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Soil Vapor Extraction and Bioventing Test Work Plan for the MOGAS Site



**Myrtle Beach Air Force Base,
South Carolina**

Prepared For

**Air Force Center for Environmental Excellence
Brooks Air Force Base
San Antonio, Texas**

and

**Myrtle Beach Air Force Base
Myrtle Beach, South Carolina**

December 1995



**PARSONS
ENGINEERING SCIENCE, INC.**

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**SOIL VAPOR EXTRACTION AND BIOVENTING TEST WORK PLAN FOR
THE MOGAS SITE**

**MYRTLE BEACH AIR FORCE BASE
MYRTLE BEACH, SOUTH CAROLINA**

December 1995

Prepared for:

**AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
BROOKS AIR FORCE BASE, TEXAS**

and

**MYRTLE BEACH AIR FORCE BASE
MYRTLE BEACH, SOUTH CAROLINA**

Prepared by:

**PARSONS ENGINEERING SCIENCE, INC.
1700 Broadway, Suite 900
Denver, Colorado 80290**

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SECTION 1

INTRODUCTION

This work plan presents an evaluation of soil vapor extraction (SVE) and bioventing, and describes the SVE pilot scale and bioventing activities to be conducted to extract and treat soil gas at Installation Restoration Program (IRP) Site SS-20 located at Myrtle Beach Air Force Base (AFB), Myrtle Beach, South Carolina. Site SS-20, locally known as the MOGAS site, is known to be contaminated with fuel hydrocarbons. The SVE pilot scale tests will use an internal combustion engine (ICE) system with advanced emission controls (VR systems[®]), and the Ultrox[®] ultraviolet (UV)/Oxidation (D-TOX[™]) system.

The proposed SVE pilot tests will be conducted in two phases. During the first phase, the ICE will be installed and operated for approximately 2 months. In the second phase, the D-TOX[™] system will be operated and monitored for approximately 2 months. Parsons Engineering Science, Inc. (Parsons ES) will evaluate the D-TOX[™] system based upon operational costs and contaminant destruction efficiency. After the SVE pilot tests are completed, the SVE systems will be converted to a low-rate air injection system for long-term bioventing to remediate residual contamination in the vadose zone soils.

SECTION 2

SITE DESCRIPTION

2.1 SITE HISTORY AND BACKGROUND

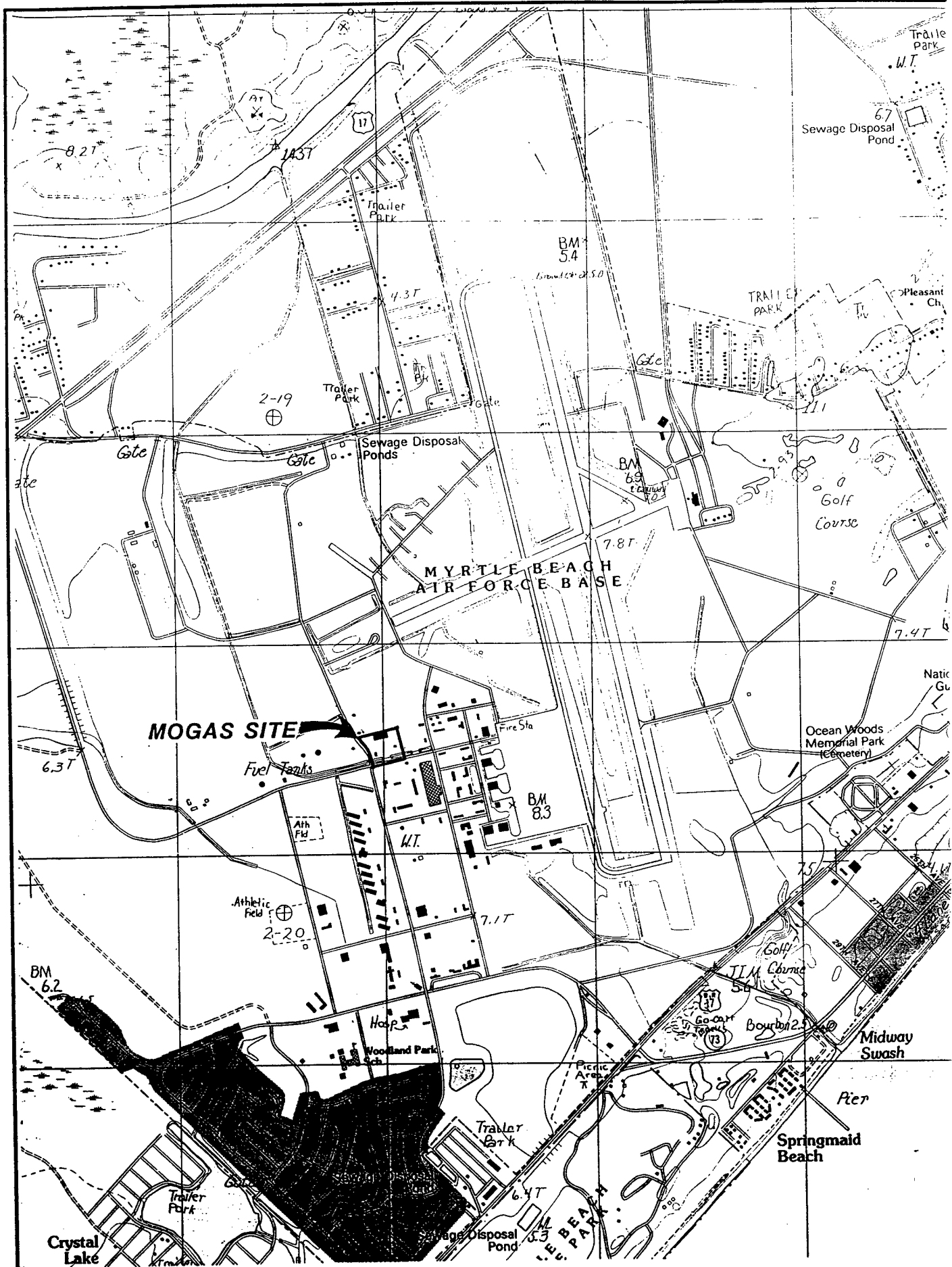
Myrtle Beach AFB was the headquarters for the 354th Tactical Fighter Wing under the direction of the Tactical Air Command (TAC). The Base is currently undergoing closure under the direction of the Air Force Base Conversion Agency. The Base is located about 4 miles southwest of downtown Myrtle Beach, South Carolina (Figure 2.1). The Base consists of about 3,793 acres situated on the Coastal Plain between the Atlantic Ocean to the south and the intracoastal waterway to the north. The MOGAS site is located west of the runways in the southwestern portion of the Base at the former Motor Pool, adjacent to Building 514. The MOGAS site is bounded on the north by forest, on the west by Third Street, by an unlined drainage ditch to the east, and by an unlined drainage ditch and Avenue D to the south. Figure 2.2 is a map of MOGAS site that shows the principal site features.

The MOGAS site is located at the former Motor Pool, where most of the area is paved with asphalt. Four 5,000-gallon underground storage tanks (USTs) were previously located at the site to store gasoline and diesel fuel for motor operations. Three of the tanks were used for gasoline, and one tank was used for diesel fuel (ES, 1981). These USTs were situated below ground at two locations south of Building 514. Each location contained two tanks (Figure 2.2). These USTs were removed in April 1993.

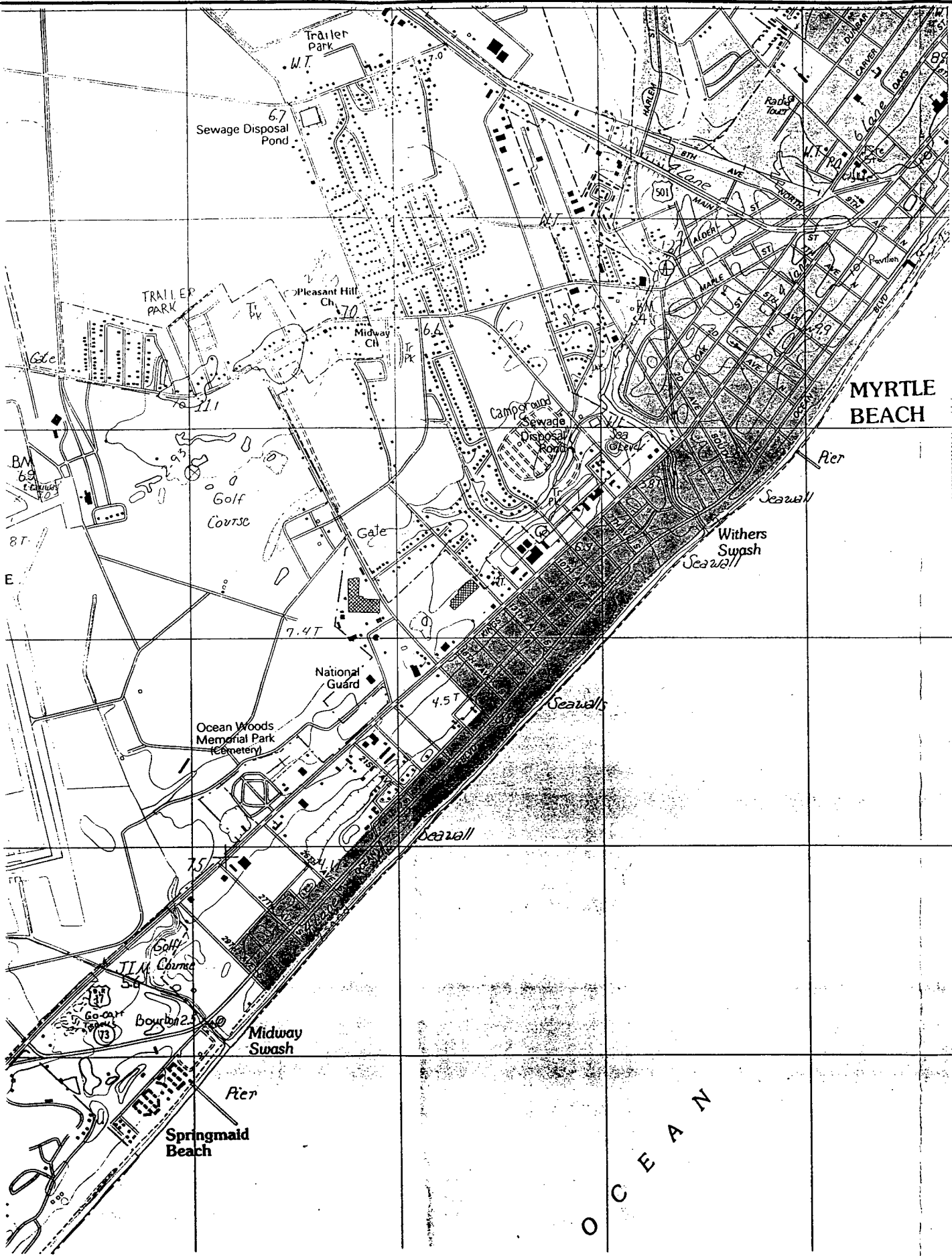
Prior to removing the USTs, Base personnel had observed a fuel sheen on the water in the southern drainage ditch and stressed vegetation lining the northern bank of the ditch. As a result of this observation, Base personnel installed two corrugated metal skimmer wells to monitor the leak. During well installation, gasoline-saturated soils were observed, and a thin layer of free product was noted on the shallow water table. These wells were used to collect an unknown quantity of free product released from the former leaking USTs that were drained and abandoned.

In April 1993, Laidlaw Environmental Services excavated and removed the four USTs and backfilled the excavations with clean soils. During excavation, soils contaminated with gasoline were observed and removed; however, the entire volume of contaminated soils was too extensive to remove at that time from the area surrounding the tank excavations. Groundwater was not reported in the excavation when the tanks were removed.

Several phases of environmental investigations have been conducted by various contractors at the MOGAS site. The initial site remedial investigation was conducted



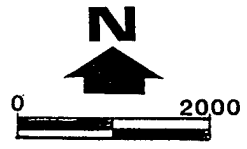
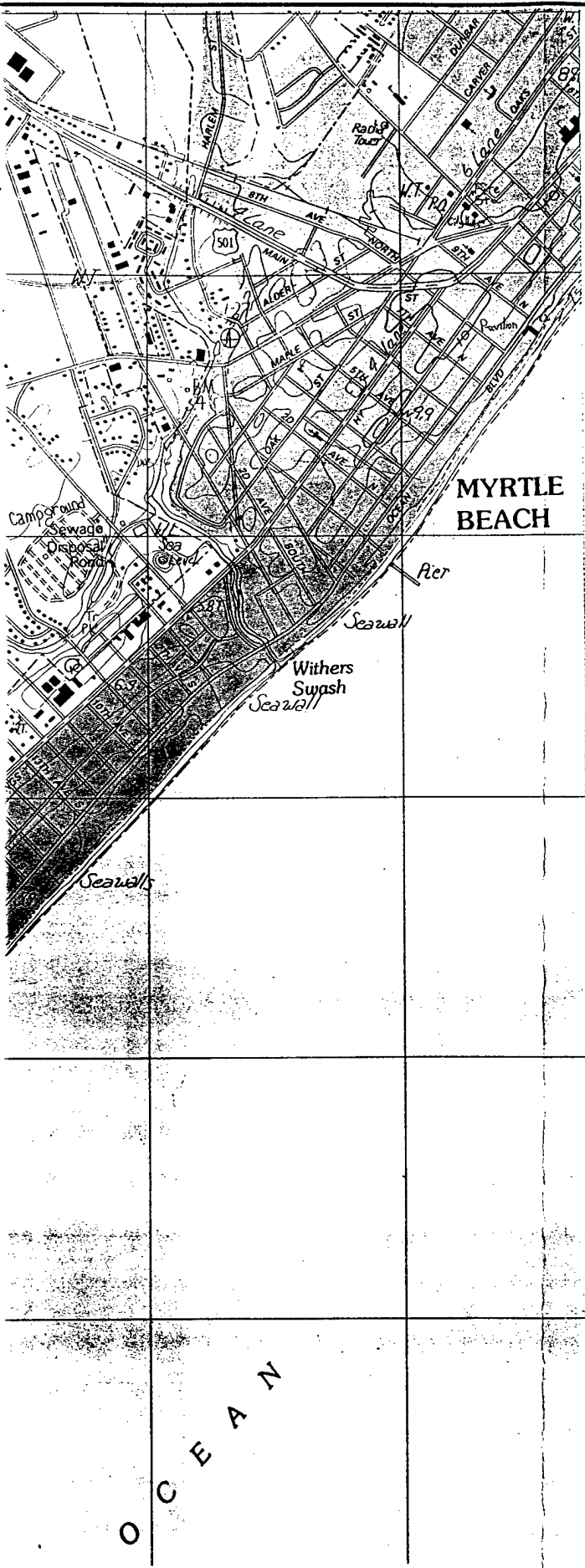
Source: US Geological Survey, 7.5 Myrtle Beach Quadrangle (1994).



MYRTLE BEACH


O C C E A N



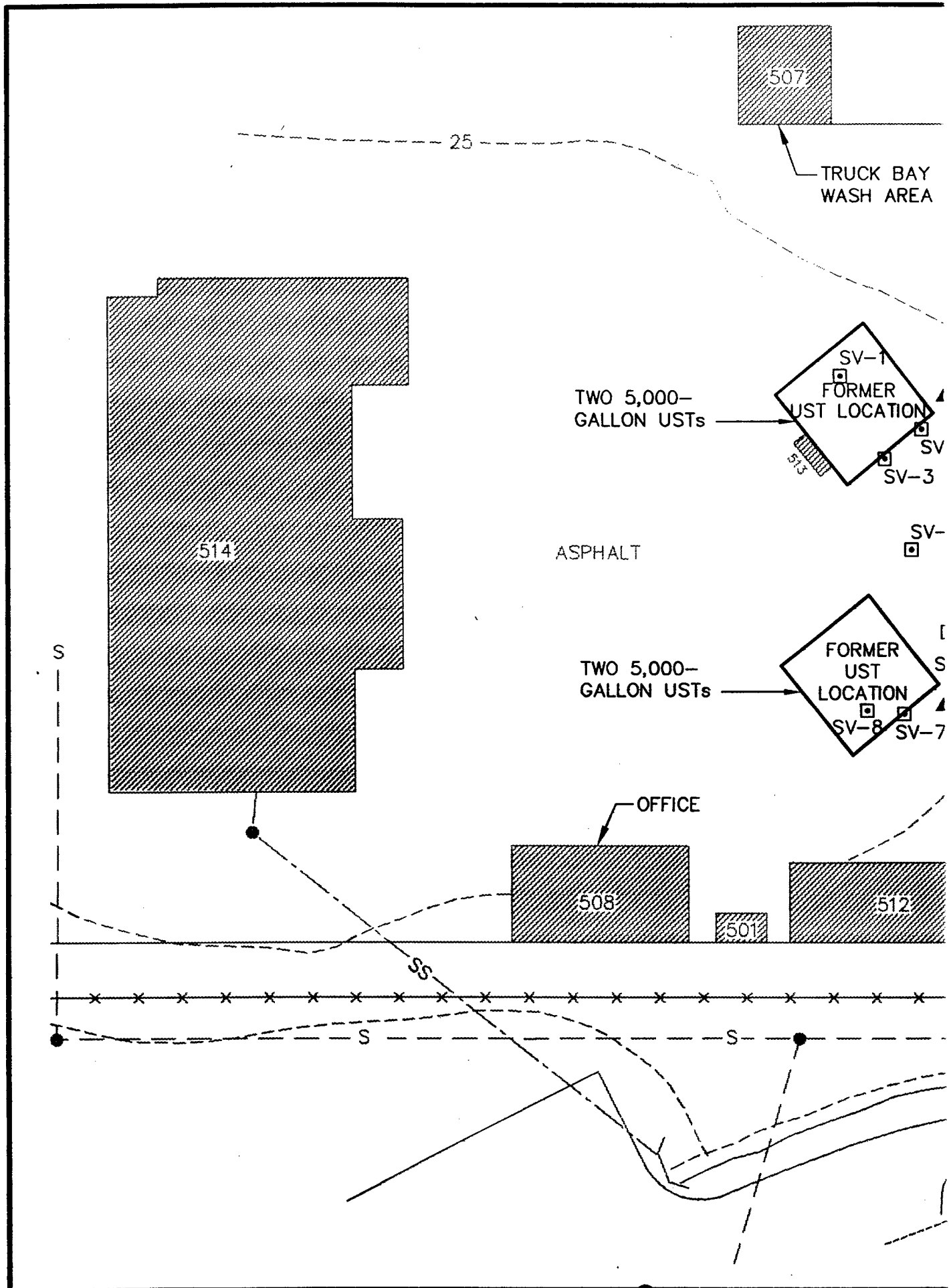


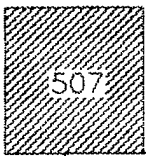
QUADRANGLE LOCATION

FIGURE 2.1
LOCATION MAP OF MYRTLE BEACH AFB, SOUTH CAROLINA
 SVE and Bioventing
 Pilot Test Work Plan
 Myrtle Beach AFB, South Carolina

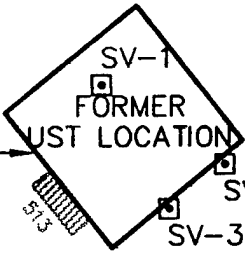


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TRUCK BAY WASH AREA

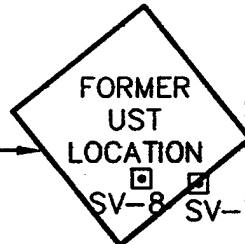


NO 5,000-GALLON USTs

573

SV-4

HALT



NO 5,000-GALLON USTs

SV-5

SV-6

SV-7

SV-8

VW-2

OFFICE

18

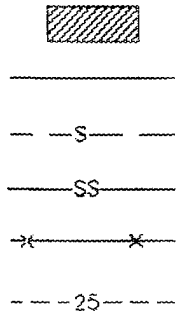
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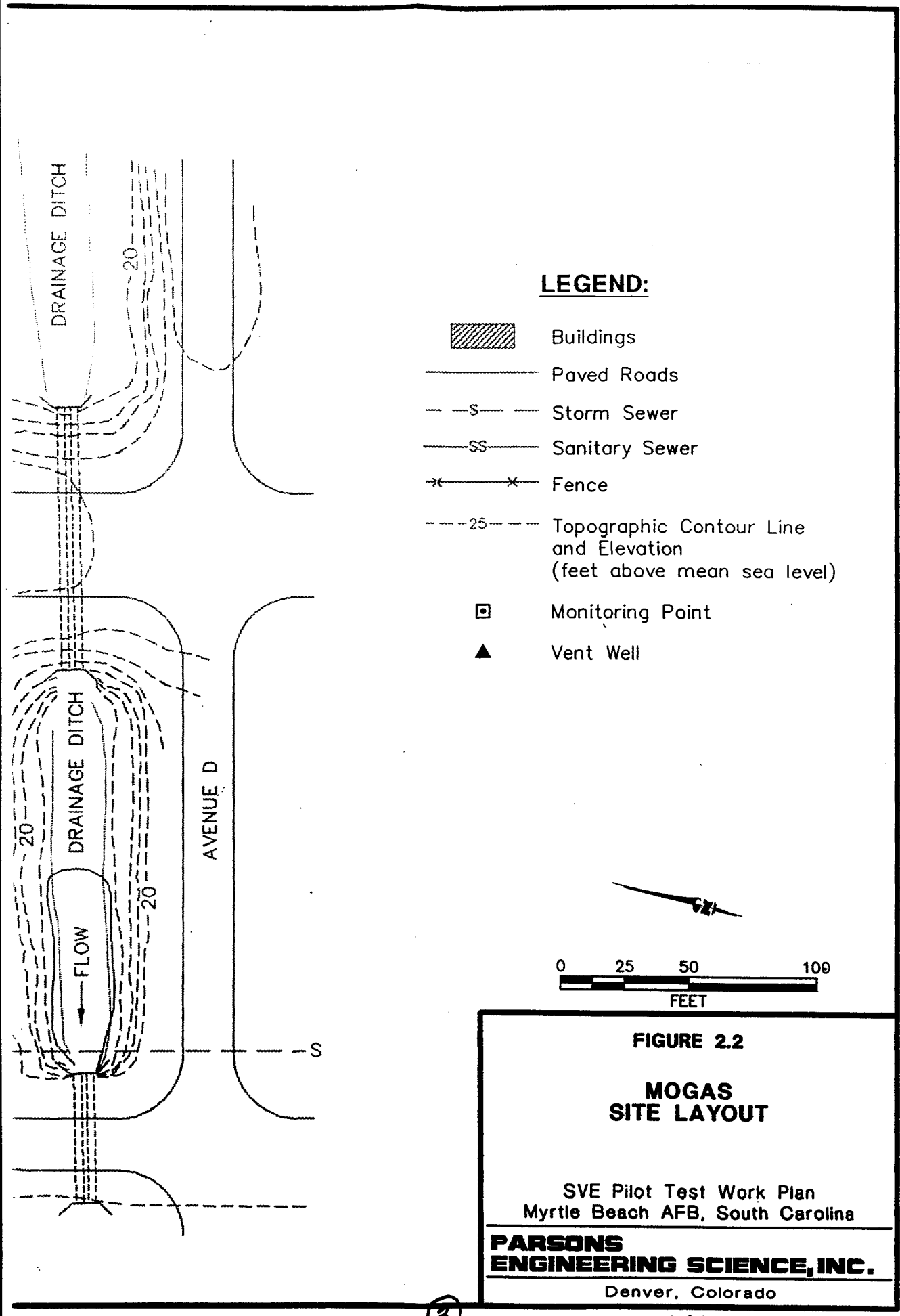
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DRAINAGE DITCH









FLOW

AVENUE D





LEGEND:

-  Buildings
-  Paved Roads
-  Storm Sewer
-  Sanitary Sewer
-  Fence
-  Topographic Contour Line and Elevation (feet above mean sea level)
-  Monitoring Point
-  Vent Well

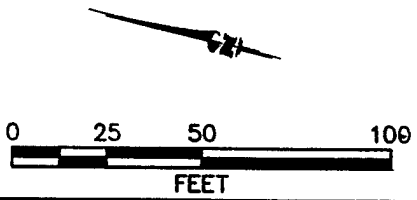


FIGURE 2.2
MOGAS
SITE LAYOUT

SVE Pilot Test Work Plan
Myrtle Beach AFB, South Carolina

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under the IRP by Environmental Resources Management (ERM) in 1988 (ERM, 1990). A soil gas survey was conducted in June 1993, by Law Engineering and Environmental Services (Law, 1994), using a subcontractor, Target Environmental, Inc. (TEI, 1993), to determine the lateral extent of fuel-related hydrocarbon contamination in the shallow subsurface soils. A subsequent site investigation was completed by Law in 1994. This investigation was completed to support development of a draft corrective action plan (CAP) for the MOGAS site, and included further delineation of the extent of BTEX contamination at the site. Investigation tasks conducted by Law included a soil gas survey, groundwater screening, soil borings, monitoring well installation, sampling and analysis of soils, groundwater, surface water, and stream sediment, and aquifer testing.

In August 1995, Parsons ES completed additional site characterization in support of the natural attenuation remedial option. As a part of this investigation, two SVE/bioventing vent wells and several vapor monitoring points were installed to support pilot- and full-scale testing of these source removal technologies (Figure 2.2).

2.2 SITE GEOLOGY AND HYDROGEOLOGY

Because SVE and bioventing are applied to unsaturated soils, this section will primarily discuss soils above the shallow aquifer. Two soil types have been identified by the Soil Conservation Service (Dudley, 1986) in the area of the MOGAS site. These soils, termed the Yemassee loamy fine sand and the Meggett loam, are part of the Brookman-Bladen soil group. The Yemassee series consists of somewhat poorly drained, moderately permeable soils that formed in loamy Coastal Plain sediments. Typically, the surface layer is black loamy fine sand about 7 inches thick. The subsurface layer, to a depth of about 14 inches, is mottled light yellowish brown loamy fine sand. The subsoil, to a depth of 56 inches, is mostly mottled gray sandy clay loam. The substratum is mottled light brownish gray loamy sand to a depth of 72 inches. The clay content ranges between 5 and 40 percent and generally increases with depth. Yemassee soil is low in organic matter (0.5 to 4 percent). The permeability (1×10^{-2} and 4×10^{-3} centimeter per second (cm/s)) and available water capacity (0.06 and 0.18 inch per inch (in/in)) of the Yemassee series is moderate. The wet bulk density ranges between 1.30 and 1.60 grams per cubic centimeter (g/cm^3). Soil pH ranges between 3.6 and 6.0. The Yemassee soil occurs beneath most of the MOGAS site.

The Meggett loam is a poorly drained soil that occurs on broad and narrow flood plains and formed in clayey Coastal Plain sediments. Typically, the surface layer is dark grayish brown loam about 4 inches thick. The subsoil, to a depth of 46 inches, is mostly mottled clay loam. The substratum is a mottled gray sand to a depth of 72 inches. Meggett soil is low in organic matter (2 to 8 percent). The permeability is slow (4×10^{-3} cm/s to 7×10^{-5} cm/s) and the available water capacity is moderate to high (0.12 and 0.20 in/in). The clay content ranges between 15 and 60 percent and generally increases with depth. The wet bulk density ranges between 1.20 and 1.75 g/cm^3 . Soil pH ranges between 4.5 and 8.4. The Meggett loam is present at the MOGAS site along the unlined drainage ditch area.

The shallow subsurface stratigraphy at the MOGAS site was determined from numerous soil borings drilled to depths of about 18 feet below ground surface (ft bgs). Sediments beneath the site consist of intercalated fine- to coarse-grained, moderately to

well-sorted, silty and clayey sands. Dark silty clays, up to 5 feet thick, are interbedded with the sand deposits. The site is covered by about 6 inches of asphalt pavement and grass. Underlying the pavement is about 7 feet of loose, dark yellowish-brown and mottled olive-gray, fine- to medium-grained sand and silty sand. Locally, the upper sand unit is underlain by about 2 to 3 feet of olive-gray sandy clay. The clay unit does not extend beneath the entire site, but appears to occur as local lenses. The clay unit is underlain by loose, gray fine- to medium-grained sand and silty sand with discontinuous silty clay lenses.

Groundwater occurs under water table conditions at depths ranging between 7 and 9 ft bgs at the MOGAS site and generally flows to the south-southwest toward the southern drainage ditch. Advective and dispersive transport of the dissolved contaminant plume is consistent with this flow direction. South of the drainage ditch groundwater appears to flow to the north, although the available water level data are limited. This is consistent with the observed groundwater flow directions at the POL site. The depth to the water table generally increases with distance from the drainage ditch. Groundwater appears to discharge, at least seasonally, to the ditch, as evidenced by the seepage of a fuel sheen from the northern bank.

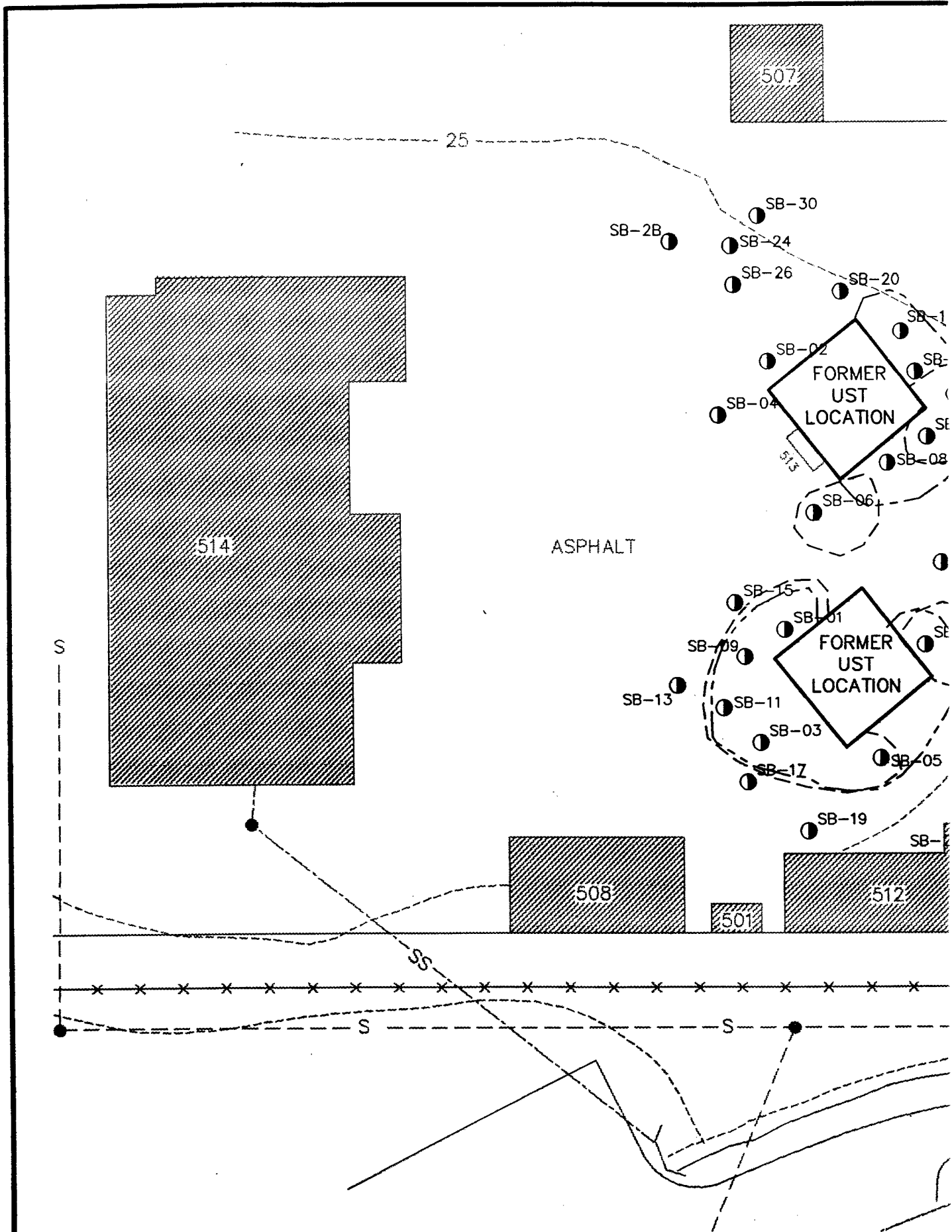
Groundwater recharge of the shallow surficial aquifer primarily occurs by infiltration of precipitation and secondarily by seepage from the surface water bodies. Annual average precipitation for the area is about 51 inches. Because the MOGAS site is mostly covered with asphalt pavement, local infiltration of precipitation is inhibited. Potential points of localized recharge at the site primarily occur as grassy and forested areas north of the site, as cracks and joints in the asphalt pavement, and as surface water drainage structures, although this has not been confirmed. Surrounding grassy and forested areas facilitate infiltration of precipitation.

The water table surface is relatively flat with a hydraulic gradient of 0.009 foot per foot (ft/ft). The hydraulic gradient appears to increase near the southern drainage ditch. Hydraulic conductivities measured at the site range between 1.4×10^{-3} and 7.5×10^{-4} cm/s. These hydraulic conductivity values are consistent with the permeabilities reported for the Yemassee loamy fine sand (Dudley, 1986). Calculated groundwater flow velocities, using an effective porosity of 0.30, at the site range from about 23 to 42 feet per year.

2.3 NATURE AND EXTENT OF CONTAMINATION

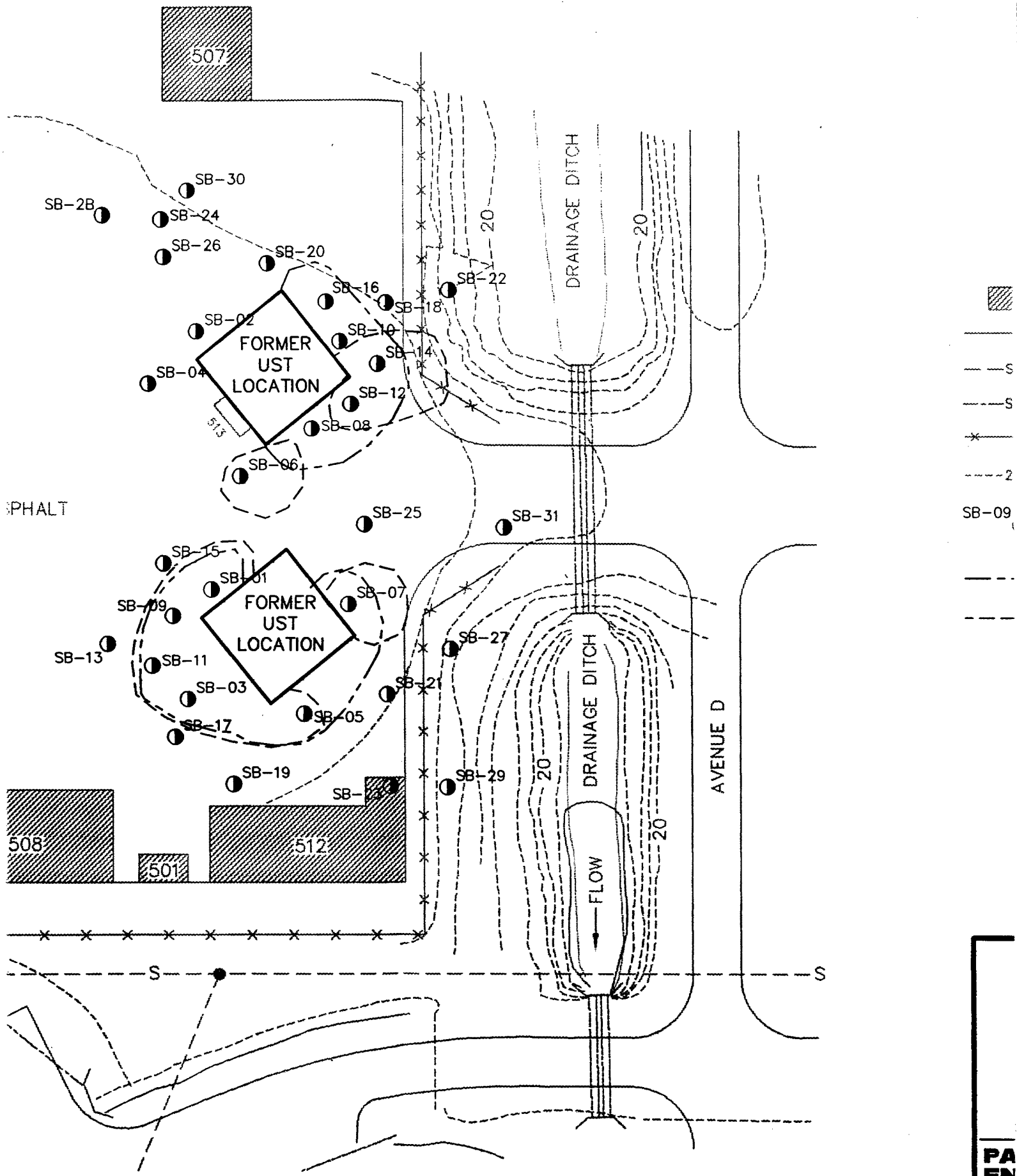
About 40 soil borings have been drilled at the MOGAS site (Figure 2.3). Most of these borings have been drilled in the vicinity of the former UST locations to depths of about 10 ft bgs. Several deeper borings were drilled to about 18 ft bgs for the installation of monitoring wells at the site. Soil samples from these borings that were analyzed for benzene, toluene, ethylbenzene, and xylenes (BTEX) and total petroleum hydrocarbons (TPH) form the basis for determining the extent of contamination at the site.

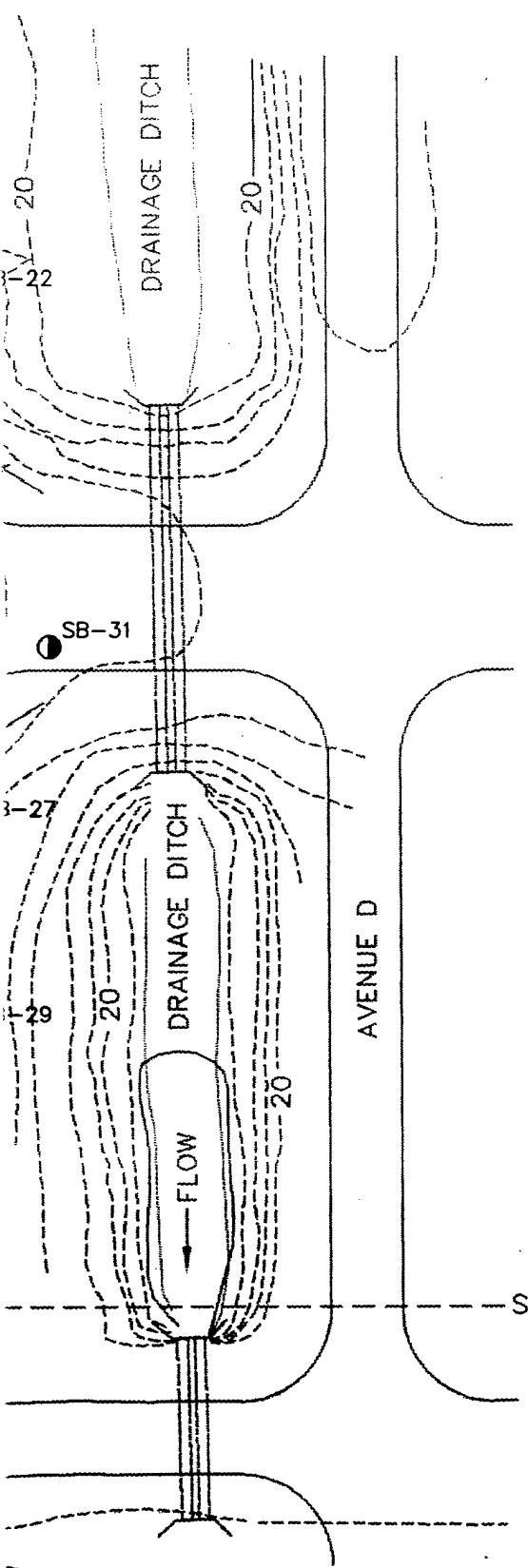
Isopleths of total BTEX, TPH, and benzene are shown on Figure 2.3. This map was prepared by Law (1994) following the completion of field activities. The distribution of soil contaminants is as expected, with BTEX and TPH generally occurring within the same spatial area. The highest concentrations of each of these



Source: Law, 1994







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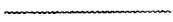
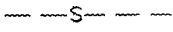
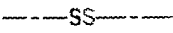
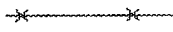
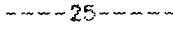
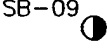
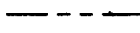
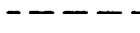
-  Buildings
-  Paved Roads
-  Storm Sewer
-  Sanitary Sewer
-  Fence
-  Contour Line and Elevation
-  SB-09 Soil Boring Location and Identification
-  BTEX Over 1 ppm
-  TPH Over 10 ppm

FIGURE 2.3

**ISOPLETH MAP OF TOTAL
BTEX AND TPH IN SOILS
MOGAS SITE**

SVE Pilot Test Work Plan
Myrtle Beach AFB, South Carolina

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analytes are generally found at depths of about 8 to 10 ft bgs in the areas surrounding the former tank locations. This depth interval corresponds to the approximate depth of the water table beneath the site and probably represents residual fuel constituents in the capillary fringe.

Contaminant distributions around each of the former tank locations are different and suggests that subsurface soil heterogeneities influenced the spreading of the gasoline. Two distinct areas of soil contaminants appear to exist. The area of highest constituent concentrations around the eastern former tank location is to the south, where the highest BTEX concentration in soil is 912 milligrams per kilogram (mg/kg). This sample, SB-12E, is from a depth of 8 to 10 ft bgs. An adjacent sample, SB-14E, exhibits a BTEX concentration of 611 mg/kg at the same depth. The highest contaminant concentrations observed adjacent to the western former tank location are generally situated to the west in the area of boreholes SB-03, SB-05, and SB-11. The highest BTEX concentration, 815 mg/kg, was measured in sample SB-03 from a depth of 8 to 10 ft bgs. Similar patterns are exhibited by TPH and benzene concentrations. Soil data collected to date appear to adequately define the horizontal extent of contamination at the site. The vertical extent of soil contamination at the site is less well known, as almost all of the soil borings terminated at a depth of about 10 ft bgs where the highest concentration of soil contaminants are observed in the capillary fringe of the water table. Soil contamination does not appear to extend through the area between the former tanks.

In August 1995, Parsons ES collected soil samples during installation of vent wells VW-1 and VW-2 as show on Figure 2.2. Samples were collected from VW-1 at depths from 7 to 9 and 10 to 12 ft bgs. At VW-2, samples were collected at depths from 7 to 9 and 11 to 13 ft bgs. Table 2.1 presents the analytical results for these soil samples. All four samples exhibited high BTEX concentrations, ranging from 369 mg/kg to 1,917 mg/kg. The highest BTEX concentration was in a sample from VW-1 from a depth of 10 to 12 ft bgs.

Parsons ES also collected soil gas data from the two vent wells and two of the soil vapor monitoring points. The samples were analyzed by Air Toxics Ltd. in Folsom, California for total volatile hydrocarbons (TVH) and BTEX, and the results are presented in Table 2.1. Concentrations of TVH ranged from 28,000 to 180,000 parts per million, volume per volume (ppmv). Concentrations of total BTEX ranged from 534 to 3,910 ppmv.

TABLE 2.1
1995 SOIL AND SOIL GAS LABORATORY ANALYTICAL RESULTS
SVE and Bioventing Pilot Test Work Plan
Myrtle Beach AFB, South Carolina

Analyte	Sampling Location			
	VW-1	VW-2	SV-2	SV-7
<u>Soil Gas Hydrocarbons</u>				
TVH ^{a/} (ppmv) ^{b/}	180,000	100,000	28,000	64,000
Benzene (ppmv)	1,300	1,300	310	800
Toluene (ppmv)	910	2,000	200	1,000
Ethylbenzene (ppmv)	62	200	9	150
Xylenes (ppmv)	120	410	15	280
	<u>VW-1</u>	<u>VW-1</u>	<u>VW-2</u>	<u>VW-2</u>
	(7-9 feet bgs ^{c/})	(10-12 feet bgs)	(7-9 feet bgs)	(11-13 feet bgs)
<u>Soil Hydrocarbons</u>				
Benzene (ug/kg) ^{d/}	190 J ^{e/}	87,000	890	29,000 J
Toluene (ug/kg)	1,700	650,000	6,200	300,000
Ethylbenzene (ug/kg)	1,100	180,000	1,000	110,000
Xylenes (ug/kg)	700	1,000,000	5,000	220,000
Xylenes (ug/kg) (duplicate)	7,000	6 U ^{f/}	42,000	500,000
Chlorobenzene (ug/kg)	220 J	20,000 J	610 U	27,000 J
Napthalene (ug/kg)	1,300	24,000	350 J	12,000
Styrene (ug/kg)	6 U	6 U	760 U	1,400 U
1,2,3-Trimethylebenzene (ug/kg)	2,600	170,000	620	82,000
1,2,4-Trimethylebenzene (ug/kg)	9,100	650,000	2,400	270,000
1,2,5-Trimethylebenzene (ug/kg)	3,400	220,000	720	110,000
1,2,3,4- Tetramethylbenzene (ug/kg)	3,000	140,000	340	62,000
<u>Soil Inorganics</u>				
Alkalinity (mg/kg as CaCO ₃) ^{g/}	30.3 U	28.8 U	30.3 U	28.6 U
Iron (mg/kg)	25,400	943	6,520	389
TKN ^{h/} (mg/kg)	6.1 U	5.3 U	5.3 U	5 U
Phosphates (mg/kg)	3 U	2.9 U	3 U	2.8 U
pH (units)	5.04	6.98	5.35	6.6
<u>Soil Physical Parameters</u>				
Moisture (percent)	17.7	13.2	17.6	12.7
Total Organic Carbon (percent)	NA ^{i/}	NA	0.06 U	0.06 U

Notes:

- a/ TVH = total volatile hydrocarbons.
- b/ ppmv = parts per million, volume per volume.
- c/ bgs = below ground surface.
- d/ ug/kg = micrograms per kilogram.
- e/ J = Estimated value.
- f/ U = Not detected above shown detection limit.
- g/ mg/kg = milligrams per kilogram.
- h/ TKN = total Kjeldahl nitrogen.
- i/ NA - not analyzed.

SECTION 3

BIOVENTING/SOIL VAPOR EXTRACTION EVALUATION

In recent years bioventing has gained recognition as a state-of-the-art remediation technology for the enhanced *in situ* biodegradation of fuel hydrocarbons. Bioventing is best suited for less volatile hydrocarbons commonly found in jet fuels, diesel fuels, and heating oils. Bioventing is most efficiently accomplished by continuously injecting low volumes of air into contaminated soil to supply the oxygen required by soil microbes for aerobic biodegradation of fuel residuals while minimizing volatile organic compound (VOC) emissions. However, in the case of soils contaminated with more volatile hydrocarbons (e.g., gasoline), air injection can result in the uncontrolled migration of significant concentrations of VOCs away from the source area. VOC migration often is unacceptable due to the potential for spreading contamination to adjacent properties or for vapor migration into surrounding buildings or utility corridors. Under these circumstances, SVE may be required to remove high levels of soil gas VOCs. Using SVE, the primary mechanism of VOC removal is volatilization. In many regions of the United States, SVE must be accompanied by treatment of the extracted vapors prior to this discharge into the atmosphere. When low-flow-rate air injection or vapor extraction is used, *in situ* biodegradation becomes the primary mechanism of removal. Combining SVE with bioventing provides a low-cost remediation approach for fuel-contaminated vadose zone soils.

At the MOGAS site, SVE will be used initially to remove accumulated hydrocarbon vapors and the more volatile fraction of fuel contaminants from subsurface soils. Then bioventing will be used to further degrade less-volatile hydrocarbon constituents in the subsurface soils. Soil gas TVH concentrations up to 180,000 ppmv were detected during a soil gas survey conducted in 1995 (Table 2.1), and SVE appears to be the best alternative to abate this contamination without increasing the potential for vapor migration. The SVE process will promote volatilization of BTEX and other VOCs from the residual fuel contamination in the soils, as well as enhance aerobic biodegradation of these compounds by drawing oxygen-rich soil gas from uncontaminated areas through the contaminated soil intervals. Once the concentrations of VOCs have been sufficiently decreased, the system will be converted to a low-flow air injection bioventing system for long-term remediation of the subsurface soils. The locations of the two vent wells installed by Parsons ES for use in the pilot tests are shown in Figure 2.2.

SECTION 4

PROPOSED VAPOR TREATMENT TECHNOLOGIES

The two extracted-vapor treatment technologies proposed for this demonstration consist of combustion in an ICE with advanced emission controls and the D-TOX™ system. Soil gas TVH concentrations up to 180,000 ppmv were detected during a soil gas survey conducted by Parsons ES in 1995. The SVE process will promote volatilization of BTEX and other VOCs from the residual fuel contamination in the unsaturated soils, as well as enhance aerobic biodegradation of these compounds by creating an influx of oxygen-rich soil gas. The ICE and D-TOX™ technologies are discussed in the following sections.

4.1 ICE System Description

Vapor extraction and combustion is an innovative technology that uses a gasoline-burning ICE with advanced emission controls to extract and burn hydrocarbon vapors from the vadose zone of contaminated soil. Vapors are extracted via vent well(s) by the intake manifold vacuum of the engine. The vapors are then burned as fuel to run the engine. The exhaust gases pass through standard catalytic converters for complete oxidation before exiting to the atmosphere.

VR Systems, Inc. of Anaheim, California has developed a Model V2C ICE unit that uses a Ford Motor Company® 140-cubic-inch-displacement (cid) engine block, heads, and accessories along with an onboard computer system that monitors engine performance. The intake manifold of the engine provides the vacuum source, up to 18 inches of mercury (Hg) or approximately 245 inches of water. Extraction flow rates range from 0 to 65 standard cubic feet per minute (scfm), depending on soil conditions and the hydrocarbon concentrations of the extracted soil gas. A system schematic of the V2C (proposed for this pilot test) unit is provided in Figure 4.1. The specifications of the V2C ICE are provided in Table 4.1.

The VR System V2C unit is designed to remove nonchlorinated hydrocarbon vapors from contaminated soil using a vapor extraction vent well such as those installed at the MOGAS site (Figure 2.2). The extracted vapors flow through a computer-monitored fuel control system, and into the intake manifold of the engine. Destruction of the majority of hydrocarbon vapors occurs through combustion in the engine. Exhaust gases from the engine pass through a small catalytic converter that completes the treatment process.

An on-board computer system provides the necessary monitoring for engine control. The data acquisition system includes a 16-channel data reporting system that monitors the engine's oil pressure/temperature, coolant temperature, exhaust temperature, exhaust percent oxygen, engine speed, and operating parameters (flow rates, inches of vacuum pressure, supplemental fuel consumption, air/fuel ratio, and engine hours). The V2C unit also is equipped with an

ITEM NO. EC3D029

DATE	REV	DATE
2/92	A	12/93
	B	2/94

SHEET OF

DESC. V2C SYSTEM SCHEMATIC

MATL FINISH

1 3/4 DIA STACK

FIRE CONTROL SYSTEM
ADX MODEL 1031
SINGLE NOZZLE &
350° F THERMOSTAT

FORD 2.3L ENGINE

VAREC FLAME ARRESTOR

WELL GAS FILTER

MOISTURE KNOCK-OUT

STATIC LINE TO
GROUNDING ROD

DAYCO VAC. HOSE
EPA 7191-2004

GROUNDING ROD
PROVIDED BY OTHERS

SILENCER

3/2 WAY CATALYST

PROPANE

7" TO 8" W. C.
REGULATOR

OPTIONAL NATURAL GAS SUPPLY
80,000 BTU/HR MAX

WELL CASING

SOIL CONTAMINATION

V. R. SYSTEMS
MODEL V2C UNIT
NOT TO SCALE

DRAWN BY: DBG DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
TOLERANCES UNLESS OTHERWISE SPECIFIED ARE AS FOLLOWS:
SCALE: NONE ANGLES: ±1' FRACTIONS ±1/16 .XX ±.01 .XXX ±.001

Source: VRI Systems Anaheim, CA.

FIGURE 4.1

VR SYSTEM DIAGRAM
MOGAS SITE

SVE and Bioventing
Pilot Test Work Plan
Myrtle Beach AFB, South Carolina



**PARSONS
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Denver, Colorado

TABLE 4.1
MANUFACTURER PERFORMANCE SPECIFICATIONS
FOR VR SYSTEMS MODEL V2C
SVE and Bioventing Pilot Test Work Plan
Myrtle Beach AFB, South Carolina

Feature	V2C
Max. Hydrocarbon Destruction Rate	15 lbs/hr
Destruction Efficiency for TVH/BTEX ^{a/}	> 99%
Engine Size in Cubic Inch Displacement	140
Max. Flow Rate in Cubic Feet/Min	65
Max. Vacuum in Inches of Mercury/Approx. Inches of Water	18/245
Required Soil Gas Hydrocarbon concentration (ppmv as gasoline) ^{b/}	40,000

Source: VR Systems, Inc., 1992.

^{a/} TVH = total volatile hydrocarbons; BTEX = benzene, toluene, ethylbenzene, and xylenes.

^{b/} The influent vapor concentration in ppmv = parts per million, volume per volume required to sustain >99% destruction efficiency without the addition of supplemental fuel (propane or natural gas).

automatic engine shutdown system. Monitored by the onboard computer, the engine shuts down automatically if one or more of the following conditions exists: engine overspeed, high coolant temperature, high oil temperature, low oil pressure, fire, or high water level in the well gas filter assembly. The computer is programmed to store and report the reason for the automatic engine shutdown.

Supplemental fuel (propane or natural gas) is used to provide smooth operation of the engine as extracted soil gas VOC concentrations fluctuate. Supplemental fuel use can be eliminated if the extracted soil gas concentrations provide sufficient fuel to sustain combustion and smooth operation of the engine. Soil vapor concentrations in excess of 40,000 ppmv are generally sufficient to fuel the engine without supplemental fuel. The computer regulates the fuel requirements of the engine through a master control unit (MCU). The MCU makes adjustments in the supplemental fuel flow to compensate for the changing influent hydrocarbon concentrations and to maintain the stoichiometric air-to-fuel ratio. By maintaining the proper air/fuel ratio, the total hydrocarbon vapor destruction efficiency typically exceeds 99 percent.

The V2C unit also is equipped with a flame arrestor to protect the vapor extraction system from "flash back" from the engine. A fire control system equipped with a dry chemical extinguisher is provided and will discharge automatically in event of a fire.

External electrical power is not required. The electronic ignition system is battery-powered and adjusts automatically in response to commands from the computer. The V2C unit also is equipped with a modem for remote monitoring. The remote monitoring capability also allows for adjustments to vacuum or engine speed to optimize engine performance and minimize supplemental fuel consumption to be made while the unit is operating.

4.2 D-TOX™ System Description

The Zimpro Corporation is currently testing the D-TOX™ unit, which was developed for treating both chlorinated hydrocarbon vapors and fuel hydrocarbon vapors using an ozone-enhanced, low-temperature catalytic UV oxidation process. A proprietary catalyst bed is used to lower the temperature of the extracted vapors to that required for complete combustion of fuel hydrocarbon vapors. The reported advantages of this unit include low operating costs and high treatment efficiencies under optimum vapor loading conditions.

The D-TOX™ system requires 480 volts of electrical power and potable cooling water. The cooling water will not receive any process contamination and will be discharged to a nearby drainage channel. The system will be monitored using a portable gas chromatograph. The system will be operated at vapor flow rates from 15 to 50 scfm and contaminant concentration levels from 200 to 5,000 ppmv. The vapor flow rates can be adjusted by manual in-line controlling valves on the inlet lines from the vent wells and ambient air. The vapor contaminant concentration can be adjusted by controlling the ambient air dilution factor. The D-TOX™ system is expected to operate most efficiently at a vapor extraction flow rate of less than 50 scfm and at VOC concentrations of 200 to 5,000 ppmv. A 30 to 40 day test is anticipated. Parsons ES will provide an independent, onsite evaluation of the D-TOX™ system. A more detailed description of the D-TOX™ pilot test has been provided to AFCEE in a separate test plan prepared by ULTROX (1995).

SECTION 5

PROPOSED PILOT TEST ACTIVITIES

This section describes the work that will be performed during SVE pilot testing by Parsons ES at the MOGAS Site. That work will include installation, startup tests, and operation and monitoring of the ICE system; installation, startup tests, and operation and monitoring of the D-TOX™ system; and conversion of the SVE system to a bioventing bioremediation system. Brief descriptions of the layout of the pilot test components and test procedures are provided in the following sections.

5.1 PILOT TEST DESIGN

5.1.1 Layout of Pilot Test Components

Two vent wells (VWs) and eight monitoring points were installed at the MOGAS site in August 1995. The vent wells were installed downgradient from the former UST locations, and soil vapor monitoring points (MPs) were installed in the immediate vicinity. The locations of the vent wells and MPs are shown in Figure 2.2.

5.1.1.1 Vent Wells

The two VWs for the MOGAS site were constructed in two sections, with approximately 7.5 feet screened in the vadose zone and the top section cased from the screened interval to the surface. For both VWs, the 7.5-foot screened interval was constructed of 0.04-inch slotted screen. Flush-threaded, 4-inch-diameter, Schedule 40 polyvinyl chloride (PVC) casing and screen was used. No organic solvents or glues were applied to the VWs or used downhole. The filter pack used was clean, well-rounded 16-40 grain size silica sand. The sand was added slowly so that the total thickness of the sand pack could be closely monitored. Sand was placed in the annular space to 1 foot above the screened interval. A 1-foot-thick bentonite seal was placed directly over the filter pack to produce an air-tight seal above the screened interval. The bentonite seal, consisting of granular bentonite, was placed in 6-inch layers, with each layer hydrated in place with potable water prior to the addition of subsequent layers. The remaining annular space was then filled to 1 ft bgs with a bentonite/cement grout. A complete seal is critical to prevent extracted/injected air from short-circuiting from/to the surface during SVE/bioventing. The VWs were completed in 18-inch-square, flush-mounted water-tight well boxes. Figure 5.1 illustrates the typical as-built VW construction details.

5.1.1.2 Monitoring Points

A typical vapor MP installation for this sites is shown in Figure 5.2. Eight MPs were installed at the MOGAS site at depths corresponding to the capillary fringe. Soil gas VOC, oxygen, and carbon dioxide concentrations may be monitored from these points. Four MPs

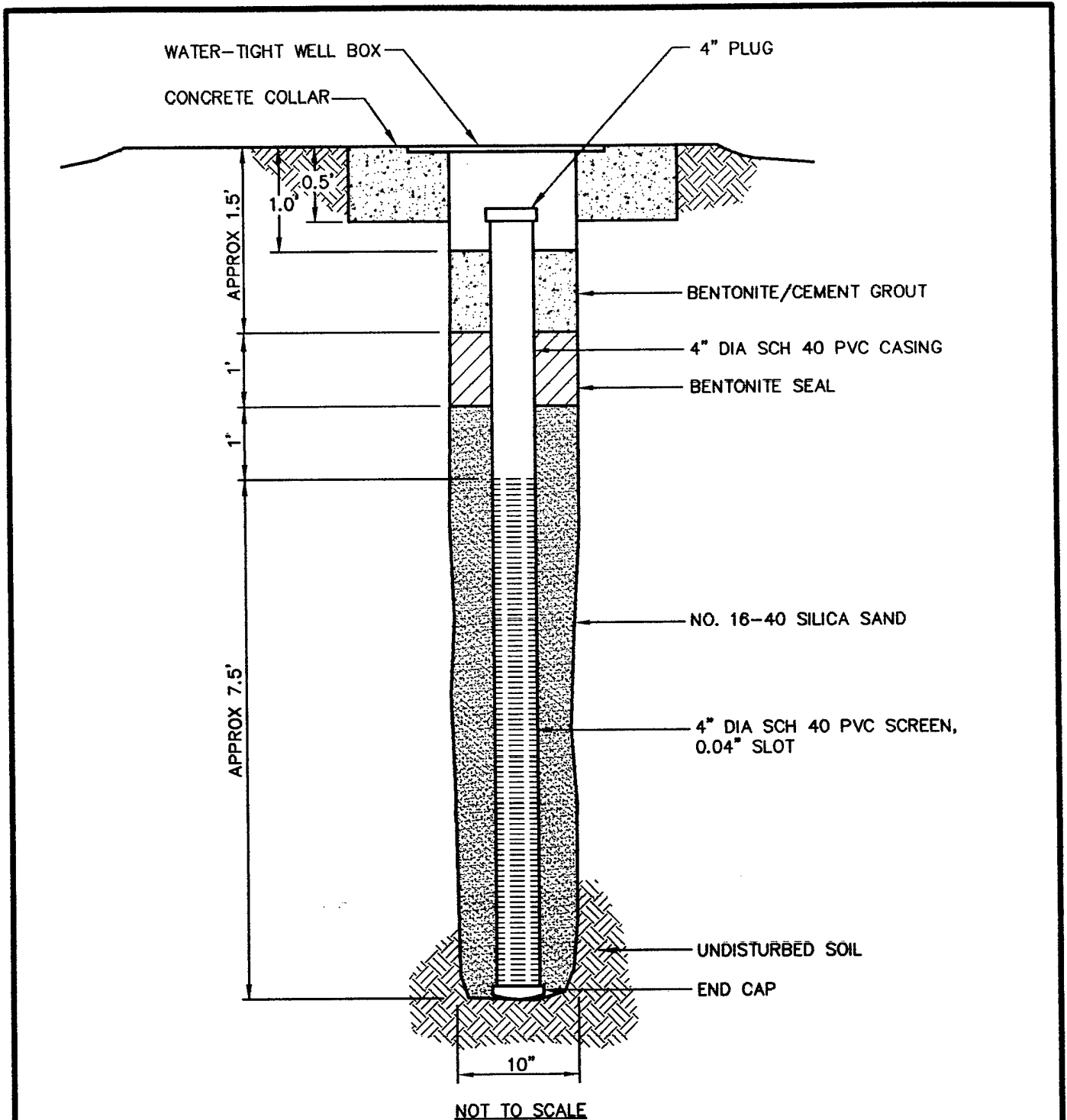


FIGURE 5.1

**TYPICAL VENT WELL
CONSTRUCTION DETAIL**

SVE & Bioventing Pilot Test Work Plan
Myrtle Beach AFB, South Carolina

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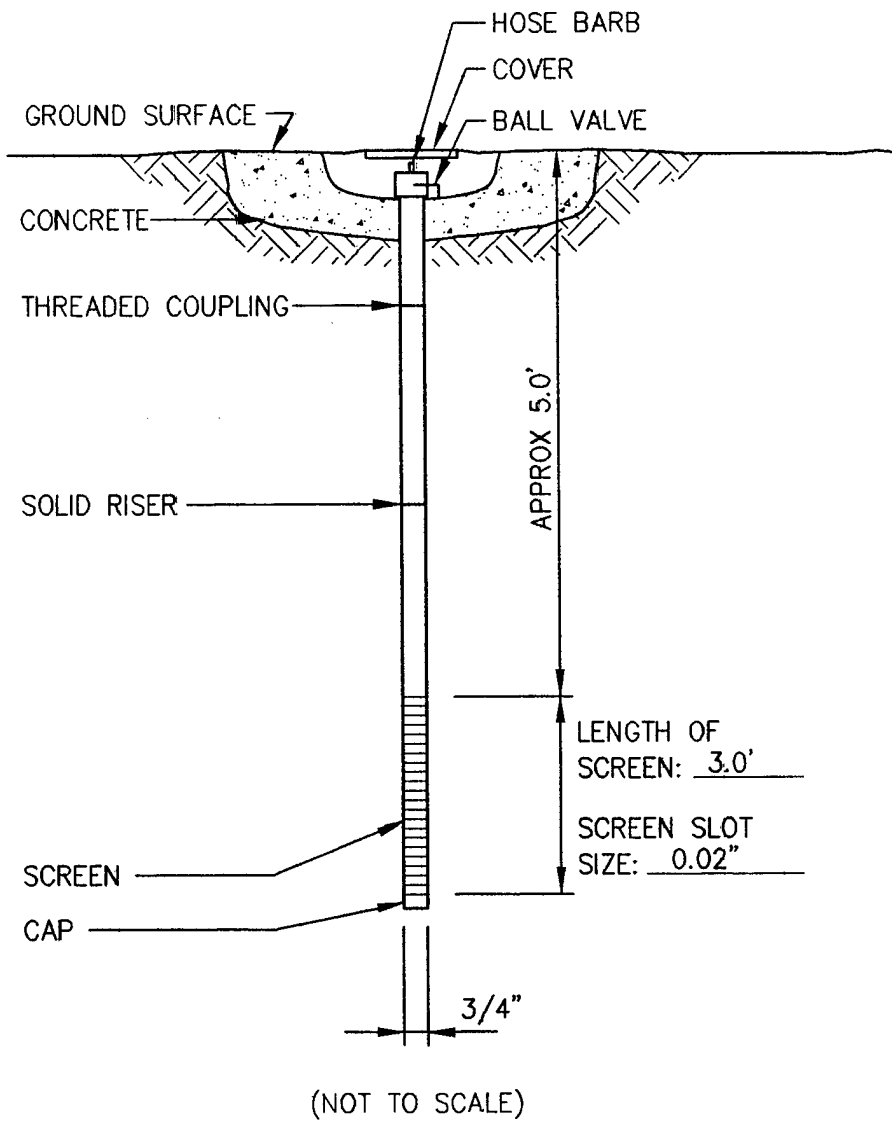


FIGURE 5.2
TYPICAL
VAPOR MONITORING POINT
CONSTRUCTION DETAIL

SVE & Bioventing Pilot Test Work Plan
 Myrtle Beach AFB, South Carolina

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Denver, Colorado

(SV-1 through SV-4) were constructed of 3-foot-long sections of 0.75-inch-diameter, 0.02-inch-slotted PVC well screen and 0.75-inch Schedule 40 PVC blank casing extended to the surface. The top 1 foot of casing was sealed with concrete. Four MPs (SV-5 through SV-8) were constructed of 5-foot-long sections of 0.75-inch-diameter, 0.02-inch slotted PVC well screen, and 0.75-inch Schedule 40 PVC blank casing extended to the surface. The screened section was placed in 6-9 silica sand. The annular space above the 3-foot-long screened section was sealed with bentonite to isolate the monitoring interval. The bentonite seal consists of granular bentonite hydrated in place. The bentonite was placed in approximately 6-inch layers and hydrated with potable water prior to placement of subsequent layers to assure complete saturation and hydration of the bentonite. The top 1 foot of the casing was sealed with concrete.

5.2 VR SYSTEM TESTING

5.2.1 Startup Test

A 2-day startup test will be performed to ensure that the ICE vapor treatment system is operating properly. Initial soil gas samples will be collected before system startup from selected MPs and analyzed for oxygen, carbon dioxide, and TVH using direct-reading instruments. These results will be compared to subsequent sampling results to determine the reductions in BTEX and TVH during system operation. These same parameters will be measured in extracted soil gas samples collected before and after the VR system to determine TVH destruction efficiency. Additionally, initial and periodic air samples will be collected in 1-liter SUMMA[®] canisters and submitted to the laboratory for BTEX and TVH analyses using US Environmental Protection Agency (EPA) Method TO-3. During this period, air flow rates and other system adjustments will be made to optimize removal rates and treatment efficiency.

Inlet and outlet TVH concentrations will be monitored using direct-reading field instruments, and air samples for laboratory TVH and BTEX analyses will be collected periodically in 1-liter SUMMA[®] canisters. TVH and BTEX results will be used to determine initial fuel removal rates, air treatment efficiency, and compliance with air quality regulations. The proposed operation and monitoring schedules for the VR system is presented in Table 5.1.

The radius of vacuum influence will be determined for each VW. To determine the radius of influence, pressure response and changes in soil gas oxygen, carbon dioxide, and TVH concentrations will be monitored at the MPs. The schedule provided in Table 5.1 is for planning purposes, and may be modified based on actual field conditions encountered during the startup tests.

5.2.2 Extended Operation

Immediately following the startup and optimization, the VR system will be operated for approximately 3 to 4 weeks. Extraction flow rates from the VWs will require periodic adjustments throughout this period of operation to maintain optimum TVH concentrations and other operating conditions.

5.2.3 System Monitoring

The system will be monitored both manually (onsite) and remotely, following the schedule presented in Table 5.1, and using the VR system's automated measuring and recording

TABLE 5.1
PROPOSED SAMPLING AND MONITORING SCHEDULE
FOR VR SYSTEM
SVE and Bioventing Pilot Test Work Plan
Myrtle Beach AFB, South Carolina

Elapsed time, Frequency	Laboratory Samples		Field Measurements				
	Soil Gas ^{a/} Before Treatment BTEX, TVH	Exhaust BTEX, TVH	Soil Gas ^{b/} O ₂ /CO ₂ /TVH	VR System ^{c/}	Exhaust TVH	System Flow Rates and Pressures	OB Vacuum Response
Startup Test, each test (3 tests, one at each VW)							
0 Hours			X				X
1 Hour			X	X	X	X	X
Hourly; first 8 hours			X	X	X	X	X
Extended Testing							
0 Hours			X				X
1 Hour			X	X	X	X	X
Hourly; first 8 hours			X	X	X	X	X
First day	X ^{d/}	X					
Daily; first week	X	X	X	X	X	X	X
1/Week	X	X	X	X	X	X	X
Monthly			X	X	X	X	X

^{a/} If extracted soil gas is diluted with fresh air prior to treatment, two laboratory samples will be collected, one before and one after dilution.

^{b/} Soil gas oxygen (O₂), carbon dioxide (CO₂), and total volatile hydrocarbons (TVH) will be measured in both the extracted soil gas and in samples collected from monitoring points.

^{c/} Measurements will include: engine coolant, oil and exhaust temperature, oil pressure, intake vacuum (inches of water), flow rate (scfm), carburetor and well valve positioning, supplemental fuel usage, duty cycle (efficiency), and engine hours.

^{d/} Laboratory samples will be analyzed within 24 hours to verify 90 + percent destruction efficiency.

devices. The following parameters will be monitored to evaluate the VR system's ability to extract and treat soil gas:

- Flow rates and pressure (vacuum) at the well head and through the VR system;
- Soil gas TVH concentrations before and after treatment;
- Vacuum response at the MPs;
- Soil gas oxygen, carbon dioxide, and TVH concentrations measured in the extracted soil gas and at the monitoring points; and
- Cost to operate system (supplemental fuel and maintenance costs).

These monitoring results will be used to determine fuel removal rates, changes in TVH concentrations with time, estimated treatment time, TVH destruction efficiency, and to estimate the cost of extended VR system operation.

Soil gas oxygen, carbon dioxide, and TVH concentrations will be measured at the well heads, upstream and downstream of the VR system, and at the MPs using a direct-reading Gastech® oxygen/carbon dioxide meter and a Gastech® TVH analyzer. The VR system unit will automatically monitor and record engine coolant, oil, and exhaust temperature, oil pressure, intake vacuum, flow rate in scfm, carburetor and well valve position (percent open), supplemental fuel usage (cfm), duty cycle, and engine hours. Vacuum also will be monitored at the VWs and MPs using magnehelic gauges.

Samples of the soil gas inlet and exhaust will also be collected periodically for laboratory analysis according to the schedule presented in Table 5.1. Samples will be collected in 1-liter SUMMA® canisters and will be submitted to the Air Toxics, Ltd., laboratory in Folsom, California for BTEX and TVH analyses using EPA Method TO-3.

5.3 D-TOX™ SYSTEM TESTING

The objectives of this short-term test will be to determine the unit's destruction efficiency under varying influent VOC loading rates, and to determine the optimum vapor VOC loading condition to obtain the highest BTEX destruction efficiency at the lowest operating cost. A series of 10, 4-hour tests are proposed using SVE rates varying from 15 to 50 scfm and vapor VOC concentrations of 200 to 5,000 ppmv. Once the optimum flow and vapor concentration is determined, the unit's reliability will be evaluated over a 30-day period. The 30-day test will be used to evaluate the long-term performance of the catalyst and the cost of standard operations.

The D-TOX™ test will be monitored by Zimpro personnel and an independent evaluator from Parsons ES. Monitoring equipment will include an onsite gas chromatograph (GC) (SRI Model 8610-PID/FID) capable of individual BTEX compound analysis, and a handheld photoionization detector (PID) Hnu® Model PI-101 meter and GasTech® Tracetehtor hydrocarbon analyzer capable of providing real-time total hydrocarbon analysis for determining when operations have stabilized during each test. Once stable operations have been achieved, Parsons ES also will collect both influent and effluent samples for laboratory analysis using EPA Method TO-3 to provide quantification of individual BTEX compounds

and TVH. During the 30-day test, laboratory samples will be collected every week, and the onsite GC and handheld instruments will be used to provide a real-time estimate of treatment efficiency. Laboratory analysis will be completed by Air Toxics Inc. of Folsom, California, an EPA-certified laboratory which has been used for other AFCEE evaluations.

5.4 BIOVENTING TEST

Bioventing tests will be conducted following the ICE tests and prior to the long-term D-TOX test. A short-term bioventing respiration test will be used to collect the data necessary to optimize the system and calculate the time necessary to remediate the site. The tests are designed to assess the potential for supplying oxygen throughout the contaminated soil interval, and to determine the rate at which indigenous microorganisms will degrade fuel when supplied with oxygen-rich soil gas. The tests will consist of air permeability and *in situ* respiration tests. The document entitled *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing* (Hinchee *et al.*, 1992) will serve as the primary reference for procedures to be used during the tests.

5.4.1 Air Permeability Test

The objective of the air permeability test is to determine the extent of the subsurface that can be oxygenated using one VW. Prior to initiating the test, baseline concentrations of oxygen, carbon dioxide, and TVH will be measured in soil gas from the VW and each MP screened interval. A Gastech® Model 3252 O₂/CO₂ meter will be used to measure oxygen and carbon dioxide concentrations. The meter will be calibrated with a 0-percent oxygen/5-percent carbon dioxide standard and the atmosphere per the manufacturer's instructions. A Gastech® Trace-Tehtor hydrocarbon analyzer will be used to measure TVH concentrations. The meter will be calibrated per manufacturer's instructions using a 2-point calibration.

Air will be injected into the VW using the blower unit, and pressure response will be measured at each MP with differential pressure gauges to determine the region influenced by the unit. Oxygen will also be monitored in the MPs to ascertain whether oxygen levels in the soil increase as the result of air injection. One air permeability/oxygen influence test lasting 4 to 24 hours will be performed.

5.4.2 *In Situ* Respiration Test

The objective of the *in situ* respiration test is to determine the rate at which soil bacteria degrade petroleum hydrocarbons. At both sites, respiration tests will be performed at vapor MPs where bacterial biodegradation of hydrocarbons is indicated by low initial oxygen levels and elevated carbon dioxide concentrations in the soil gas. The soil will be oxygenated to levels greater than 15 percent using the SVE system. At the end of the ICE pilot test, the ICE system will be turned off, and oxygen carbon dioxide, and TVH concentrations will be monitored for the following 48 to 72 hours or until oxygen concentrations decline by at least 5 percent. The decline in oxygen and the increase in carbon dioxide concentrations over time will be used to estimate rates of bacterial degradation of fuel residuals. Additional details on the *in situ* respiration test procedures are provided in Section 5.7 of the protocol document (Hinchee *et al.*, 1992).

SECTION 6

BASE SUPPORT REQUIREMENTS

The following Base support is needed before mobilization of equipment and the Parsons ES pilot test team:

- Assistance in obtaining an air permit (completed),
- Assistance in obtaining approval from the Base to install and operate the VR system and D-TOX system (completed),
- Provision of any paperwork required to obtain gate passes for approximately two Parsons ES employees, several VR and D-TOX system representatives, and one propane distributor representative.

During the approximate 4-month period of VR and D-TOX system operation, Base personnel will be requested to perform the following activities:

- If Base personnel are available, check the VR system once each week to ensure that the system is operating and to record engine operating parameters. Parsons ES will provide a brief training session on these procedures. D-TOX operation will be the sole responsibility of Zimpro personnel.
- Arrange site access for a Parsons ES technician to conduct periodic system monitoring and maintenance activities.
- If problems develop with the VR system, notify Mr. Steve Archabal or Mr. Doug Downey of Parsons ES at (303) 831-8100.

SECTION 7

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