if background O_2 concentrations are less than 18 percent. Additional details on the *in-situ* respiration test are found in Section 5.7 of the protocol document.

A mobile drill rig will be used to advance the VW boreholes and to collect split spoon soil samples. The air injection VWs will be constructed of 4-inch (ID) Schedule 40 PVC, with 5 feet of 0.02-inch slotted screen per well. High-yield well screens may be used to increase air flow rates and to decrease backpressure created at the well screen. Each VW will be installed to an approximate total depth of 9 feet bgs, with the screened interval extending from 4 feet to 9 feet bgs. A PVC casing will be installed

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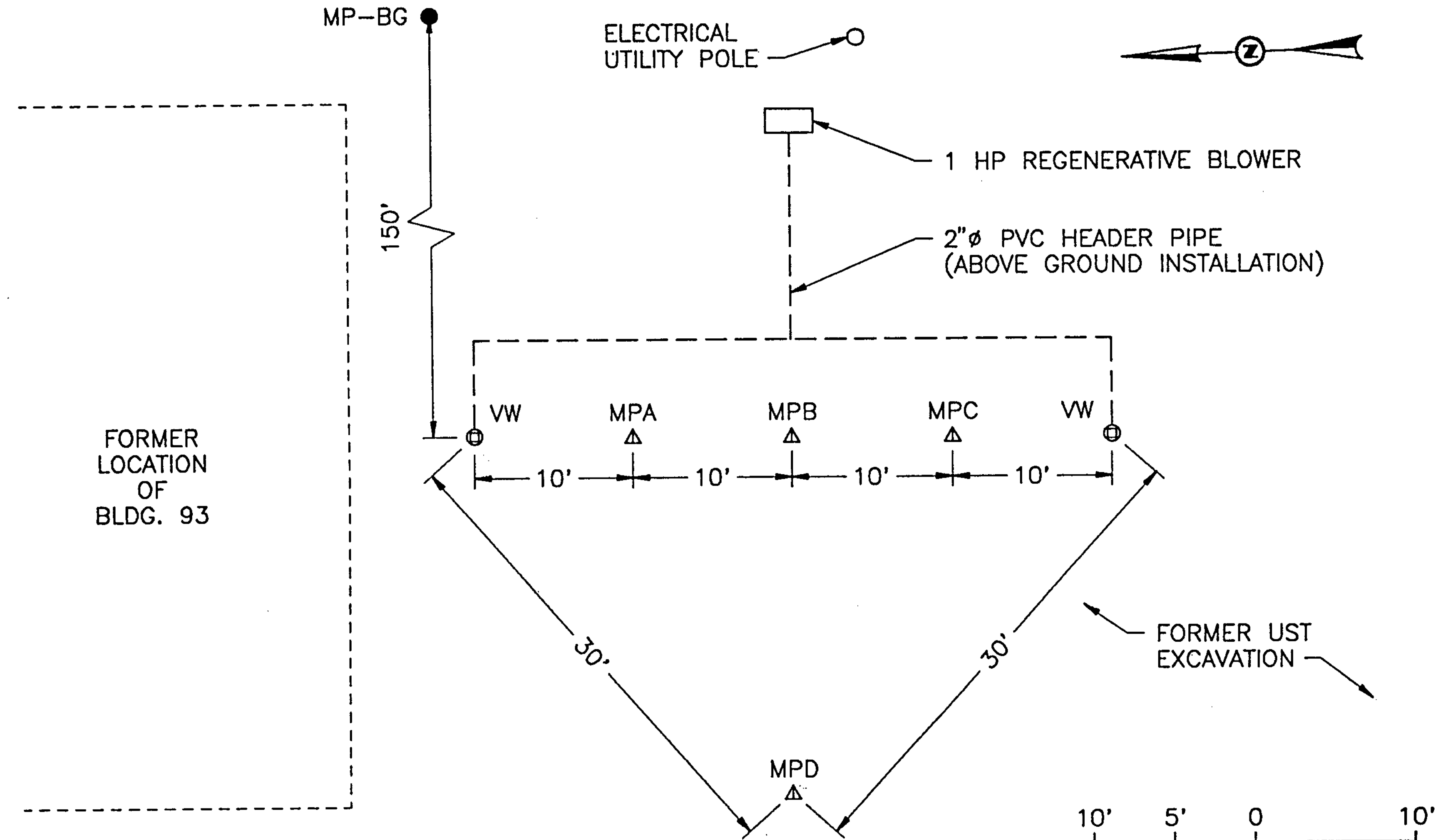


LEGEND

VW ⊕ Proposed air injection vent well.

MPA △ Proposed soil vapor/pressure monitoring point.

MP-BG ● Proposed background monitoring point.

Note: Final location of bioventing system may vary from the location depicted above. The relative configuration of VWs and MPs will remain unchanged.

Proposed Vent Well and Monitoring Point Locations

IRP Site SS-41
Charleston A.F.B.
Charleston, South Carolina

Figure 3.1

ES ENGINEERING-SCIENCE

above the screen, with approximately 4 feet bgs and a 2-foot stickup. Flush-threaded PVC casing and screen will be used with no organic solvents or glues. A filter pack of coarse silica sand will be placed around the screen in the borehole annulus. A bentonite pellet seal and grout seal will be placed above the filter pack to seal the borehole. A complete seal is critical to prevent injected air from short-circuiting to the surface during the bioventing test. A crown of clean, backfill soil will be mounded around the casing stickup to promote surface drainage away from the VW and to minimize possible air losses around the well casing. Figure 3.2 illustrates a typical air injection VW construction for this site.

A typical multi-depth VMP installation for this site is shown in Figure 3.3. The VMPs will be installed using 4-inch diameter hand augers. Soil gas O_2 and CO_2 concentrations will be monitored at depth intervals of 3-3.5 feet and 6.5-7 feet at each VMP location. These proposed monitoring depths assume that the seasonal high water table may be as high as 4 feet bgs in the test area. It is possible that the deeper screened intervals may be submerged during high water table conditions. If it is apparent that the water table will be exceptionally high even during the summer months (i.e. less than 6 feet bgs), then only the shallow VMP screen (3-3.5 feet) will be installed.

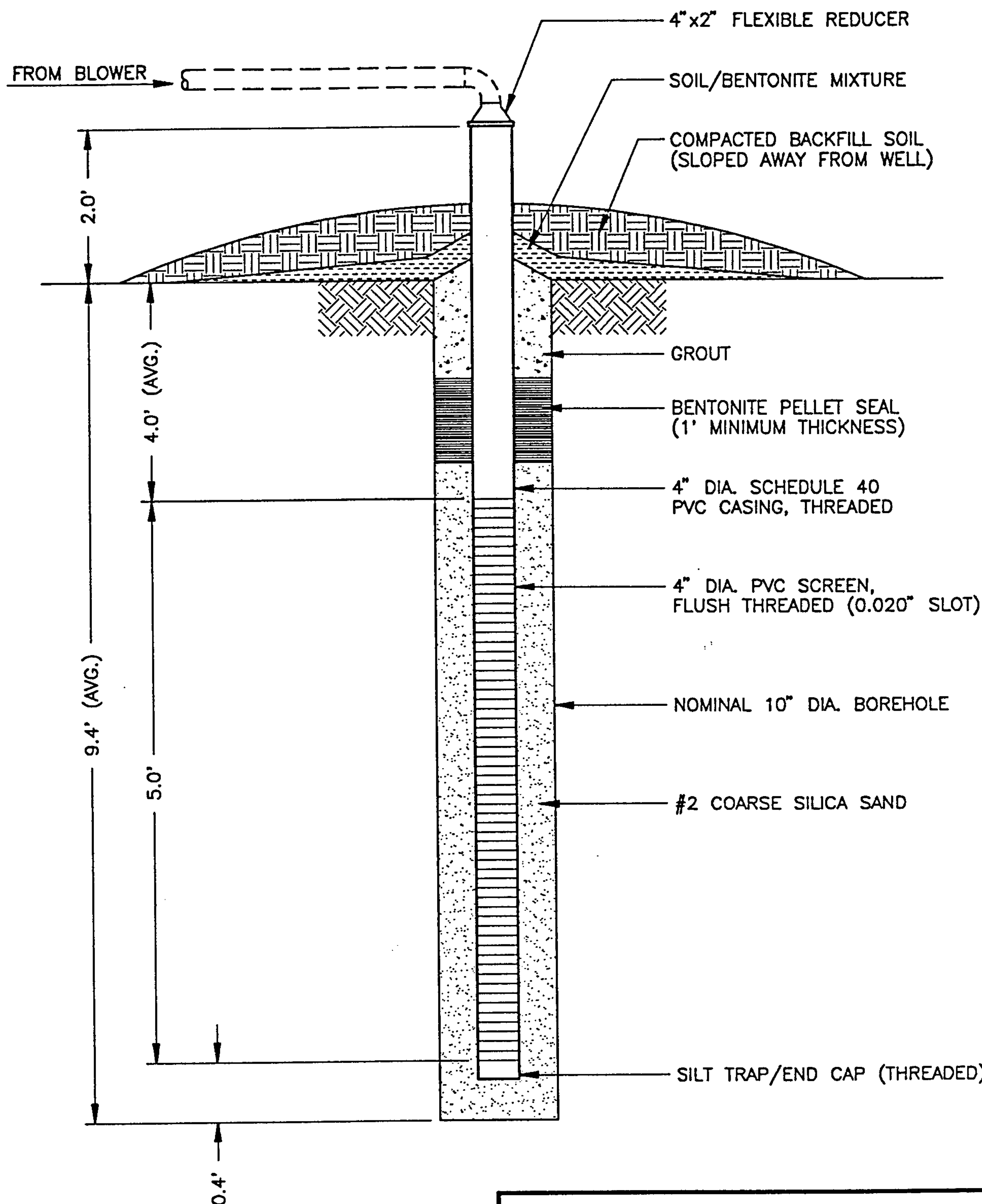
Multi-depth monitoring will confirm that the entire soil profile is receiving oxygen and will be used to measure fuel biodegradation rates at both depths. The annular space between these two monitoring points will be sealed with bentonite to isolate the monitoring intervals. Data from the temporary, background vapor monitoring point will also be used to determine the relative natural diffusion of atmospheric oxygen into the shallow soils. Additional details on vapor monitoring point construction are found in Section 4 of the protocol document.

3.2 Soil and Soil Gas Sampling

3.2.1 Soil Sampling

Three soil samples will be collected from the pilot test area during the installation of the VWs and VMPs. Sampling procedures will generally follow those outlined in the protocol document, with minor modifications for collecting samples using a hand auger or split spoon sampler. One sample will be collected from the most contaminated interval of one VW. One soil sample will be collected from the interval of highest apparent contamination in two of the borings for the VMPs. Soil samples will be analyzed for TPH, BTEX, soil moisture, pH, particle sizing, alkalinity, total iron and nutrients.

Samples will be collected from the VMPs by hand augering to the desired sampling depth and transferring the soil sample directly from the hand auger bucket to the sample jars. A PID or total hydrocarbon vapor analyzer (see protocol Section 4.5.2.) will be used to insure that breathing zone levels of volatiles do not exceed 1 ppmv while conducting soil borings and to screen soil samples for relative fuel contamination. Soils from the most contaminated interval of the VMPs and VW will be submitted for laboratory analyses. Soil samples will be labeled following the nomenclature specified in the protocol document (Section 5.5), wrapped in protective plastic, and placed in an ice chest for shipment. A chain of custody form will be filled out and the ice chest shipped to PACE Laboratory in Novato, California for analysis. This laboratory has



NOTES:

1. Drawing is not to scale.
2. Header pipe from blower (dashed line) will not be installed during well construction.

Proposed Injection Vent Well Construction

IRP Site SS-41
Charleston A.F.B.
Charleston, South Carolina

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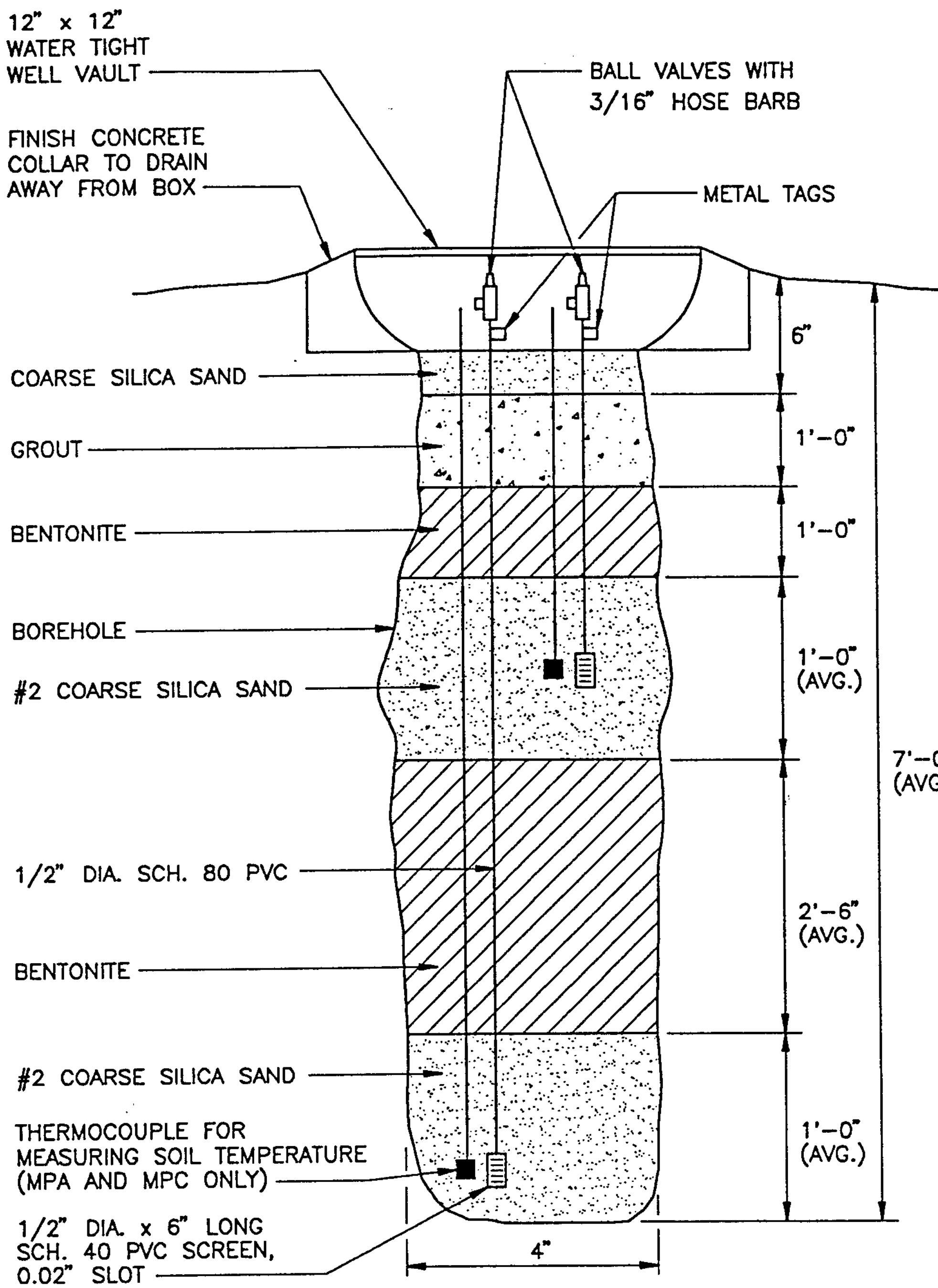
Figure 3.3



DRAWING IS NOT TO SCALE

Typical Monitoring Point Construction Detail

IRP Site SS-41
Charleston A.F.B.
Charleston, South Carolina

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been audited by the U.S. Air Force and meets all quality assurance/quality control and certification requirements for the State of California.

3.2.2 Soil Gas Sampling

A total hydrocarbon analyzer (see protocol document, Section 4.5.2) will be used during the soil borings to screen sample intervals for fuel contamination. Once the monitoring points are installed and adequately purged, soil gas samples will be collected using SUMMA^R canisters. Three SUMMA^R canister soil gas samples will be collected, one from the most contaminated VW and one each from the VMPs closest to and furthest from the VWs. Quantitative soil gas samples will be used to predict potential air emissions, to determine the reduction of BTEX and total volatile hydrocarbons (TVH) during the extended test, and to detect potential migration of these vapors from the source area.

Soil gas samples will be placed in a small box and packed with foam pellets for protection during shipment. Samples will not be placed on ice to prevent condensation of hydrocarbon compounds. A chain-of-custody form will be completed and shipped with the samples to the Air Toxics, Inc. laboratory in Folsom, California. The soil gas samples will be analyzed for BTEX compounds and TVH.

3.3 Blower System

A 1-HP vacuum blower (Gast model 2067-P106) capable of injecting 16 scfm at 2 psi will be used to conduct the initial air permeability test at this site. Air injection will be used to provide oxygen to soil bacteria and to minimize emissions of volatiles to the atmosphere. If initial testing indicates that less pressure and air flow is required to supply oxygen throughout the test area soil column, a smaller blower will be installed for extended testing. Figure 3.4 is a schematic of a typical air injection system that will be used for pilot testing at this site.

The maximum power requirement anticipated for this pilot test is a 230-Volt, single-phase, 30 Amp service. ES understands that electrical power was removed from this site during facility demolition. Electrical service will be restored to the site through the installation of step-down transformer. Although only 30-Amp service is needed to operate the single test blower, ES recommends that the base install 100-Amp service to this site to support future equipment installations associated with site remediation. Additional details on power supply requirements are described in Section 5.0, Base Support Requirements.

4.0 EXCEPTIONS TO PROTOCOL PROCEDURES

The testing procedures that will be used to measure the air permeability of the soil and *in-situ* respiration rates are described in Sections 4 and 5 of the attached protocol document. No deviations from the established testing protocol are anticipated.

One exception to the typical test designs presented in the protocol document is the installation of two vent wells. This design is necessary to maximize the radius of oxygen influence throughout the test area and to minimize potential short-circuiting of air. Air flow rates to individual wells can then be reduced without affecting the test results. The VW screens may also be installed several feet into the water table if water levels are elevated during installation.

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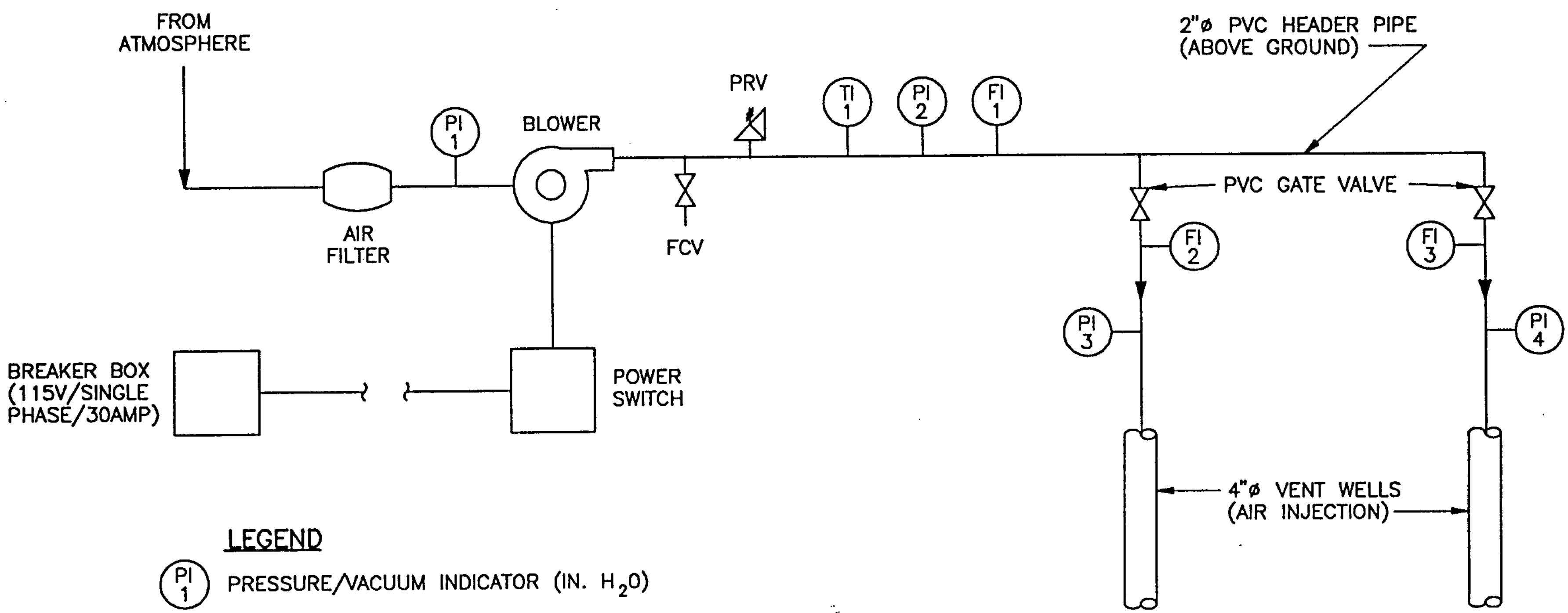

LEGEND

- PI 1 — PRESSURE/VACUUM INDICATOR (IN. H_2O)
- TI 1 — TEMPERATURE INDICATOR (°F)
- FI 1 — AIR FLOW MEASURING PORT
- FCV — FLOW CONTROL VALVE (MANUAL AIR BLEED)
- PRV — PRESSURE RELIEF VALVE (AUTOMATIC)

NOTE: Blower diagram shown is for permanent installation for extended testing. A low-flow vacuum pump is proposed for the initial air permeability and respiration tests.

DRAWING IS NOT TO SCALE

Blower System Instrumentation Diagram for Air Injection

IRP Site SS-41
Charleston A.F.B.
Charleston, South Carolina

Figure 3.4

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Soil borings for VMP installations will be advanced using a hand auger at this site. Since a drill rig will not be used, the typical borehole diameter for each monitoring point will be approximately 4 inches, as illustrated in Figure 3.3.

5.0 BASE SUPPORT REQUIREMENTS

5.1 Test Preparation

The following base support is needed prior to the arrival of an excavation contractor and the Engineering-Science test team:

- Confirmation of regulatory approval for the pilot test.
- Assistance in obtaining a digging permit at Site SS-41.
- A breaker box mounted to a power pole on the site which can supply 230-Volt, Single-Phase 30 Amp service for the initial and extended pilot test. The breaker box should be located five feet above the ground and include one 230-Volt outlet and two 110 volt outlets to support pilot testing equipment. The base should also provide assistance in wiring the permanent blower directly to a power switch and to the breaker box.
- Provide any paperwork required to obtain gate passes and security badges for approximately two ES employees and three drilling contractor employees. Vehicle passes will be needed for three trucks.
- Arrange for flightline security training for two ES employees for unescorted access to Site SS-41. Also, arrange for flightline training for applicable subcontractors if ES or base personnel are not allowed to escort subcontractors to the work area.

During the initial three-week pilot test, the following base support is needed:

- Twelve square feet of desk space and a telephone in a building located as near to the site as practical.
- A decontamination pad where the drilling contractor can clean the drill rig and augers.
- Accept responsibility for soil cuttings from vent wells and monitoring point borings, including any drum sampling to determine hazardous waste status.
- The use of a fax machine for transmitting 15 to 20 pages of test results.

During the one year extended pilot test at Site SS-41:

- Check the blower system at the site once a week to ensure that it is operating and to record the air injection pressures at each VW. Engineering-Science will provide a brief training session and an O&M checklist for this procedure.
- Notify Mr. Grant Watkins, Engineering-Science, Inc., Cary, NC (919) 677-0080; or Mr. Doug Downey, Engineering-Science, Inc. Denver (303) 831-8100; or Mr. Marty Faile of the AFCEE, (210) 536-4342, if the blower or motor stop operating.
- Arrange site access for an Engineering-Science technician to conduct *in-situ* respiration tests approximately six months and one year after the initial pilot test.

5.2 Permit Requirements

Base personnel are responsible for obtaining all permits from the South Carolina Department of Health and Environmental Control (SCDHEC) that are required to perform the test as described in this work plan. If required, Engineering-Science will assist this effort by providing test design criteria and reference documents for regulatory review. Unless directed by AFCEE or the Charleston AFB POC, no direct contact will be made between Engineering-Science and the regulatory agencies.

Based on preliminary review of the test procedures and previous experience at the base, the SCDHEC will require an Underground Injection Control (UIC) Permit to perform any air injection into the subsurface. This permit will regulate the vent wells as a Class V.A.-G injection well system. The permit will be required for both the short-term air permeability/respiration tests and the extended bioventing test. Therefore, the proposed test schedule is dependent on timely permit approval by SCDHEC. The Agency will also issue approval for construction of the VMPs and the vent wells.

6.0 PROJECT SCHEDULE

The following schedule is contingent upon timely approval of this pilot test work plan:

Event	Date
Draft Test Work Plan to AFCEE/Charleston AFB	October 13, 1993
Approval To Proceed	October 20, 1993
Begin Initial Pilot Test	November 8, 1993
Complete Initial Pilot Test	November 17, 1993
Interim Results Report	December 22, 1993
Respiration Test	May 1994
Final Respiration Test	November 1994

After a period of one year, a decision will be made by AFCEE and the base to either remove the system or to expand the system for full-scale remediation at the site.

7.0 POINTS OF CONTACT

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Denver, Colorado 80290
(303) 831-8100

8.0 REFERENCES

Westinghouse, Inc., *Report of Geotechnical Engineering and Environmental Services, ADAL Apron/Hydrant Fuel System, Charleston Air Force Base, North Charleston, South Carolina.* November, 1991.

PART II
DRAFT
INTERIM PILOT TEST RESULTS REPORT
IRP SITE SS-41
FORMER FLIGHTLINE FUEL PUMP HOUSE
CHARLESTON AFB, SOUTH CAROLINA

Prepared for:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AFB, TEXAS

and

HEADQUARTERS 437 AIRLIFT WING (AMC)
CHARLESTON AFB, SOUTH CAROLINA

January, 1994

Prepared by:
Engineering-Science, Inc.
1700 Broadway, Suite 900
Denver, Colorado

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PART II

DRAFT

INTERIM PILOT TEST RESULTS REPORT
IRP SITE SS-41
FORMER FLIGHTLINE FUEL PUMP HOUSE
CHARLESTON AFB, SOUTH CAROLINA

An initial bioventing pilot test was performed at IRP Site SS-41, located at Charleston Air Force Base (AFB), South Carolina from November 17 through 20, 1993. Site SS-41 was previously designated as former flightline fuel pump house (Building 93). The purpose of this Part II report is to describe the results of the initial pilot test at Site SS-41 and to make specific recommendations for extended testing to determine the long-term impact of bioventing to remediate site contaminants. Descriptions of the history, geology, and contaminants of Site SS-41 are outlined in Part I of this report, Bioventing Pilot Test Work Plan.

1.0 PILOT TEST DESIGN AND CONSTRUCTION

Two air injection vent wells (VWs), four permanent vapor/pressure monitoring points (VMPs), and a blower/air injection piping system were installed from November 15-22, 1993 by the Cary, North Carolina office of Engineering-Science, Inc. (ES). Subcontractor support was provided by General Engineering Laboratories, Inc. (GEL) of Charleston, South Carolina for drilling and soil grading services. The system installation and testing was directed by Mr. Grant Watkins, P.G., the ES site manager. The following sections describe in more detail the final design, installation, and testing of the bioventing system at this site.

Based on site conditions encountered by ES, minor changes were made to the original plan for the bioventing system construction and layout. As stated in the work plan (Part I of this report), the fuel pump house (Building 93), underground storage tanks (USTs), and adjacent structures were removed by a demolition contractor throughout the summer and early fall of 1993. Final backfilling and soil grading operations were ongoing at the site up to the date that the VWs were installed. An additional 3 to 4 feet of sandy clay to clayey sand backfill soil was spread over the site by the demolition contractor prior to the system installation. ES was also informed by the base point of contact (POC) that some of the contaminated soil had been excavated and transported off-site during the UST removals.

1.1 Soil Gas/Soil Boring Survey of Pilot Test Area

Engineering-Science previously conducted a limited soil vapor survey of the site during a base-wide search of candidate bioventing sites in February, 1993. During the original survey, eight soil gas points and three soil borings were advanced around the fuel pump house to determine soil gas composition and the distribution of soil contamination at the site. This initial survey was conducted while the fuel pump house, piping, and USTs were still intact. Results are presented in Part I, Section 2.1.2 of this report.

Subsequent to the facility demolition, ES performed a second soil gas/soil boring survey prior to installing the VWs and VMPs. The purpose of the second soil gas/boring survey was to better define the areas of remaining contamination and to optimize the VW locations since much of the soil had been disturbed during demolition of the facility. Eight shallow soil borings (SB1-SB8) and two soil gas points (SG1, SG2) were installed to determine soil gas composition and relative soil contamination. Figure 1.1 shows the relative locations of the additional soil borings and soil gas points installed by ES.

The eight soil borings were installed with a small-diameter hand auger. One boring (SB3) was extended to the water table to determine the depth of groundwater at the test site. Soil cuttings were collected at 2-foot intervals and screened for total volatile hydrocarbon (TVH) organic vapors using a portable GasTech hydrocarbon analyzer. Headspaces within the boreholes were also screened for TVH using the hydrocarbon meter. Headspace TVH concentrations ranged from lows of 0 ppm (SB5) and 2.0 ppm (SB1), to highs of 1,400 ppm (SB7) and >10,000 ppm (SB3). Two soil gas samples (SG1, SG2) were collected at depths ranging from 3 to 4.5 feet below ground surface (bgs). The soil gas samples were field-screened for oxygen (O_2), carbon dioxide (CO_2), and TVH. Soil gas conditions varied from oxygen-depleted (0% oxygen) at SG1 to oxygen-defficient (5.8% oxygen) at SG2.

Results of the second soil gas/soil boring survey indicate that an area of residual, hydrocarbon-contaminated soil exists in the southwest corner of the bermed area that surrounds the former fuel pump house. Approximate dimensions of the contaminated area are estimated as >150 feet (north-south) by 65 feet (east-west). Residual soil contamination identified by the soil gas survey appears to be centered around the fuel transfer pipeline left intact during the facility demolition (see Figure 1.1). Soil gas measurements show that relative soil hydrocarbon contamination decreases in the vicinity of the former UST locations, where much of the fuel contaminated soil was removed and replaced with clean backfill. Soils around the existing fuel transfer pipeline were apparently not disturbed as evidenced by the soil lithologies and soil gas O_2, CO_2, and TVH concentrations.

1.2 Vent Well Installations

Two air injection VWs were installed at the site for interim testing and long-term use during the bioventing study. The VWs were located within the center of the oxygen-depleted, fuel-contaminated area identified during the second soil gas survey. The VWs were aligned parallel to the fuel transfer pipeline in a north-south orientation. The VWs were also placed at a sufficient distance from the adjacent drainage ditch to prevent air short-circuiting along the edge of the ditch. Figure 1.1 shows the location of the VWs relative to the site features. Figure 1.2 shows the VWs and VMP detailed layout for the bioventing system.

The VWs were installed using a mobile drill rig advancing 10-inch diameter hollow stem augers. Soil samples were collected at approximate 2-foot intervals using both a

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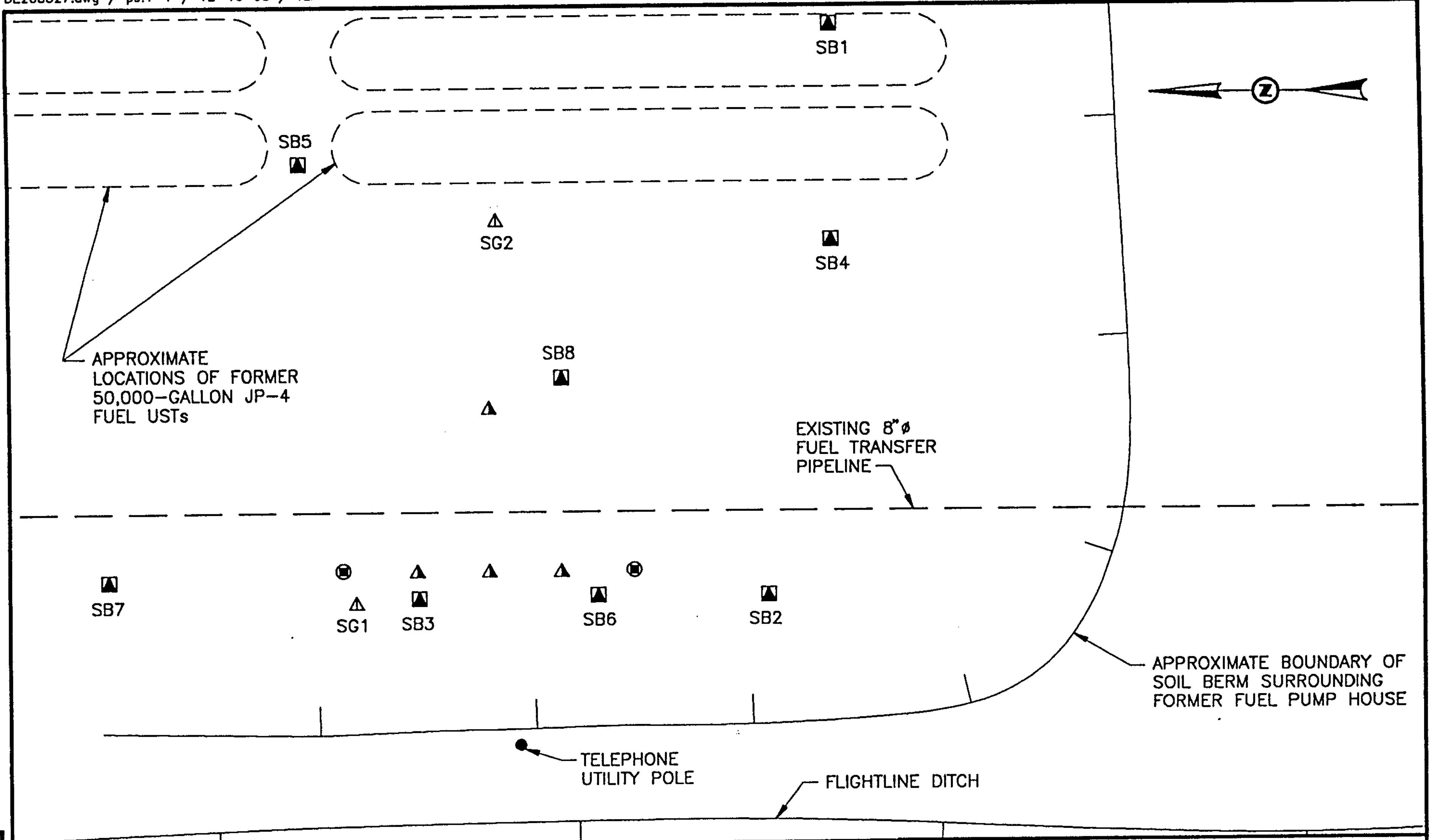

LEGEND

- SB1 ◪ Exploratory Soil Boring (Nov., 1993)
- SG1 △ Exploratory Soil Gas Point (Nov., 1993)
- ⊛ Air Injection Vent Well
- ▲ Soil Vapor/Pressure Monitoring Point

Note:

1. All facility and appurtenance locations are approximated.

20' 10' 0 20'

Approximate Scale in Feet

Bioventing Pilot Test Location

IRP Site SS-41
Charleston A.F.B.
Charleston, South Carolina

Figure 1.1

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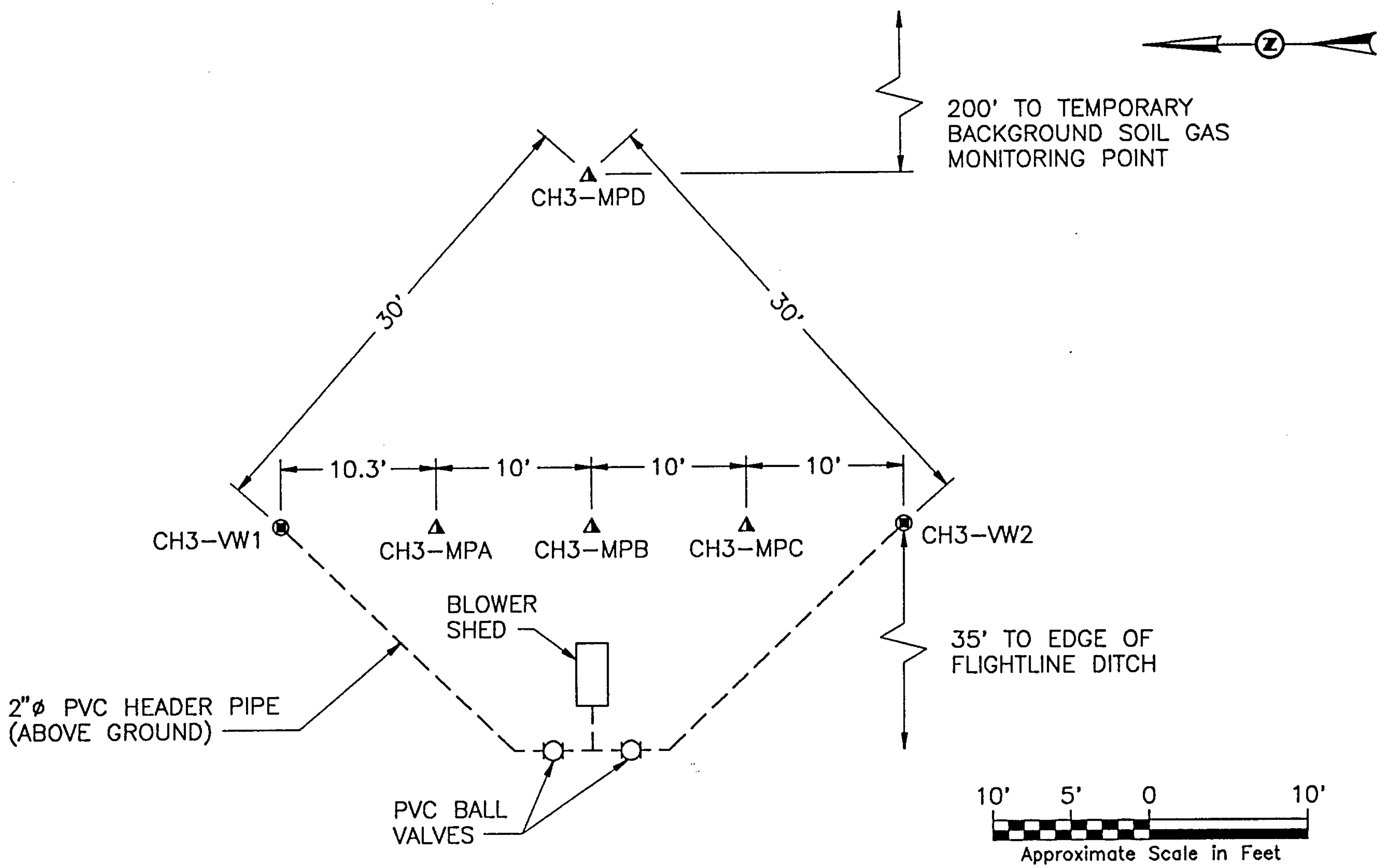

LEGEND

CH3–VW1 ⊛ Air injection vent well (4"ø).

CH3–MPA ▲ Permanent, multi-depth soil vapor/pressure monitoring point.

Figure 1.2

Vent Wells, Vapor Monitoring Points, and Blower Locations

IRP Site SS–41
Charleston A.F.B.
Charleston, South Carolina

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split spoon sampling device and hand augers advanced through the hollow stem augers. Each borehole was advanced to 12.5 feet bgs. Soil lithologies were characterized and several of the samples from each borehole were screened for TVH using a portable field hydrocarbon analyzer. Using the TVH field screening results to establish relative contamination, one soil sample from vent well CH3-VW2 was submitted for laboratory analyses. Lithologic descriptions obtained during VW and VMP installations were used to develop a hydrogeologic cross section, shown in Figure 1.3. Appendix A contains borehole logs and well construction records for the VWs and VMPs.

Both VWs were constructed using 4-inch diameter PVC screens and casing installed in the boreholes. Groundwater was encountered at a depth of approximately 10 feet bgs during the VW installation. ES installed the bottom of the VW screen beneath the water table to a total depth of 11.65 feet bgs to ensure that an adequate length of screen would be exposed in the unsaturated zone if the water table declines. Approximately 5 feet of screen was exposed above the water table at each VW at the time of installation.

Figure 1.4 shows a typical construction schematic for the VWs. Two threaded screen sections (one 2.5-foot and one 5.0-foot section) were used to construct each VW. Both sections consist of 0.020-inch slotted "high-yield" screens. The "high-yield" screens have a greater number of slots per linear foot than do conventional monitoring well screens. The increased open area per linear foot of screen reduces pressure losses associated with the screen and improves air exchange between the VW and the formation.

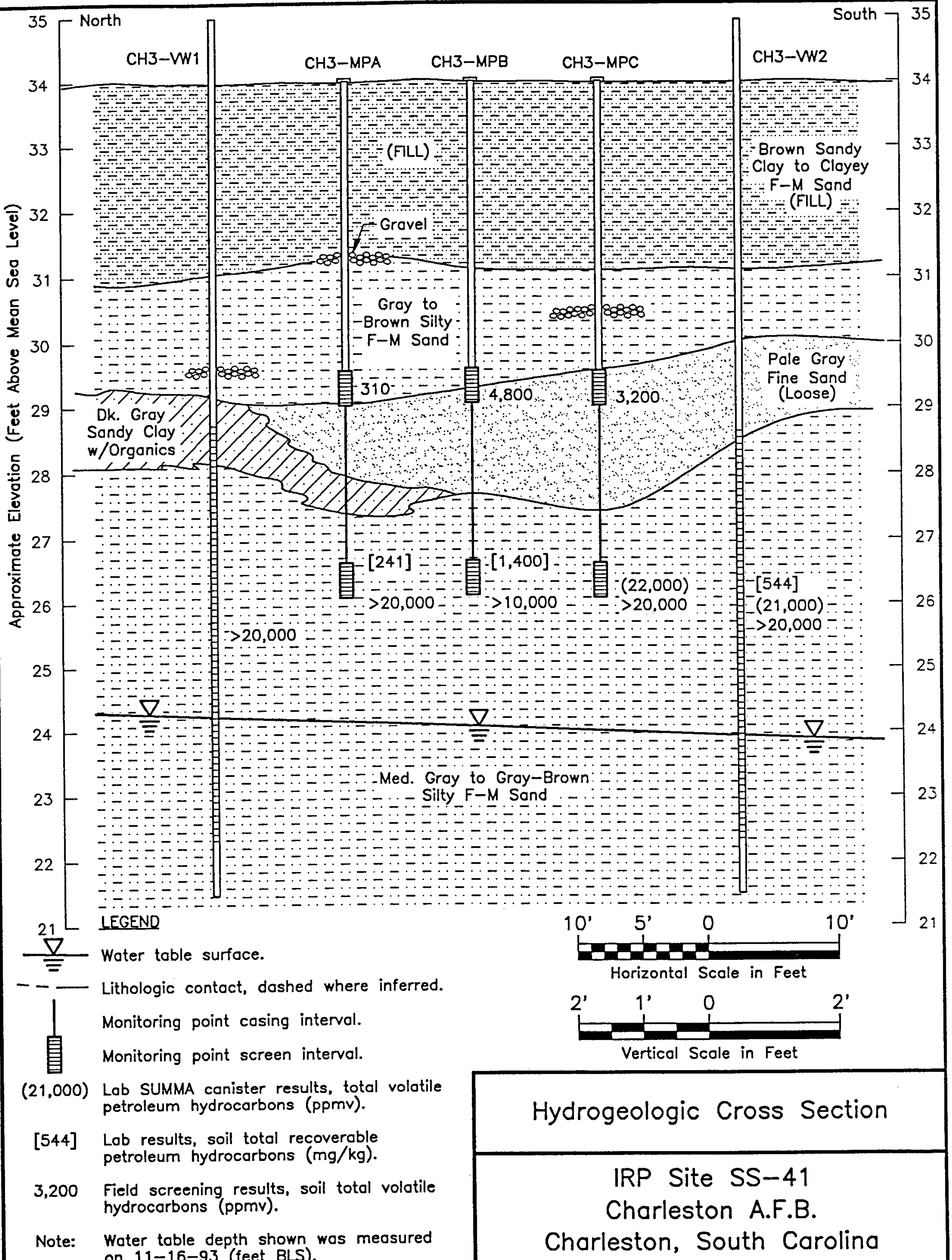
Each VW was completed with 1.3 feet of PVC casing stickup above ground surface. The surface bentonite/soil caps proposed in the work plan (Part I, Section 3.1) were not installed around the VWs because the test site was capped by several feet of sandy clay backfill. The clayey backfill soils have apparent lower permeability than the underlying, residual sandy soils based on field textural characterization. Consequently, the surficial clay backfill serves the intended function as a low-permeability surface cap to minimize short-circuiting of injected air.

1.3 Monitoring Point Installations

Four multi-depth, vapor/pressure monitoring points (VMPs) were installed according to the work plan and bioventing test protocols. Three of the VMPs (CH3-MPA, CH3-MPB, CH3-MPC) were installed on 10-foot centers on an axis between the two VWs, as depicted in Figure 1.2. The fourth VMP (CH3-MPD) was installed 30 feet from both VWs toward the east. Boreholes for the VMPs were advanced using a stainless steel hand auger. Soil samples were collected from the boreholes at regular intervals and screened in the field for TVH concentrations. Samples from two of the VMPs were submitted for laboratory analyses (see Section 2.1 below).

Each of the VMPs was constructed using 0.5-inch threaded PVC screen and casing. The top of each VMP was fitted air tight with a gas ball valve equipped with a hose barb. Two VMPs (CH3-MPA and CH3-MPB) were equipped with thermocouple probes to measure soil temperature. All four VMPs were similarly constructed as multi-depth monitoring points. The screened intervals were placed from 4.5 to 5.0 feet bgs and from 7.5 to 8.0 feet bgs in each VMP borehole. These screened intervals are

Figure 1.3



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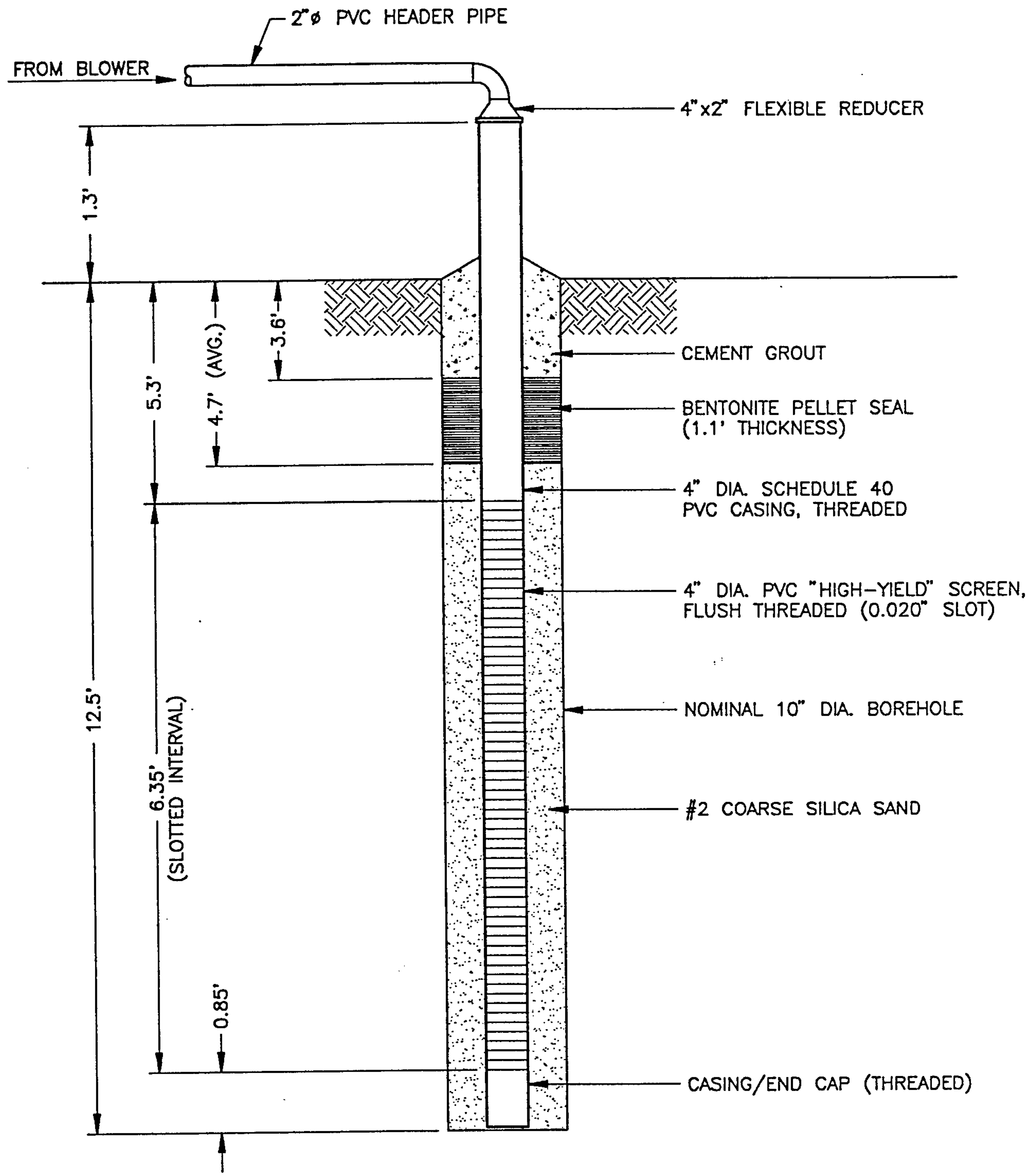

NOTES:

1. Drawing is not to scale.
2. Well construction schematic is typical for both vent wells, CH3-VW1 and CH3-VW2.
3. Vent wells were installed on 11/15/93.
4. Water table surface was 10.28' below ground surface in CH3-VW2 on 11/16/93.

As-Built Air Injection Vent Well Construction

IRP Site SS-41
Charleston A.F.B.
Charleston, South Carolina

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expected to remain above the water table for most of the year, with the possible exception of anonymously-high water table conditions. Figure 1.5 shows the typical construction schematic for the VMPs. Borehole logs and VMP construction records are included in Appendix A.

A temporary background VMP, designated as CH3-BG-4, was installed in clean soils 200 feet east of the VWs using a retractable soil gas probe. The background VMP was used to monitor background soil gas conditions not affected by hydrocarbon contamination. Soil gas O_2 concentration at CH3-BG-4 was 19.2 percent, indicating that abiotic and/or nonfuel O_2 uptake is not a major factor at this site. The background soil O_2 concentration observed at Site SS-41 is consistent with background O_2 concentrations found at other bioventing sites on the base.

1.4 Blower System Installation

A 1-horsepower Gast R4110-2 regenerative blower and air injection piping system were installed at Site SS-41 for the extended pilot test. The Gast blower was installed in a weatherproof enclosure. Air is routed to the VWs through an above-ground, PVC manifold (header) pipe. Each segment of the manifold pipe is equipped with a PVC ball valve so that the air flow to each VW can be controlled individually. This configuration allows one VW to be shut down while the other VW receives air injection. Figure 1.6 shows the configuration, instrumentation, and specifications for the blower and air injection system.

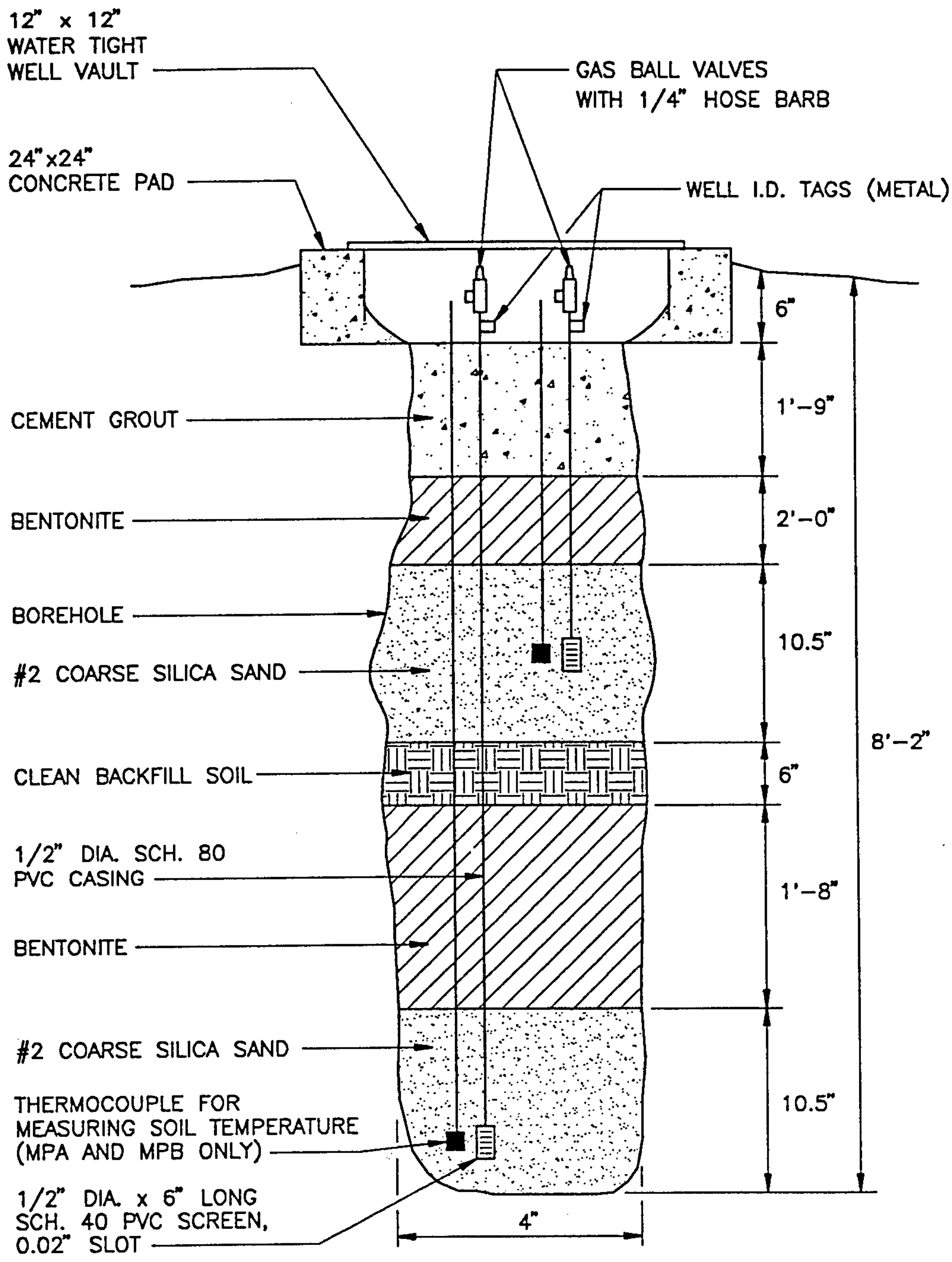
At the time of the blower system installation, electrical power was not available at Site SS-41. ES used a Gast model 2067 rotary vane compressor pump operated by a gas-powered generator to perform the initial air permeability test at the site. The base is currently arranging for electrical service to be installed at the test site. Once electrical power is brought to the site and the regenerative blower is wired for service, air injection will commence for the one-year pilot test.

2.0 PILOT TEST SOIL AND SOIL GAS SAMPLING RESULTS

2.1 Soil Sampling Results

During installation of the VW and VMP boreholes, ES collected soil samples at regular intervals for field screening of hydrocarbon organic vapors. Three sets of soil samples were collected for laboratory analyses, one set each from CH3-VW2 (8-foot depth), CH3-MPA (7.5-foot depth), and CH3-MPB (7.5-foot depth). Organic vapor concentrations generally increased with depth. For comparative evaluation, soil samples for laboratory analyses were collected from the same unsaturated zone intervals that the deeper screens were installed in the VMPs (see Figure 1.3).

The three sets of soil samples were analyzed by the PACE, Inc. laboratory in Huntington Beach, California for these parameters: total recoverable petroleum hydrocarbons (TRPH); benzene, toluene, ethylbenzene, xylenes (BTEX); iron; alkalinity; pH; total Kjeldahl nitrogen (TKN); phosphates; percent moisture; and particle size distribution. Table 2.1 summarizes the results of these analyses. TRPH concentrations ranged from 241 milligrams per kilogram (mg/kg) at CH3-MPA-7.5 to



DRAWING IS NOT TO SCALE

MONITORING POINT CONSTRUCTION DETAILS

Monitoring Point No.	Screened Intervals (FT)	Thermocouple Depths (FT)
CH3-MPA	4.5-5.0/7.5-8.0	5.0/8.0
CH3-MPB	4.5-5.0/7.5-8.0	5.0/8.0
CH3-MPC	4.5-5.0/7.5-8.0	NA
CH3-MPD	4.5-5.0/7.5-8.0	NA

Note:
1. Construction schematic is typical for all monitoring points.

As-Built Monitoring Point Construction Detail

IRP Site SS-41
Charleston A.F.B.
Charleston, South Carolina

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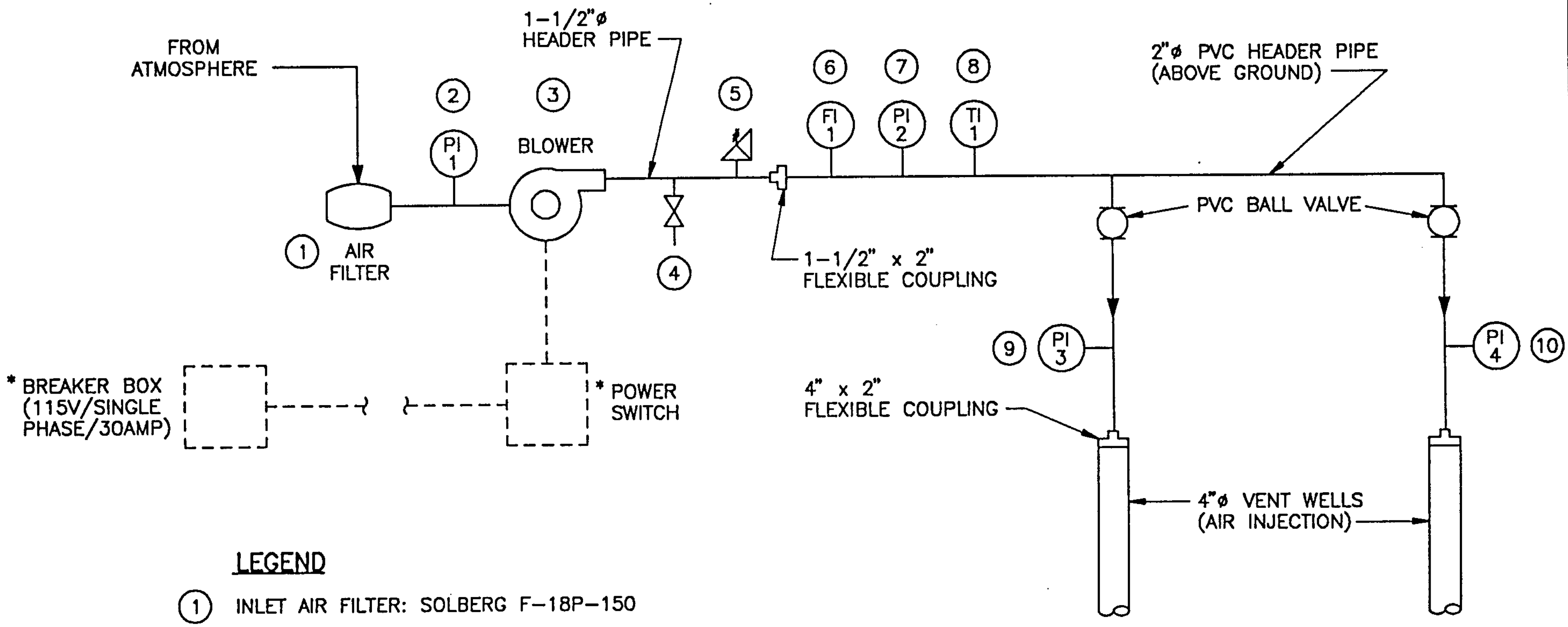

LEGEND

1. INLET AIR FILTER: SOLBERG F-18P-150
2. VACUUM GAUGE (IN. H_2O)
3. BLOWER: GAST R4110-2
4. MANUAL PRESSURE RELIEF (AIR BLEED) VALVE: 1-1/2" GATE VALVE
5. AUTOMATIC PRESSURE RELIEF VALVE
6. AIR FLOW GAUGE (PITOT TUBE)
7. PRESSURE GAUGE (IN. H_2O)
8. TEMPERATURE GAUGE (°F)
9. PRESSURE GAUGE (IN. H_2O)
10. PRESSURE GAUGE (IN. H_2O)

* NOTE: Breaker box and power switch were not installed at time of blower system construction.

DRAWING IS NOT TO SCALE

As-Built Blower System for Air Injection

IRP Site SS-41
Charleston A.F.B.
Charleston, South Carolina

Figure 1.6

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TABLE 2.1

SOIL AND SOIL GAS ANALYTICAL RESULTS
IRP SITE SS-41
CHARLESTON AFB, SOUTH CAROLINA

Analyte (Units)[a/]	Sample Location-Depth (feet below ground surface)		
Soil Hydrocarbons	VW2-8	MPA-7.5	MPB-7.5
TRPH (mg/kg)	544	241	1,400
Benzene (mg/kg)	ND[c/]	ND[c/]	ND[c/]
Toluene (mg/kg)	23	46	14
Ethylbenzene (mg/kg)	2.8	ND[c/]	2.9
Xylenes (mg/kg)	19	17	16
Soil Gas Hydrocarbons	VW2	MPC-8	MPD-8
TVH (ppmv)	21,000	21,000[b/]	17,000
Benzene (ppmv)	ND[c/]	ND[c/]	ND[c/]
Toluene (ppmv)	ND[c/]	ND[c/]	ND[c/]
Ethylbenzene (ppmv)	5.9	5.3[b/]	3.4
Xylenes (ppmv)	8.1	11.5[b/]	9.9
Soil Inorganics	VW2-8	MPA-7.5	MPB-7.5
Iron (mg/kg)	930	280	370
Alkalinity (mg/kg as $CaCO_3$)	ND[c/]	ND[c/]	ND[c/]
pH (units)	4.5	5.1	4.6
TKN (mg/kg)	40	100	42
Phosphates (mg/kg)	40	40	30
Soil Physical Parameters	VW2-8	MPA-7.5	MPB-7.5
Moisture (% wt.)	15.3	14.6	13.9
Gravel (%)	0.0	0.0	0.0
Sand (%)	71.1	81.8	82.2
Silt (%)	11.4	11.2	8.3
Clay (%)	17.5	6.9	9.6

a/ TRPH = Total recoverable petroleum hydrocarbons; mg/kg = milligrams per kilogram; TVH = total volatile hydrocarbons; ppmv = parts per million, volume per volume; $CaCO_3$ = calcium carbonate; TKN = total Kjeldahl nitrogen.

b/ Results averaged with duplicate sample.

c/ ND = not detected.

1,400 mg/kg at CH3-MPB-7.5. Soil total BTEX concentrations ranged from 32.9 to 63 mg/kg. Benzene was not detected in any of the soil samples.

2.2 Soil Gas Sampling Results

Three soil gas samples were collected using SUMMA[R] canisters, one each from CH3-MPC-8, CH3-MPD-8, and CH3-VW2. The samples were collected according to bioventing program protocols and were analyzed for total volatile hydrocarbons (TVH) and BTEX compounds. Analytical results indicate soil gas TVH concentrations ranging from 17,000 ppmv at CH3-MPD-8 to 21,000 ppmv at CH3-MPC-8. Soil gas BTEX concentrations were relatively low, ranging from no detection (ND) to 11.5 ppmv for individual BTEX compounds. The aromatic compounds benzene and toluene were not detected in any of the soil gas samples. These results indicate that potential benzene emissions during bioventing should not be a concern for this site. Table 2.1 summarizes the soil gas sampling results.

2.3 Lithologic Characterization

Residual (undisturbed) soils encountered during the VMP and VW installations consisted primarily of gray to brown, silty fine to medium sands (see Figure 1.3). This silty sand unit is rather consistent across the site. The upper 3 to 4 feet of soil in the test area consists of a brown sandy clay and clayey sand used to backfill the site following demolition. Residual sandy soils below the backfill contain a slightly greater silt fraction and some discontinuous clay lenses up to a depth of 5 feet bgs. Crushed stone was encountered within this lithologic unit, suggesting that portions of this soil horizon have been reworked.

In addition to the predominant silty sands found beneath most of the site, two distinct lithologic units were identified in the soil borings. A pale gray, very fine, loose sand was encountered from about 4 to 6 feet bgs in all of the borings south of CH3-VW1 (see Figure 1.3). Noticeably higher concentrations of hydrocarbon vapors were present in this unit compared to the overlying soils. North of CH3-MPB and in boring CH3-MPD a dark gray, organic sandy clay was encountered. The top of this discontinuous clay unit was found at depths ranging from 5 to 6.5 feet bgs. This clay layer is overlain by the fine sand layer in the vicinity of CH3-MPA.

Underlying the clay and fine sand units is a gray to gray-brown silty fine to medium sand. Particle size analyses of samples collected from this soil horizon show approximately 71% to 82% sand-size particles. Strong hydrocarbon odors were also noted in this soil horizon, although visible soil staining was not present. The water table surface occurs within this lower silty sand unit at a depth of about 10 feet bgs.

3.0 PILOT TEST RESULTS

ES conducted a soil air permeability test and *in situ* respiration tests at the site in November, 1993. As discussed above, pre-test soil gas samples were collected for qualitative (field screening) analyses and quantitative (laboratory) analyses prior to conducting the tests. Test procedures and results for each of the tests are discussed in the following section.

3.1 Initial Soil Gas Chemistry

Prior to initiating any air injection, all VMPs were purged until oxygen concentrations had stabilized, and then initial O_2, CO_2, and TVH concentrations were measured using portable gas analyzers. In contaminated soils, microorganisms had depleted soil gas oxygen concentrations to 1 percent or less in all the VMPs. In contrast, background soil gas O_2 concentrations outside the zone of contamination was 19.2 percent at a depth of 4 feet. Initial soil gas chemistry results (O_2, CO_2, TVH, temperature) obtained by field screening are listed in Table 3.1. TRPH data are also provided to demonstrate the relationship between lower oxygen levels and fuel contamination in the soils.

3.2 Air Permeability Test

A soil air permeability test was conducted at this site on November 20, 1993 according to protocol procedures. Using a rotary vane compressor pump, air was injected into CH3-VW2 at a flow rate of 6.3 standard cubic feet per minute (scfm) and a pressure of 27.5 inches of water. Pressure responses were measured at multiple depths in the surrounding VMPs using either a digital manometer or Magnehelic pressure gauges. Vent well CH3-VW1 was also fitted air tight and monitored for pressure responses during the test. Air was injected for 130 minutes until relative steady-state pressures were achieved and maintained at the VMPs. Table 3.2 contains the time-pressure responses for each VMP.

Soil gas permeabilities were calculated using the HyperVentilate^R model. Pressure response data were evaluated using solutions from both dynamic and steady-state equations. Soil permeability (k) values obtained for the shallow VMPs ranged from 2.13 darcys (CH3-MPB-5) to 5.90 darcys (CH3-MPA-5) using the dynamic equation. In the deeper VMPs, the permeability values ranged from 2.07 darcys (CH3-MPC-8) to 5.01 darcys (CH3-MPD-8). These soil permeability values are reasonable for a fine-to-medium sand soil matrix. Initial air permeability testing indicates that a soil pressure response can be induced at distances exceeding 40 feet. Approximate steady-state pressure at CH3-VW1 ($r=40.3$ feet) was 3.99 inches of water. A soil permeability value of 4.15 darcys was derived by the steady-state solution, which agrees well with results obtained using the dynamic solutions. It is likely that soil pressure responses were created at distances of 40 to 50 feet from the VW during the test.

3.3 Oxygen Influence

The depth and radius of oxygen increase in the subsurface resulting from air injection into the VWs during pilot testing is the primary design parameter for full scale bioventing systems. Optimization of full-scale VW systems requires pilot testing to determine the volume of soil that can be oxygenated at a given flow rate and VW screen configuration.

Soil pressure responses measured during the air permeability test do not necessarily equate to soil gas flow when determining an effective radius of oxygen influence. The ability to actually transport gases (oxygen) through the soil column is far more important in a bioventing design than the ability to create a pressure response in the

TABLE 3.1

INITIAL SOIL GAS CHEMISTRY
IRP SITE SS-41
CHARLESTON AFB, SOUTH CAROLINA

Sample Location	Depth (ft)	O_2 (%)	CO_2 (%)	TVH (ppmv)[a]	TPH (mg/kg)[b]	Temp. (°F)
MPA	8.0	0.1	9.2	>20,000	241	63.9
MPB	8.0	0.3	7.7	>20,000	1,400	64.5
MPC	8.0	0.0	8.0	>20,000	NM	NM
MPD	8.0	0.0	12.2	8,000	NM	NM
MPA	5.0	NM[c]	NM[c]	NM[c]	NM	60.2
MPB	5.0	0	7.9	4,800	NM	61.3
MPC	5.0	NM[c]	NM[c]	NM[c]	NM	NM
MPD	5.0	NM[c]	NM[c]	NM[c]	NM	NM
Background	4.0	19.2	0.5	NM	NM	NM
VW-2	8.0	1.0	8.1	>20,000	544	NM

a/ GasTech hydrocarbon analyzer field screening results, parts per million by volume.
b/ Laboratory results, milligrams per kilogram.
c/ NM = Not sampled due to VMP construction water in well screen.
NS = Not sampled.

TABLE 3.2

PRESSURE RESPONSE (inches of water)
AIR PERMEABILITY TEST
SITE SS-41
CHARLESTON AFB, SOUTH CAROLINA

Depth (feet)	MPA		MPB		MPC		MPD		VW1
	8'	5'	8'	5'	8'	5'	8'	5'	(5' - 10')
Elapsed Time (min: sec)									
00:30	-	-	0.09	0	1.0	2.3	-	-	-
1:00	-	-	-	-	2.0	5.3	-	-	0
1:30	-	-	1.85	3.5	4.0	7.47	-	-	-
2:00	0	0	2.99	4.0	5.5	9.25	0	0	-
2:30	-	-	4.33	5.5	7.0	10.54	-	-	0
3:00	-	-	5.14	6.5	8.0	11.54	-	-	-
4:00	1.0	0.6	6.88	8.0	9.5	13.27	0.15	0	-
5:00	1.5	0.75	-	-	11.0	14.6	-	-	-
5:30	-	-	8.89	10.0	-	-	-	-	-
6:00	-	-	-	-	12.2	15.44	-	-	-
7:00	-	-	10.40	12.0	13.2	16.23	0.5	-	-
8:00	-	-	11.13	12.9	14.0	16.85	0.65	0.15	-
9:00	-	-	-	-	14.5	17.39	-	-	-
10:00	-	-	12.16	14.0	15.0	17.78	-	-	-
11:00	-	-	-	-	15.5	18.2	-	-	-
12:00	-	-	-	-	16.0	18.48	-	-	-
13:00	-	-	-	-	16.5	18.75	-	-	0.80
14:00	-	-	13.61	15.5	16.8	18.99	-	-	-
16:00	-	-	-	-	17.2	19.39	-	-	-
18:00	-	-	-	-	17.5	19.69	-	-	1.25
20:00	5.3	4.2	-	-	18.0	19.94	-	-	-
22:00	5.6	4.4	-	-	18.1	>20.0	-	-	-
24:00	-	-	-	-	18.1	20.0	-	-	1.75
26:00	-	-	15.42	17.5	18.4	20.0	-	-	-
28:00	-	-	15.67	17.7	18.6	20.1	-	-	-

TABLE 3.2 (CONTINUED)

PRESSURE RESPONSE (inches of water)
AIR PERMEABILITY TEST
SITE SS-41
CHARLESTON AFB, SOUTH CAROLINA

Depth (feet)	MPA		MPB		MPC		MPD		VW1
	8'	5'	8'	5'	8'	5'	8'	5'	(5' - 10')
Elapsed Time (min: sec)									
30:00	-	-	-	-	18.8	20.3	-	-	-
32:00	-	-	16.5	18.0	-	-	-	-	-
35:00	-	-	17.0	18.5	-	-	3.46	3.05	2.42
37:00	7.0	6.3	-	-	-	-	3.58	3.17	-
40:00	7.3	6.3	-	-	-	-	-	-	2.67
45:00	-	-	17.5	19.0	-	-	3.96	3.58	-
50:00	-	-	-	-	19.9	-	4.15	3.78	3.01
55:00	-	-	-	-	20.0	21.4	4.30	3.94	3.14
60:00	-	-	-	-	20.0	21.4	4.42	4.07	3.25
70:00	-	-	-	-	20.0	21.5	4.65	4.34	-
75:00	-	-	18.00	19.2	-	-	-	-	-
80:00	-	-	-	-	20.0	21.3	4.85	4.55	-
90:00	8.6	8.3	-	-	20.0	21.4	5.00	4.73	-
100:00	-	-	18.0	19.2	-	-	-	-	3.92
110:00	8.4	8.3	-	-	-	-	-	-	3.95
120:00	-	-	-	-	-	-	5.10	4.85	3.99

soil. Soil gas composition (O_2, CO_2, TVH) was measured at the VMPs during the air permeability test to monitor the diffusion of injected air (oxygen) outward from the injection VW. After 98 minutes of air injection into CH3-VW2, O_2 had increased from 4.0 percent to 14.5 percent at CH3-MPC-8 and from 3.5 percent to 7.2 percent at CH3-MPB-8. After 130 minutes of air injection, O_2 had increased from 1.6 percent to 3.0 percent in CH3-MPA-8. Slight O_2 increases (0.4 percent to 0.9 percent) were also measured in CH3-MPD-8 at this time. These data indicate that during the test period, O_2 diffused outward greater than 30 feet from CH3-VW2 at the given test air flow rates (6.3 scfm) and injection pressures (27.5" water). Table 3.3 summarizes the change in soil gas oxygen concentrations that occurred during the air permeability test.

3.4 *In Situ* Respiration Tests

An *in situ* respiration test was conducted at both VWs and all four VMPs beginning on November 18, 1993. Respiration testing was conducted in accordance with procedures outlined in the bioventing protocol document referenced in the work plan submitted by ES. Testing procedures included helium injection into the VMPs for use as a tracer to test for air leaks. Air with a 4.0 to 5.5 percent helium mixture was injected into the four VMPs for 16.5 hours. Air injection into the VMPs also increased the O_2 concentrations in the adjacent VWs to 17.0 percent (CH3-VW-1) and 19.3 percent (CH3-VW-2) after 16.5 hours. This allowed *in situ* respiration testing to be conducted at both VWs as well. Background respiration testing was not conducted because the background MP (CH3-BG-4) contained initial O_2 levels of 19.2 percent, indicating that abiotic and/or non-fuel oxygen uptake was not a factor at this site.

Oxygen uptake and CO_2 production were monitored for 45 hours during the respiration tests. Figures 3.1 through 3.7 contain the field data plots of O_2 utilization and helium obtained during the test. Oxygen was readily utilized by indigenous soil microorganisms, indicating microbial fuel degradation can be stimulated at the site by oxygen enhancement. Referencing the data plots in Figures 3.1 through 3.7, the "k" values shown on the graphs are the estimated oxygen utilization rates that are used to calculate fuel biodegradation rates. Oxygen utilization rates ranged from a low of 0.0053 percent per minute at CH3-VW1 to a high of 0.0072 percent per minute at CH3-MPD-8. Table 3.4 provides a summary of the oxygen utilization rates.

Recovered helium concentrations were relatively constant, although ES noted that the initial helium concentrations measured at the VMPs were less than those measured at the helium mixing chamber. The relatively constant helium levels indicated that little O_2 was lost from the soil due to diffusion or leaks in the VMP seals.

The magnitude of biological oxygen utilization and fuel degradation can be estimated based on the initial pilot test results. Background soil gas conditions suggest that abiotic and non-fuel oxygen uptake is insignificant at this site. Assuming that no abiotic or non-fuel O_2 uptake occurred during the respiration tests, the observed O_2 utilization rates indicate that between 450 to 770 milligrams of hydrocarbons per kilogram of soil can be biodegraded per year at this site. This estimate is based on average air-filled porosities of 0.045 to 0.05 liters per kilogram of soil, and a conservative ratio of 3.5 milligrams of oxygen consumed for every 1 milligram of fuel

TABLE 3.3

INFLUENCE OF AIR INJECTION AT VENTING WELL ON MONITORING POINT OXYGEN LEVELS IRP SITE SS-41 CHARLESTON AFB, SOUTH CAROLINA

VMP	Distance From VW (ft)	Depth (ft)	Initial O_2 (%)*	Final O_2 (%)[a/]
A	30	8.0	1.6	3.0
B	20	8.0	3.5	7.2
C	10	8.0	4.0	14.5
D	30	8.0	0.4	0.9
A	30	5.0	b/	9.8
B	20	5.0	5.3	6.0
C	10	5.0	b/	17.8
D	30	5.0	b/	b/

a/ Readings taken near end of air permeability test. Elapsed times for final O_2 readings were 98 minutes for MPC and MPB, and 130 minutes for MPA and MPD.

b/ No reading collected.

*Note: Initial O_2 readings were collected at the end of respiration testing prior to beginning the air permeability test.

Figure 3.1
Respiration Test
Oxygen and Helium Concentrations
Site SS-41, VW1
Charleston AFB, South Carolina

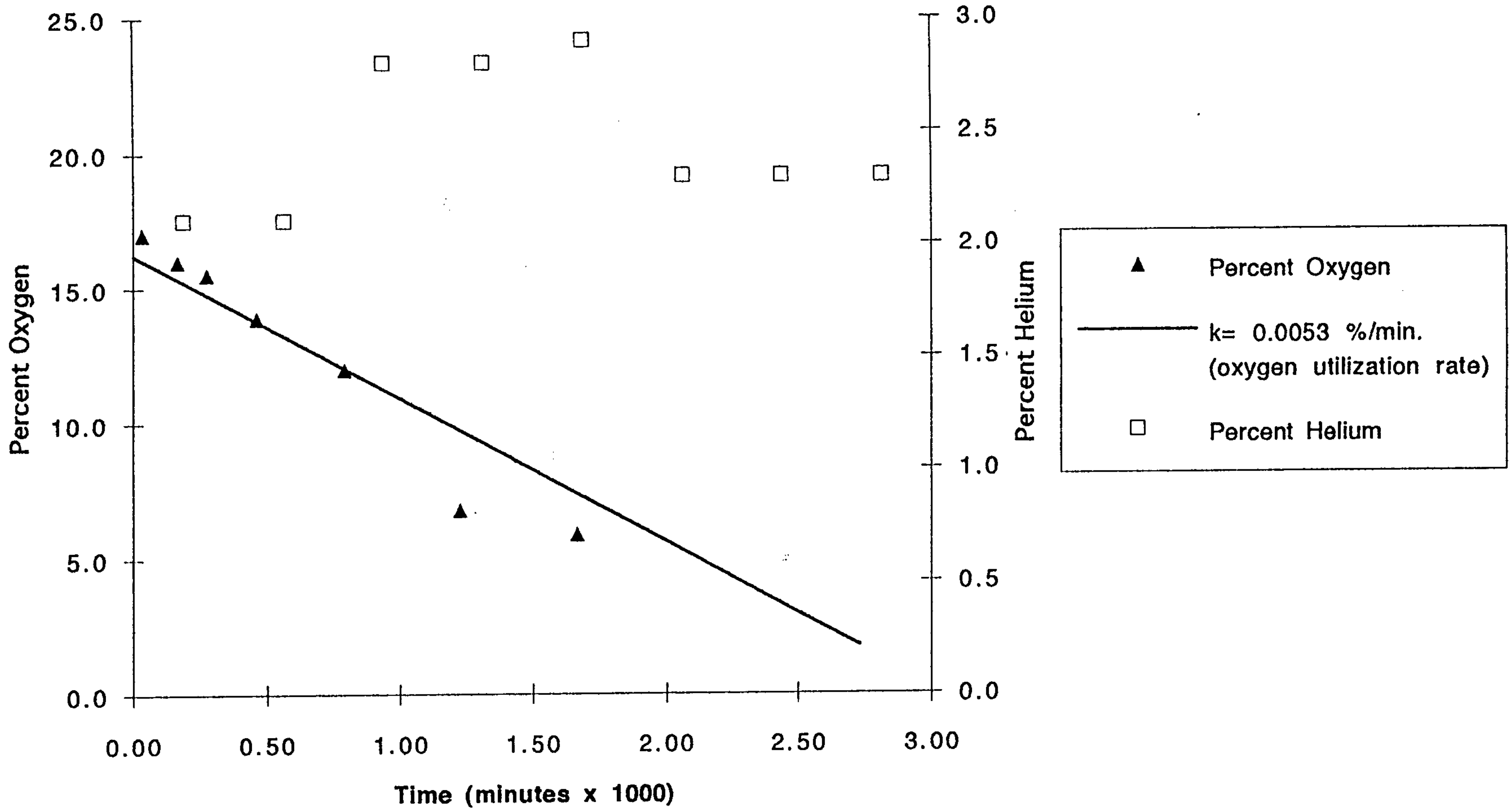


Figure 3.2
Respiration Test
Oxygen and Helium Concentrations
Site SS-41, VW2
Charleston AFB, South Carolina

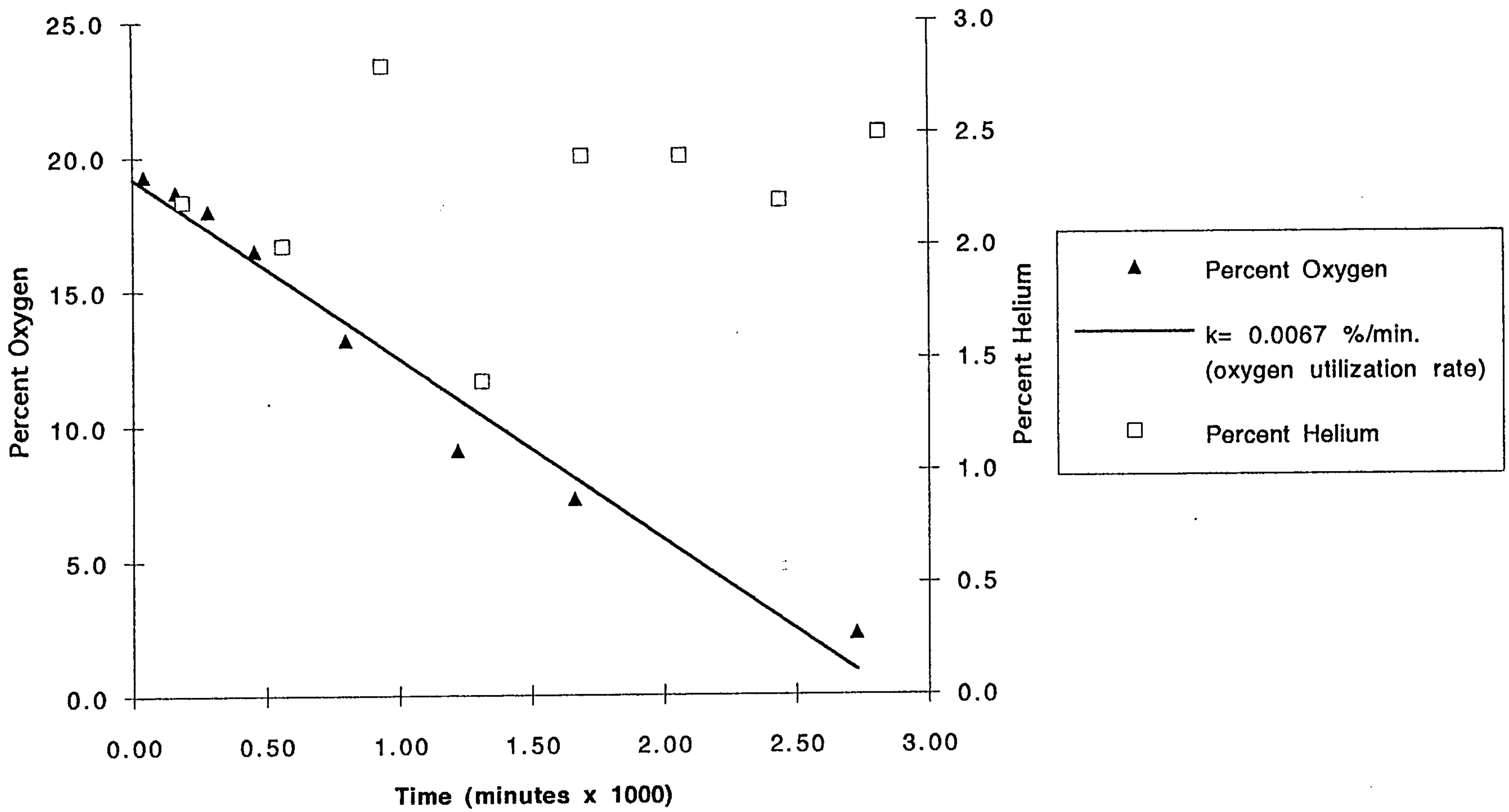


Figure 3.3
Respiration Test
Oxygen and Helium Concentrations
Site SS-41, MPA-8
Charleston AFB, South Carolina

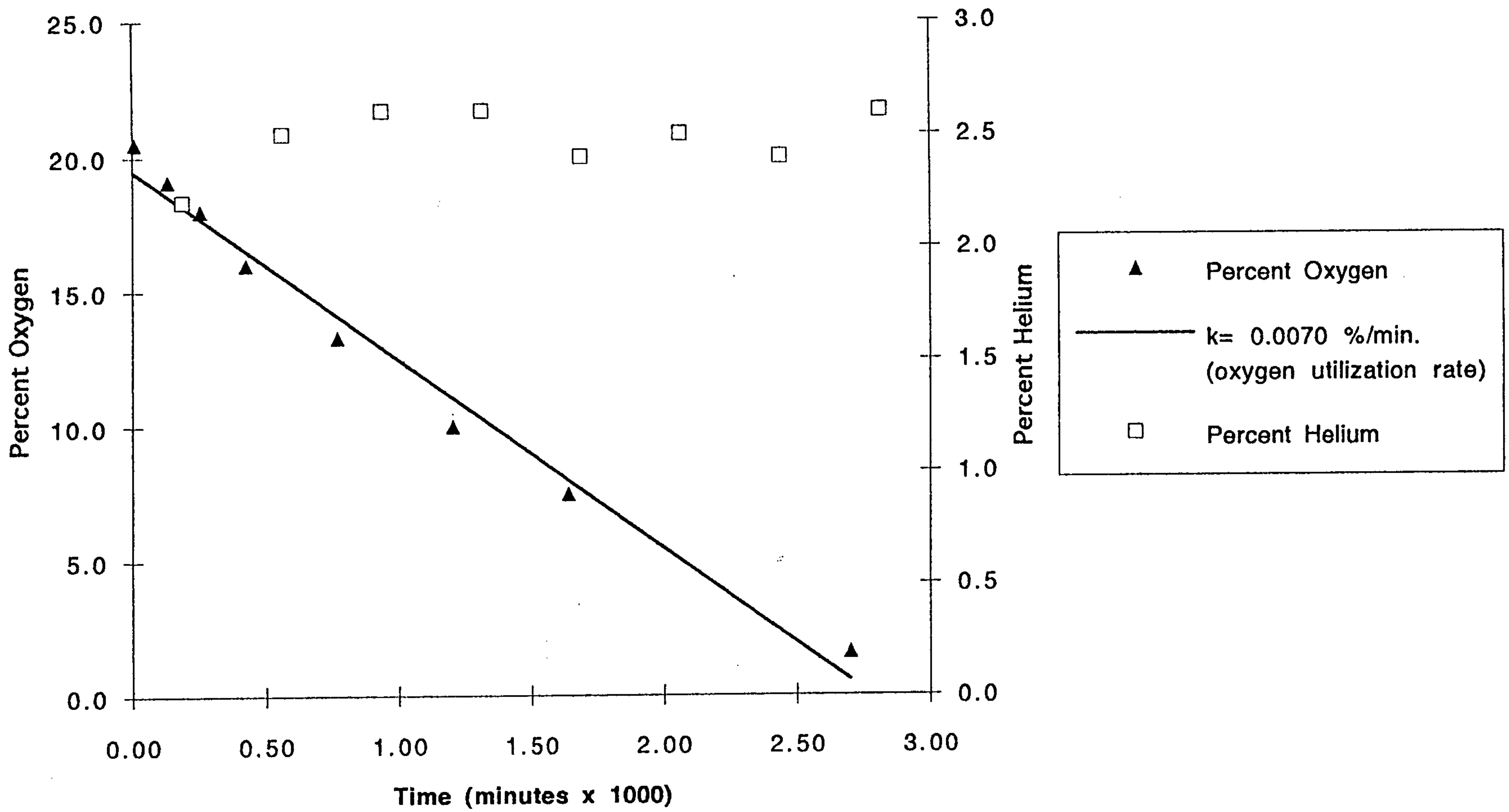


Figure 3.4
Respiration Test
Oxygen and Helium Concentrations
Site SS-41, MPB-5
Charleston AFB, South Carolina

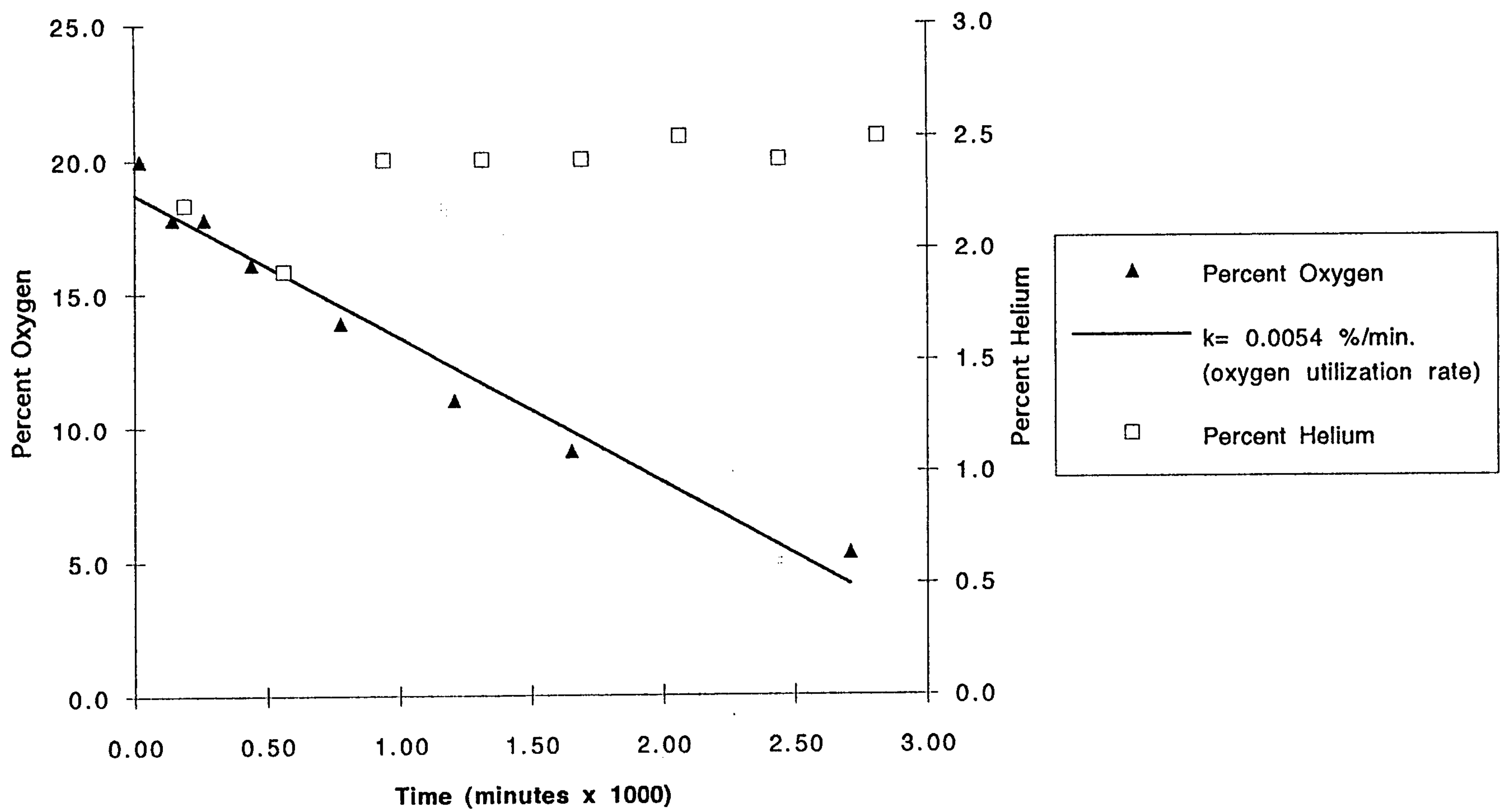


Figure 3.5
Respiration Test
Oxygen and Helium Concentrations
Site SS-41, MPB-8
Charleston AFB, South Carolina

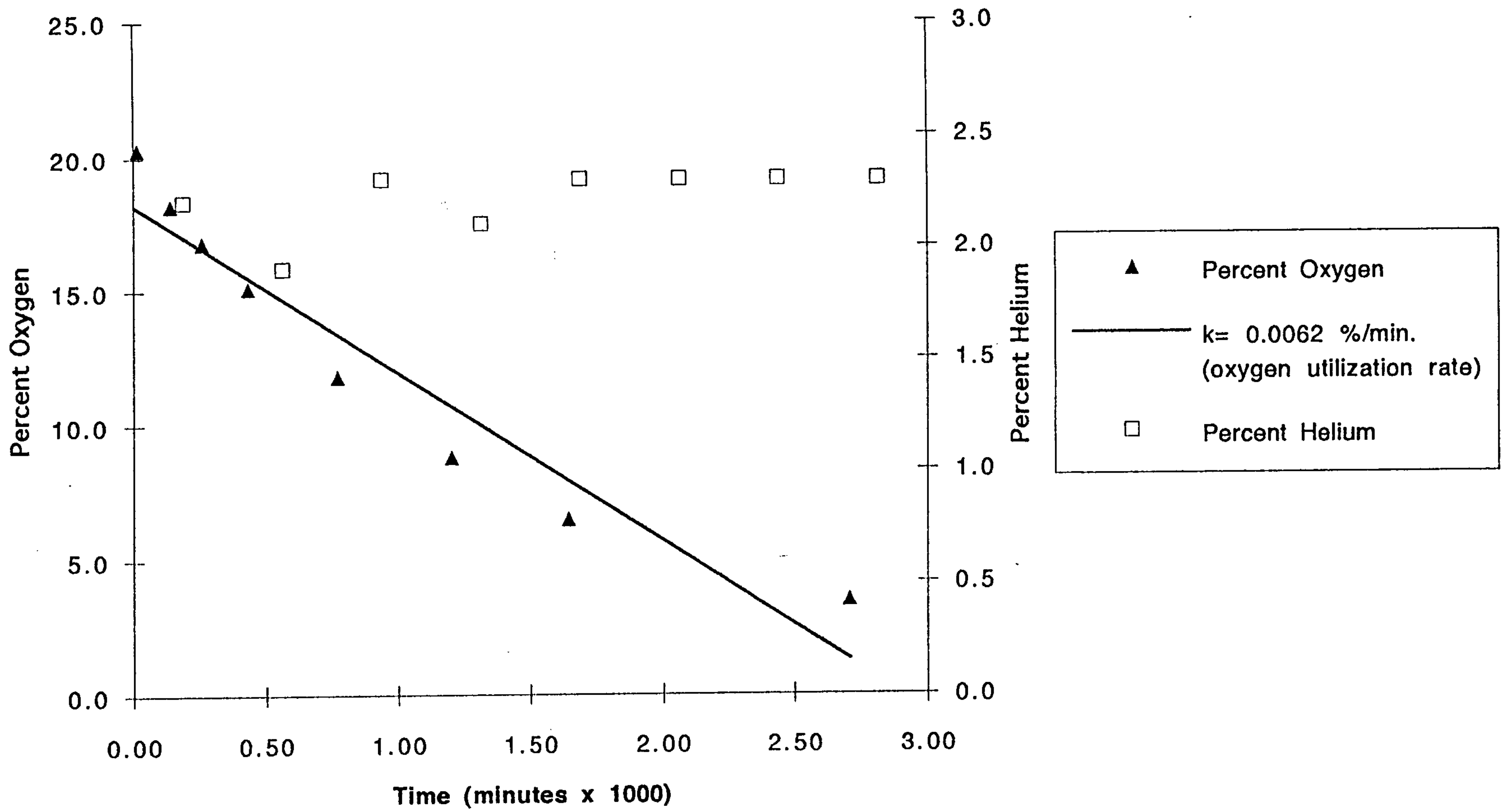


Figure 3.6
Respiration Test
Oxygen and Helium Concentrations
Site SS-41, MPC-8
Charleston AFB, South Carolina

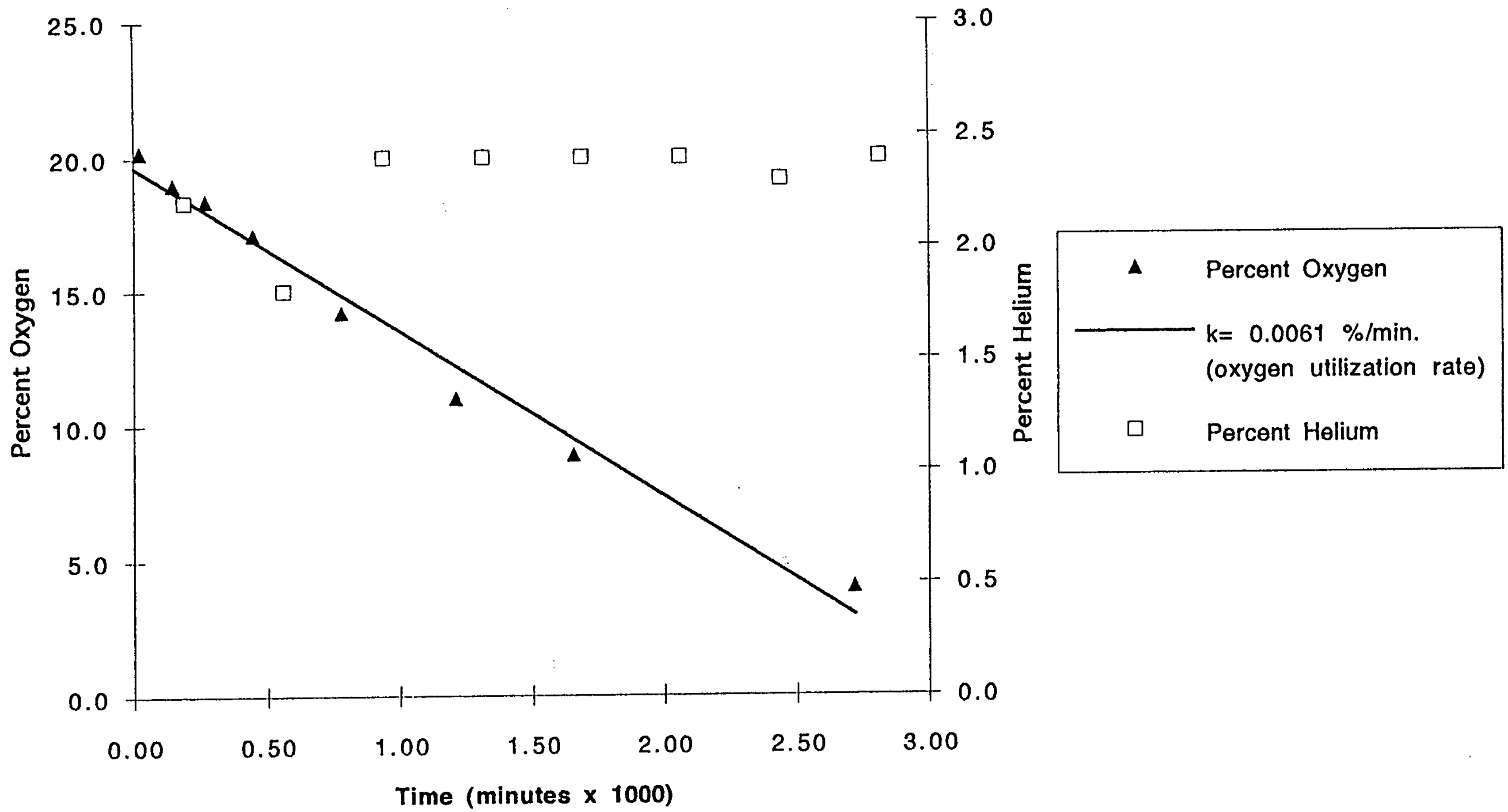


Figure 3.7
Respiration Test
Oxygen and Helium Concentrations
Site SS-41, MPD-8
Charleston AFB, South Carolina

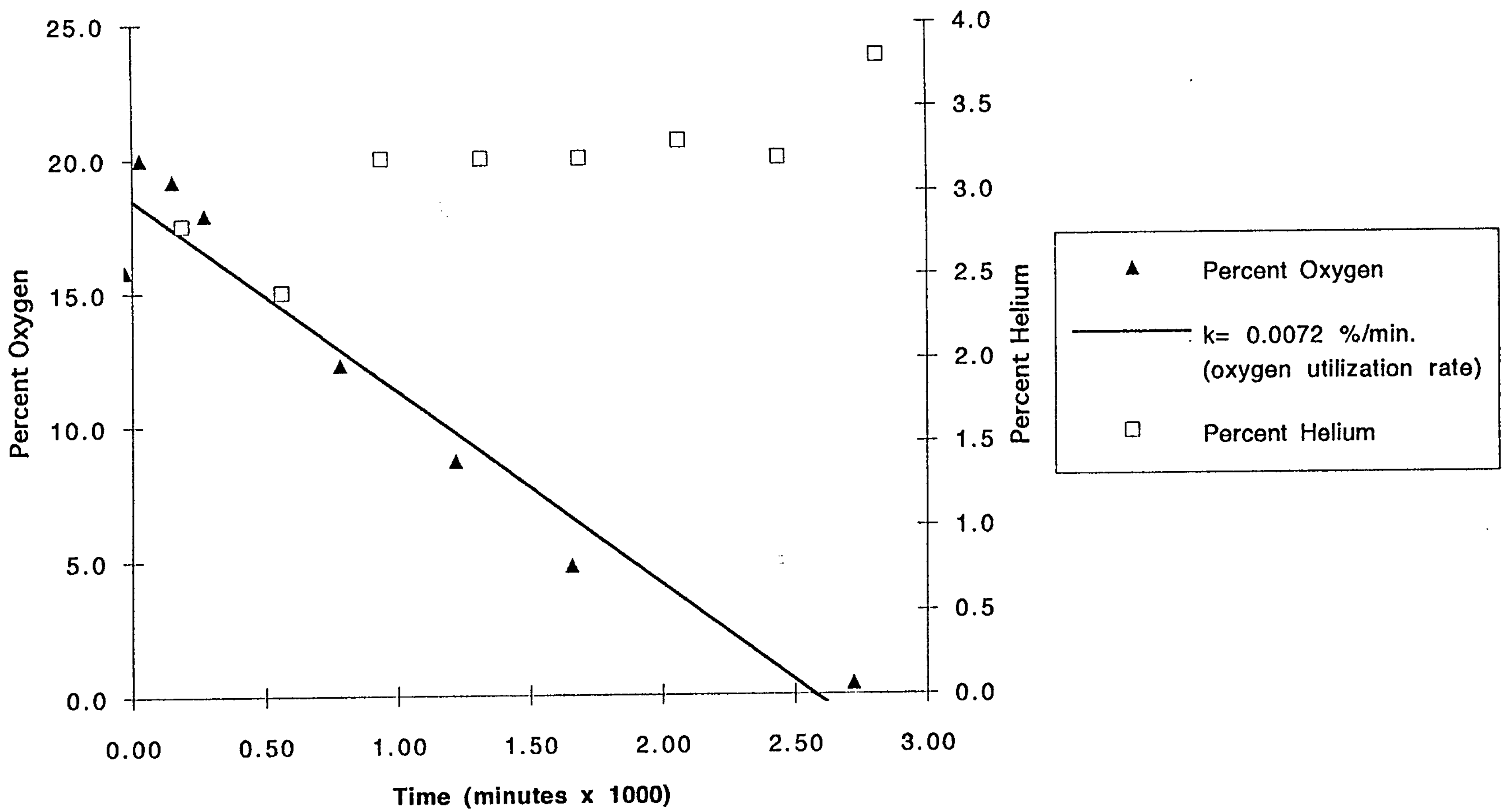


TABLE 3.4

APPARENT OXYGEN UTILIZATION RATES
IRP SITE SS-41
CHARLESTON AFB, SOUTH CAROLINA

VMP	Test Duration (min)	Apparent O_2 Utilization (%/min)
MPA-8	2,700	0.0070
MPB-5	2,710	0.0054
MPB-8	2,710	0.0062
MPC-8	2,720	0.0061
MPD-8	2,720	0.0072
VW-1	2,730	0.0053
VW-2	2,730	0.0067

biodegraded. Actual biodegradation rates can be highly localized and may be affected by temperature, soil moisture, fuel (carbon) concentrations, and other factors.

3.5 Potential Air Emissions

Soil concentrations of total BTEX compounds did not exceed 63 mg/kg, and no benzene was detected in any of the soil samples. Similarly, no benzene or toluene was detected in the soil vapor samples, and the highest soil vapor total BTEX concentration was only 16.8 ppmv. These data suggest that potential benzene or BTEX air emissions during bioventing should not be a concern at this site.

While injecting air during the air permeability test, ES did not detect any significant increases in hydrocarbon vapors emitted to the atmosphere. However, ES observed through routine health and safety air monitoring that this location on the flightline periodically had ambient (background) air TVH concentrations of 2 to 8 ppmv due to nearby test firings of aircraft engines. Some minor losses of VOCs to the atmosphere are possible during the initiation of bioventing due to the shallow nature of the soil contamination. Potential emissions of VOCs that do occur at system startup should rapidly decrease as accumulated vapors move outward from the injection point and are biodegraded as they move through the soil.

Initial field testing also demonstrated that the low-permeability soil cap at the test site will further minimize emissions and air short-circuiting during full-scale operations. Additionally, initial test results suggest that long-term air flow rates into the individual VWs can be less than those used during the air permeability test, while still maintaining an adequate radius of oxygen influence. Reduced injection flow rates will further minimize potential VOC emissions.

4.0 RECOMMENDATIONS

Initial testing has demonstrated that oxygen has been depleted in the contaminated soils and that aerobic fuel biodegradation can be stimulated at this site by the introduction of oxygen. The Air Force Center for Environmental Excellence (AFCEE) has recommended that air injection be initiated at this site to determine the long-term radius of oxygen influence and the effects of time, available nutrients, and changing temperatures on fuel biodegradation rates.

A small, 1-horsepower regenerative blower has been installed at the site to provide air injection for the one-year pilot study. As soon as electrical service is established at this site, the blower should begin operation for the one-year study. Adjustments will be made to the system at startup so that pressures and air injection flow rates into both VWs are balanced. Based on oxygen transport observed during the air permeability test, ES anticipates that an air flow of 4 scfm to 6 scfm into each VW will be sufficient to oxygenate soils at the test site. The sandy soils at the site are relatively permeable and allow sufficient soil gas flow at moderate pressures. The oxygen-delivery radius of influence is expected to exceed 30 feet per VW with air injection rates between 4 to 6 scfm in each VW. A larger effective radius of oxygen influence is possible if higher air injection flow rates are used, although this may increase the potential for fugitive air emissions.

After the system has been operating for six months, ES will return to the site to perform a repeat respiration test and to measure the radius of oxygen influence. After one year of operation, final soil samples and soil gas samples will be collected from the site, and a final respiration test will be conducted, to determine the degree of remediation achieved during the first year of *in situ* treatment.

Based on the results of the first year of pilot-scale bioventing, AFCEE will recommend one of two options for the site:

1. Upgrade the system, if necessary, and continue operation of the bioventing system for full-scale remediation of the site. AFCEE can assist the base in obtaining regulatory approval for upgrading and continued operation.
2. If final soil sampling analytical results indicate significant contaminant removal has occurred, AFCEE may recommend additional sampling to confirm that cleanup criteria have been achieved for this site.

5.0 REFERENCES

Hinchee, R.E., S.K. Ong., R.N. Miller, D.C. Downey, and R. Frendt. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing.* Prepared for the Air Force Center for Environmental Excellence. May. Denver, Colorado.

Engineering-Science, Inc., 1992. *Field Sampling Plan for AFCEE Bioventing.* Denver, Colorado.

APPENDIX A

SOIL BORING LOGS
AND
WELL CONSTRUCTION RECORDS

ENGINEERING-SCIENCE, INC.

SOIL BORING LOG AND WELL CONSTRUCTION RECORD

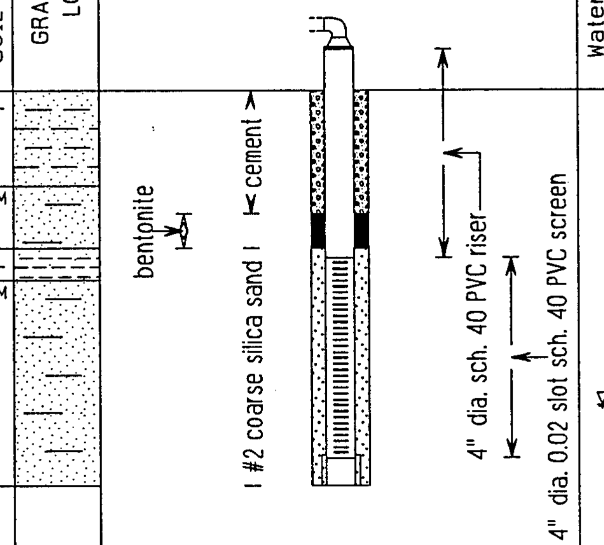
Client Charleston Air Force Base, Charleston, SC
Site SS-41
Project Identification Number 722407-28050
Geol./Eng. Supervising Soil Boring Watkins
Drilling Method (s) Hollow Stem Auger
Sampling Method (s) Split Spoons & Hand Auger
Soil Boring Start Date 11/15/93
Soil Boring Termination Date 11/15/93
Drilling Company TET, Inc.
Borehole Diameter (inches) 10
Borehole Depth (feet below surface) 12.5
Surface Elevation (feet MSL) na
Top of Casing Elevation (feet MSL) na

Soil Boring Identification Number CH3-VW1
Well Identification Number CH3-VW1
Geol./Eng. Supervising Well Installation Watkins
Casing Installation Date 11/15/93
Seal Grouting Date 11/15/93
Casing Material 4" dia. schedule 40 PVC
Screen Material 4" dia. 0.02" slot schedule 40 PVC
Casing Interval (feet below surface) -1.3 to 5.3
Screened Interval (feet below surface) 5.3 to 11.65
Total Well Depth (feet below surface) 12.5
Water Level Measurement Date 11/16/93
Depth to Water (feet below top of casing) 11.28
Water Level Elevation (feet MSL) na

Comments: This borehole was completed as an air injection vent well with a 4"x2" flexible reducer and 2" diameter header pipe from the blower.

DEPTH (feet)	SAMPLE	Soil PID (ppm)	LITHOLOGIC DESCRIPTION	SOIL CLASS
0			Brown sandy clay to clayey fine to medium sand, FILL. No odor.	ML
			Gray to brown silty fine to medium SAND with gravel at 4.5'. No odor.	SM
5	X	260	Dark gray sandy CLAY with organics. Slight odor.	CL
	X	4200	Medium gray to gray-brown silty fine to medium SAND. Moist to wet. Strong fuel odor.	SM
10				
			Soil boring terminated at 12.5' below ground surface.	
15				
20				
25				
30				

WELL DIAGRAM



ENGINEERING-SCIENCE, INC.

SOIL BORING LOG AND WELL CONSTRUCTION RECORD

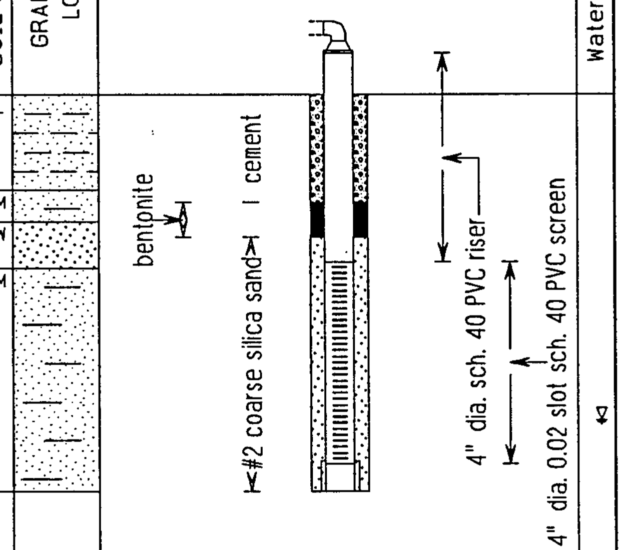
Client: Charleston Air Force Base, Charleston, SC
Site: SS-41
Project Identification Number: 722407-28050
Geol./Eng. Supervising Soil Boring: Watkins
Drilling Method (s): Hollow Stem Auger
Sampling Method (s): Split Spoons & Hand Auger
Soil Boring Start Date: 11/15/93
Soil Boring Termination Date: 11/15/93
Drilling Company: TET, Inc.
Borehole Diameter (inches): 10
Borehole Depth (feet below surface): 12.5
Surface Elevation (feet MSL): na
Top of Casing Elevation (feet MSL): na

Soil Boring Identification Number: CH3-VW2
Well Identification Number: CH3-VW2
Geol./Eng. Supervising Well Installation: Watkins
Casing Installation Date: 11/15/93
Seal Grouting Date: 11/15/93
Casing Material: 4" dia. schedule 40 PVC
Screen Material: 4" dia. 0.02" slot schedule 40 PVC
Casing Interval (feet below surface): -1.3 to 5.3
Screened Interval (feet below surface): 5.3 to 11.65
Total Well Depth (feet below surface): 12.5
Water Level Measurement Date: 11/16/93
Depth to Water (feet below top of casing): 11.58
Water Level Elevation (feet MSL): na

Comments: This borehole was completed as an air injection vent well with a 4"x2" flexible reducer and 2" diameter header pipe from the blower.

DEPTH (feet)	SAMPLE	Soil PID (ppm)	LITHOLOGIC DESCRIPTION	SOIL CLASS
0			Brown sandy clay to clayey fine to medium sand, FILL. No odor.	ML
			Gray to brown silty fine to medium SAND. No odor.	SM
5	X	740	Pale gray fine SAND, loose. Fuel odor.	SW
	X X	1200 4500	Medium gray to gray-brown silty fine to medium SAND. Moist to wet. Strong fuel odor.	SM
10				
			Soil boring terminated at 12.5' below ground surface.	
15				
20				
25				
30				

WELL DIAGRAM



ENGINEERING-SCIENCE, INC.
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

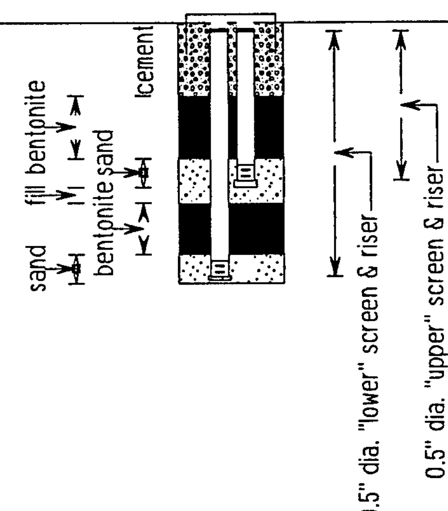
Client: Charleston Air Force Base, Charleston, SC
Site: SS-41
Project Identification Number: 722407-28050
Geol./Eng. Supervising Soil Boring: Watkins
Drilling Method (s): Hand Auger
Sampling Method (s): Hand Auger
Soil Boring Start Date: 11/16/93
Soil Boring Termination Date: 11/16/93
Drilling Company: Engineering-Science, Inc.
Borehole Diameter (inches): 4
Borehole Depth (feet below surface): 8.2
Lower Casing Installation Date: 11/16/93
Lower Seal Grouting Date: 11/16/93
Lower Casing Material: 0.5" dia. schedule 80 PVC
Lower Screen Material: 0.5" dia. 0.02" slot schedule 40 PVC
Surface Elevation (feet MSL): na
Top of Casing Elev., Lower Well (feet MSL): na
Top of Casing Elev., Upper Well (feet MSL): na

Soil Boring Identification Number: CH3-MPA
Well Identification Number: CH3-MPA
Geol./Eng. Supervising Well Installation: Watkins
Lower Casing Interval (feet below surface): 0.3 to 7.5
Lower Screened Interval (feet below surface): 7.5 to 8
Total Lower Well Depth (feet below surface): 8.1
Upper Casing Installation Date: 11/16/93
Upper Seal Grouting Date: 11/16/93
Upper Casing Material: 0.5" dia. schedule 80 PVC
Upper Screen Material: 0.5" dia. 0.02" slot schedule 40 PVC
Upper Casing Interval (feet below surface): 0.3 to 4.5
Upper Screened Interval (feet below surface): 4.5 to 5
Total Upper Well Depth (feet below surface): 5.2
Water Level Measurement Date: na
Depth to Water (feet below top of casing): na
Water Level Elevation (feet MSL): na

Comments: This borehole was completed as a multi-depth vapor monitoring point with gas ball valves and 1/4" hose barbs.

DEPTH (feet)	SAMPLE	Soil PID (ppm)	LITHOLOGIC DESCRIPTION	SOIL CLASS	GRAPHIC LOG
0			Brown sandy clay to clayey fine to medium sand, FILL with gravel at 2.75'. No odor	ML	
			Gray to brown silty fine to medium SAND.	SM	
5	X	310	Pale gray fine SAND, loose.	SW	
			Dark gray sandy CLAY with organics. Strong fuel odor at 6.3'.	CL	
	X	6100	Medium gray to gray-brown silty fine to medium SAND. Moist. Strong fuel odor.	SM	
10			*Soil boring terminated at 8.2' below ground surface.*		
15					
20					
25					

MONITORING POINT DIAGRAM



ENGINEERING-SCIENCE, INC.
SOIL BORING LOG AND WELL CONSTRUCTION RECORD

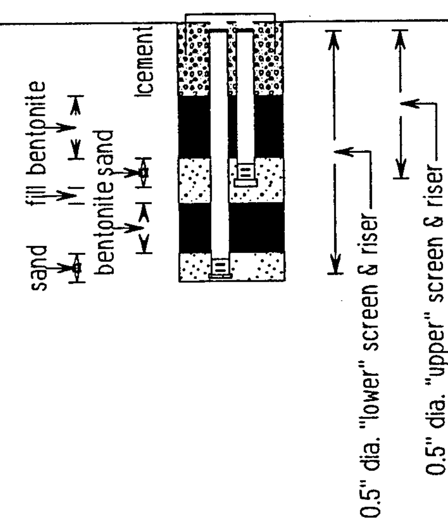
Client: Charleston Air Force Base, Charleston, SC
Site: SS-41
Project Identification Number: 722407-28050
Geol./Eng. Supervising Soil Boring: Watkins
Drilling Method (s): Hand Auger
Sampling Method (s): Hand Auger
Soil Boring Start Date: 11/16/93
Soil Boring Termination Date: 11/16/93
Drilling Company: Engineering-Science, Inc.
Borehole Diameter (inches): 4
Borehole Depth (feet below surface): 8.2
Lower Casing Installation Date: 11/16/93
Lower Seal Grouting Date: 11/16/93
Lower Casing Material: 0.5" dia. schedule 80 PVC
Lower Screen Material: 0.5" dia. 0.02" slot schedule 40 PVC
Surface Elevation (feet MSL): na
Top of Casing Elev., Lower Well (feet MSL): na
Top of Casing Elev., Upper Well (feet MSL): na

Soil Boring Identification Number: CH3-MPB
Well Identification Number: CH3-MPB
Geol./Eng. Supervising Well Installation: Watkins
Lower Casing Interval (feet below surface): 0.3 to 7.5
Lower Screened Interval (feet below surface): 7.5 to 8
Total Lower Well Depth (feet below surface): 8.1
Upper Casing Installation Date: 11/16/93
Upper Seal Grouting Date: 11/16/93
Upper Casing Material: 0.5" dia. schedule 80 PVC
Upper Screen Material: 0.5" dia. 0.02" slot schedule 40 PVC
Upper Casing Interval (feet below surface): 0.3 to 4.5
Upper Screened Interval (feet below surface): 4.5 to 5
Total Upper Well Depth (feet below surface): 5.2
Water Level Measurement Date: na
Depth to Water (feet below top of casing): na
Water Level Elevation (feet MSL): na

Comments: This borehole was completed as a multi-depth vapor monitoring point with gas ball valves and 1/4" hose barbs.

DEPTH (feet)	SAMPLE	Soil PID (ppm)	LITHOLOGIC DESCRIPTION	SOIL CLASS
0			Brown sandy clay to clayey fine to medium sand, FILL. No odor.	ML
			Gray to brown silty fine to medium SAND.	SM
5	X	3000	Pale gray fine SAND, loose. Fuel odor.	SW
	X	7100	Medium gray to gray-brown silty fine to medium SAND. Moist. Strong fuel odor.	SM
			Soil boring terminated at 8.2' below ground surface.	
10				
15				
20				
25				

MONITORING POINT DIAGRAM



ENGINEERING-SCIENCE, INC.

SOIL BORING LOG AND WELL CONSTRUCTION RECORD

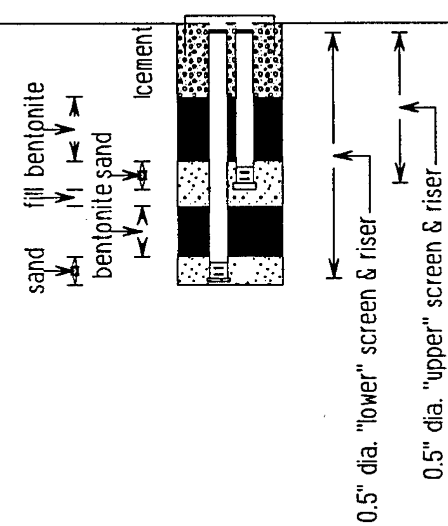
Client: Charleston Air Force Base, Charleston, SC
Site: SS-41
Project Identification Number: 722407-28050
Geol./Eng. Supervising Soil Boring: Watkins
Drilling Method (s): Hand Auger
Sampling Method (s): Hand Auger
Soil Boring Start Date: 11/16/93
Soil Boring Termination Date: 11/16/93
Drilling Company: Engineering-Science, Inc.
Borehole Diameter (inches): 4
Borehole Depth (feet below surface): 8.2
Lower Casing Installation Date: 11/16/93
Lower Seal Grouting Date: 11/16/93
Lower Casing Material: 0.5" dia. schedule 80 PVC
Lower Screen Material: 0.5" dia. 0.02" slot schedule 40 PVC
Surface Elevation (feet MSL): na
Top of Casing Elev., Lower Well (feet MSL): na
Top of Casing Elev., Upper Well (feet MSL): na

Soil Boring Identification Number: CH3-MPC
Well Identification Number: CH3-MPC
Geol./Eng. Supervising Well Installation: Watkins
Lower Casing Interval (feet below surface): 0.3 to 7.5
Lower Screened Interval (feet below surface): 7.5 to 8
Total Lower Well Depth (feet below surface): 8.1
Upper Casing Installation Date: 11/16/93
Upper Seal Grouting Date: 11/16/93
Upper Casing Material: 0.5" dia. schedule 80 PVC
Upper Screen Material: 0.5" dia. 0.02" slot schedule 40 PVC
Upper Casing Interval (feet below surface): 0.3 to 4.5
Upper Screened Interval (feet below surface): 4.5 to 5
Total Upper Well Depth (feet below surface): 5.2
Water Level Measurement Date: na
Depth to Water (feet below top of casing): na
Water Level Elevation (feet MSL): na

Comments: This borehole was completed as a multi-depth vapor monitoring point with gas ball valves and 1/4" hose barbs.

DEPTH (feet)	SAMPLE	Soil PID (ppm)	LITHOLOGIC DESCRIPTION	SOIL CLASS	GRAPHIC LOG
0			Brown sandy clay to clayey fine to medium sand, FILL. No odor.	ML	
			Gray to brown silty fine to medium SAND, some gravel at 3.5'. Fuel odor at 3.5'.	SM	
5	X	3200	Pale gray fine SAND, loose. Strong fuel odor.	SW	
	X	5400	Medium gray to gray-brown silty fine to medium SAND. Moist. Strong fuel odor.	SM	
			Soil boring terminated at 8.2' below ground surface.		
10					
15					
20					
25					

MONITORING POINT DIAGRAM



ENGINEERING-SCIENCE, INC.

SOIL BORING LOG AND WELL CONSTRUCTION RECORD

Client Charleston Air Force Base, Charleston, SC
Site SS-41
Project Identification Number 722407-28050
Geol./Eng. Supervising Soil Boring Watkins
Drilling Method (s) Hand Auger
Sampling Method (s) Hand Auger
Soil Boring Start Date 11/17/93
Soil Boring Termination Date 11/17/93
Drilling Company Engineering-Science, Inc.
Borehole Diameter (inches) 4
Borehole Depth (feet below surface) 8.2
Lower Casing Installation Date 11/17/93
Lower Seal Grouting Date 11/17/93
Lower Casing Material 0.5" dia. schedule 80 PVC
Lower Screen Material 0.5" dia. 0.02" slot schedule 40 PVC
Surface Elevation (feet MSL) na
Top of Casing Elev., Lower Well (feet MSL) na
Top of Casing Elev., Upper Well (feet MSL) na

Soil Boring Identification Number CH3-MPD
Well Identification Number CH3-MPD
Geol./Eng. Supervising Well Installation Watkins
Lower Casing Interval (feet below surface) 0.3 to 7.5
Lower Screened Interval (feet below surface) 7.5 to 8
Total Lower Well Depth (feet below surface) 8
Upper Casing Installation Date 11/17/93
Upper Seal Grouting Date 11/17/93
Upper Casing Material 0.5" dia. schedule 80 PVC
Upper Screen Material 0.5" dia. 0.02" slot schedule 40 PVC
Upper Casing Interval (feet below surface) 0.3 to 4.5
Upper Screened Interval (feet below surface) 4.5 to 5
Total Upper Well Depth (feet below surface) 5.2
Water Level Measurement Date na
Depth to Water (feet below top of casing) na
Water Level Elevation (feet MSL) na

Comments: This borehole was completed as a multi-depth vapor monitoring point with gas ball valves and 1/4" hose barbs.

DEPTH (feet)	SAMPLE	Soil PID (ppm)	LITHOLOGIC DESCRIPTION	SOIL CLASS	GRAPHIC LOG
0			Brown clayey sand to sandy clay, FILL. No odor.	ML	
			Dark gray sandy CLAY, stiff. No odor.	CL	
5	X	210	Gray silty fine to medium SAND, loose. No odor.	SM	
			GRAVEL.	GP	
				SM	
	X	1100	Pale gray-brown silty fine to medium SAND. Moist. Slight fuel odor.		
			Dark gray clay. Slight fuel odor.	CL	
10			*Soil boring terminated at 8' below ground surface.*		
15					
20					
25					

MONITORING POINT DIAGRAM