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SITE-SPECIFIC TECHNICAL REPORT FOR BIOSLURPER TESTING AT MARCH AFB, CALIFORNIA

DRAFT

PREPARED FOR:

AIR FORCE CENTER FOR ENVIRONMENTAL EXCELLENCE
TECHNOLOGY TRANSFER DIVISION
(AFCEE/ERT)
8001 ARNOLD DRIVE
BROOKS AFB, TEXAS 78235-5357

AND

MARCH AFB, CALIFORNIA

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SITE-SPECIFIC TECHNICAL REPORT (A003)

for

BIOSLURPER TESTING AT MARCH AFB, CALIFORNIA

by

J. Kramer, J.A. Kittel, A. Leeson, and G. Headington

for

Mr. Patrick Haas
U. S. Air Force Center for Environmental Excellence
Technology Transfer Division
(AFCEE/ERT)
Brooks AFB, Texas 78235-5357

April 16, 1996

Battelle
505 King Avenue
Columbus, Ohio 43201-2693

Contract No. F41624-94-C-8012

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ABBREVIATIONS AND ACRONYMS

AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
gpm	gallons per minute
ICE	internal combustion engine
LNAPL	light, nonaqueous-phase liquid
MP	monitoring point
MW	monitoring well
ppmv	parts per million by volume
PVC	polyvinyl chloride
scfm	standard cubic feet per minute
TPH	total petroleum hydrocarbons
UST	underground storage tank
VOC	volatile organic compound

EXECUTIVE SUMMARY

This report summarizes the field activities conducted at March AFB for a short-term field pilot test to compare vacuum-enhanced free-product recovery (bioslurping) to traditional free-product recovery techniques to remove light, nonaqueous-phase liquid (LNAPL) from subsurface soils and aquifers. The field testing at March AFB is part of the Bioslurper Initiative, which is funded and managed by the U.S. Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division. The AFCEE Bioslurper Initiative is a multisite program designed to evaluate the efficacy of the bioslurping technology for (1) recovery of LNAPL from groundwater and the capillary fringe, and (2) enhancing natural in situ degradation of petroleum contaminants in the vadose zone via bioventing.

The main objective of the Bioslurper Initiative is to develop procedures for evaluating the potential for recovering free-phase LNAPL present at petroleum-contaminated sites. The overall study is designed to evaluate bioslurping and identify site parameters that are reliable predictors of bioslurping performance. To measure LNAPL recovery in a wide variety of in situ conditions, tests are being performed at many sites. The test at March AFB is one of more than 40 similar field tests to be conducted at various locations throughout the United States and its possessions.

The intent of field testing is to collect data to support determination of the predictability of LNAPL recovery and to evaluate the applicability, cost, and performance of the bioslurping technology for removal of free product and remediation of the contaminated area. The on-site testing is structured to allow direct comparison of the LNAPL recovery achieved by bioslurping with the performance of more conventional LNAPL recovery technologies. The test method included an initial site characterization followed by LNAPL recovery testing. The three LNAPL recovery technologies tested at March AFB were skimmer pumping, bioslurping, and drawdown pumping.

Bioslurper pilot test activities were conducted at two monitoring wells located at the Panero JP-4 Spill Site. Site characterization activities were conducted to evaluate site variables that could affect LNAPL recovery efficiency and to determine the bioventing potential of the site. Testing included baildown testing to evaluate the mobility of LNAPL, soil sampling to determine physical/chemical site characteristics, soil gas permeability testing to determine the radius of influence, and in situ respiration testing to evaluate site microbial activity.

Following the site characterization activities, the pump tests were conducted. At monitoring well MW-04, pilot tests for skimmer pumping and bioslurping were conducted. The LNAPL recovery testing was conducted in the following sequence at monitoring well MW-04: 48 hours in the skimmer configuration, approximately 21 hours in the bioslurper configuration (with 24 hours of downtime in the middle of the test), 10 hours in the drawdown configuration, and an additional 18 hours in the bioslurper configuration.

At monitoring well MW-03, pilot tests for bioslurping were conducted under low and high vacuum. The low-vacuum pump test was conducted for approximately 20 hours and the high-vacuum pump test was conducted for approximately 48 hours.

Measurements of extracted soil gas composition, LNAPL thickness, and groundwater level were taken throughout the testing. The volume of LNAPL recovered and groundwater extracted were quantified over time.

No LNAPL was recovered during any of the pump tests at monitoring well MW-04. Groundwater was extracted at relatively high rates, ranging from 351 gallons/day during the initial skimmer pump tests up to 6,400 gallons/day during the second bioslurper pump test. These results indicate that free-product recovery was not possible at this monitoring well possibly due to the relative immobility of the free product.

The bioslurper pump test was conducted under low and high vacuum to evaluate the effects on LNAPL recovery rates. Under low-vacuum conditions, LNAPL recovery averaged 2.2 gallons/day, whereas groundwater recovery averaged 1,700 gallons/day. Under high-vacuum conditions, LNAPL recovery increased significantly to an average of 10 gallons/day. Groundwater recovery rates were almost double those under low-vacuum, averaging 3,300 gallons/day. These results demonstrate that operation of the bioslurper under high-vacuum conditions may improve free-product recovery; however, significant quantities of groundwater also will be generated.

Implementation of vacuum-enhanced recovery at the March AFB test site may facilitate enhanced recovery of LNAPL from the water table and simultaneous in situ biodegradation of hydrocarbons in the vadose zone via bioventing. Groundwater extraction rates can also be expected to be increased. The bioslurper pilot test demonstrated the feasibility of performing vacuum-enhanced recovery at the Panero site at March AFB; however, to determine the sustainability of fuel and groundwater recovery, longer term testing should be performed using the existing Panero system extraction wells with an induced vacuum.

The soil vapor extraction test performed on Well #SVE-1A demonstrated that a significant mass of hydrocarbons could be extracted from this well. During the 1-month test, approximately 6,400 lb of petroleum hydrocarbons were extracted from the subsurface using an internal combustion engine (ICE). Supplemental fuel usage was low initially, but increased toward the end of the test. It is not known if the vertical contamination profile present in the vicinity of Well #SVE-1A is representative of a large portion of the Panero site.

DRAFT SITE-SPECIFIC TECHNICAL REPORT (A003)

for

BIOSLURPER TESTING AT MARCH AFB, CALIFORNIA

April 16, 1996

1.0 INTRODUCTION

This report describes activities performed and data collected during field tests at March Air Force Base (AFB), California, to compare vacuum-enhanced free-product recovery (bioslurping) to traditional free-product recovery technologies for removal of light, nonaqueous-phase liquid (LNAPL) from subsurface soils and aquifers. The field testing at March AFB is part of the Bioslurper Initiative, which is funded and managed by the U.S. Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division. The AFCEE Bioslurper Initiative is a multisite program designed to evaluate the efficacy of the bioslurping technology for (1) recovery of LNAPL from groundwater and the capillary fringe and (2) enhancing natural in situ degradation of petroleum contaminants in the vadose zone via bioventing.

1.1 Objectives

The main objective of the Bioslurper Initiative is to develop procedures for evaluating the potential for recovering free-phase LNAPL present at petroleum-contaminated sites. The overall study is designed to evaluate bioslurping and identify site parameters that are reliable predictors of bioslurping performance. To measure LNAPL recovery in a wide variety of in situ conditions, tests are being performed at many sites. The test at March AFB is one of more than 40 similar field tests to be conducted at various locations throughout the United States and its possessions. Aspects of the testing program that apply to all sites are described in the *Test Plan and Technical Protocol for Bioslurping* (Battelle, 1995). Test provisions specific to activities at March AFB are described in the Site-Specific Test Plan provided in Appendix A.

The intent of field testing is to collect data to support determination of the predictability of LNAPL recovery and to evaluate the applicability, cost, and performance of the bioslurping technology for removal of free product and remediation of the contaminated area. The on-site testing is structured to allow direct comparison of the LNAPL recovery achieved by bioslurping with the performance of more conventional LNAPL recovery technologies. The test method included an initial site characterization followed by LNAPL recovery testing. The three LNAPL recovery technologies tested at March AFB were skimmer pumping, bioslurping, and drawdown pumping. The specific test objectives, methods, and results for the March AFB test program are discussed in the following sections.

1.2 Testing Approach

Bioslurper pilot test activities were conducted at two monitoring wells located at the Panero JP-4 Spill Site. Site characterization activities were conducted to evaluate site variables that could affect LNAPL recovery efficiency and to determine the bioventing potential of the site. Testing included baildown testing to evaluate the mobility of LNAPL, soil sampling to determine physical/chemical site characteristics, soil gas permeability testing to determine the radius of influence, and in situ respiration testing to evaluate site microbial activity.

Following the site characterization activities, the pump tests were conducted. At monitoring well MW-04, pilot tests for skimmer pumping and bioslurping were conducted. The LNAPL recovery testing was conducted in the following sequence at monitoring well MW-04: 48 hours in the skimmer configuration, approximately 21 hours in the bioslurper configuration (with 24 hours of downtime in the middle of the test), 10 hours in the drawdown configuration, and an additional 18 hours in the bioslurper configuration.

At monitoring well MW-03, pilot tests for bioslurping were conducted under low- and high-vacuum. The low-vacuum pump test was conducted for approximately 20 hours and the high-vacuum pump test was conducted for approximately 48 hours.

Measurements of extracted soil gas composition, LNAPL thickness, and groundwater level were taken throughout the testing. The volume of LNAPL recovered and groundwater extracted were quantified over time.

At the request of the Air Force, an extended soil vapor extraction (SVE) test was performed on Well #SVE-1A, to investigate the feasibility of removing hydrocarbons from the subsurface through vapor extraction alone.

2.0 SITE DESCRIPTION

March AFB is located at the north end of the Perris Valley in Riverside County, California. The Panero aircraft refueling system site is located on 45 acres of land on the eastern half of the base. The refueling system at the site includes an underground tank farm comprising 34 50,000-gallon steel underground storage tanks (USTs), one 25,000-gallon underground defueling tank, one 550-gallon steel underground vapor recovery tank, a pump house consisting of 34 600-gpm jet fuel pumps, and approximately 7,500 feet of associated underground steel piping used to deliver fuel to and from fueling hydrants.

The soils at the Panero JP-4 Spill Site consist of alluvial deposits eroded from the surrounding higher bedrock terrain. The deposits consist of alternating, discontinuous layers of fine- to coarse-grained, unconsolidated material. A soil gas survey was conducted in November 1989; analyses of the shallow soil borings (4 feet below ground surface [bgs]) indicated the presence of jet fuel contamination to the south and west of the pump house. Analyses of deeper soil gas samples indicated more extensive contamination, with the highest concentration being $>136,000$ μg/L total volatile organic compounds (VOCs).

Figure 1 illustrates the location of groundwater monitoring wells at the Panero JP-4 Spill Site. Free product has been detected at a number of the monitoring wells at this site.

3.0 BIOSLURPER SHORT-TERM PILOT TEST METHODS

This section documents the initial conditions at the test site and describes the test equipment and methods used for the short-term pilot test at March AFB.

3.1 Initial LNAPL/Groundwater Measurements and Baildown Testing

Monitoring wells MW-04 and MW-03 were evaluated for use in the bioslurper pilot testing. Initial depths to LNAPL and to groundwater were measured using an oil/water interface probe (ORS Model #1068013). LNAPL was removed from the well with a Teflon™ bailer until the LNAPL thickness could no longer be reduced. The rate of increase in the thickness of the floating LNAPL layer was monitored using the oil/water interface probe for approximately 41 hours in MW-04 and 1 hour in MW-03.

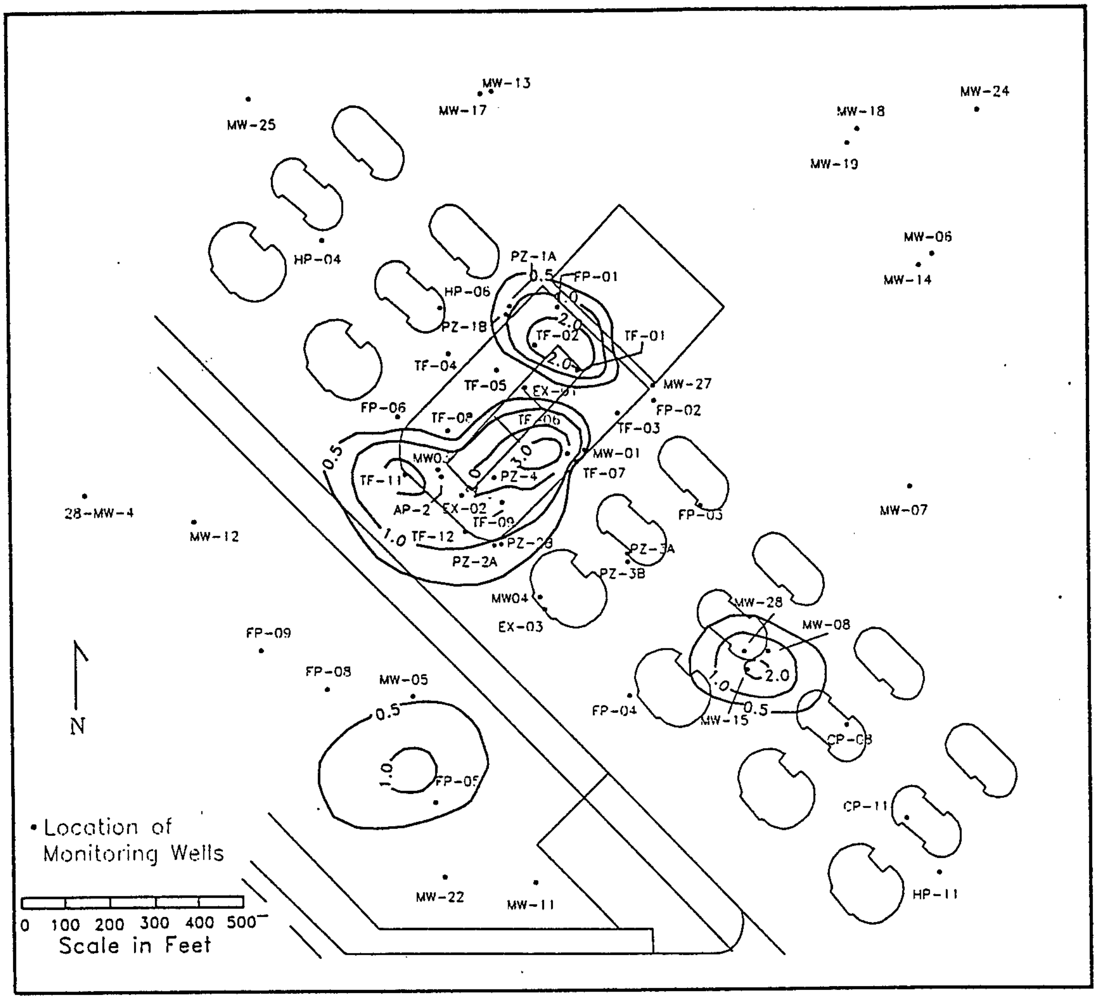

Figure 1. Schematic Diagram Showing Locations of Monitoring Wells at the Panero JP-4 Spill Site, March AFB, CA

An LNAPL sample was collected from monitoring well TF-03 for analysis of benzene, toluene, ethylbenzene, and xylenes (BTEX) and for boiling point fractionation. The sample was sent to Alpha Analytical, Inc., in Sparks, Nevada.

3.2 Well Construction Details

Short-term bioslurper pump tests were conducted at existing monitoring wells MW-04 and MW-03. Monitoring well MW-04 is constructed of 4-inch-diameter, schedule 80 polyvinyl chloride (PVC). Monitoring well MW-03 is constructed of 4-inch-diameter, stainless steel tubing. Exact depths and screen lengths are unknown.

3.3 Soil Gas Monitoring Point and Thermocouple Installation

Three monitoring points were installed and were labeled MPA, MPB, and MPC. The locations of the monitoring points are illustrated in Figure 2.

The monitoring points consisted of sets of ¼-inch tubing, with 1-inch-diameter, 6-inch-long screened areas. The screened lengths were positioned at the appropriate depths, and the annular space corresponding to the screened length was filled with silica sand. The interval between the screened lengths was filled with bentonite clay chips, as was the space from the top of the shallowest screened length to the ground surface. After placement, the bentonite clay was hydrated with water to expand the chips and provide a seal. The screened interval in each monitoring point were installed at depths of 15, 25, and 34 feet. Type K thermocouples were installed with monitoring point MPA at depths of 15 and 34 feet.

After installation of the monitoring points, initial soil gas measurements were taken with a GasTech portable O_2/CO_2 meter and a GasTech TraceTechtor portable hydrocarbon meter. Oxygen limitation was observed at most screened intervals, with oxygen concentrations typically less than 10% (Table 1).

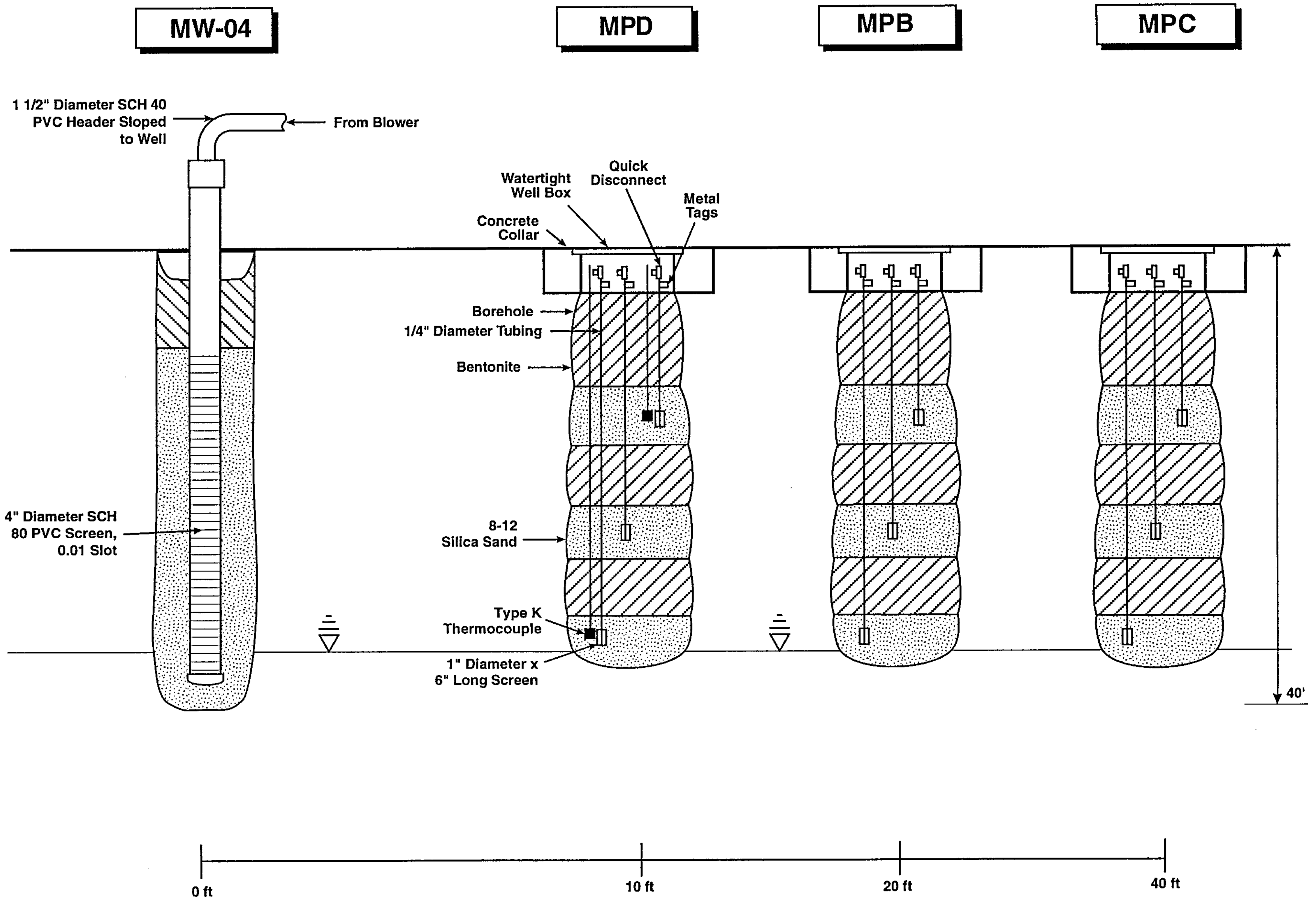

Figure 2. Construction Details of Monitoring Well MW-04 and Adjacent Soil Gas Monitoring Points at the Panero JP-4 Spill Site, March AFB, CA

F/Leeson/59-2

Table 1. **Initial Soil Gas Compositions at the Panero JP-4 Spill Site, March AFB, CA**

Monitoring Point	Depth (ft)	Oxygen (%)	Carbon Dioxide (%)	TPH (ppmv)[a]
MPA	15	5.0	7.0	0
	25	5.0	5.5	400
	34	5.5	3.5	13,000
MPB	15	8.5	5.7	880
	25	15.9	2.8	540
	34	6.5	5.2	12,200
MPC	15	9.0	4.9	2,200
	25	0	8.0	20,000
	34	2.5	7.0	800

[a] TPH is total petroleum hydrocarbons.

3.4 Soil Sampling and Analysis

Three soil samples were collected during the installation of monitoring point MPA and were labeled MAR-MPA-32.0′-35.0′, MAR-MPA-35.0′-35.5′, and MAR-MPA-35.5-36.0. The soil samples were collected using a Geoprobe. The samples were placed in an insulated cooler, chain-of-custody records and shipping papers were completed, and the samples were sent to Alpha Analytical, Inc., in Sparks, Nevada. Sample MAR-MPA-32.0′-35.0′ was analyzed for bulk density, moisture content, particle size, and porosity. Samples MAR-MPA-35.0′-35.5′ and MAR-MPA-35.5-36.0 were analyzed for BTEX and TPH. The laboratory analytical report is provided in Appendix B.

3.5 LNAPL Recovery Testing

3.5.1 System Setup

The bioslurping pilot test system is a trailer-mounted mobile unit. The vacuum pump (Atlantic Fluidics Model A100, 7.5-hp liquid ring pump), oil/water separator, and required support equipment were carried to the test location on a trailer. The trailer was located near the monitoring well, the well cap was removed, a coupling and tee were attached to the top of the well, and the slurper tube was lowered into the well. The slurper tube was attached to the vacuum pump. Different configurations of the tee and the placement depth of the slurper tube allow for simulation of skimmer pumping, operation in the bioslurping configuration, or simulation of drawdown pumping. Extracted groundwater was treated by passing the effluent through an oil/water separator and allowed to settle in a 500-gallon tank. The groundwater was then discharged to the sanitary sewer.

A brief system startup test was performed prior to LNAPL recovery testing to ensure that all system components were working properly. The system checklist is provided in Appendix C. All site data and field testing information were recorded in a field notebook and then transcribed onto pilot test data sheets provided in Appendix D.

3.5.2 Initial Skimmer Pump Test

Prior to test initiation, depths to LNAPL and groundwater were measured. The slurper tube was then set at the LNAPL/groundwater interface with the wellhead open to the atmosphere via a PVC connecting tee (Figure 3). The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started on February 9, 1996, to begin the skimmer pump test. The test was operated continuously for approximately 48 hours. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the skimmer pump test. Test data sheets are provided in Appendix D.

3.5.3 Bioslurper Pump Test

Bioslurper pump tests were conducted at monitoring wells MW-04 and MW-03. Both a low-vacuum and a high-vacuum test were performed at monitoring well MW-03. Details of the tests are described in the following sections.

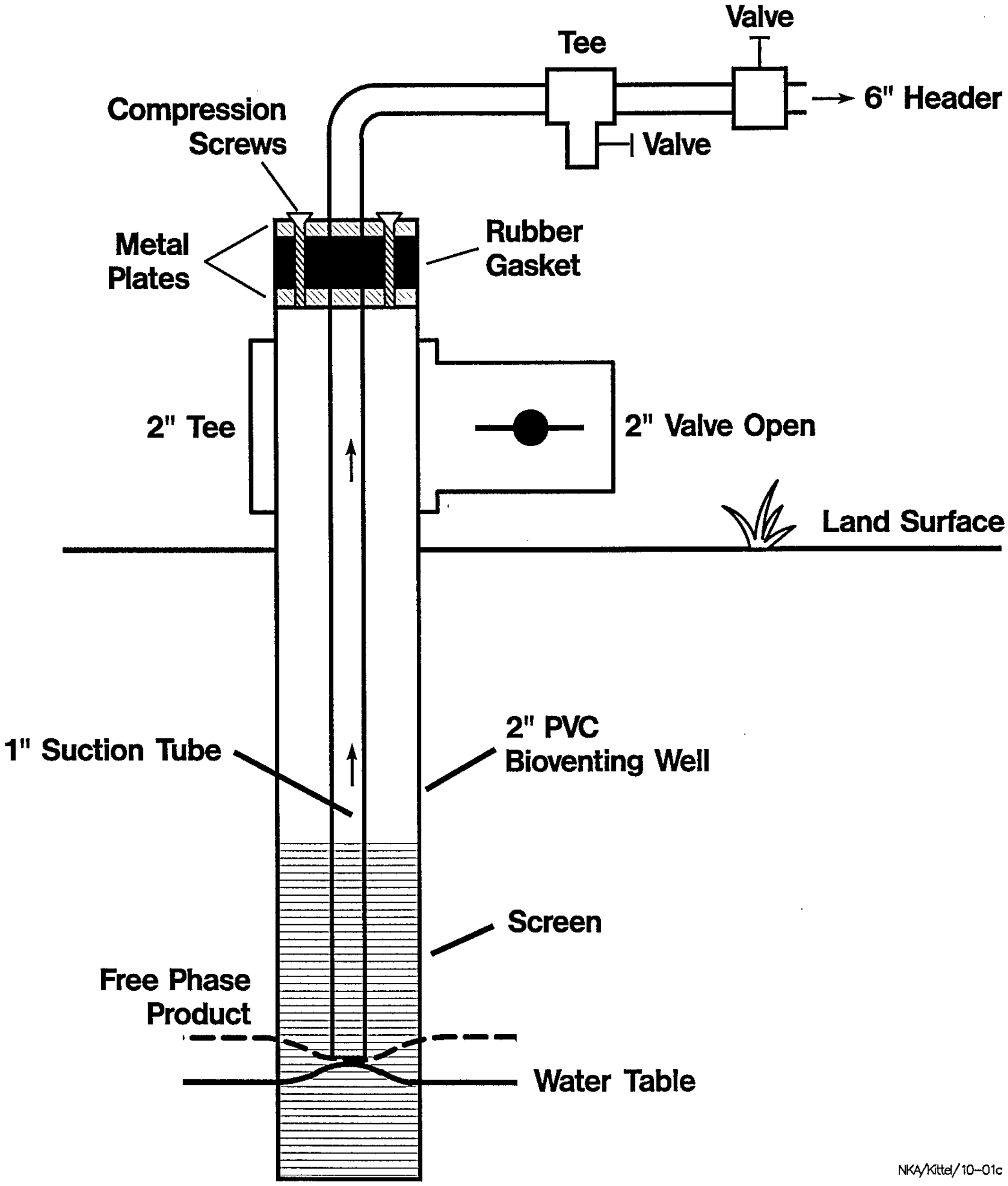

Figure 3. Slurper Tube Placement and Valve Position for the Skimmer Pump Test

3.5.3.1 Monitoring Well MW-04

Upon completion of the initial skimmer pump test, preparations were made to begin the bioslurper pump test. Prior to test initiation, depths to LNAPL and groundwater were measured. The slurper tube was then set at the LNAPL/groundwater interface. The PVC connecting tee was removed, sealing the wellhead and allowing the pump to establish a vacuum in the well (Figure 4). A pressure gauge was installed at the wellhead to measure the vacuum inside the extraction well. The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started on February 11, 1996, to begin the bioslurper pump test. The test was initiated approximately 2 hours after the skimmer pump test and was operated for approximately 21 hours with 24 hours of downtime during the middle of testing. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix D.

3.5.3.2 Monitoring Well MW-03

Prior to test initiation, depths to LNAPL and groundwater were measured. The bioslurper system was set up as described in Section 3.5.3.1. The liquid ring pump was started on February 15, 1996, and operated at a vacuum of approximately 8.5 inches of H_2O to begin the low-vacuum bioslurper pump test. The test was operated continuously for approximately 20 hours. The liquid ring pump was started on February 16, 1996, and was operated at a vacuum of approximately 27 inches of H_2O to begin the high-vacuum bioslurper pump test. The test was operated continuously for approximately 48 hours. The LNAPL and groundwater extraction rates were monitored throughout the tests, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix D.

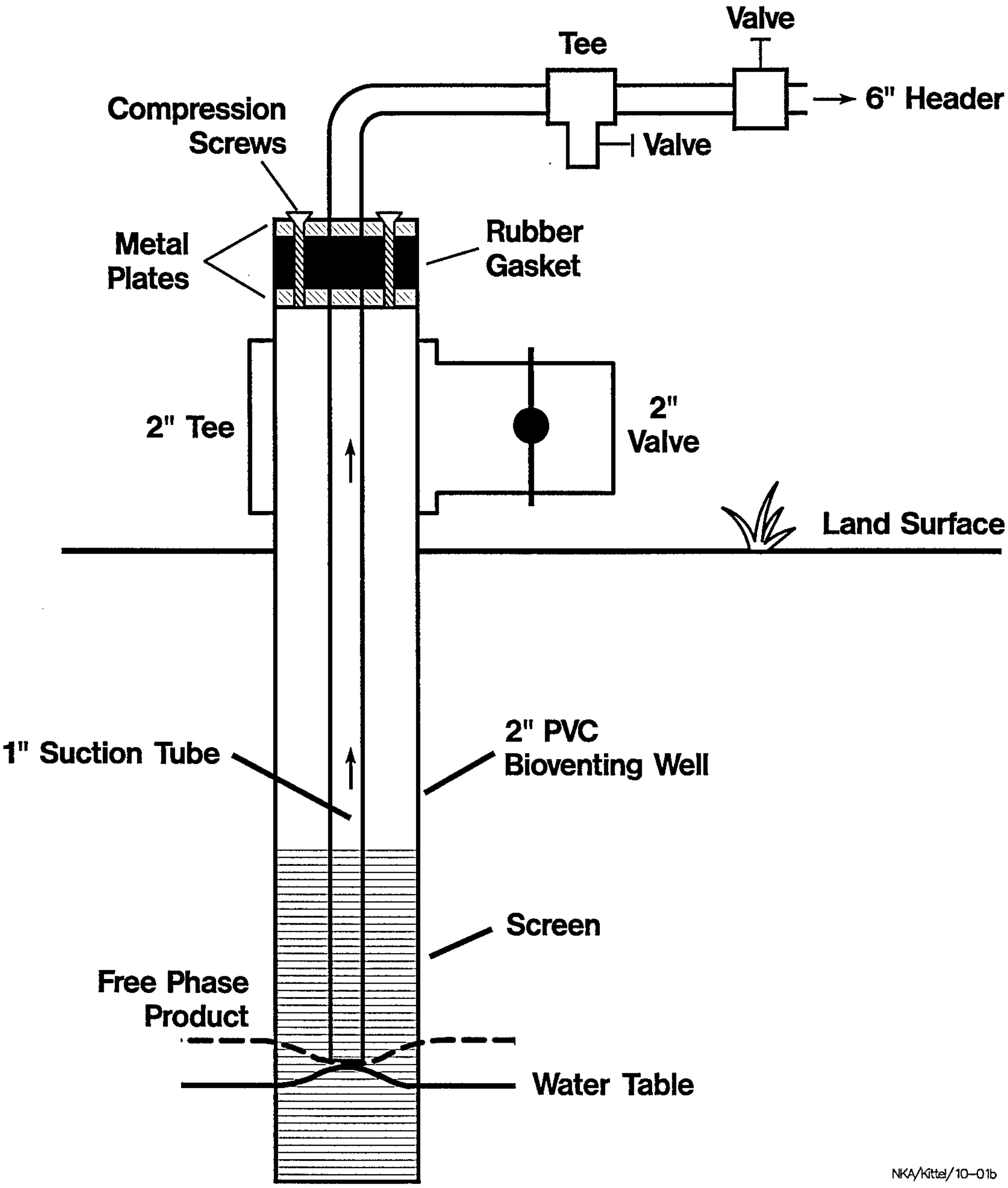

Figure 4. Slurper Tube Placement and Valve Position for the Bioslurper Pump Test

3.5.4 Drawdown Pump Test

Upon completion of the bioslurper pump test, preparations were made to begin the drawdown pump test. Prior to test initiation, depths to LNAPL and groundwater were measured. The slurper tube was positioned similar to the skimmer configuration, but the pump was operated to achieve drawdown of the water table (Figure 5). The liquid ring pump and oil/water separator were primed with known amounts of groundwater to ensure that any LNAPL or groundwater entering the system could be quantified. The flow totalizers for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started on February 13, 1996, to begin the drawdown pump test. The test was initiated approximately 1 hour after the bioslurper pump test and was operated continuously for 10 hours. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the drawdown pump test. Test data sheets are provided in Appendix D.

3.5.5 Second Bioslurper Pump Test

Prior to test initiation, depths to LNAPL and groundwater were measured. The bioslurper system was set up as described in Section 3.5.3.1. The liquid ring pump was started on February 15, 1996, to begin the bioslurper pump test. The test was operated continuously for approximately 18 hours. The LNAPL and groundwater extraction rates were monitored throughout the tests, as were all other relevant data for the bioslurper pump test. Test data sheets are provided in Appendix D.

3.6 Off-Gas Sampling and Analysis

Five soil gas samples were collected during the bioslurper pump tests. Samples MAR-SL-01 and MAR-ICE-01 were collected during the bioslurper pump test at monitoring well MW-04 and were collected from the seal tank headspace and the off-gas of the internal combustion engine (ICE) unit, respectively. Samples STACK-02, MAR-SL-02, and MAR-ICE-02 were collected during the high-vacuum bioslurper pump test at monitoring well MW-03. Sample STACK-02 was collected from the bioslurper off-gas shortly after bioslurper initiation because the ICE unit stopped. Samples MAR-SL-02 and MAR-ICE-02 were collected from the seal tank headspace and the ICE unit off-gas, respectively, approximately 45 hours after test initiation. The samples were collected in Tedlar™ bags and transferred to Summa™ canisters. The samples were sent under chain of custody to Air Toxics, Ltd., in Rancho Cordova, California, for analyses of BTEX and TPH.

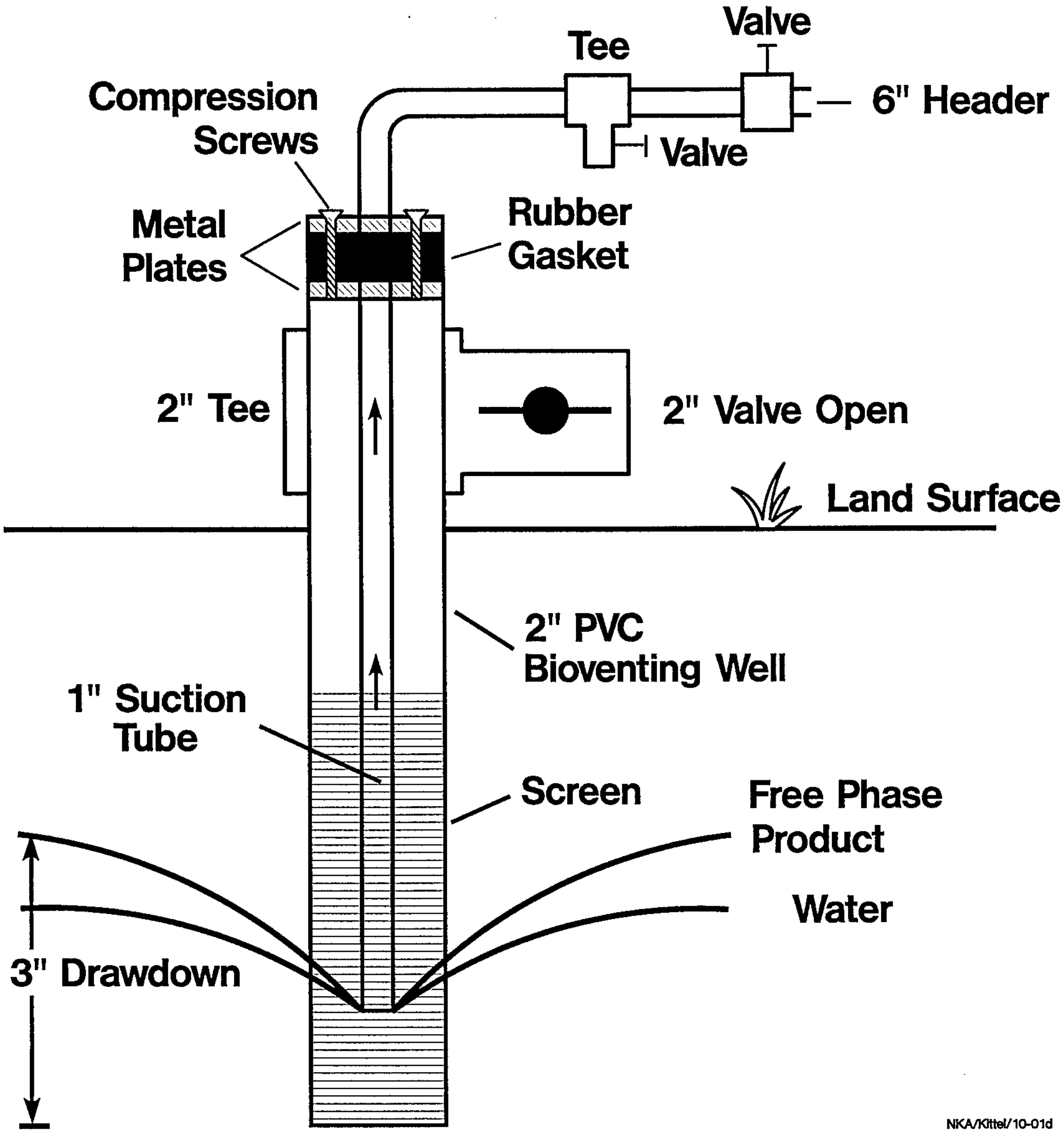

Figure 5. Slurper Tube Placement for the Drawdown Simulation Recovery Test

3.7 Groundwater Sampling and Analysis

Two groundwater samples were collected during the bioslurper pump test. Both samples were collected from the oil/water separator and were labeled HAV-OWS-Water-Samp1 and HAV-OWS-Water-Samp2. Samples were collected in 40-mL septa vials containing HCl preservative. Samples were checked to ensure no headspace was present and were then shipped on ice and sent under chain of custody to Alpha Analytical, Inc., in Sparks, Nevada for analyses of BTEX and TPH.

3.8 Soil Vapor Extraction Testing

It was determined that extended testing using the trailer mounted bioslurper was impractical at this site both technically and logistically. At the request of the Air Force an extended soil vapor extraction (SVE) test was conducted in place of the bioslurper extended test. The model V-3 ICE used for vapor treatment during the bioslurper pilot testing was connected to an existing site vapor extraction well, Well# SVE-1A. The SVE test was initiated on February 22, 1996. The system was monitored remotely via modem by the ICE manufacturer, VR systems of Anahiem California.

4.0 RESULTS

This section documents the results of the site characterization, the comparative LNAPL recovery pump test, and other supporting tests conducted at March AFB.

4.1 Baildown Test Results

Results from the baildown test in monitoring wells MW-04 and MW-03 are presented in Table 2. A total volume of 1.2 L (0.32 gallons) was removed by hand-bailing from monitoring well MW-04. In monitoring well MW-04, the LNAPL thickness recovered to approximately 60% of initial levels by the end of the 41-hour test period. In monitoring well MW-03, the LNAPL thickness

Table 2. Results of Baildown Testing in Monitoring Wells MW-04 and MW-03

Monitoring Well	Sample Collection Time (Date-Time)	Depth to LNAPL (ft)	Depth to Groundwater (ft)	LNAPL Thickness (ft)
MW-04	Initial Reading 2/5/96-1545	35.00	35.73	0.73
	2/5/96-1615	35.09	35.46	0.37
	2/5/96-1617	35.07	35.46	0.39
	2/5/96-1620	35.06	35.48	0.42
	2/5/96-1715	35.04	35.47	0.43
	2/6/96-0740	35.03	35.47	0.44
	2/7/96-0845	34.90	35.33	0.43
MW-03	Initial Reading 2/15/96-1416	36.78	37.02	0.24
	2/15/96-1430	36.715	36.98	0.265
	2/15/96-1500	36.71	36.95	0.24
	2/15/96-1510	36.72	36.98	0.26
	2/15/96-1527	36.71	36.97	0.26

recovered to initial levels within 1 hour. The results of these tests indicate that these wells may be suitable for bioslurping.

4.2 Soil Sample Analyses

Table 3 shows the TPH and BTEX concentrations measured in soil samples collected from the Panero JP-4 Spill Site. TPH and BTEX concentrations were relatively low with TPH and most BTEX components below detection limits. Benzene was detected in both samples, averaging 0.069 mg/kg. The results of the physical characterization of the soil are presented in Table 4.

4.3 LNAPL Pump Test Results

Results from the LNAPL pump tests are presented in the following sections. Due to the very low LNAPL recovery at monitoring well MW-04, a graph illustrating LNAPL recovery during each pump test was not prepared.

4.3.1 Pump Test Results at Monitoring Well MW-04

No LNAPL was recovered during any of the pump tests at this monitoring well (Table 5). Groundwater was extracted at relatively high rates, ranging from 351 gallons/day during the initial skimmer pump tests up to 6,400 gallons/day during the second bioslurper pump test (Table 5). These results indicate that free product recovery was not possible at this monitoring well possibly due to the relative immobility of the free product.

4.3.2 Bioslurper Pump Test Results at Monitoring Well MW-03

The bioslurper pump test was conducted under both low and high vacuum to evaluate the effects on LNAPL recovery rates. Results from these two pump tests are presented in Table 6. Under low-vacuum conditions, LNAPL recovery averaged 2.2 gallons/day, while groundwater recovery averaged 1,700 gallons/day. Under high-vacuum conditions, LNAPL recovery increased significantly to an average of 10 gallons/day (Figure 6). Groundwater recovery rates were almost double the rates under low-vacuum conditions, averaging 3,300 gallons/day. These results demonstrate that operation of the bioslurper under high-vacuum conditions may improve free product recovery; however, significant quantities of groundwater also will be generated.

Table 3. TPH and BTEX Concentrations in Soil Samples from the Panero JP-4 Spill Site, March AFB, CA

Parameter	Concentration (mg/kg)	
	MAR-MPA-35.0′-35.5′	MAR-MPA-35.5′-36.0′
TPH as diesel	<10	<10
Benzene	0.028	0.11
Toluene	<0.020	0.057
Ethylbenzene	<0.020	<0.020
Xylenes	<0.020	<0.020

Table 4. Physical Characterization of Soil from the Panero JP-4 Spill Site, March AFB, CA

Parameter	Sample
	MAR-MPA-32.0-35.0
Moisture Content (%)	15.5
Porosity (%)	61.5
Specific Gravity (g/cm^3)	1.02
Particle Size (%)	
Sand	65.5
Silt	25.9
Clay	8.6

Table 5. Pump Test Results at Monitoring Well MW-04, Panero JP-4 Spill Site, March AFB, CA

Recovery Rate (gal/day)	Initial Skimmer Pump Test		Bioslurper Pump Test		Drawdown Pump Test		Second Bioslurper Pump Test	
	LNAPL	Groundwater	LNAPL	Groundwater	LNAPL	Groundwater	LNAPL	Groundwater
Day 1	0	577	0	3,016	0	3,816	0	6,408
Day 2	0	140	0	4,690	NA	NA	NA	NA
Average	0	351	0	4,370	0	3,816	0	6,408
Total Recovered (gal)	0	690	0	3,825	0	3,722	0	4,996

NA = Not applicable.

Table 6. Pump Test Results at Monitoring Well MW-03, Panero JP-4 Spill Site, March AFB, CA

Recovery Rate (gal/day)	Low-Vacuum (~8.5" H_2O) Bioslurper Pump Test		High-Vacuum (~27" H_2O) Bioslurper Pump Test	
	LNAPL	Groundwater	LNAPL	Groundwater
Day 1	2.15	1,691	13.80	3,274
Day 2	NA	NA	7.13	3,316
Average	2.15	1,691	10.13	3,297
Total Recovered (gal)	1.8	1,416	20.0	6,512

NA = Not applicable.

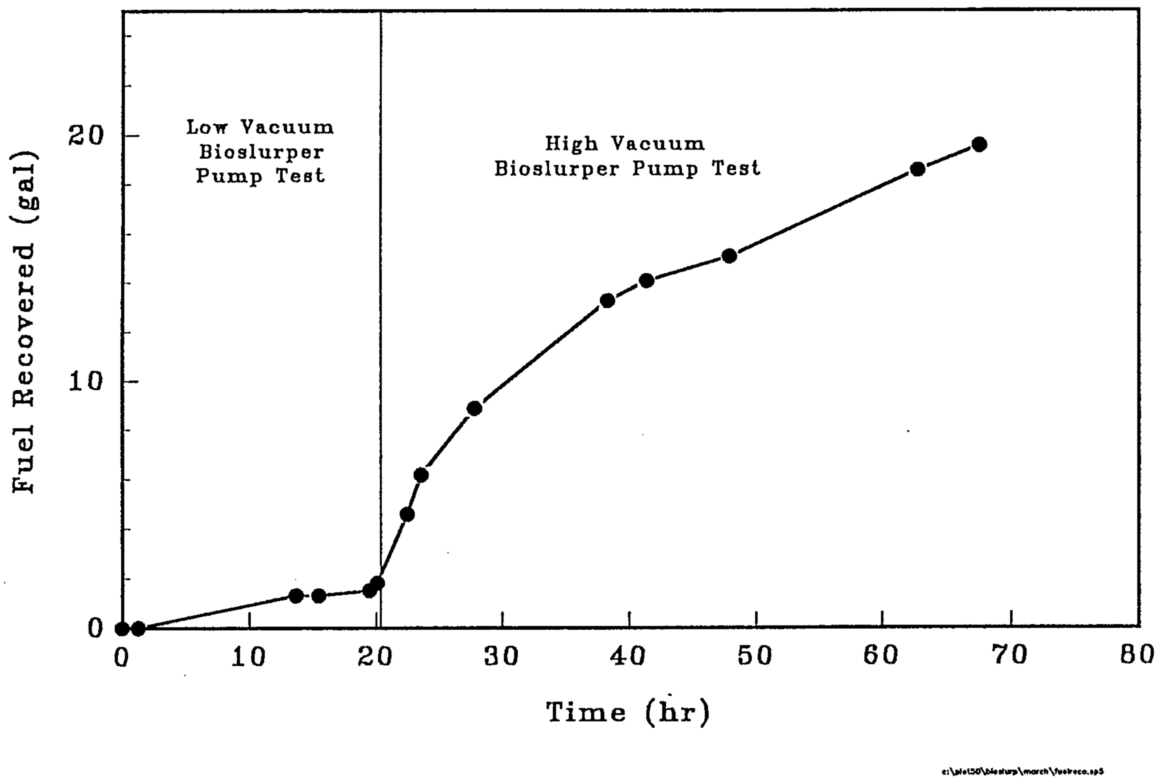

Figure 6. Fuel Recovery Versus Time During the Low- and High-Vacuum Bioslurper Pump Tests in Monitoring Well MW-03

4.3.3 Extracted Groundwater, LNAPL, and Off-Gas Analyses

The groundwater samples collected during the bioslurper pump test were not analyzed due to a lab error.

Off-gas samples from the bioslurper system also were collected during the bioslurper pump test. The results from the off-gas analyses are presented in Table 7. Given a vapor discharge rate of 23 scfm and using an concentration of 66 ppmv TPH and 0.021 ppmv benzene, approximately 0.89 lb/day of TPH and 0.00014 lb/day benzene were emitted to the air during the bioslurper pump test.

The BTEX composition of LNAPL is shown in Table 8. The distribution of C-range compounds were not analyzed. A new fuel sample will be taken during the in situ respiration test for C-range analysis, and will be included in the final report.

4.4 Bioventing Analyses: Soil Gas Permeability Testing

The radius of influence is calculated by plotting the log of the pressure change at a specific monitoring point versus the distance from the extraction well. The radius of influence is then defined as the distance from the extraction well where 0.1 inch of H_2O can be measured. Results from the soil gas permeability testing were inconclusive, possibly due to low-vacuum conditions.

4.5 Soil Vapor Extraction Results

The SVE test was conducted on Well #SVE-1A from February 22, 1996 through March 21, 1996. The system operated for a total of 688 hours, or 28.6 days. The SVE test ran continuously except for one shutdown on March 10, 1996, due to a high-level alarm in the moisture knockout tank. The tank was drained and the system was restarted on March 11, 1996.

The ICE performance data were printed out once daily as shown in Table 9. An estimate of the mass of hydrocarbons extracted from the subsurface can be made based on the supplemental fuel usage. Based on a run time of 688 hours, and an estimated total fuel requirement (supplemental + extracted soil hydrocarbon vapors) of 15 lb/hr (provided by VR Systems), a total of 10,320 lb of

Table 7. BTEX and TPH Concentrations in Off-Gas During the Bioslurper Pump Test at March AFB, CA

Parameter	Concentration (ppmv)				
	MAR-SL-01	MAR-ICE-01	Stack-02	MAR-SL-02	MAR-ICE-02
TPH as jet fuel	5,900	34	100,000	48,000	0.28
Benzene	460	0.047	1,600	590	<0.0020
Toluene	460	0.055	3,100	1,400	<0.0020
Ethylbenzene	69	0.016	110	170	<0.0020
Xylenes	340	0.072	340	2,900	<0.0020

Table 8. BTEX Concentrations in LNAPL from March AFB, CA

Compound	Concentrations (mg/kg)
Benzene	<30
Toluene	<30
Ethylbenzene	31
Total Xylenes	81

Table 9. ICE Performance Data

Date	Time	Rpm	Exh	Carb	Bypass	Flow	Vac	Duty	Fuel cfm	Fuel Total	Gal Prop	Eng hrs
2/20	--	1709	1137	26	10.3	56	43	57	0.0	69488		555
2/21	--	1721	1138	26.8	10.3	53	46	55		70013	14.6	578
2/22	--	1740	1125	25.7	9.5	52	48	52		70682	18.6	601
2/23	--	1752	998	21.7	0	36	33	76		71419	20.5	626
2/24	AM	2000	1119	30	6.3	44	?	49	0.0	72824	39	---
2/24	17:00	2000	1098	30.8	3.7	40	?	47	1.26	73087	7.3	---
2/24	21:00	Change rpm to 1800										
2/24	21:00	1800	1159	29.9	12.3	55	23	52	0.0	73470	10.6	660
2/25	09:00	1800	1161	29	12.3	56	26	52	0.0	73977	14	672
2/26	10:00	1800	1160	29	12	56	26	57	0.0	74882	25	697
2/27	07:00	1771	1157	28.2	14.1	60	26	49	.72	75635	21	718
2/27	13:00	1800	1112	27	8.3	52	18	82	0.0	75664	1	724
2/28	18:30	1793	1152	28	14	60	28	41	.83	76380	20	742
2/29	07:00	1783	1159	27	14	61	26	47	0.0	77189	22	766
3/1	07:00	1750	1154	?	13	60	23	55	0.0	77905	20	790
3/1	13:30	1800	1151	27	9.6	54	21	48	0.0	77994	2.5	797
3/4	AM	1764	1158	27	16	65	28	53	0.0	80231	62	863
3/5	08:00	1750	1160	29.5	16	66	26	51	0.0	81176	26	887
3/6	07:30	1750	1153	26	16.7	67	25	54	0.0	82112	26	911
3/6	14:45	1738	1173	27.6	16.6	67	26	54	0.0	82312	5.5	918
3/7	07:28	1790	1161	26.0	16.6	68	27	52	0.0	83020	20	935
3/8	06:00	1747	1149	26	16.5	69	28	46	.92	83953	26	958
3/8	18:00	1800	1164	28	16.4	67	24	55	0.0	84289	19	969
3/9	09:30	1750	1178	27.4	16.4	68	23	56	0.0	84965	19	985
3/9	21:30	1760	1165	26.9	16.4	68	25	48	.82	85461	14	997
3/10	16:38	SHUTDOWN										
3/11	13:16	RESTART DRAIN 50 GALLON WATER CHANGE DITHERING VALVE										
3/13	18:00	UNIT RUNNING NO INFORMATION RECORDED										
3/14	19:29	1829	1157	28.7	17.9	70	27	53	1.08	90881	151	1082
3/15	6:25	1822	1152	26.3	17.9	71	28	52	1.14	91688	22	1093
3/18	6:07	1847	1152	30.0	18.6	71	28	49	1.23	96588	135	1165
3/19	9:08	1832	1167	28	18.1	69	28	59	.85	98538	54	1192
3/20	6:29	1823	1147	25.4	17.8	71	28	58	1.15	100157	45	1213
3/21	12:05	1847	1156	28.6	17.0	66	25	41	1.3	102454	64	1243

fuel was required to operate the system for the 1-month-long test. A total of 3,937 lb (915 gal × 4.3 lb/gal propane) of supplemental propane were used during the test, leaving 6,383 lb of hydrocarbons extracted from Well #SVE-1A. Note that this estimate is based on ICE performance assumptions and not from direct measurement of the hydrocarbon concentration of the extracted well gas.

During the test the initial supplemental fuel usage was quite low at approximately 20 gallons of propane per day. After the system shutdown, supplemental fuel usage increased to more than 50 gallons per day.

5.0 DISCUSSION

No LNAPL was recovered during any of the pump tests at monitoring well MW-04. Groundwater was extracted at relatively high rates, ranging from 351 gallons/day during the initial skimmer pump tests up to 6,400 gallons/day during the second bioslurper pump test. These results indicate that free-product recovery was not possible at this monitoring well possibly due to the relative immobility of the free product.

The bioslurper pump test was conducted under both low and high vacuum at MW-03 to evaluate the effects on LNAPL recovery rates. Under low-vacuum conditions, LNAPL recovery averaged 2.2 gallons/day, while groundwater recovery averaged 1,700 gallons/day. Under high-vacuum conditions, LNAPL recovery increased significantly to an average of 10 gallons/day. Groundwater recovery rates were almost double those under low vacuum, averaging 3,300 gallons/day. These results demonstrate that operation of the bioslurper under high-vacuum conditions may improve free-product recovery and significantly increase groundwater extraction rates.

Implementation of vacuum-enhanced recovery at the March AFB test site may facilitate enhanced recovery of LNAPL from the water table and simultaneous in situ biodegradation of hydrocarbons in the vadose zone via bioventing. Groundwater extraction rates also can be expected to be increased. The bioslurper pilot test demonstrated the feasibility of performing vacuum-enhanced recovery at the Panero site at March AFB; however, to determine the sustainability of fuel and groundwater recovery, longer term testing should be performed using the existing Panero system extraction wells with an induced vacuum.

The soil vapor extraction test performed on Well #SVE-1A demonstrated that a significant mass of hydrocarbons could be extracted from this well. During the 1-month test, approximately

6,400 lb of petroleum hydrocarbons were extracted from the subsurface using an ICE. Supplemental fuel usage was low initially, but increased toward the end of the test. It is not known if the vertical contamination profile present in the vicinity of Well #SVE-1A is representative of a large portion of the Panero site.

6.0 REFERENCES

Battelle. 1995. *Test Plan and Technical Protocol for Bioslurping*, Report prepared by Battelle Columbus Operations for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

Hinchee, R.E., S.K. Ong, R.N. Miller, D.C. Downey, and R. Frandt. 1992. *Test Plan and Technical Protocol for a Field Treatability Test for Bioventing* (Rev. 2), Report prepared by Battelle Columbus Operations, U.S. Air Force Center for Environmental Excellence, and Engineering Sciences, Inc. for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

APPENDIX A

SITE-SPECIFIC TEST PLAN FOR BIOSLURPER FIELD ACTIVITIES AT MARCH AFB, CALIFORNIA

SITE-SPECIFIC TEST PLAN FOR BIOSLURPER TESTING AT THE PANERO JP-4 SPILL SITE MARCH AFB, CALIFORNIA

FINAL

PREPARED FOR:

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TECHNOLOGY TRANSFER DIVISION
(AFCEE/ERT)
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AND

722 CES/CEVR
MARCH AFB, CALIFORNIA

5 OCTOBER 1995

SITE-SPECIFIC TEST PLAN FOR BIOSLURPER TESTING AT MARCH AIR FORCE BASE, CALIFORNIA (A002)

CONTRACT NO. F41624-94-C-8012

FINAL

to

U.S. Air Force Center for Environmental Excellence
Technology Transfer Division
(AFCEE/ERT)
8001 Arnold Drive
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Brooks AFB, TX 78235

for

March AFB, CA

October 5, 1995

by

Battelle
505 King Avenue
Columbus, OH 43201

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FINAL

U.S. Air Force Center for Environmental Excellence
Technology Transfer Division
(AFCEE/ERT)
Brooks AFB, TX

October 5, 1995

1.0 INTRODUCTION

The Air Force Center for Environmental Excellence (AFCEE) Technology Transfer Division is conducting a nationwide application of an innovative technology for free-product recovery and soil bioremediation. The technology tested in the Bioslurper Initiative is vacuum-enhanced free-product recovery/bioremediation (bioslurping). The field test and evaluation are intended to demonstrate the initial feasibility of bioslurping by measuring system performance in the field. The Bioslurper Initiative has been designed to evaluate the effectiveness of bioslurping as a light, nonaqueous-phase liquid (LNAPL) recovery technology relative to conventional gravity-driven LNAPL recovery technologies. System performance parameters, mainly free-product recovery, will be determined at numerous sites. Field testing will be performed at many sites to determine the effects of different organic contaminant types and concentrations and different geological conditions on bioslurping effectiveness.

Plans for the field test activities are presented in two documents. The first is the overall Test Plan and Technical Protocol for the entire program, titled *Test Plan and Technical Protocol for Bioslurping* (Battelle, 1995). The overall Test Plan and Technical Protocol is supplemented by plans specific to each test site. The concise site-specific plans communicate vapor and water discharge rates for dealing with regulatory issues to base personnel.

The overall Test Plan and Technical Protocol was developed as a generic plan for the Bioslurper Initiative to improve the accuracy and efficiency of Test Plan preparation. The field program requires installation and operation of the bioslurping system supported by a wide variety of site characterization, performance monitoring, and chemical analysis activities. The basic methods to be applied from site to site do not change. Preparation and review of the overall Test Plan and Technical Protocol allows efficient documentation and review of the basic approach to the test program. Peer and regulatory review were performed for the overall Test Plan and Technical Protocol to ensure the credibility of the overall program.

This letter report is the site-specific plan for application of bioslurping at March Air Force Base (AFB), California. It was prepared based on site-specific information received by Battelle from March AFB and other pertinent site-specific information to support the overall Test Plan and Technical Protocol.

Site-specific information for March AFB included data for the Panero JP-4 Spill Site (IRP Operable Unit 3, or OU-3). After reviewing the data, Well PAN MW-15 appears to be the best candidate for the bioslurper field test; however, the water table has been rising in this area, which may make this well unsuitable. If PAN MW-15 is unsuitable for testing, other wells will be tested as alternatives for bioslurper field test activities and dewatering to 1 ft below the water table will be evaluated.

2.0 SITE DESCRIPTION

The information presented in the Site Description portion of this Test Plan was obtained from the document titled *Remedial Investigation Report for March Air Force Base OU-3 (Panero Site)*. This document is referenced as RIRM, 1993 in the Test Plan text.

March AFB is located at the north end of the Perris Valley in Riverside County, California. The base is approximately 60 miles east of Los Angeles and 90 miles north of San Diego. Most Air Force activity occurs in the eastern section of the base. The Panero aircraft refueling system site is located on 45 acres of land on the eastern half of the base. Figure 1 is a map that shows the location of the Panero JP-4 Spill Site. The refueling system at the site includes an underground tank farm comprising thirty-four 50,000-gallon steel underground storage tanks (USTs), one 25,000-gallon steel underground defueling tank, a 550-gallon steel underground vapor recovery tank, a pump house consisting of thirty-four 600 gpm jet fuel pumps, and approximately 7,500 ft of associated underground steel piping used to deliver fuel to and from fueling hydrants.

The soils beneath the Panero JP-4 Spill Site consist of alluvial deposits eroded from the surrounding higher bedrock terrain. The deposits consist of alternating, discontinuous layers of fine- to coarse-grained, unconsolidated material. A soil gas survey was conducted in November 1989; analyses of the shallow soil borings (4 ft bgs) indicated the presence of jet fuel contamination to the south and west of the pump house. Analyses of deeper soil gas samples (7 to 14 ft bgs) indicated more extensive contamination, with the highest concentration being $>136,000$ μg/L total volatiles.

Groundwater at the Panero JP-4 Spill Site typically occurs at depths ranging from 33 to 44 ft bgs. Groundwater investigations (RIRM, 1993) included pump testing on selected wells and slug testing at all monitoring wells within the site to determine aquifer transmissivity and hydraulic conductivity. The average hydraulic conductivity found at the Panero JP-4 Spill Site was 12.47 ft/day. The groundwater migration in the vicinity of the site tends to follow the regional gradient to the southeast. At the Panero JP-4 Spill Site, the gradient varies from 0.0058 ft/ft to 0.0033 ft/ft. Data taken during a pumping test on various wells at the Panero JP-4 Spill Site gives an average aquifer transmissivity of 357.3 ft^2/day.

Soil samples were collected from borings made in June 1990. The highest TPH concentration was 66,000 mg/kg. Benzene also was detected at a maximum concentration of 210 mg/kg. This concentration was detected in borings sampled from the southwest area of the pump house and found at a depth of 50 to 52 ft bgs.

A site map that shows the locations of groundwater monitoring wells at the Panero JP-4 Spill Site is provided in Figure 2. Free product thicknesses shown on this map are from May 1993; a more current estimate of the free product thicknesses is provided in Figure 3. Additional maps showing the areal extent of free product thicknesses from February 1993 through February 1995 are provided in

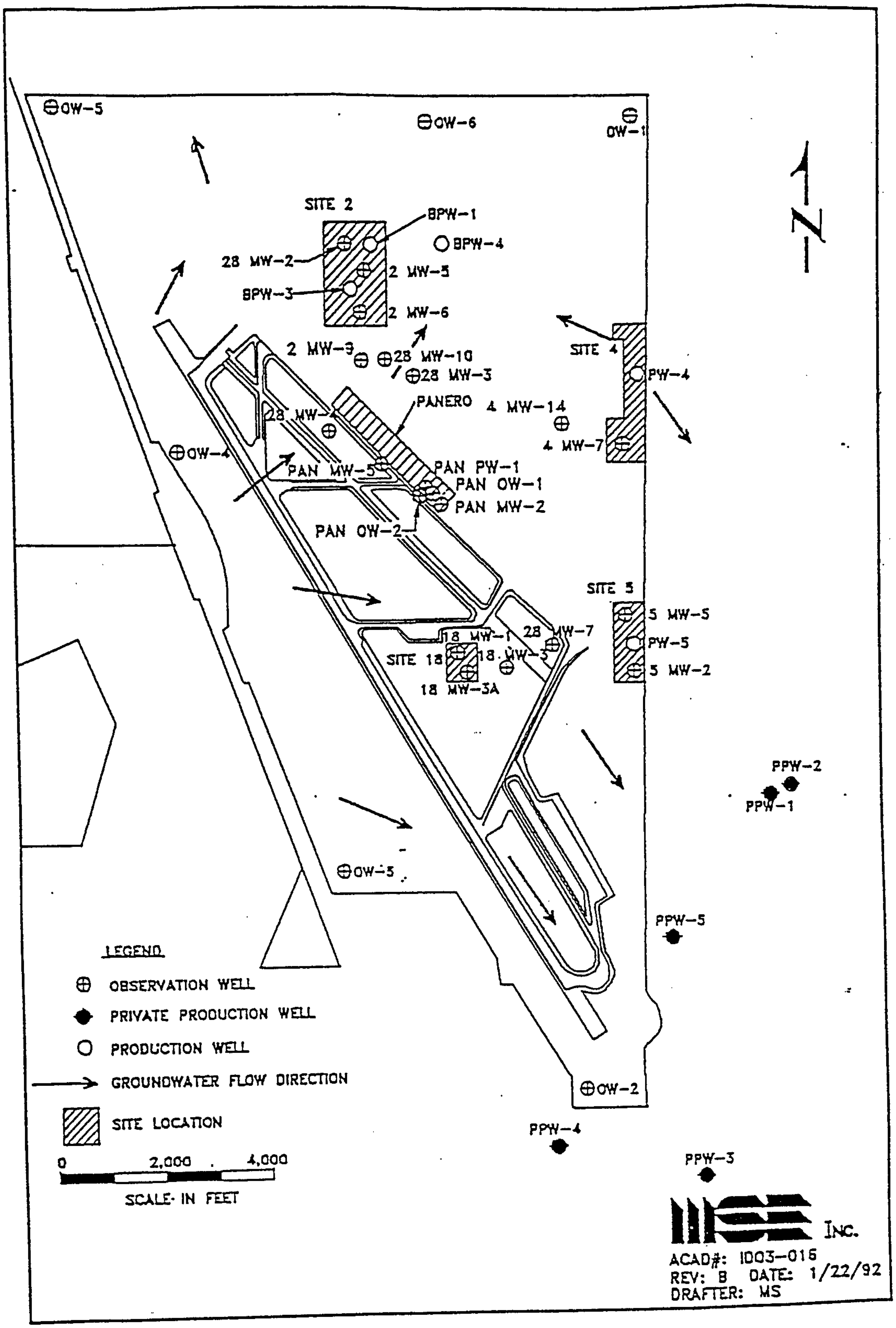


Figure 1. Location of the Panero JP-4 Spill Site, March AFB, CA

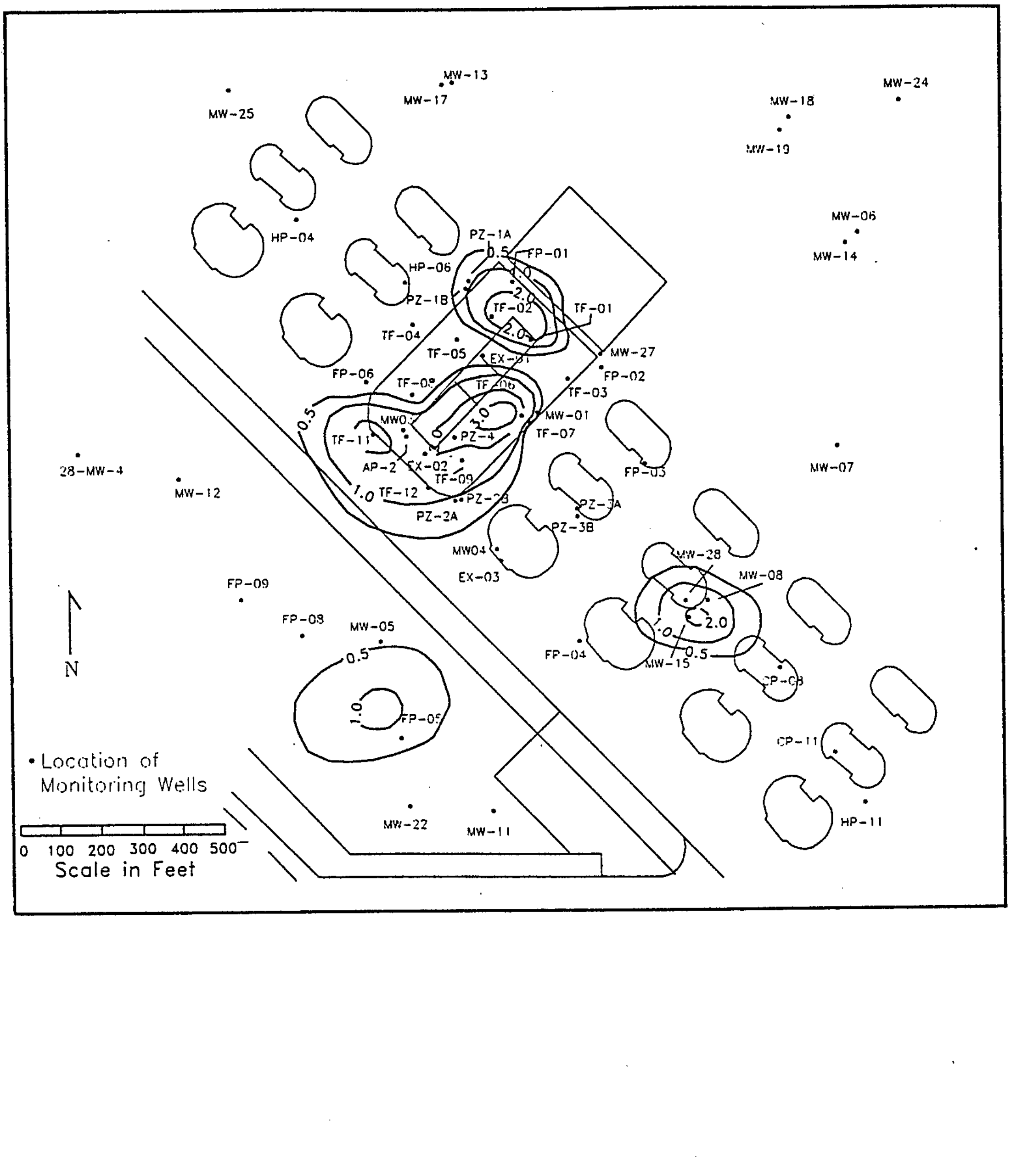


Figure 2. Schematic Diagram Showing Groundwater Monitoring Well Locations at the Panero JP-4 Spill Site, March AFB, CA

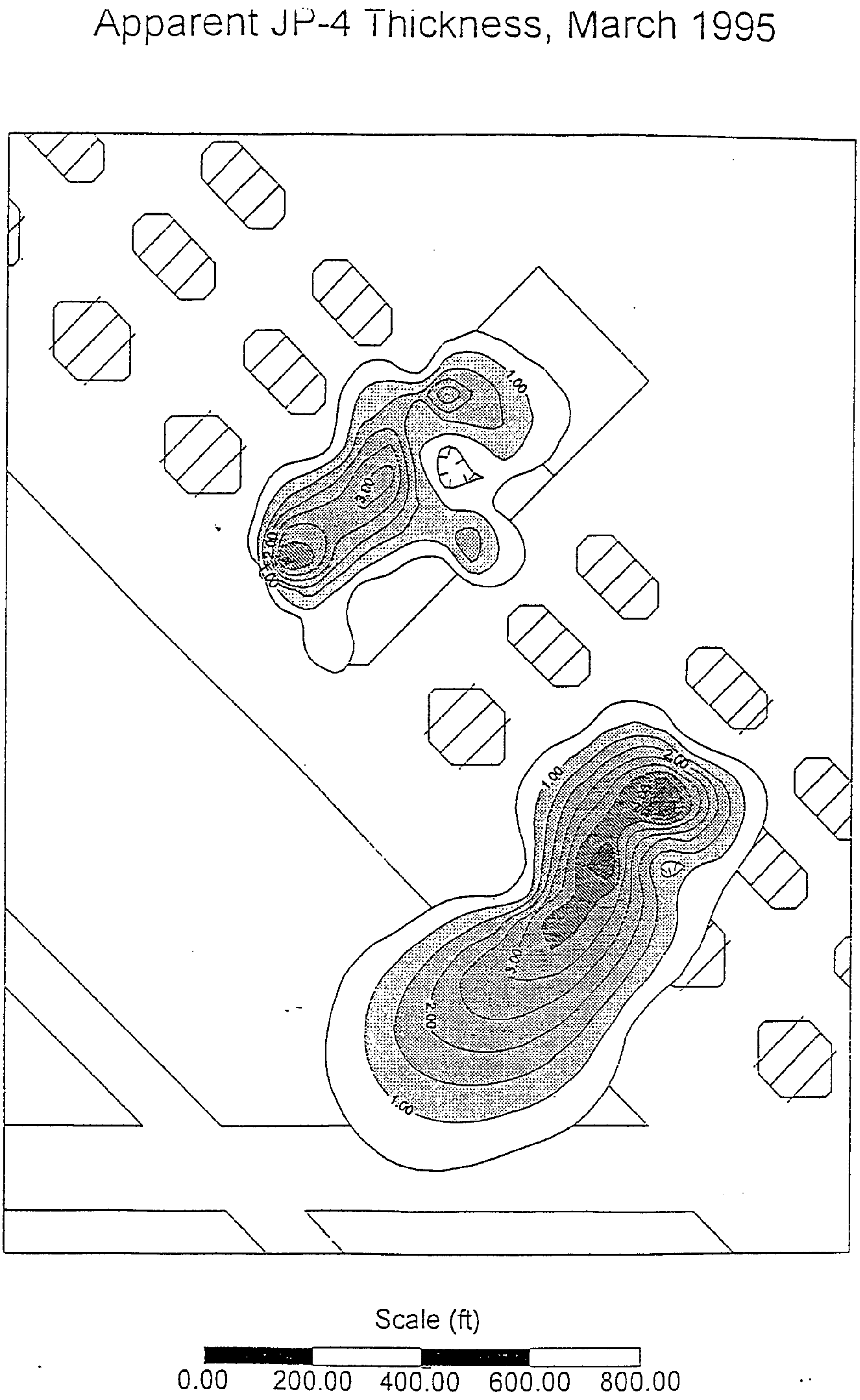


Figure 3. Schematic Diagram Showing Free Product Thickness and Estimated Areal Extent of Free Product, March 1995, at the Panero JP-4 Spill Site, March AFB, CA

Table 1. Screened Interval and Free Product Thickness in Wells at the Panero JP-4 Spill Site, March AFB, CA (April 1995)

Well Number	Screened Interval (ft bgs)	Depth to Free Product (ft)	Free Product Thickness (ft)
PAN MW-01	40 — 80	38.29	0.35
PAN MW-11	32.9 — 62.9	35.65	2.62
PAN MW-15	40.5 — 70.5	34.61	6.21
PAN FP-01	38 — 68	38.34	3.07
PAN FP-02	35 — 65	37.64	0.10
PAN FP-04	35 — 65	37.20	0.30
PAN FP-06	36.6 — 66.6	38.63	0.27
PAN TF-05	38 — 68	38.05	3.68
PAN TF-08	34.5 — 64.5	37.25	2.97

Appendix A. Free-product (JP-4 jet fuel) was observed in several wells at this site (Table 1). Well PAN MW-15 had the largest free product thickness during April 1995. Site characterization will be limited to the Panero JP-4 Spill Site and the initial focus will be on Well PAN MW-15. If preliminary site characterization indicates that Well PAN MW-01 is unsuitable or if site logistics prevent the use of this well, other wells will be evaluated as a substitute for the bioslurper test. Due to the rising water table, dewatering to 1 ft below the water table may be evaluated.

3.0 PROJECT ACTIVITIES

The field activities described in the following sections are planned for the bioslurper pilot test at March AFB. Additional details about the activities are presented in the overall Test Plan and Technical Protocol. As appropriate, specific sections in the overall Test Plan and Technical Protocol are referenced. Table 2 shows the schedule of activities for the Bioslurper Initiative at March AFB.

3.1 Mobilization to the Site

After the site-specific Test Plan is approved, Battelle staff will mobilize equipment to the site. Some of the equipment will be shipped via air express to March AFB prior to staff arrival. The Base Point of Contact (POC) will be asked in advance to find a suitable holding facility to receive the bioslurper pilot test equipment so that it will be easily accessible to the Battelle staff when they arrive with the remainder of the equipment. The exact mobilization date will be confirmed with the Base POC as far

Table 2. Schedule of Bioslurper Pilot Test Activities

Pilot Test Activity	Schedule
Mobilization	Day 1-2
Site Characterization	Day 2-3
LNAPL/Groundwater Interface Monitoring and Baildown Tests	
Soil Gas Survey (Limited)	
Slug Tests	
Monitoring Point Installation (3 monitoring points)	
Soil Sampling (benzene, toluene, ethylbenzene, and xylenes (BTEX); TPH; physical characteristics)	
System Installation	Day 2-3
Test Startup	Day 3
Skimmer Pump Test (2 days)	Day 3-4
Bioslurper Pump Test (4 days)	Day 6-9
Soil Gas Permeability Testing	Day 6
Skimmer Pump Test (continued)	Day 10
In Situ Respiration Test - Air/Helium Injection	Day 10
In Situ Respiration Test - Monitoring	Day 11-16
Drawdown Pump Test (2 days)	Day 11-12
Demobilization/Mobilization	Day 13-14

in advance of fieldwork as is possible. The Battelle POC will provide the Base POC with information on each Battelle employee who will be on site. Battelle personnel will be mobilized to the site after receiving confirmation that the shipped equipment has been received by March AFB.

3.2 Site Characterization Tests

3.2.1 Baildown Tests

The baildown test is the primary test for selection of the bioslurper test well. Baildown tests will be performed at wells that contain measurable thicknesses of LNAPL to estimate the LNAPL recovery potential at those particular wells. In most cases, the well exhibiting the highest rate of LNAPL recovery will be selected for the bioslurper extraction well. A sample of free LNAPL will be collected at this point for analyses of boiling point distribution and BTEX concentration. Detailed procedures for the baildown tests are provided in Section 5.6 of the overall Test Plan and Technical Protocol.

3.2.2 Soil Gas Survey (Limited)

A small-scale soil gas survey will be conducted to identify the best location for installation of the soil gas monitoring points. The soil gas survey will be conducted in areas where historical site data indicate the highest contamination levels. Soil gas monitoring points will be located in areas that exhibit the following soil gas characteristics.

1. Relatively high TPH concentrations (10,000 ppmv or greater).
2. Relatively low oxygen concentrations (between 0% and 2%).
3. Relatively high carbon dioxide concentrations (depending on soil type, between 2% and 10% or greater).

Additional information on the soil gas survey is provided in Section 5.2 of the overall Test Plan and Technical Protocol.

3.2.3 Slug Tests

Slug tests will be performed to determine aquifer characteristics where the bioslurper test well is located. Slug tests will be performed using an in situ pressure transducer and a Hermit data logger data to track pressure (water level) changes induced by a polyvinyl chloride capsule (slug) containing a known volume of water. Slug tests will be performed on wells that do not contain any measurable LNAPL thickness. The candidate wells will be identified upon arrival at the site after the initial LNAPL thickness measurement is made. Using the data collected during the slug test, the ability of the aquifer to recharge with water at the Panero JP-4 Spill Site will be examined. Additional information about the slug test method can be found in Section 5.7 of the overall Test Plan and Technical Protocol.

3.2.4 Monitoring Point Installation

Monitoring points will be installed to determine the radius of influence of the bioslurper system in the vadose zone. A general arrangement of the bioslurping well and monitoring points is shown in Figure 4.

Upon completion of the soil gas survey and baildown tests, at least three soil gas monitoring points will be installed to measure soil gas changes that occur during bioslurper operation. Drill cuttings which are generated will be containerized immediately to prevent dust problems on the flightline. The monitoring points should be located in highly contaminated soils within the free-phase plume and should be positioned to allow detailed monitoring of the in situ changes in soil gas composition caused by the bioslurper system. A schematic diagram of a typical soil gas monitoring points is shown in Figure 5. All monitoring points will be completed at grade. Information on monitoring point installation can be found in Section 4.2.1 of the overall Test Plan and Technical Protocol.

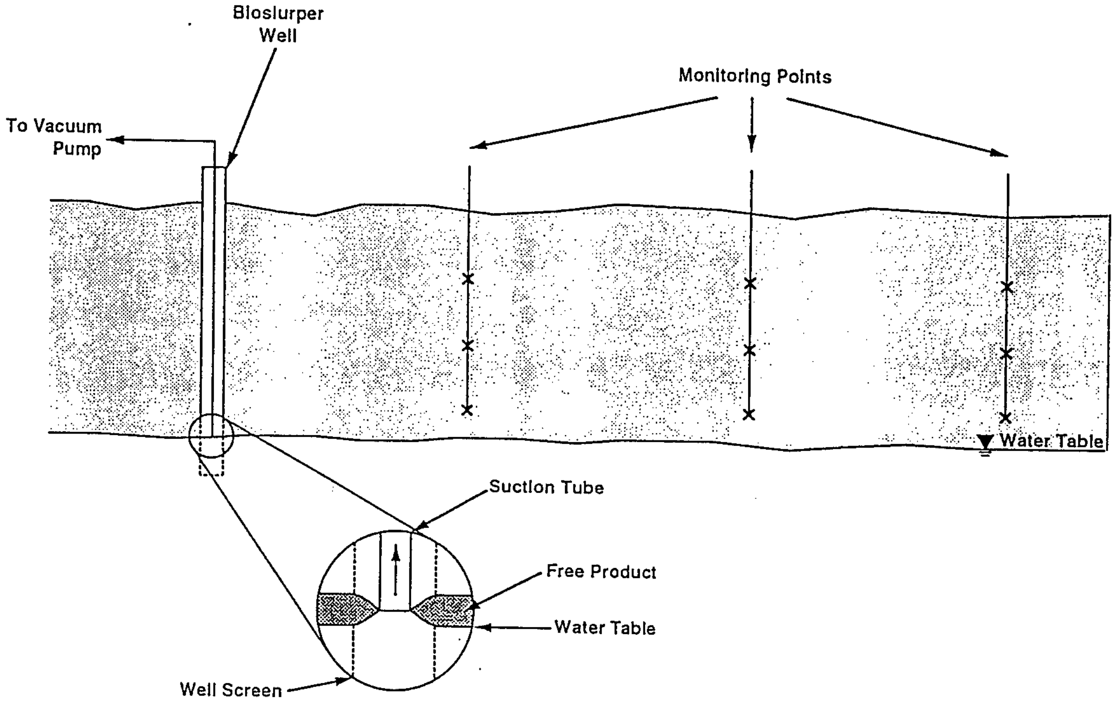


Figure 4. General Bioslurper Well and Monitoring Point Arrangement

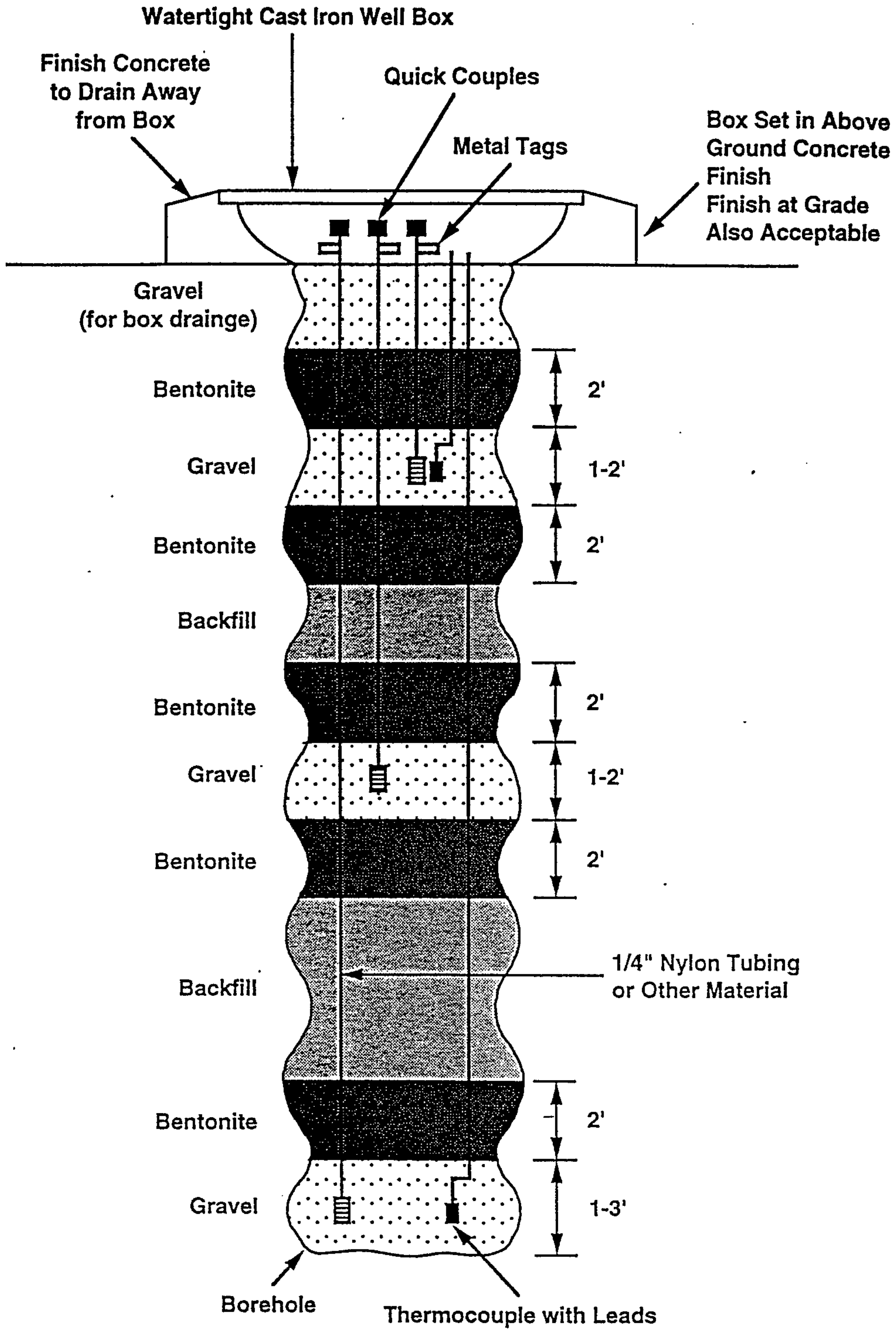


Figure 5. Schematic Diagram of a Typical Soil Gas Monitoring Point

3.2.5 Soil Sampling

Soil samples will be collected to determine the physical and chemical composition of the soil near the bioslurper test site. Soil samples will be collected from the boreholes advanced for monitoring point installation at two or three locations at the site. Generally, samples will be collected from the capillary fringe over the free product. Drill cuttings which are generated will be containerized immediately to prevent dust problems on the flightline.

Soil samples from each boring will be analyzed for BTEX, bulk density, moisture content, particle size distribution, porosity, and TPH. Section 5.5.1 of the overall Test Plan and Technical Protocol contains additional information on the field measurements and sample collection procedures for soil sampling.

3.3 Bioslurper System Installation and Operation

3.3.1 System Setup

After the preliminary site characterization has been completed and the bioslurper candidate well has been selected, the shipped equipment will be mobilized from the holding facility to the test site, and the bioslurper system will be assembled. Figure 6 shows a flow diagram of the bioslurper process. Figure 7 is a schematic diagram of a typical bioslurper extraction well that will be installed using an existing recovery well at March AFB.

Before the LNAPL recovery tests are initiated, all relevant baseline field data will be collected and recorded. These data will include soil gas concentrations, initial soil gas pressures, the depth to groundwater, and the LNAPL thickness. Ambient soil and all atmospheric conditions (e.g., temperature, humidity, barometric pressure) also will be recorded. All emergency equipment (i.e., emergency shutoff switches and fire extinguishers) will be installed and checked for proper operation at this time.

A clear, level 20- by 10-ft area near the well selected for the bioslurper test installation will be identified to station the equipment required for bioslurper system operation. Additional information on bioslurper system installation is provided in Section 6.0 of the overall Test Plan and Technical Protocol.

3.3.2 System Shakedown

A brief startup test will be conducted to ensure that the system is constructed properly and operates safely. All system components will be checked for problems and/or malfunctions. A checklist will be provided to document the system shakedown.

3.3.3 System Startup and Test Operations

After installation is complete and the bioslurper system is confirmed to be operating properly, the LNAPL recovery tests will be started. The Bioslurper Initiative has been designed to evaluate the effectiveness of bioslurping as an LNAPL recovery technology relative to conventional gravity-driven LNAPL recovery technologies. The Bioslurper Initiative Test Plan and Technical Protocol includes three separate LNAPL recovery tests: (1) a skimmer pump test, (2) a bioslurper pump test, and (3) a

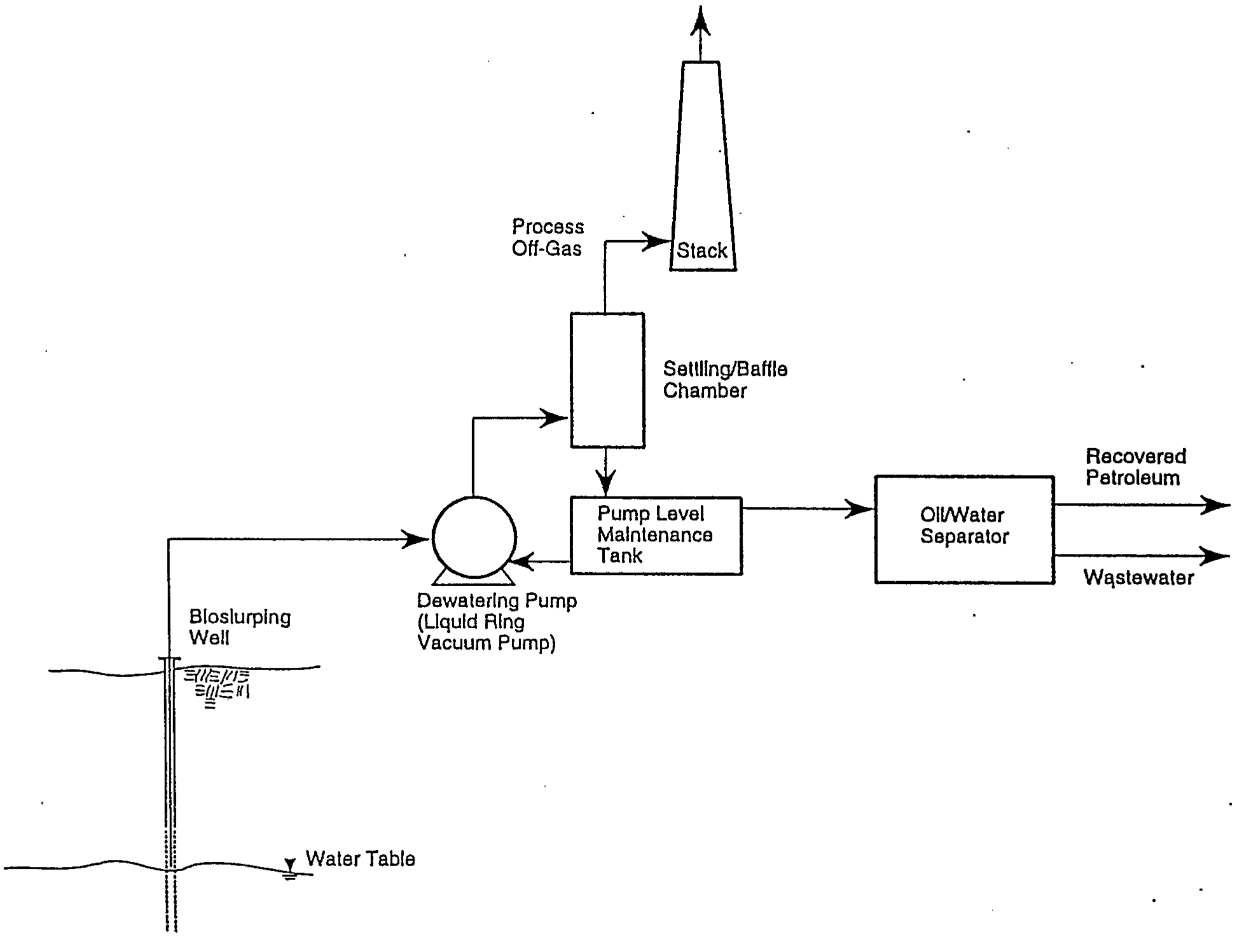


Figure 6. Bioslurper Process Flow

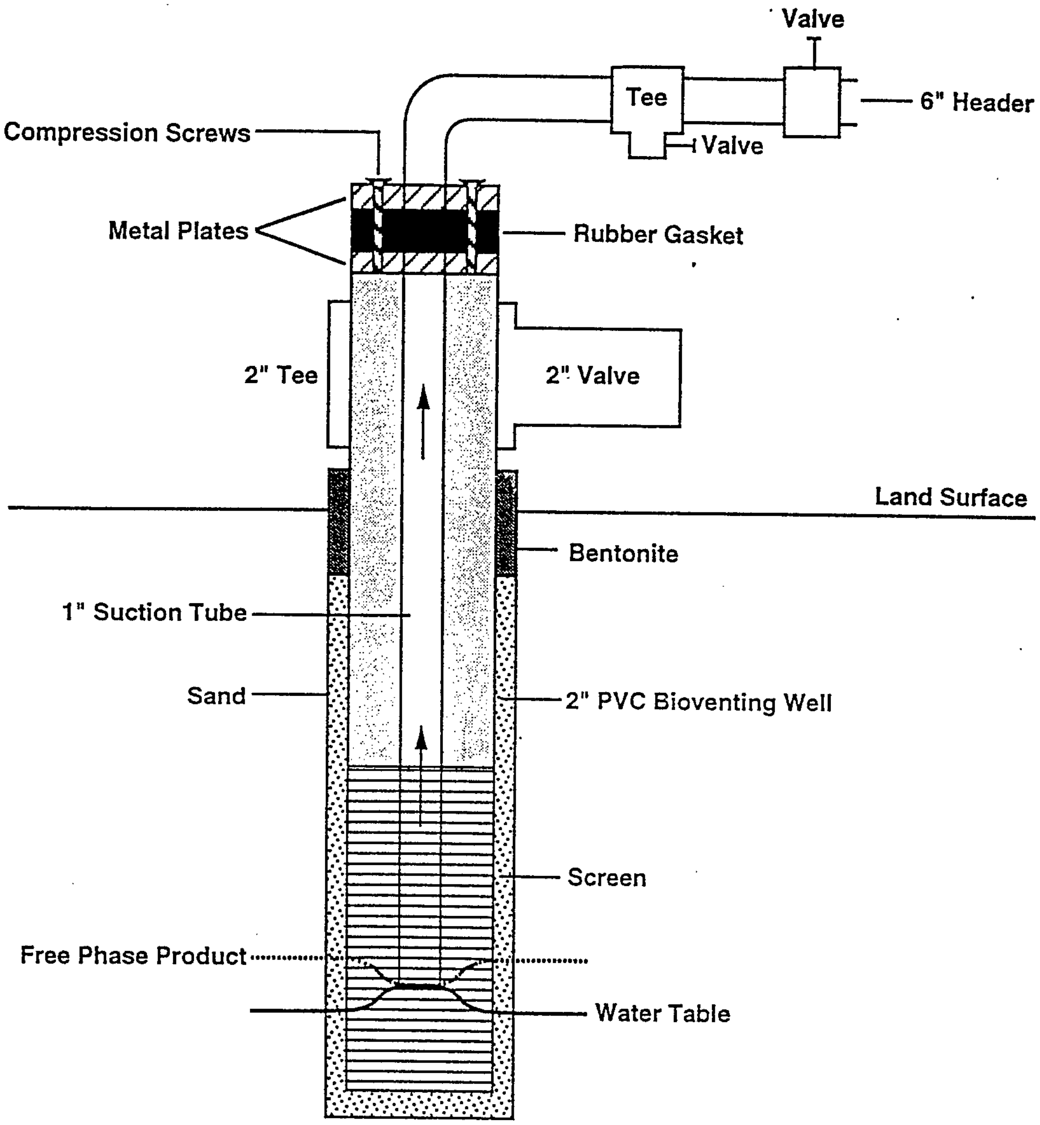


Figure 7. Schematic Diagram of a Typical Bioslurper Well

drawdown pump test. The three recovery tests are described in detail in Section 7.3 of the overall Test Plan and Technical Protocol.

The bioslurper system operating parameters that will be measured during operation are vapor discharge, aqueous effluent, LNAPL recovery volume rates, vapor discharge volume rates, and groundwater discharge volume rates. Vapor monitoring will consist of periodic monitoring of TPH using hand-held instruments supplemented by two samples collected for laboratory analysis of BTEX and TPH. Two samples of aqueous effluent will be collected for analysis of BTEX and TPH. Recovered LNAPL volume will be recorded using an in-line flow-totalizing meter. The off-gas discharge volume will be measured using a calibrated pitot tube, and the groundwater discharge volume will be recorded using an in-line flow-totalizing meter. Section 8.0 of the overall Test Plan and Technical Protocol describes process monitoring of the bioslurper system.

3.3.4 Soil Gas Profile/Oxygen Radius of Influence Test

Changes in soil gas profiles will be measured before and during the bioslurper pump test. Soil gas will be monitored for concentrations of oxygen, carbon dioxide, and TPH using field instruments. These measurements will be used to determine the oxygen radius of influence of the bioslurper system.

3.3.5 Soil Gas Permeability Tests

A soil gas permeability test will be conducted concurrently with startup of the bioslurper pump test. Soil gas permeability data will support the process of estimating the vadose zone radius of influence of the bioslurper system. Soil gas permeability results also will aid in determining the number of wells required if it is decided to treat the site with a full-scale bioslurper system. The soil gas permeability test method is described in Section 5.7 of the overall Test Plan and Technical Protocol.

3.3.6 LNAPL and Water-Level Monitoring

During the bioslurper pump test, the LNAPL and water levels will be monitored in a well adjacent to the extraction well if such a well exists. The top of the monitoring well will be sealed from the atmosphere to contain the subsurface vacuum. Additional information for the monitoring of fluid levels during the bioslurper pilot test can be found in Section 4.3.4 of the overall Test Plan and Technical Protocol.

3.3.7 In Situ Respiration Tests

An in situ respiration test will be conducted after completion of the bioslurper operating tests. The in situ respiration test will involve injection of air and helium into selected soil gas monitoring points, followed by monitoring changes in concentration of oxygen, carbon dioxide, TPH, and helium in soil gas at the injection point. Measurement of the soil gas composition typically will be conducted at 2, 4, 6, and 8 hours and then every 4 to 12 hours for about 2 days. Timing of the tests will be adjusted based on oxygen-use rate. If oxygen depletion occurs rapidly, more frequent monitoring will be required. If oxygen depletion is slow, less frequent readings will be acceptable. The oxygen utilization rate will be used to estimate the biodegradation rate at the site. Further information on the procedures and data collection for in situ respiration testing is given in Section 5.8 of the overall Test Plan and Technical Protocol.

3.3.8 Extended Testing

The AFCEE/ERT will extend the operation of the bioslurper system for up to 6 months if LNAPL recovery rates are promising and viable long-term vapor and aqueous discharge requirements have been established. When extended testing is to be performed, the Air Force will need to provide electrical power for long-term operation of the bioslurper pump. Disposition of all generated wastes and routine operation and maintenance of the system will be the Air Force's responsibility. Battelle will provide technical support during the extended testing operation.

3.4 Demobilization

Once all necessary tests have been completed at March AFB, the equipment will be disassembled by Battelle staff and will be moved back to the holding facility, where it will remain until its next destination is determined. Battelle staff will receive this information and will be responsible for shipment of the equipment to the next site before they leave March AFB.

4.0 BIOSLURPER SYSTEM DISCHARGE

4.1 Vapor Discharge Disposition

Because of the short duration of the bioslurper pilot test, it can be assumed that the concentrations of TPH released to the atmosphere will be approximately 65 lb/day and benzene will be <1.0 lb/day without treatment. This value is based on the average discharge rates at two bioslurper test sites (Travis AFB and Wright-Patterson AFB) that are contaminated with a similar type of fuel as that found at the Panero JP-4 Spill Site. The discharge value may vary depending on concentrations in soil gas and the permeability of the soil. The data for benzene and TPH discharge levels for five previous bioslurper sites are presented in Table 3.

Table 3. Benzene and TPH Vapor Discharge Levels at Previous Bioslurper Test Sites

Site Location	Fuel Type	Extraction Rate (scfm)	Benzene (ppmv)	TPH (ppmv)	Benzene Discharge (lb/day)	TPH Discharge (lb/day)
Andrews AFB	No. 2 Fuel Oil	8.0	16	2,000	0.0010	0.20
Site 1, Bolling AFB	No. 2 Fuel Oil	4.0	0.20	153	0.00030	0.0090
Site 2, Bolling AFB	Gasoline	21	370	70,000	2.3	470
Johnston Atoll	Jet Fuel	10	0.60	975	0.0017	5.7
Travis AFB	Jet Fuel	20	100	10,800	0.58	130
Wright-Patterson AFB	Jet Fuel	3.0	ND	595	0	1.0

ND = Not detected.

Vapor discharge will be treated through an internal combustion engine (ICE). The ICE is subject to a categorical permitting exclusion and is the best available technology for treatment of hydrocarbon vapors. The ICE is capable of >99% destruction of hydrocarbon vapors; therefore, given this treatment efficiency, vapor emissions at this site after treatment with the ICE would be <1.0 lb/day TPH and <0.01 lb/day benzene. A cost and performance document on the ICE is provided in Appendix B.

To ensure the safety and regulatory compliance of the bioslurper system, field soil gas screening instruments will be used to monitor vapor discharge concentration. The volume of vapor discharge will be monitored daily using airflow instruments. If state regulatory requirements will not permit the expected amount of organic vapor discharge to the atmosphere, the Base POC should inform AFCEE and Battelle so that alternative plans can be made prior to mobilization to the site. Table 4 presents information typically required to complete an air release registration form.

Table 4. Air Release Summary Information

Data Item	Air Release Information
Contractor Point-of-Contact	Jeff Kittel, (614) 424-6122
Contractor address	Battelle, 505 King Avenue, Columbus, OH 43201
Estimated total quantity of petroleum product to be recovered	To be determined
Description of petroleum product to be recovered	JP-4 jet fuel
Planned date of test start	To be determined
Test duration	9-10 days (active pumping)
Maximum expected volatile organic compound level in air	~65 lb/day TPH, <1.0 lb/day benzene
Stack height above ground level	10 ft

4.2 Aqueous Influent/Effluent Disposition

The flowrate of groundwater pumped by the bioslurper will be less than 5 gpm. However, it may be necessary in California to obtain a groundwater pumping waiver or registration permit. If one is required, it is hereby requested.

Operation of the bioslurper system will generate an aqueous waste discharge that will be passed through an oil/water separator. The wastewater will be disposed by discharge directly to the Base oil/water separator of the Panero treatment system. Since existing Base wastewater channels can be used, no water discharge permits will be required.

4.3 Free-Product Recovery Disposition

The bioslurper system will recover free-phase product from the pilot tests performed at March AFB. Free product recovered by the bioslurping tests will be turned over to the Base for disposal and/or recycling. The volume of free product recovered will not be known until the tests have been performed. The maximum recovery rate for this system is 5 gpm, but the actual rate of LNAPL recovery likely will be much lower.

5.0 SCHEDULE

The schedule for the bioslurper fieldwork at March AFB will depend on approval of the project Test Plan. Battelle will determine a definitive schedule as soon as possible after approval is received. Battelle will have two to three staff members on site for approximately 2 weeks to conduct all necessary pilot testing. At the conclusion of the field testing at March AFB, all staff will return their Base passes and remove all bioslurper field testing equipment from the Base before they leave the site.

6.0 PROJECT SUPPORT ROLES

This section outlines some of the major functions of personnel from Battelle, March AFB, and AFCEE during the bioslurper field test.

6.1 Battelle Activities

The obligations of Battelle in the Bioslurper Initiative at March AFB will be to supply the staff and equipment necessary to perform all the tests on the bioslurper system. Battelle also will provide technical support in the areas of water and vapor discharge permitting, digging permits, staff support during the extended testing period, and any other technical areas that need to be addressed.

6.2 March AFB Support Activities

To support the necessary field tests at March AFB, the Base must be able to provide the following:

a. Any digging permits and utility clearances need to be obtained prior to the initiation of the fieldwork. Any underground utilities should be clearly marked to reduce the chance of utility damage and/or personal injury during soil gas probe and possible well installation. Battelle will not begin field operations without these clearances and permits.

b. The Air Force will be responsible for obtaining Base and site clearance for the Battelle staff that will be working at the Base. The Base POC will be furnished with all necessary information on each staff member at least 1 week prior to field startup.

c. Access to the Base oil/water separator of the Panero treatment system must be furnished so that Battelle staff can discharge the bioslurper aqueous effluent directly to this treatment system.

d. Regulatory approval, if required, must be obtained by the Base POC prior to startup of the bioslurper pilot test. As stated previously, it is likely that a waiver to allow air releases or a point source air release registration will be required for emissions of approximately 65 lb/day of TPH and <1.0 lb/day of benzene. A waiver for pumping and discharging groundwater at a rate of 5 gpm is hereby requested. The Base POC will obtain all necessary Base permits prior to mobilization to the site. Battelle will provide technical assistance in preparing regulatory approval documents.

e. The Base will be responsible for the disposition of all waste generated from the pilot testing. Such waste includes any soil cuttings generated from drilling, and all aqueous wastestreams produced from the bioslurper tests. All free product recovered from the bioslurper operation will be disposed of or recycled by the Base. Battelle will provide technical assistance in disposing of the waste generated from the bioslurper pilot test.

f. Before field activities begin, the Health and Safety Plan will be finalized with information provided by the Base POC. Table 5 is a checklist for the information required to complete the Health and Safety Plan. All emergency information will be obtained by the Site Health and Safety office before operations begin.

6.3 AFCEE Activities

The AFCEE POC will act as a liaison between Battelle and March AFB staff. The AFCEE POC will ensure that all necessary permits are obtained and the space required to house the bioslurper field equipment is found.

The following is a listing of Battelle, AFCEE, and March AFB staff who can be contacted in cases of emergency and/or for required technical support during the Bioslurper Initiative tests at March AFB.

Battelle POCs	Jeff Kittel	(614) 424-6122
	Eric Drescher	(614) 424-3088
AFCEE POC	Patrick Haas	(210) 536-4314
March AFB POC		
Regulatory POCs		

7.0 REFERENCE

Battelle. 1995. *Test Plan and Technical Protocol for Bioslurping*. Prepared by Battelle Columbus Operations for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas.

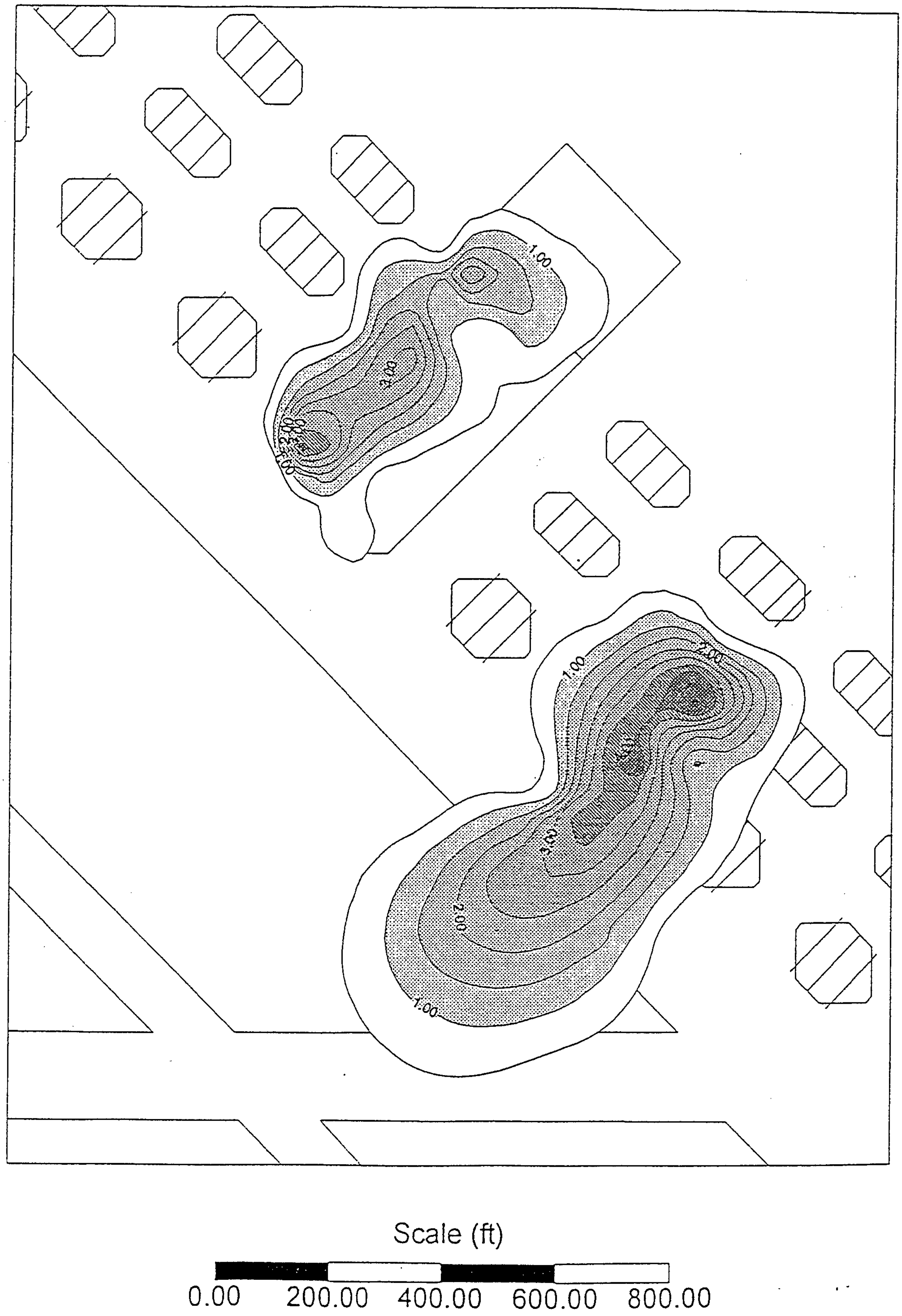
Table 5. Health and Safety Information Checklist

Emergency Contacts	Name	Telephone Number
Hospital: March AFB		
Fire Department		
Ambulance and Paramedics		
Police Department		
Explosives Unit		
EPA Emergency Response Team		
Other		
Program Contacts		
Air Force	Patrick Haas	(210) 536-4314
Battelle	Jeff Kittel	(614)424-6122
	Eric Drescher	(614) 424-3088
March AFB		
Other		
Emergency Routes		
Hospital (maps attached)		
Other		

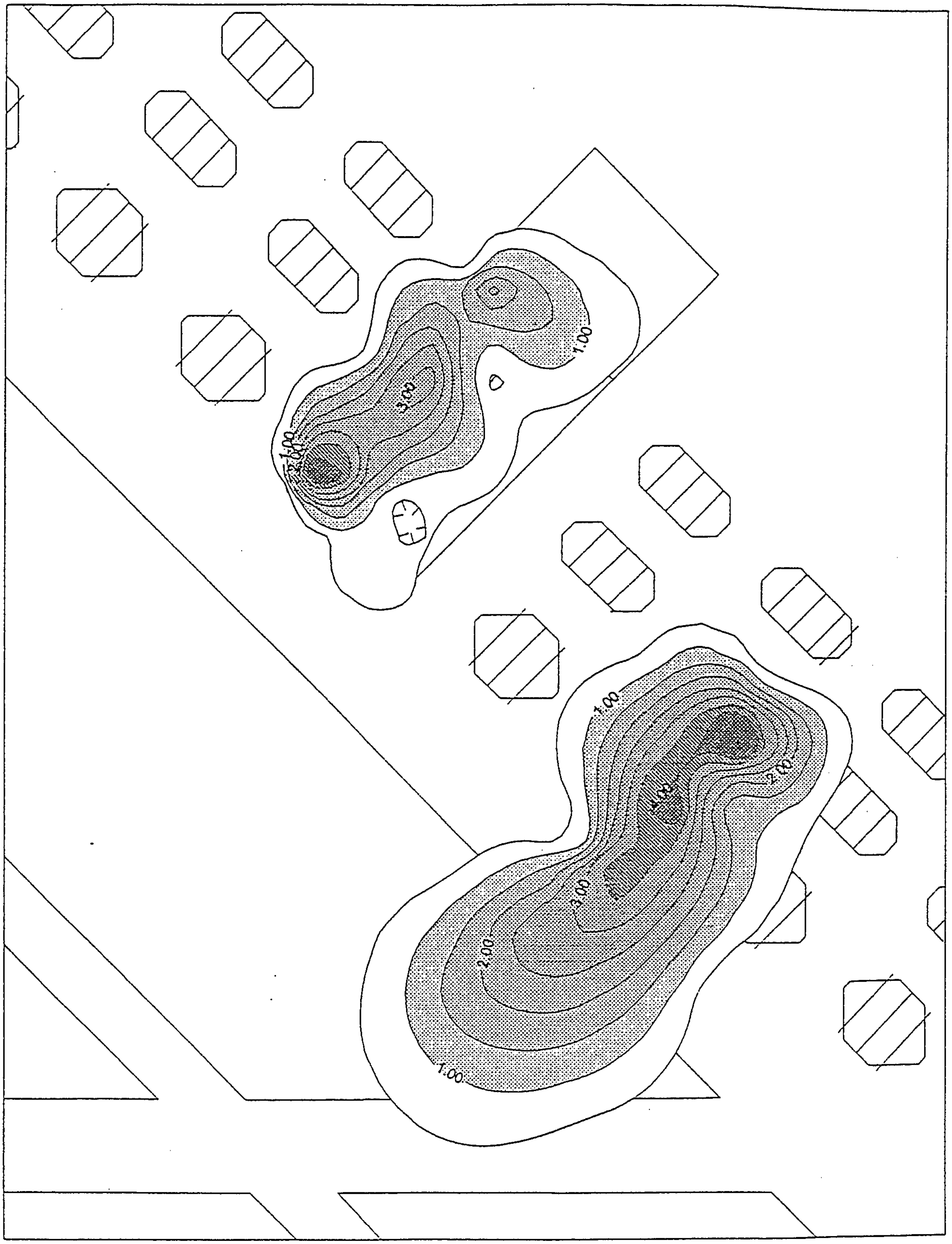
APPENDIX A

SITE MAPS SHOWING AREAL EXTENT AND THICKNESSES OF FREE PRODUCT AT THE PANERO JP-4 SPILL SITE, MARCH AFB, CA

Apparent JP-4 Thickness, February 1995



Apparent JP-4 Thickness, January 1995



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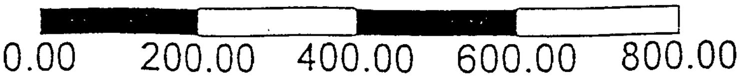
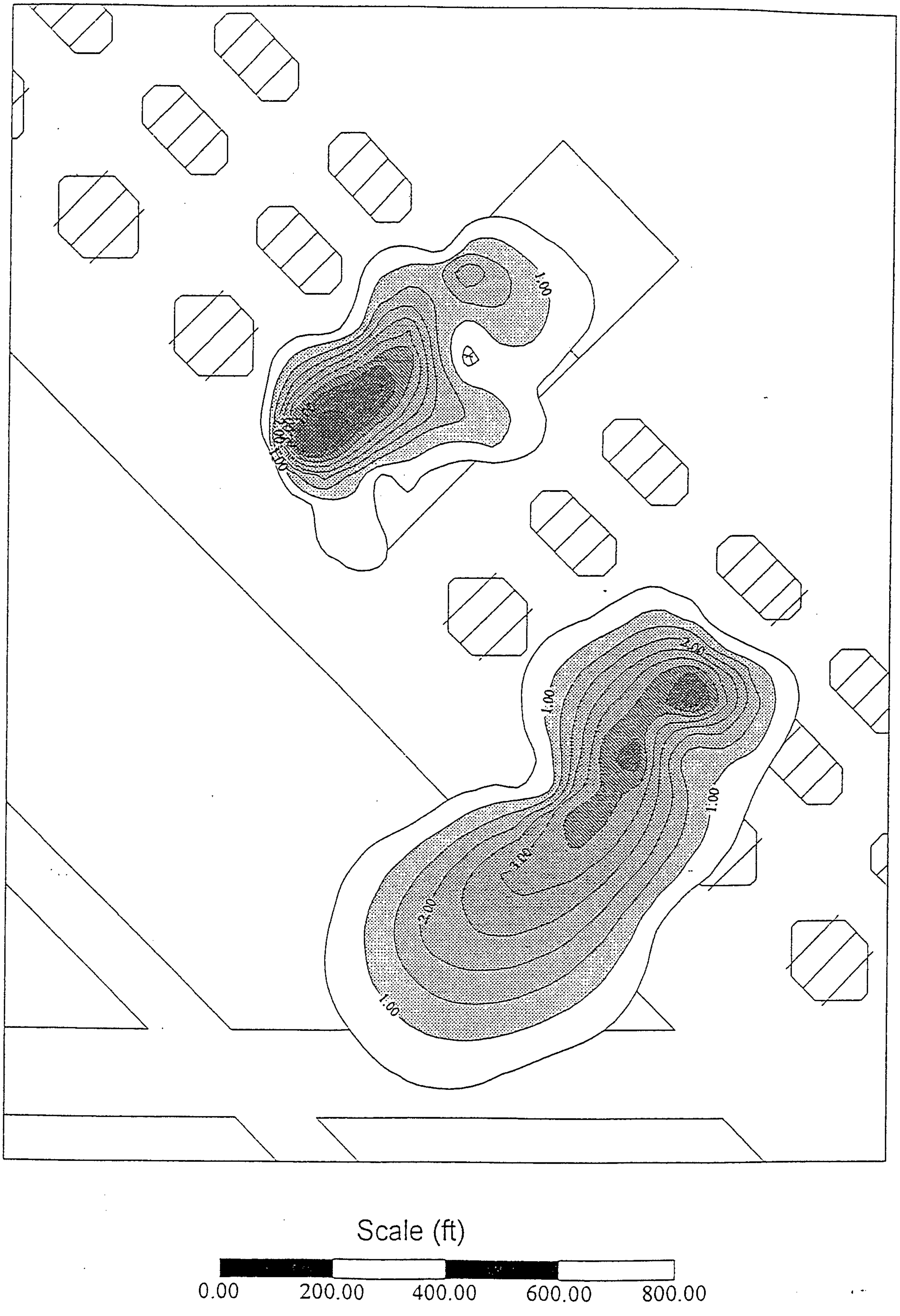


Apparent JP-4 Thickness, December 1994

Apparent JP-4 Thickness, November 1994

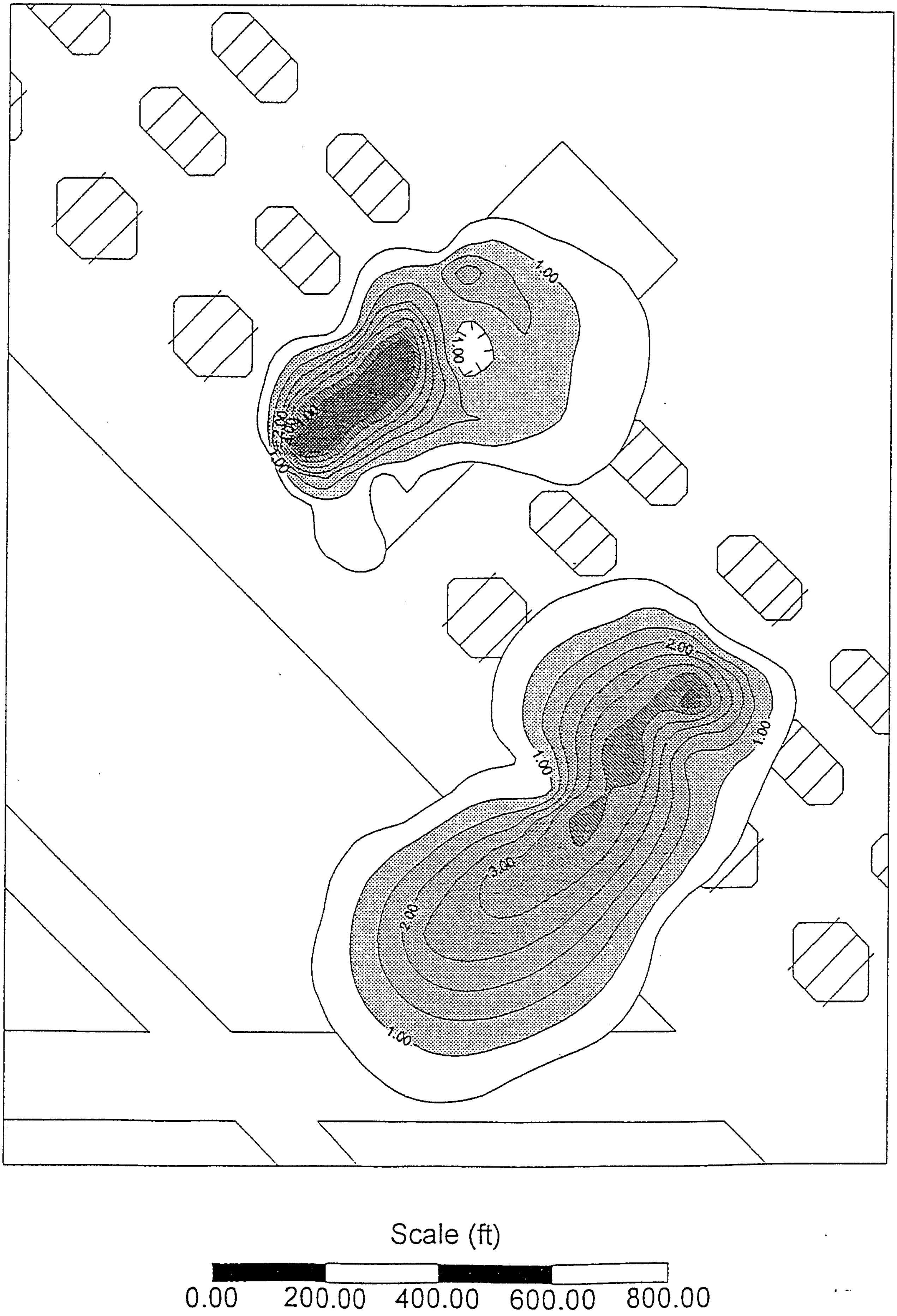


Apparent JP-4 Thickness, October 1994

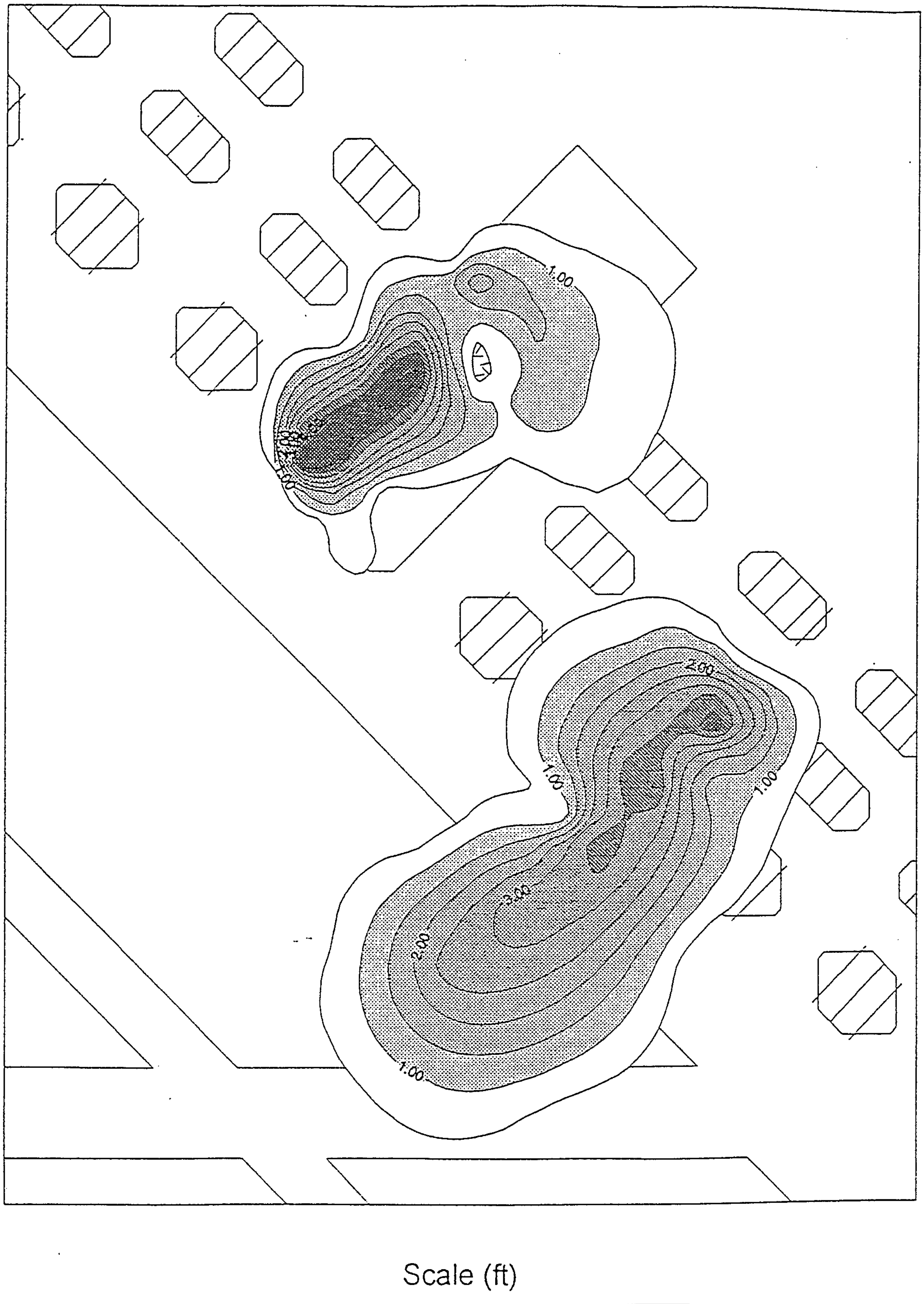
Apparent JP-4 Thickness, September 1994

Apparent JP-4 Thickness, August 1994

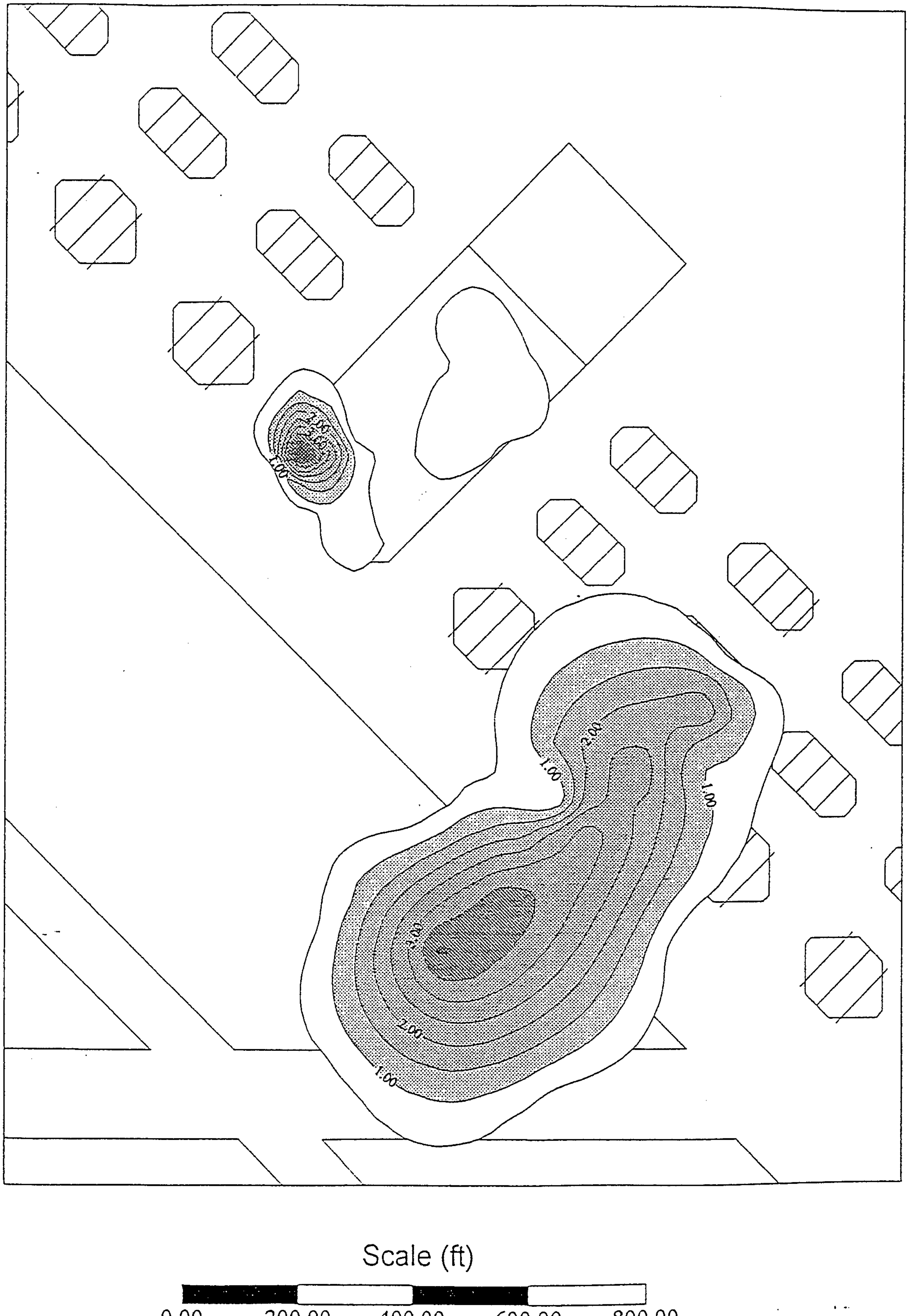
Apparent JP-4 Thickness, July 1994



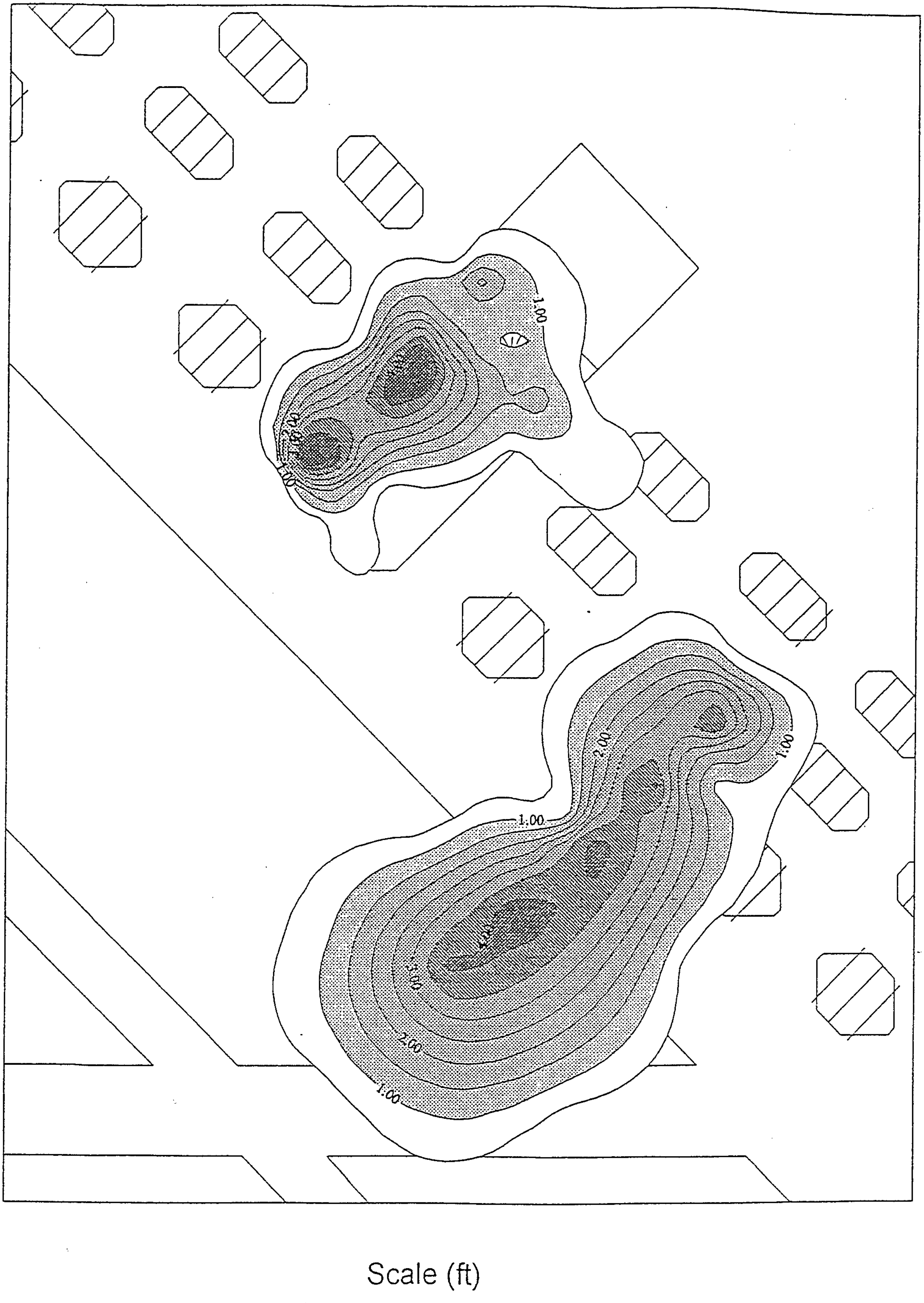
Apparent JP-4 Thickness, June 1994



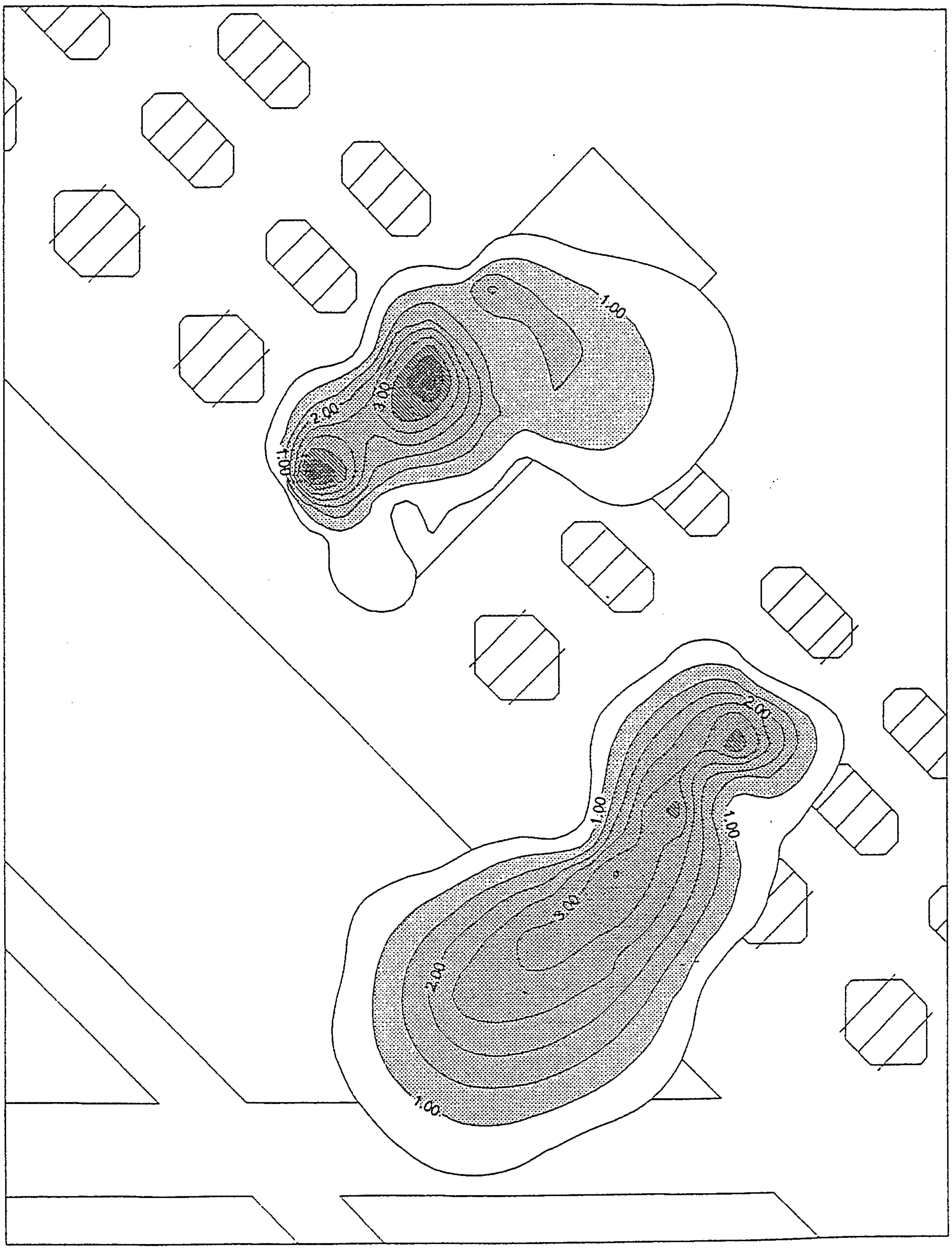
Apparent JP-4 Thickness, May 1994



Apparent JP-4 Thickness, April 1994



Apparent JP-4 Thickness, March 1994



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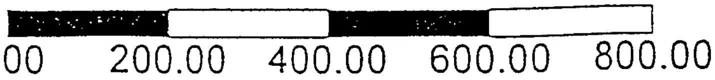
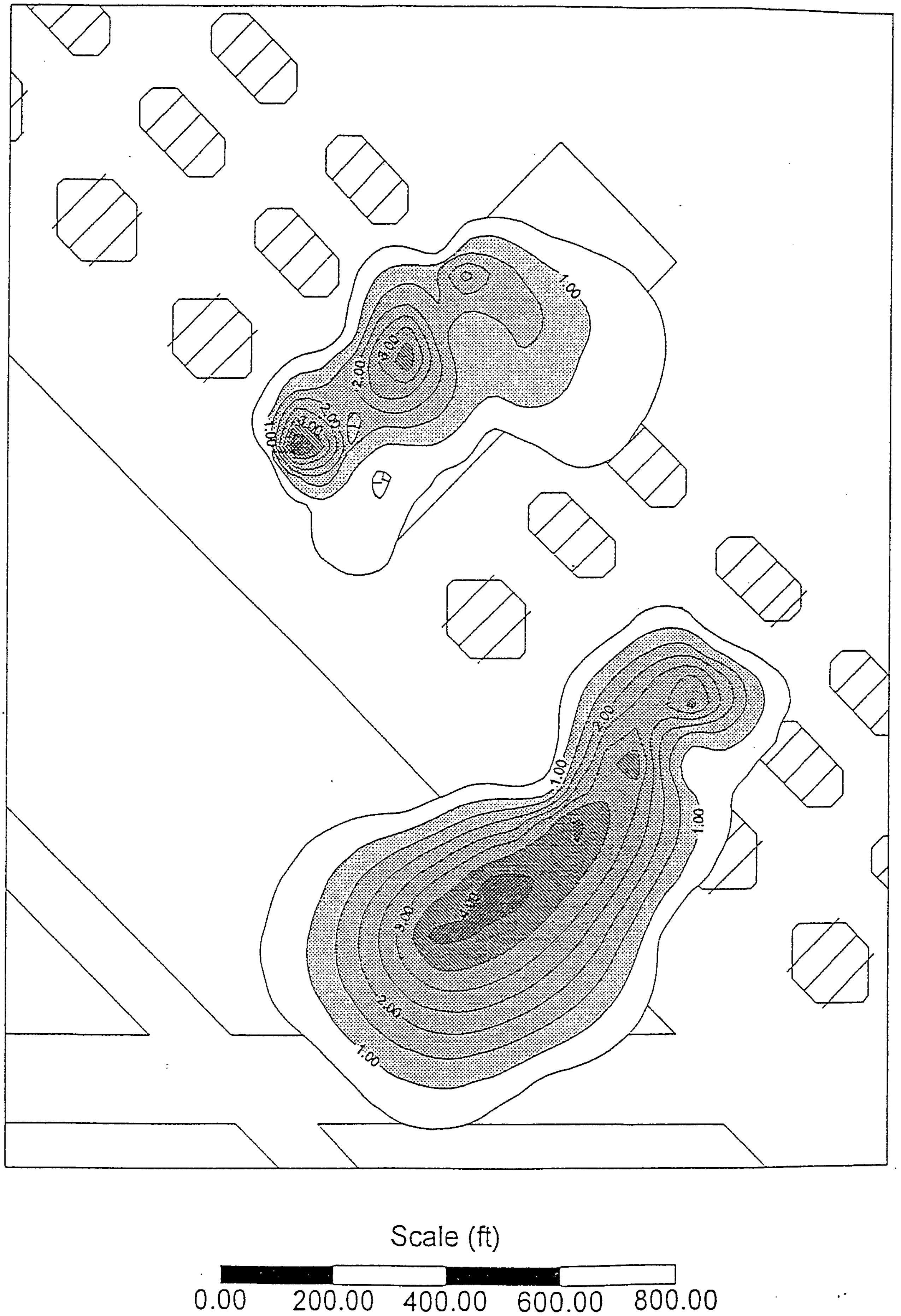


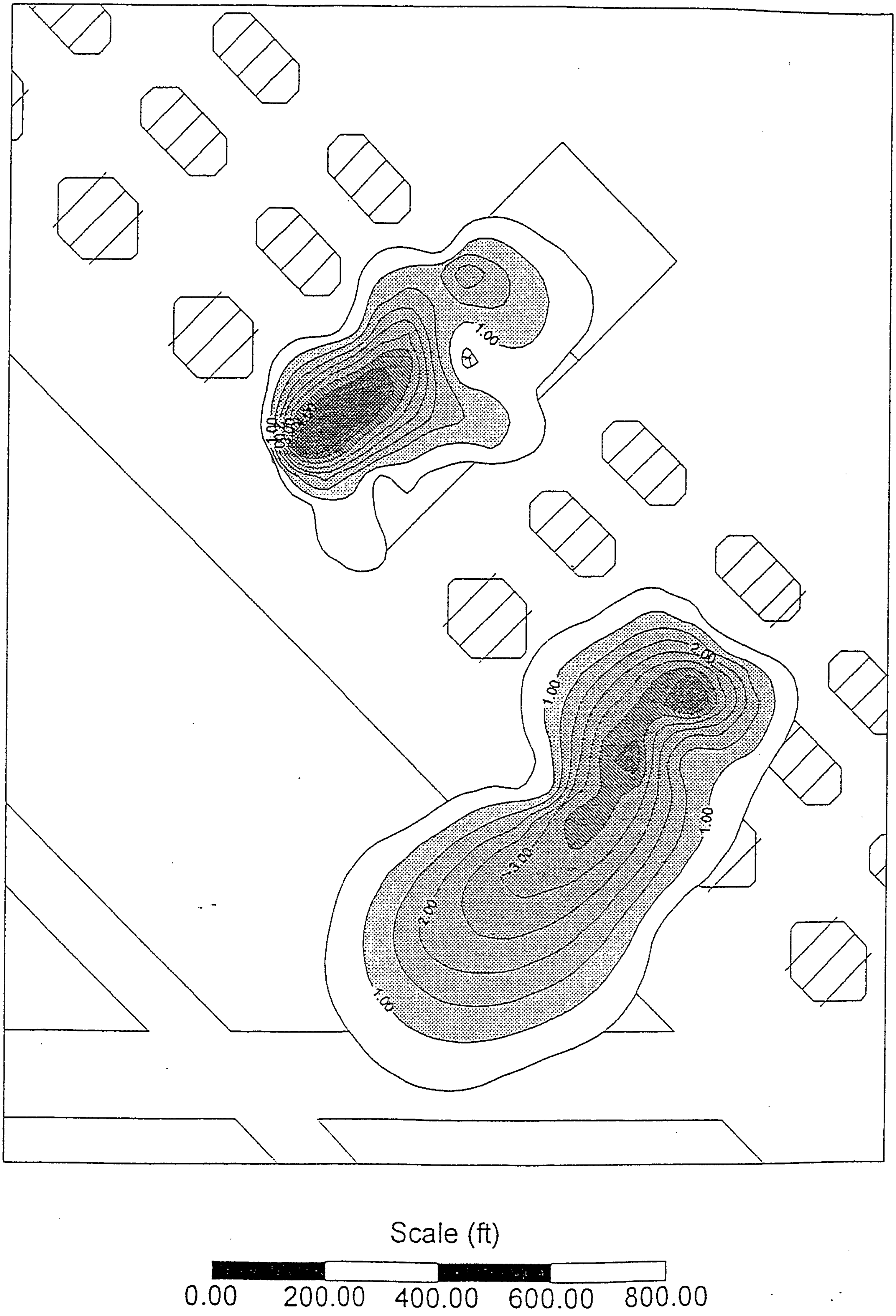
Apparent JP-4 Thickness, Febuary 1994

Apparent JP-4 Thickness, January 1994

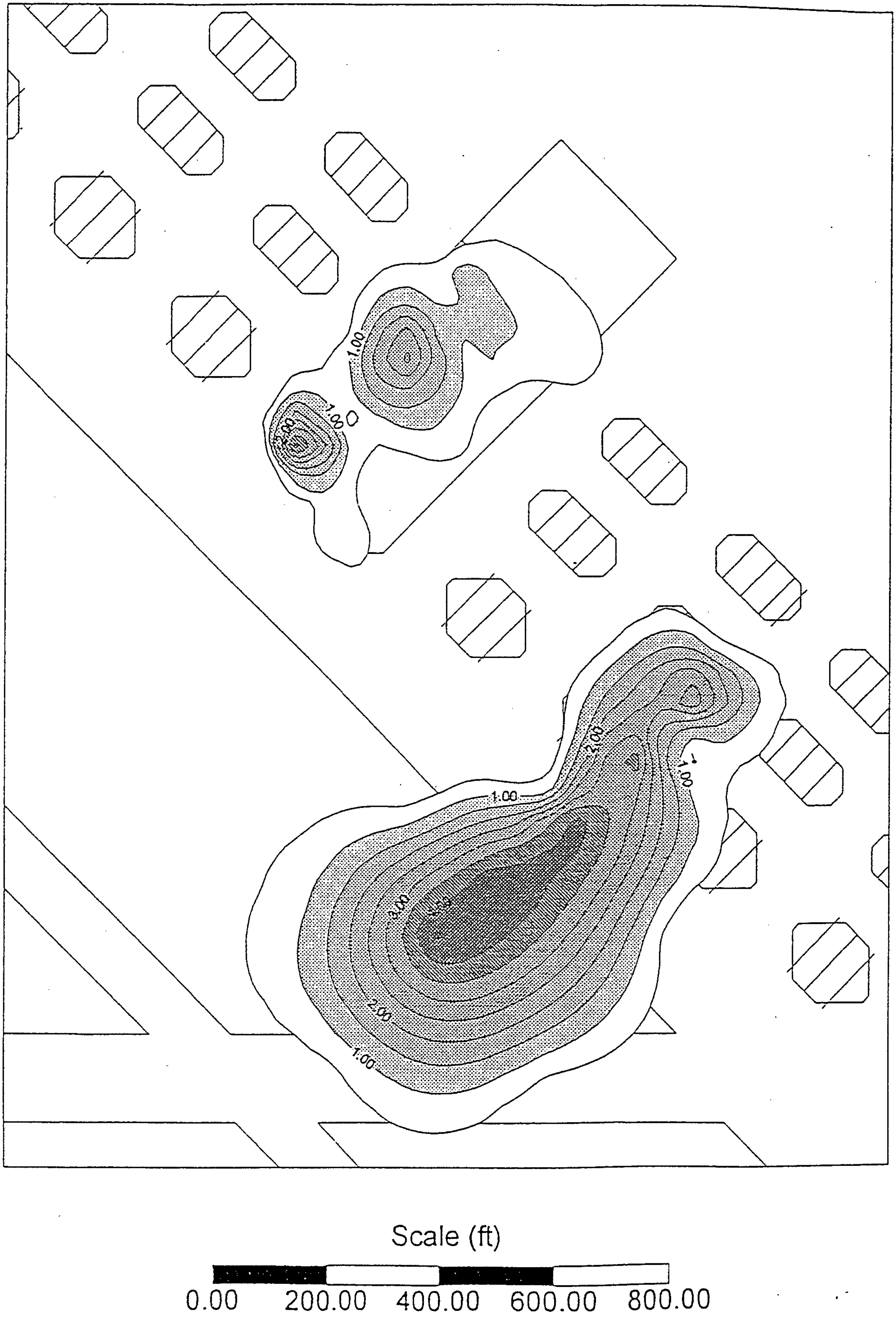
Apparent JP-4 Thickness, December 1993



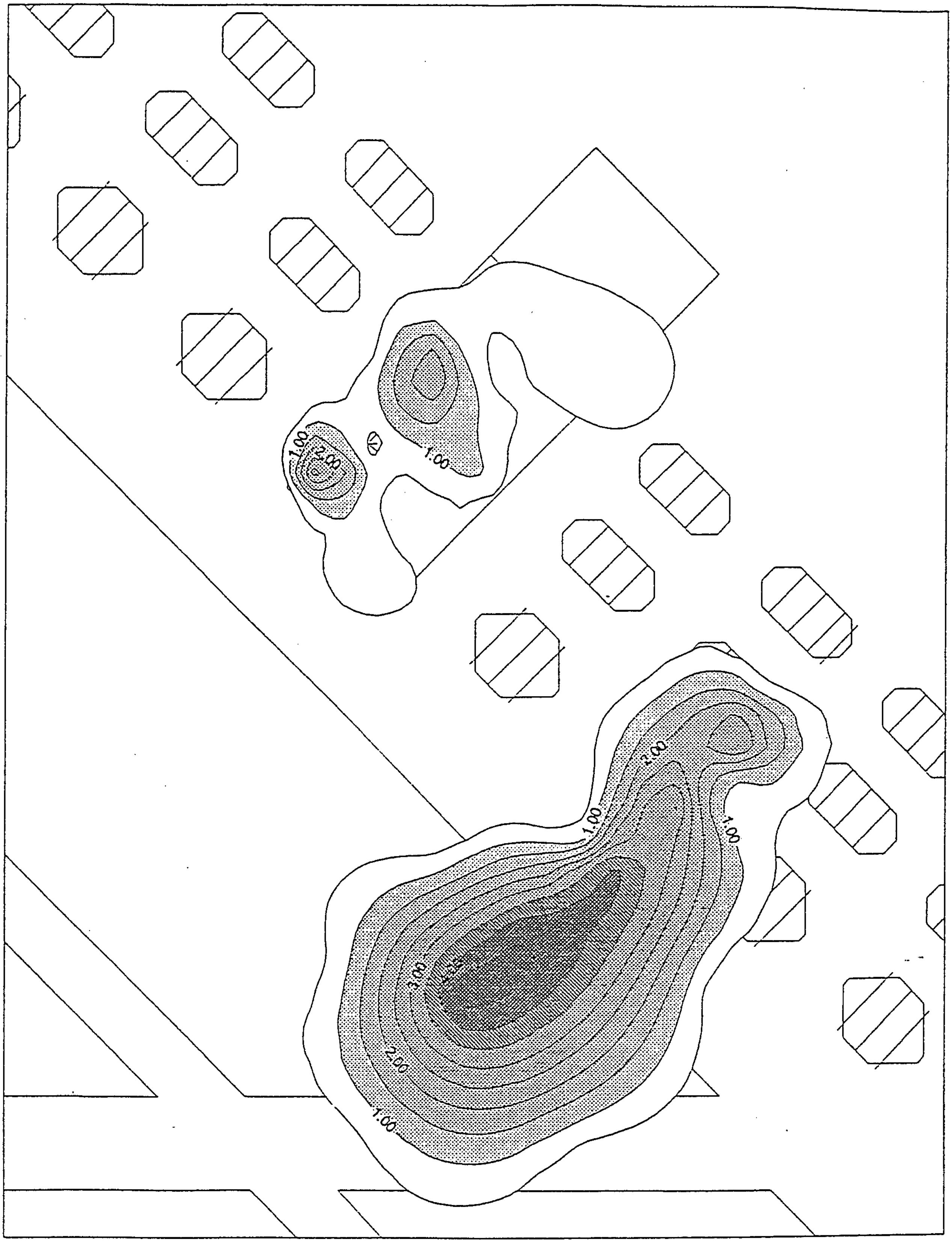
Apparent JP-4 Thickness, November 1993

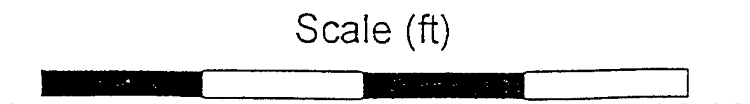


Apparent JP-4 Thickness, October 1993

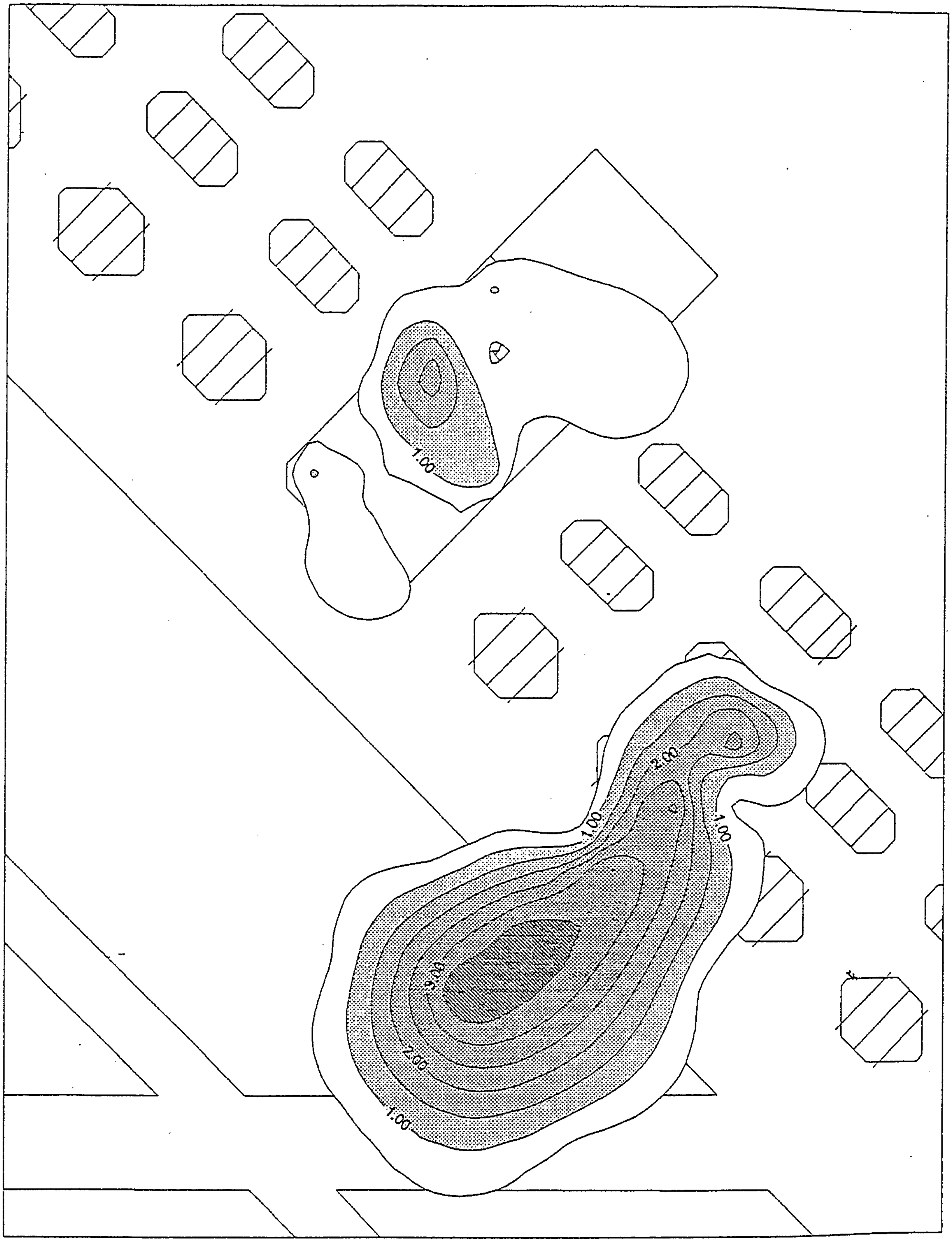


Apparent JP-4 Thickness, September 1993



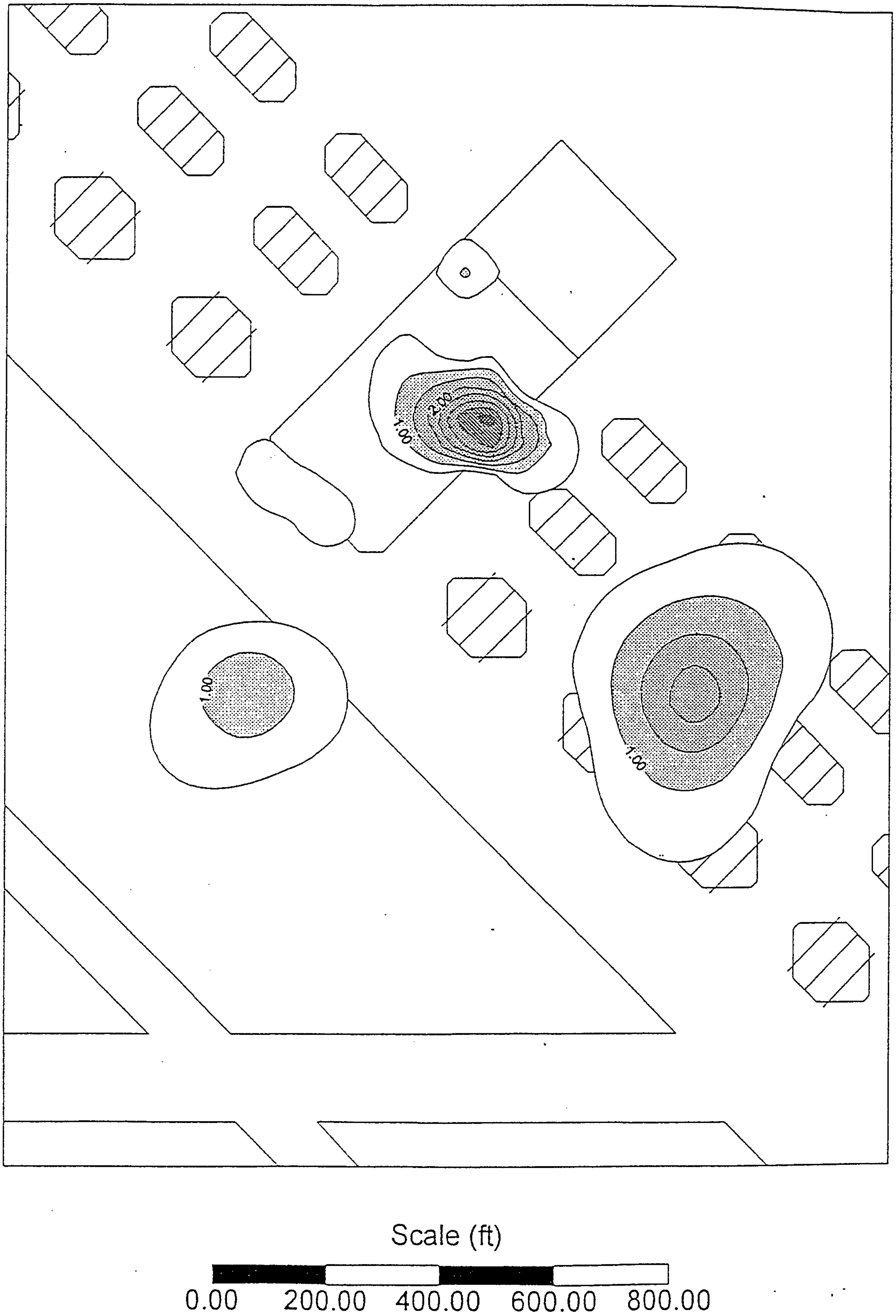


Apparent JP-4 Thickness, August 1993

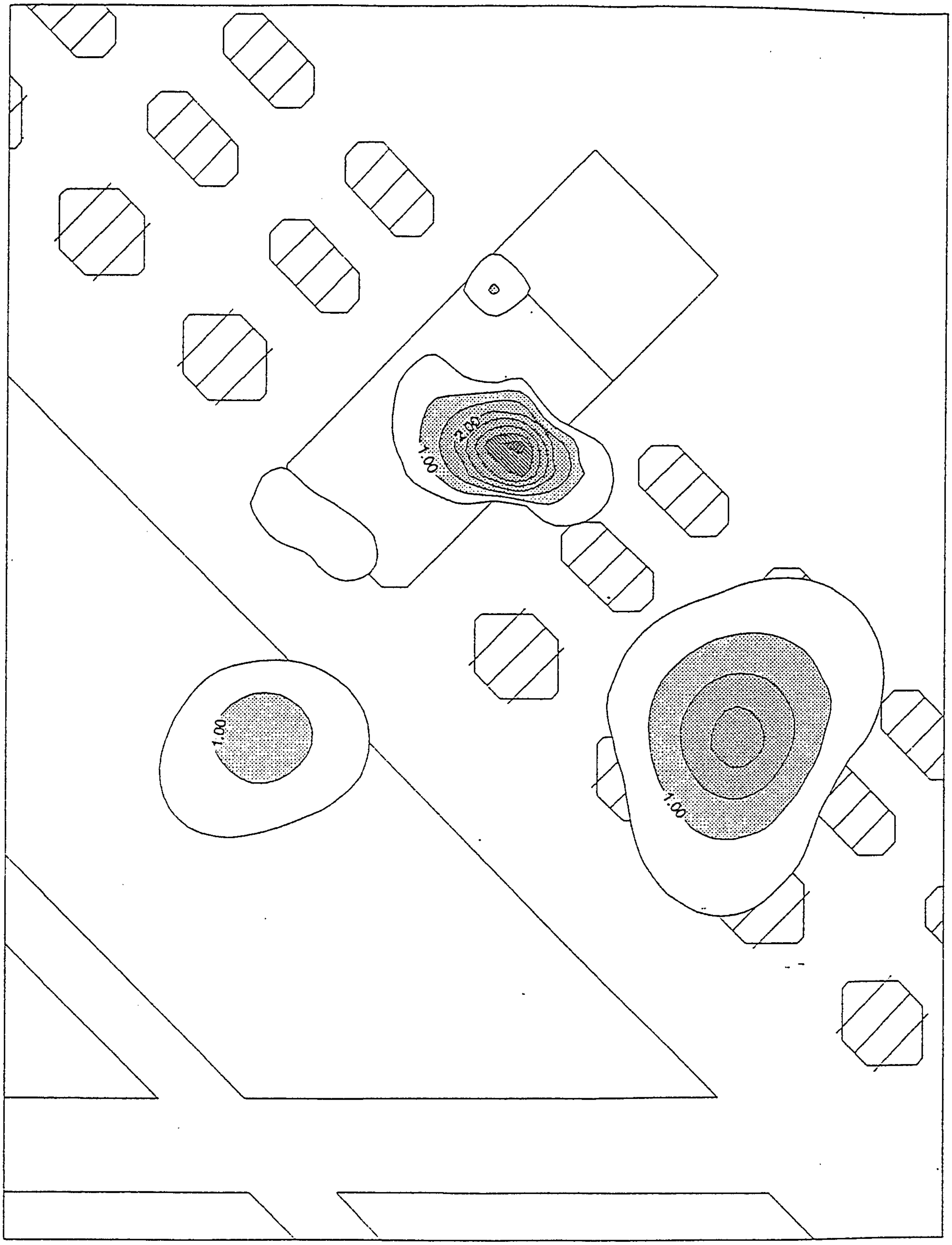


Scale (ft)

Apparent JP-4 Thickness, June 1993

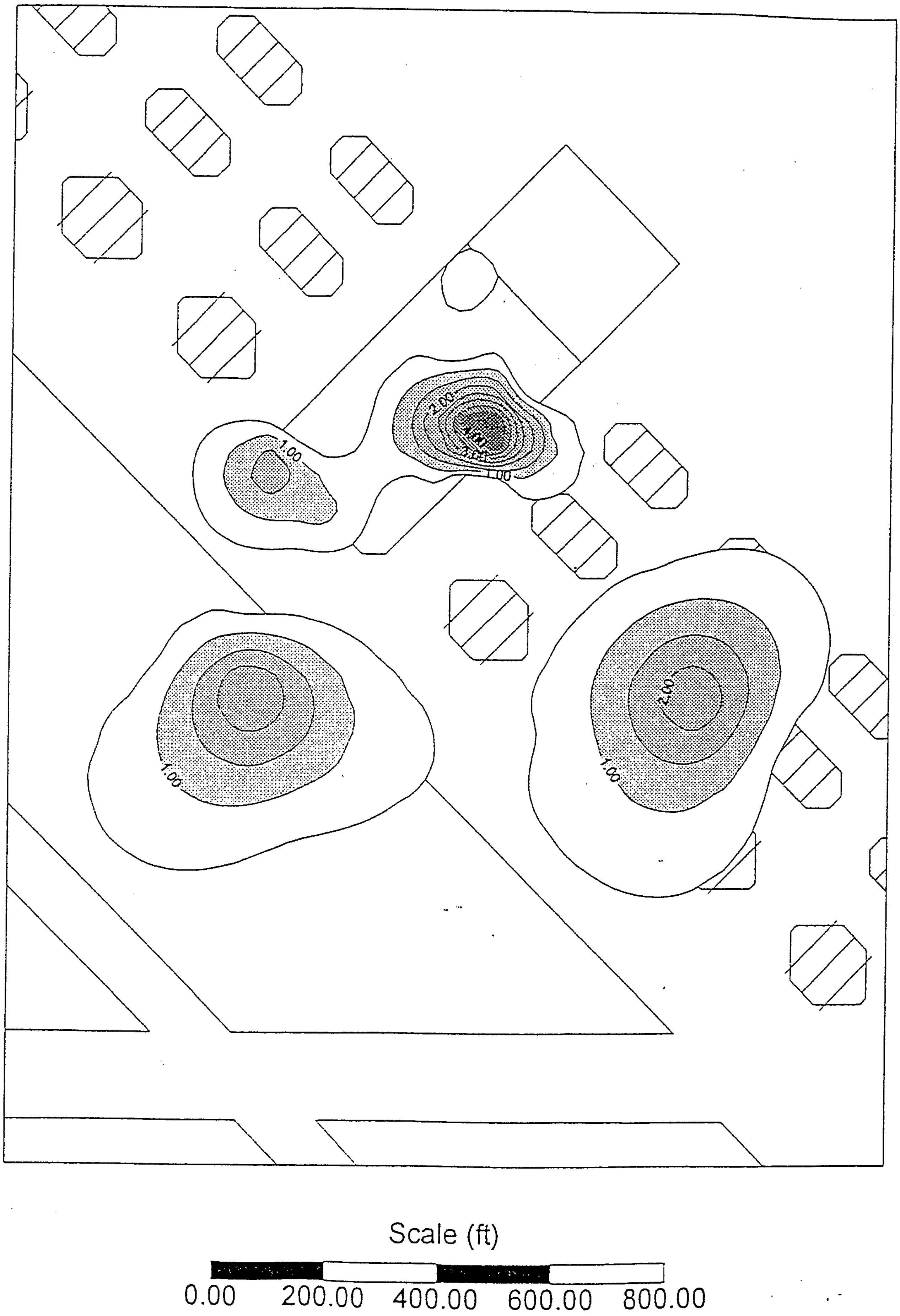


Apparent JP-4 Thickness, May 1993

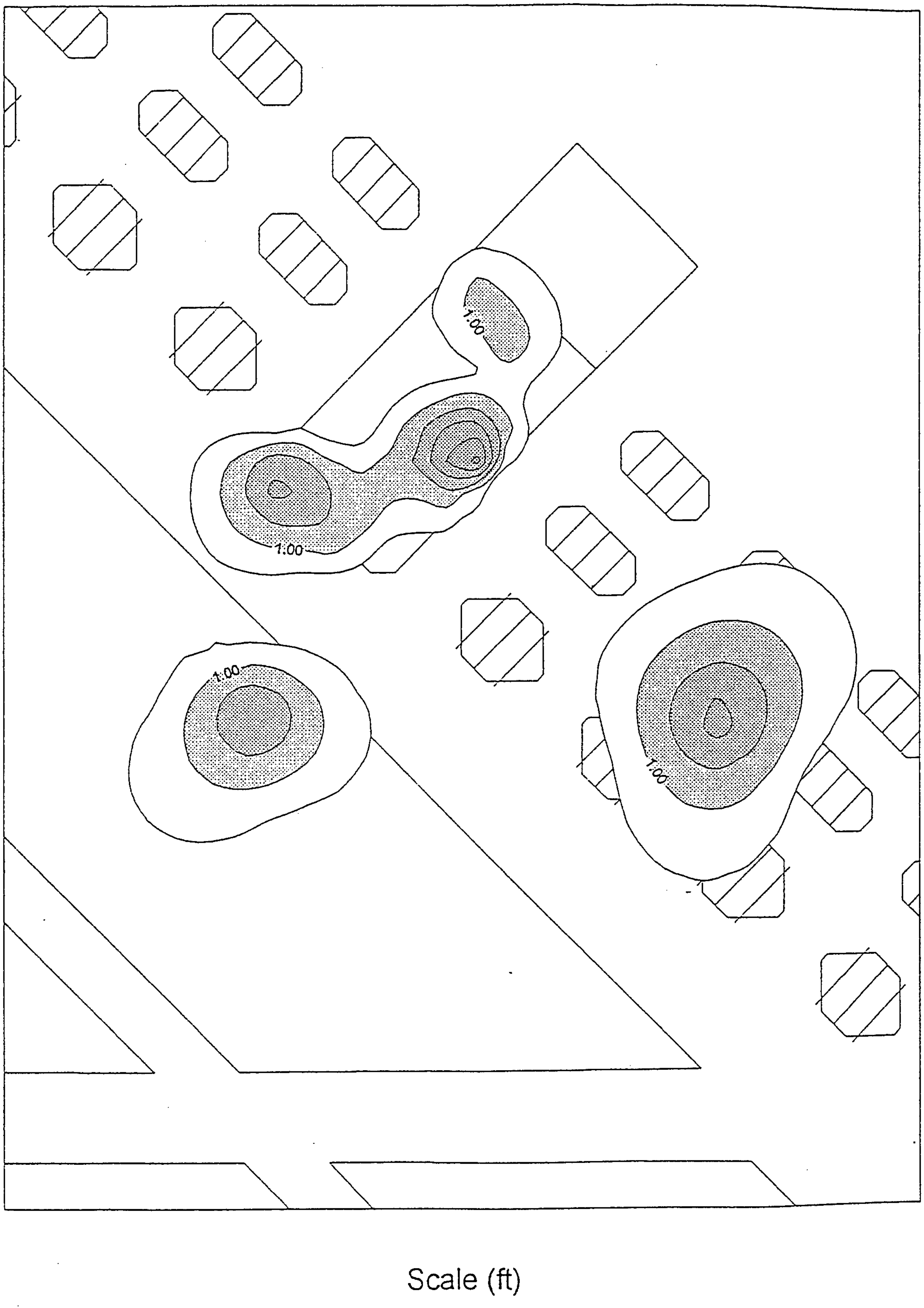


Scale (ft)

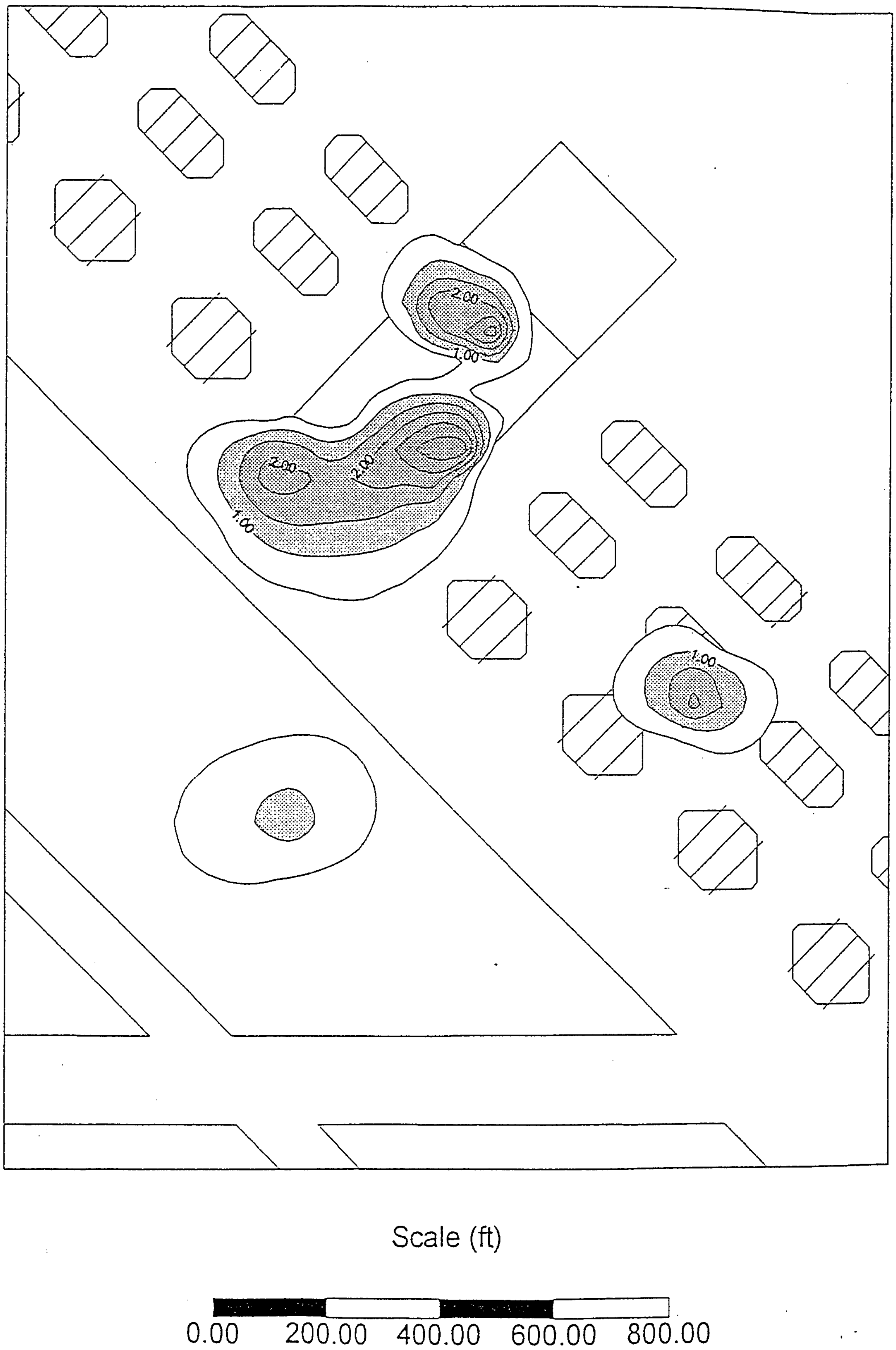
Apparent JP-4 Thickness, April 1993



Apparent JP-4 Thickness, March 1993



Apparent JP-4 Thickness, Febuary 1993



APPENDIX B

COST AND PERFORMANCE DOCUMENT ON INTERNAL COMBUSTION ENGINES

A PERFORMANCE AND COST EVALUATION OF INTERNAL COMBUSTION ENGINES FOR THE DESTRUCTION OF HYDROCARBON VAPORS FROM FUEL-CONTAMINATED SOILS

by

S.R. Archabal and D.C. Downey

Engineering-Science, Inc.

Denver, Colorado

for

U.S. Air Force

Center for Environmental Excellence

Brooks Air Force Base, Texas

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SECTION 1

INTRODUCTION

This document describes the performance and costs associated with a modified internal combustion engine (ICE) used for the destruction of hydrocarbon vapors extracted from fuel contaminated soils. During the period of 18 October 1993 to 14 January 1994, an ICE treatment system manufactured by VR Systems Inc. in Anaheim, California was tested at the Patrick Air Force Base (AFB), Florida, active Base Exchange (BX) service station. The ICE test was conducted in conjunction with an ongoing soil vapor extraction/bioventing pilot test directed and funded by the Air Force Center for Environmental Excellence (AFCEE), Technology Transfer Division (ERT). The purpose of this test was to independently measure both the performance and the cost of ICE operation, and to determine how this technology can be most effectively used to complement the bioventing technology.

Bioventing is an *in situ* remediation technology which is best suited for less volatile hydrocarbons commonly found in jet fuels, diesel fuels, and heating oils. Bioventing can be accomplished through air injection or extraction; however, injection of air into sites contaminated with more volatile hydrocarbon products (e.g., gasoline) can result in uncontrolled migration of high concentrations of volatile organic compounds (VOCs). One solution to this problem is the use of soil vapor extraction techniques during the initial months of remediation to remove and treat high levels of soil gas VOCs. Additionally, while the VOCs are being extracted from the soil, they are replaced by atmospheric air which contains the oxygen (i.e., electron acceptor) required to subsequently promote *in situ* biodegradation. This short period of vapor extraction (higher cost) is then followed by long-term air injection (lower cost) to provide oxygen for the biodegradation of less volatile or adsorbed hydrocarbons in the soil.

In many states, VOCs must be treated before discharge into the atmosphere. In the State of Florida, soil vapor extraction must include a vapor treatment technology capable of removing 99 percent of the VOCs prior to discharge. Activated carbon cannisters and thermal destruction units, such as ICEs, are used for treatment of hydrocarbon vapors. Significant information on the performance and cost of activated carbon is already available. Less information is available on ICE performance, particularly data that have been independently measured and verified.

This document is organized into five sections including this introduction. Section 2 provides a more complete description of the technology and the vendor's information on performance and cost. Section 3 reports the results of the 3-month field test with an emphasis on VOC destruction efficiency, operating costs, and reliability and maintainability issues. Section 4 provides a summary of this technology evaluation and discusses how this technology can best be integrated into an *in situ* bioventing project. Section 5 includes the references cited in this report.

SECTION 2

DESCRIPTION OF TECHNOLOGY

2.1 VAPOR EXTRACTION AND COMBUSTION

Vapor extraction and combustion is an innovative technology which 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 from the ground by the intake manifold vacuum of the engine. The vapors are then burned as fuel to run the engine. The exhaust gases pass through catalytic converters for final purification before exiting to the atmosphere.

VR Systems, Inc. of Anaheim, California[1] has developed a vapor extraction technology which incorporates the use of a modified ICE. The VR Systems Model V3 unit uses a Ford Motor Company® 460-cubic-inch-displacement (CID) engine block, heads, and accessories along with an onboard computer system which 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. Flow rates range from 0 to 250 standard cubic feet per minute (scfm), depending on soil conditions and the hydrocarbon concentrations of the extracted soil gas.

The VR System units are not designed to remove or treat chlorinated vapors from soil. These vapors once thermally treated can produce an off-gas air steam containing hydrochloric acid (HCl) vapor and potentially other highly toxic gases, depending on which type of chlorinated vapor is being destroyed. Additionally, the highly corrosive vapors produced as a treatment by-product destroys the engine and related equipment. There are other thermal oxidation systems equipped with condensing units (scrubbers) on the exhaust to effectively treat chlorinated vapors.

The VR System units are designed to remove nonchlorinated hydrocarbon vapors from contaminated soil utilizing a vapor extraction vent well like the one installed at the Patrick AFB, BX Service Station as part of the bioventing pilot test (ES, 1993). 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 within the engine. Exhaust gases from the engine pass through a small catalytic converter which 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 which

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[1] Point of Contact: Mr. Tom Davis, Telephone: 714-826-0483, FAX: 714-826-8746

monitors the engine's vital signs (oil pressure/temperature, coolant temperature, exhaust temperature, exhaust percent oxygen, and engine speed), and operation (flow rates, inches of vacuum pressure, supplemental fuel consumption, air/fuel ratio, and engine hours). The V3 unit also is equipped with an automatic engine shutdown system. Monitored by the on-board computer, automatic shutdown occurs if one or more of the following conditions is present: 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 (in a printout) the reason for the automatic engine shut down.

Supplemental fuel (propane or natural gas) is used to provide smooth operation of the engine as extracted soil gas vapor concentrations fluctuate. Elimination of supplemental fuel usage can be achieved if the extracted soil gas vapor concentrations provide sufficient fuel to sustain combustion and smooth operation of the engine. The computer regulates the fuel requirements of the engine by the means of 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 V3 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 to automatically discharge in case 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 V3 unit is also equipped with a modem for remote monitoring and to make necessary adjustments to vacuum or engine speed to optimize engine performance and minimize supplemental fuel consumption. During high water table conditions, it may be necessary to set limits on flow rate and vacuum pressure to prevent a high water shut down of the unit. The remote monitoring capability also allows for adjustments to be made while the unit is operating.

2.2 VENDOR'S STATEMENT OF SYSTEM CAPABILITIES/COSTS

2.2.1 Capabilities

VR Systems, Inc. manufactures vapor recovery systems in three sizes. A system schematic of the V3 unit is provided in Figure 2.1. Other VR System models and system schematics are provided in Appendix A. Table 2.1 provides the physical dimensions of each model. The specifications of each model are provided in Table 2.2. Additional costs for accessories [e.g., a modem for remote monitoring, cellular phone adaptation, liquid crystal display (LCD) monitor, 3.5-inch disk drive (Model V3), and other equipment] can be found in Appendix A.

2.2.2 Special Considerations/Limitations

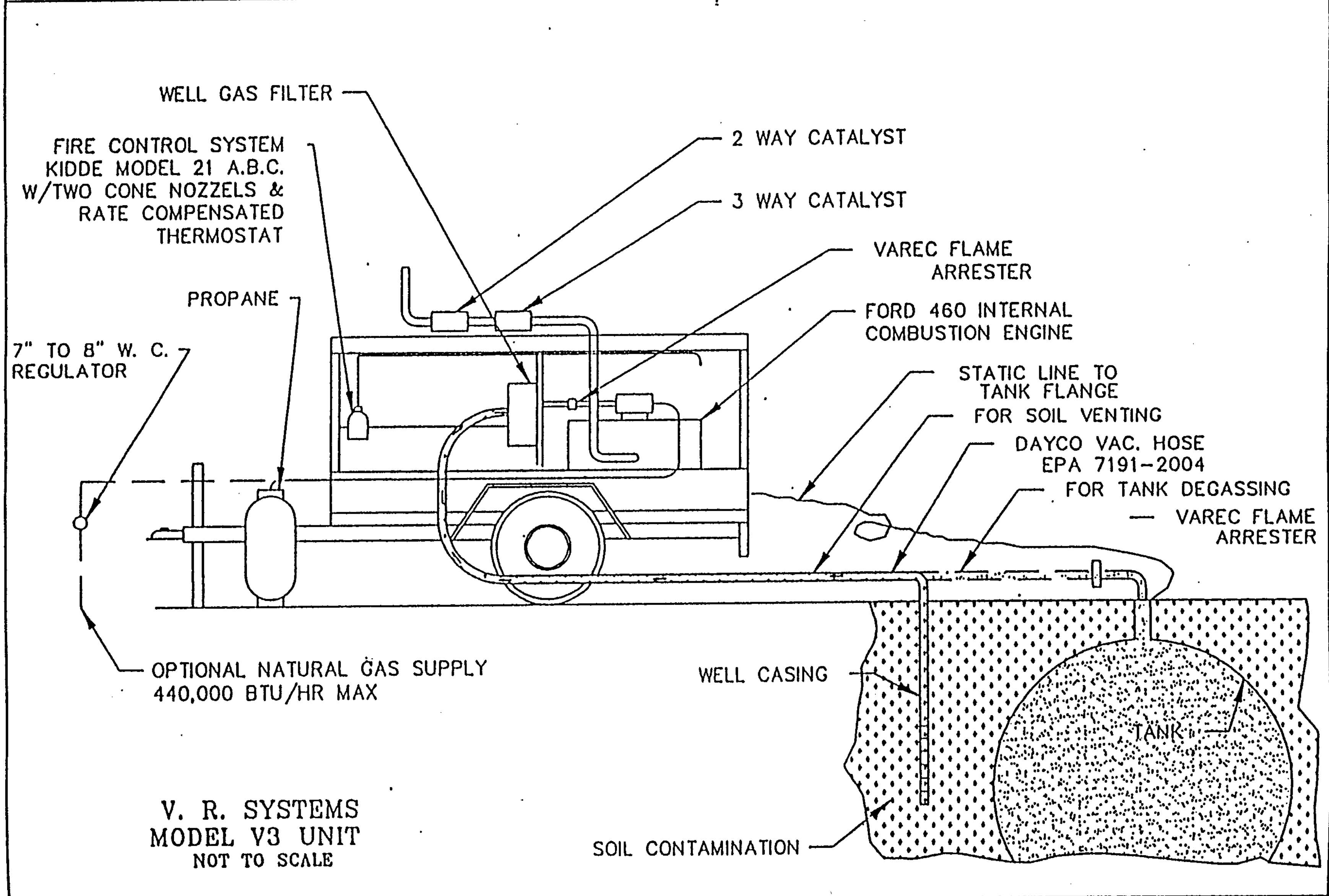
Site-specific conditions can limit the application and performance of ICEs. Limitations pertaining to the VR Systems technology and appropriate corrective actions (CAs) are listed below:

- Optimum ambient temperature operating range is 0° to 56°C (32° to 125°F).

Figure 2.1

MATL	FINISH	DESC.	SHEET	ITEM NO.
		V3 SYSTEM SCHEMATIC	OF	EC2H021

DATE 2/92
REV DATE 2/92



V. R. SYSTEMS
MODEL V3 UNIT
NOT TO SCALE

DRAWN BY: DBG
SCALE: NONE

DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
TOLERANCES UNLESS OTHERWISE SPECIFIED ARE AS FOLLOWS:
ANGLES: ±1° FRACTIONS ±1/16 .XX ±.01 .XXX ±.001

VR SYSTEMS
ANAHEIM, CA.

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TABLE 2.1

DIMENSIONS FOR VR SYSTEMS MODELS V2C, V3, V4[a/]
VAPOR EXTRACTION/INTERNAL COMBUSTION ENGINE EVALUATION
PATRICK AFB, FLORIDA

Model	Length	Width	Height[b/]
V2C	10'9"	5'4"	5'4"
V3	13'5"	6'4"	5'5"
V4	15'7"	6'4"	5'5"

[a/] Dimensions are approximate and subject to change.

[b/] Does not include exhaust stack.

TABLE 2.2

MANUFACTURER PERFORMANCE SPECIFICATIONS
FOR VR SYSTEMS MODELS V2C, V3, AND V4
VAPOR EXTRACTION/INTERNAL COMBUSTION ENGINE EVALUATION
PATRICK AFB, FLORIDA

Feature	V2C	V3	V4
Max. Hydrocarbon Destruction Rate	15 lbs/hr	55 lbs/hr	110 lbs/hr
Destruction Efficiency for TVH/BTEX[a/]	>99%	>99%	>99%
Engine Size in Cubic Inch Displacement	140	460	920 (2 x 460)
Max. Flow Rate in Cubic Feet/Min	65	250	500
Max. Vacuum in Inches of Mercury/Approx. Inches of Water	18/245	18/245	18/245
Required Soil Gas Hydrocarbon concentration (ppmv as gasoline)[b/]	40,000	40,000	40,000

[a/] TVH = total volatile hydrocarbons; BTEX = benzene, tolune, 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).

- Relative humidity of the extracted air stream must be less than 95% or noncondensing.

  CA: If a high water table exists or condensation occurs in the extraction hose, then a water knock-out chamber can be installed in-line between the vapor extraction well and the ICE unit to prevent high-water shut down of the system.

- ICE will require supplemental fuel at some point during cleanup activities (propane or natural gas).

  CA: Optimize engine speed and vapor flow rate to reduce excessive supplemental fuel consumption.

- Limited basic engine warranty, covers the first 4,000 hours or 12 months of operation, whichever comes first. The warranty does not include accessories such as the starter, alternator, plugs, wires, etc.

  CA: If factory-recommended maintenance is conducted, VR Systems, Inc. has demonstrated a life expectancy of the engine ranging from 16,000 to 20,000 hours. This equates to around 2 to 2.5 years of continuous operation, 24 hours per day, at 1,800 to 2,200 revolutions per minute (rpm). To rebuild the engine costs around $3,500, which equates to around $0.18 per hour of operation.

- Noise associated with the operation of the engine could be considered a potential concern for areas near residential areas or other occupied buildings. The noise level varies accordingly with engine speed. A noise test was conducted by VR Systems on April 9, 1991, with the Model V3 unit at various rpms and radial distances from the unit of 3 and 10 meters. Results of the test are provided in Appendix A.

  CA: Noise abatement in areas where noise is a concern, can be controlled by instituting one or more of the following: programming the computer to adjust engine speeds at certain times of day to minimize noise impacts to local receptors; constructing a 6- or 8-foot privacy fence around the unit and possibly installing noise suppression insulation to the inside of the fence; or purchasing one of the new Quiet Run models now available in the V2 and V3 series. More information on the Quiet Run models is available through VR Systems.

- Soil type is a consideration for areas where low-permeability soil conditions are present and where minimal vapor flow rates from the soil are expected.

  CA: An evaluation of the radius of influence and extraction rates of vapor extraction wells determined during pilot testing should be taken into consideration during equipment selection.

2.2.3 Vendor Costs

Table 2.3 provides a summary of the VR Systems capital, rental, estimated supplemental fuel operating costs, and an approximate monthly service schedule operating cost.

Should a customer decide to rent the equipment, the rental equipment would be maintained by the customer for normal wear items like those provided on Table 2.3. If a major repair becomes necessary during a rental period, such as excessive wear of

TABLE 2.3

CAPITAL AND OPERATING COSTS
(2/15/94)
VAPOR EXTRACTION/INTERNAL COMBUSTION ENGINE EVALUATION PATRICK AFB, FLORIDA

Cost Item	V2C	V3	V4
Purchase	$40,450.00	$73,450.00	98,880.00
Rental (Monthly)	$3,480.00	$6,235.00	$8,923.00
Mobilization/Demobilization 500 miles from vendor via commercial carrier	$1,000.00	$1,000.00	$1,400.00
Daily Maximum Supplemental Fuel Costs (Approx.)@ 2,000-rpm Engine Speed (Assumes all BTUs are supplied by supplemental fuel - propane at $0.80/gal.)	$20.00	$70.00	$140.00
Monthly Service Maintenance[a] (Approximate as of 2/16/94)	$220.00	$220.00	$374.00
Miscellaneous Services/Equipment[b] (As required as of 2/16/94)			

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[a] Monthly service estimates include: engine oil, oil filters, air filter(s), spark plugs, well gas filter(s), and labor (performed by a VR Systems trained technician).

[b] Additional labor and equipment pricing as required may include:

- Maintenance Labor @ $45/hr.
- Travel time @ $30.00/hr.
- Mileage (first 20 miles free) @ $0.28/mi.
- Long Distance (requiring air travel), air fare plus per diem
- Additional equipment not included in the monthly service, will be installed only as required are:
  Computer air cleaner @$7.22/each
  Distributor cap @ $23.75/each
  Spark plug wires @$63.00/set
  Rotor @ $3.82/each

Note: All materials shown are at retail cost, and can be purchased in bulk for generally 40 to 50% less.

engine rings and valves, or other critical engine or computer parts, VR Systems would be responsible for repairing the unit to meet factory specifications.

2.3 REGULATORY ACCEPTANCE

The acceptance of this technology has been widespread. VR Systems has provided a list of jurisdictions where their systems have been tested and/or are currently operating. The states and countries are as follows:

Permitted

- Arizona
- California:
  - Great Basin Valleys
  - Lake Tahoe
  - Mountain Counties
  - North Central Coast
  - North Coast
  - Northwest Plateau
  - Sacramento Valley
  - San Diego
  - San Francisco Bay
  - San Joaquin Valley
  - South Central Coast
  - South Coast
  - Southeast Desert
- Florida
- Hawaii
- Idaho
- Illinois
- Massachusetts
- New Jersey
- New Mexico
- New York
- Ohio
- Oregon
- Pennsylvania
- Washington
- Ontario, Canada
- Mexico
- Argentina

1- to 5-Day Pilot Testing

- Alabama
- Colorado
- Georgia
- Kansas
- Louisiana
- Oklahoma
- Michigan
- Missouri
- Montana
- Nevada
- North Carolina
- Tennessee
- Texas
- Utah
- Alberta, Canada

During the Patrick AFB field demonstration, a work plan describing the bioventing pilot test and the vapor extraction treatment technology was submitted to the State of Florida for approval prior to commencing the field activities. For long-term testing (more than a 1- to 5-day pilot test), regulatory approval is generally required. Approval for long-term vapor extraction treatment is site-specific (geographically) and may or may not require a permit application, and possibly only a work plan or letter notification will be necessary. For shorter term pilot tests (1-5 days), permits may not be required. Local regulatory officials should be contacted to verify local policy.

SECTION 3

FIELD DEMONSTRATION RESULTS

3.1 SITE DESCRIPTION

An extended pilot study evaluation of the Model V3 vapor extraction ICE unit was conducted between October 18, 1993 and January 14, 1994. The field demonstration was performed at Patrick AFB, Florida at the BX Service Station.

The BX Service Station site is part of an ongoing bioventing pilot test study. Soil and groundwater contamination exists from previous unleaded gasoline leaks from underground storage tanks (USTs). A soil gas survey was initially conducted to verify site conditions, and to ensure that sufficient soil contamination existed to conduct the bioventing pilot test. The initial soil gas sample laboratory results ranged from 38,000 parts per million, volume per volume (ppmv) to 100,000 ppmv for total volatile hydrocarbons (TVH) within the study area (ES, 1993).

The average water table depth is approximately 5 feet below ground surface (bgs). A horizontal vent well (HVW) was installed at 4 feet bgs as part of the bioventing pilot test. The HVW was placed in the center of the highest TVH readings obtained during the initial soil gas survey at this site. The HVW was constructed of 4-inch, Schedule 40 polyvinyl chloride (PVC) pipe with 30 feet of 0.03-inch slotted well screen. The entire length of screened interval was placed within the contaminated soil area. The entire study area at this site is paved, which significantly reduces or eliminates the potential for short-circuiting and increases the area of influence for air injection or soil vapor extraction through the HVW.

Because initial soil vapor concentrations at this site were very high, bioventing through the use of air injection was ruled out due to the potential for vapor migration. Soil vapor extraction was required to significantly reduce soil vapor concentrations before the system could be converted to a more standard air injection bioventing system. Several emission control technologies were evaluated based on efficiency, maximum TVH influent concentration capacities, maintenance requirements, and cost over the period necessary for vapor extraction. Based on the technology review, a decision was made to use the ICE vapor extraction system manufactured by VR Systems, Inc. and to evaluate its performance and cost of operation.

3.2. REGULATORY APPROVAL/REQUIREMENTS

Florida Department of Environmental Protection (FDEP) policy states that all vacuum extraction units must use a catalytic or thermal oxidation device, or its equivalent (carbon absorption), to reduce VOC emissions by at least 99 percent during the first two months of operation. After 2 months of operation, the reduced untreated effluent concentrations are evaluated with the SCREEN air modeling program. If the results show that the emissions are below acceptable ambient air standards at the area of greatest impact, the air emissions controls may be discontinued after concurrence from the FDEP.

3.3 TEST CONDITIONS

Table 2.2 provides the performance specifications for the V3 model. The range of extraction flow rates for this model is 0 to 250 scfm, with a vacuum capacity of up to 245 inches of water. During the initial 2-day demonstration, a maximum flow rate of 150 scfm was established. This flow rate was used because it was the maximum achievable through the HVW and required the least amount of supplemental fuel. During the extended test, an average flow rate of 80 scfm was used. The reduction in flow from 150 scfm to 80 scfm was due primarily to a higher water table condition which restricted air flow through the HVW. When a higher vapor extraction flow rate was attempted, the greater vacuum produced a mounding of the water table into the HVW.

A 55-gallon condensate knockout drum was installed between the HVW and the VR Systems unit. The drum was installed to reduce the potential for high-humidity soil gas (>95% relative humidity) condensing and accumulating within the intake hose and filter assembly that would result in a high-water shut down of the system. Following the installation of the drum, no significant accumulation of condensate occurred in the lines.

Propane was used as the supplemental fuel during the test. For the extended test period, a 500-gallon propane tank was setup approximately 30 feet from the VR System unit. During the test period, a local propane distributor would top off the propane tank approximately twice per week. This servicing was performed with the system operating and no supervision was needed during this activity.

3.4 OBSERVED PERFORMANCE

3.4.1 Initial 2-Days at 150 SCFM

Table 3.1 reflects the changes in influent concentrations over time for TVH and BTEX during the initial 2 days of the test. The average flow rate during this period was 150 scfm at an average engine speed of 1,790 rpm. Due to the age and natural weathering of the gasoline spill, initial BTEX concentrations at this site comprised a relatively small fraction of the TVH.

TABLE 3.1

CHANGE IN INFLUENT CONCENTRATIONS FOR TVH AND BTEX OVER TIME @ 150 SCFM
VAPOR EXTRACTION/INTERNAL COMBUSTION ENGINE EVALUATION
PATRICK AFB, FLORIDA

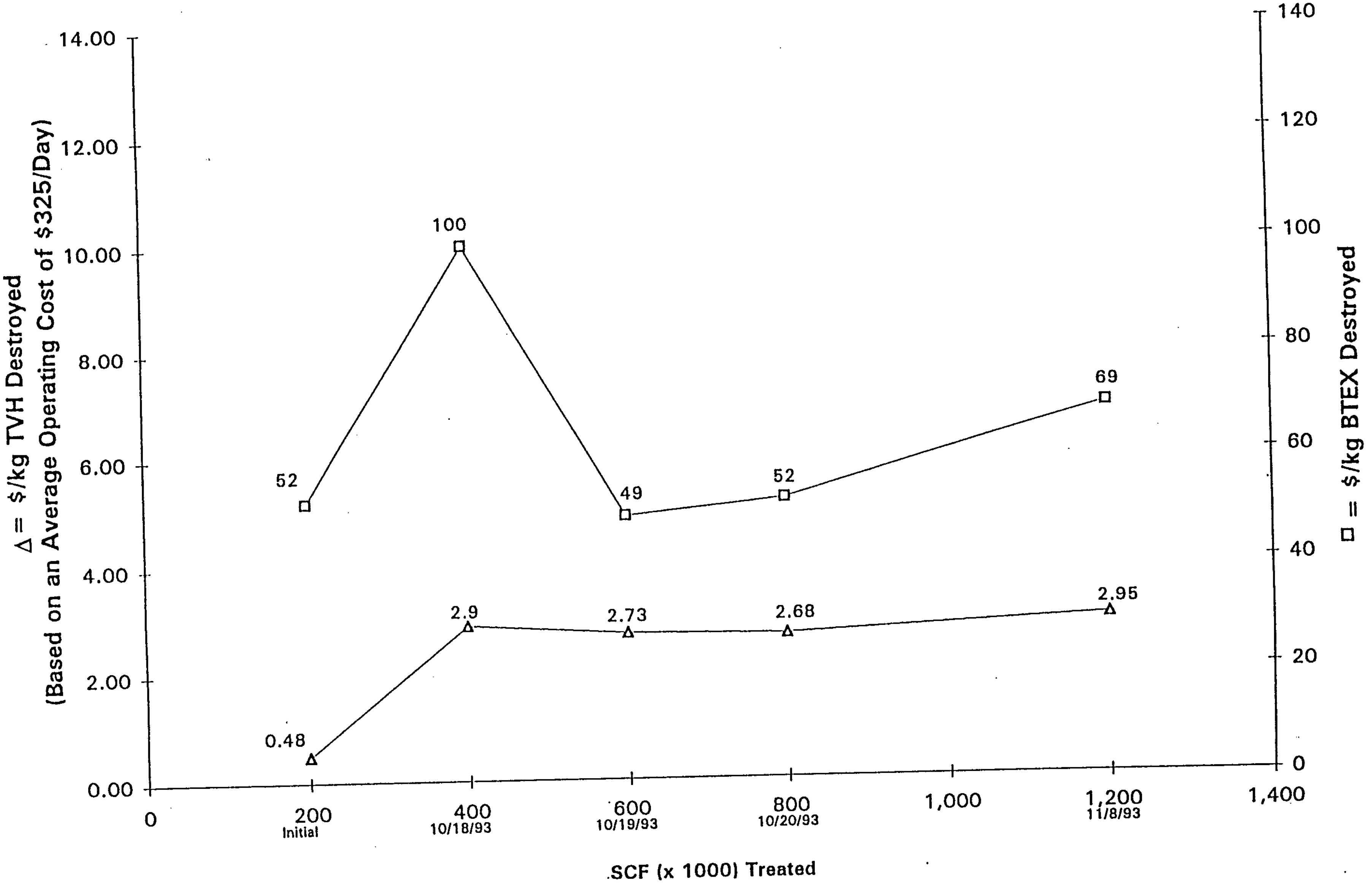
	Concentrations	
Influent Constituent	Initial (ppmv)	After 2-Days (ppmv)
TVH	26,800	4,400
Benzene	—[a]	—[a]
Toluene	15	4.7
Ethylbenzene	14	12
Xylenes	200	110

[a] Below Detection Limit.

During the 2-day initial test period, a variety of rpm ranges were used to find the optimum engine speed which yielded the highest vapor flow from the well, while using the least amount of supplemental propane. Also, during the initial 13 hours of operation, the VR System engine was treating a severely oxygen-depleted soil gas. Bioactivity in the area had completely depleted soil gas oxygen supplies. Adjustments by the onboard computer of the influent flow rates were made to maintain the proper oxygen/fuel ratio and a VOC destruction efficiency of >99 percent. As the influent soil gas was oxygen depleted (<2%), the computer had to compensate by adding dilution air through the carburetor and supplemental propane until the soil gas oxygen supply increased to greater than 17 to 18 percent. The majority of the supplemental fuel used over the course of the 2-day test was consumed during this initial 13-hour adjustment period.

Propane consumption during the initial 2 days (44 hours) was 1,925 cubic feet (cf) at an average rate of 43.75 cf/hour. Propane costs during this test were $0.80 per gallon. Using a conversion factor of 36 cf/gallon of propane, an average cost for the supplemental fuel propane was approximately $1.00/hr. Based on laboratory influent and effluent sampling results, the cost per kilogram (kg) of TVH and BTEX destroyed was calculated. Based on the laboratory results and an initial flow rate of 150 scfm, a graphical representation of the cost per kg of TVH and BTEX destroyed was generated for the initial 800,000 standard cubic feet (SCF) of soil gas treated during the first 5 days of operation (Figure 3.1). During this period, the average operating cost was $325.00 per day. A breakdown of the daily operating cost is as follows:

Figure 3.1
Cost Per Kilogram of BTEX and TVH Destroyed
at 150 SCFM Initial Flow Rate



• Equipment rental	$230.00/day,
• Supplemental fuel (propane)	$24.00 to $57.00/day, and
• Labor (1 hour per day)	$50.00/hour to check on and sample system.

As the actual daily costs ranged from $305.00 to $337.00, an average daily cost of $325.00 was used.

During the initial startup of vapor extraction, the soil gas being removed will typically be oxygen depleted and contain elevated concentrations of carbon dioxide (CO_2) and methane, which are produced by the *in situ* biological activity. During the initial 800,000 scf of soil gas removal at Patrick AFB, a wide range of operating costs were observed. After the initial soil gas had been replaced by oxygenated soil gas, the need for dilution air subsided and contaminant destruction rates became more uniform.

The ratio of BTEX to TVH at this site is not representative of a recent spill or leak, where BTEX comprises up to 20 percent of the TVH. It appears that the majority of the BTEX constituents normally expected in unweathered gasoline were no longer present. During the initial startup period at this site, BTEX comprised 5 percent of the TVH, indicating an older (weathered) gasoline. The cost for each kilogram of BTEX destroyed will vary based on the site-specific BTEX concentrations. At this site, costs for BTEX destruction were high due to the low percentage of BTEX in the residual fuel.

3.4.2 Long-Term (Weeks 2-13) Performance

During the extended test period, the average flow rate was reduced from 150 scfm (initially) to 80 scfm due to a seasonally high water table which reduced the HVW efficiency. To minimize upconing, the onboard computer was programmed to operate the engine at 7 to 11 inches of water vacuum to prevent high-water shut down of the equipment. Limitations placed on the vacuum reduced the overall efficiency of the V3 unit. Despite these inefficiencies, the primary goals of determining the destruction efficiency, operating cost range, reliability, and maintainability were successfully achieved during the evaluation.

3.4.3 Destruction Efficiency

The VR System provided greater than 99-percent destruction efficiency for BTEX and greater than 96-percent destruction efficiency for TVH throughout the test period. Figure 3.2 illustrates the range of soil gas influent BTEX and TVH concentrations encountered during the test and the significant reduction that occurred as a result of 80 days of soil vapor extraction. Figure 3.3 illustrates the destruction efficiencies that were achieved. A 4-percent reduction in TVH destruction efficiency occurred when the engine rings and valves began to wear, allowing a fraction of the supplemental propane to pass unburned through the engine exhaust. When a new replacement unit was installed at the site, destruction efficiencies returned to greater than 99 percent for all hydrocarbons. It is important to note that laboratory analysis confirmed that the unburned fuel was propane and not BTEX compounds from the soil vapor extraction

Figure 3.2
Influent BTEX and TVH Concentration Reduction over Total SCF Treated

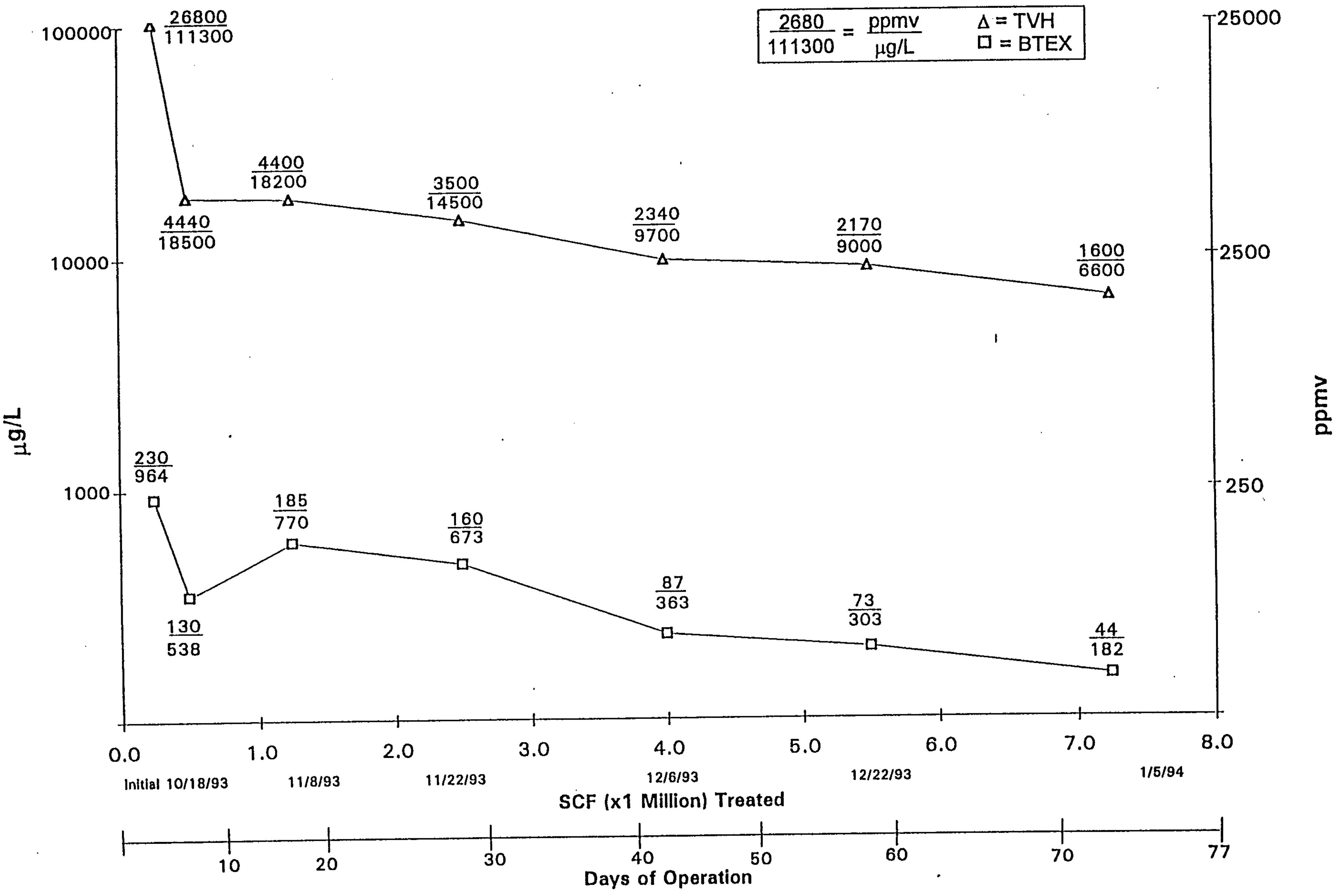
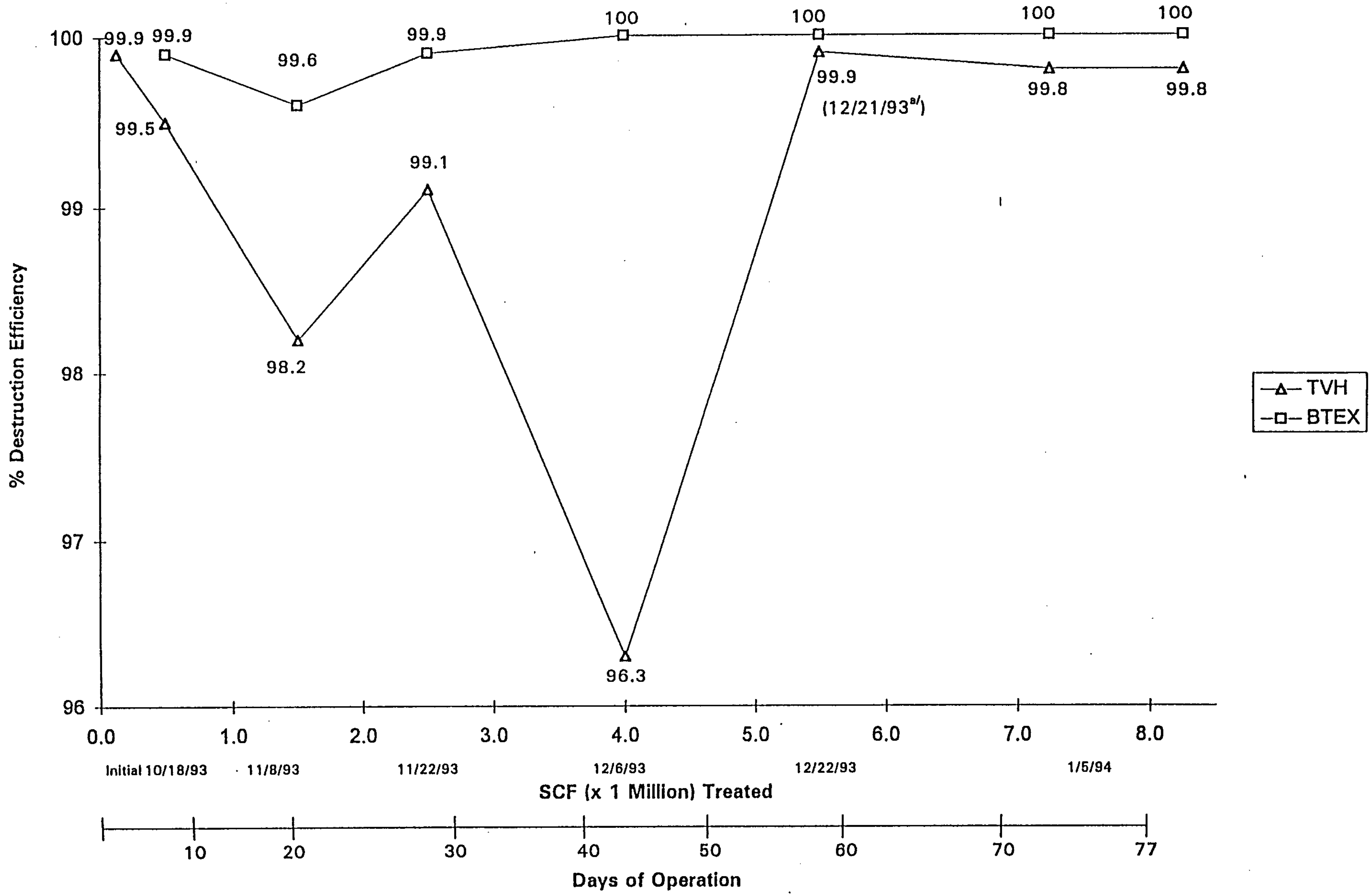


Figure 3.3
VR Systems Destruction Efficiency for BTEX and TVH of Influent Vs. Effluent



[a] NOTE: 12/21/93 Replaced VR Systems Unit With Upgraded V3 Model.

system. Weekly monitoring of influent and effluent TVH is recommended to ensure that normal engine wear does not result in unacceptable emissions to the atmosphere.

3.4.4 Cost of Extended Operation

During the extended test, an average influent flow rate of 80 scfm was achieved. As shown in Figure 3.4, the cost per kilogram of TVH and BTEX destroyed ranged from $0.83 to $15.40 and $97.00 to $550.00, respectively. The cost increase is due to the decreasing soil vapor concentrations and increased supplemental fuel requirements.

3.5 RELIABILITY

The VR Systems, Inc. Model V3 ICE proved very reliable during the overall evaluation. However, during the normal operation of an ICE, certain mechanical parts may become worn over time, resulting in a decrease in destruction efficiency. The engine parts that directly impact destruction efficiency include rings, exhaust valves, and the catalytic converter.

A reduction in destruction efficiency occurred at this site as a result of ring wear and improper clearance of the exhaust valve seats. This resulted in unburned propane passing through the exhaust system, an elevated TVH reading during effluent sampling, and a reduced TVH destruction efficiency during the December 6, 1993 sampling event (Figure 3.3). To correct this problem, a VR System technician replaced the engine valves at no cost. When the problem reoccurred, a new version of the V3 system was brought in to replace the older system. The upgraded V3 model included a different ring package as well as a new type of valve seating. Approximately 10.5 days of downtime (12 percent) were incurred during the 3-month evaluation. Replacement of the original unit ensured that the 99-percent destruction rate required by the State of Florida could be achieved throughout the duration of the test.

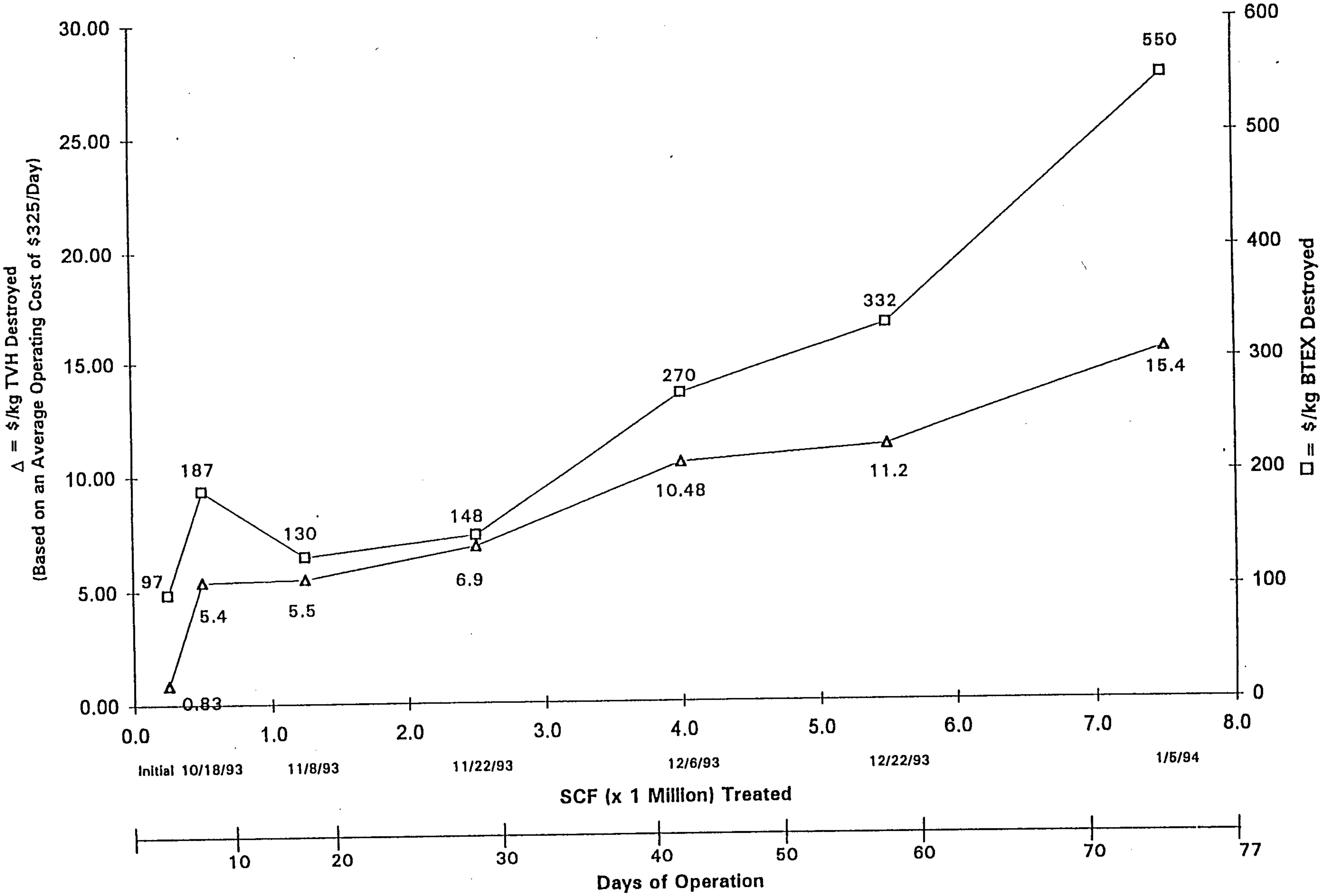
3.6 MAINTAINABILITY

All ICE units require routine maintenance. As with an automobile, the extent of maintenance is dependent upon the total engine running time.

During the Patrick AFB test, the engine spark plugs, oil, and oil filter were changed monthly. It is recommended that a person familiar with the ICEs be used for primary system oversight. Familiarity with the proper tools, and engine parts is very useful during routine ICE maintenance and/or troubleshooting. Routine maintenance (i.e., for every 720 hours of engine opeation) can be performed by either a qualified engine mechanic from the base motor pool, specifically assigned to and familiar with the required unit maintenance, or for a fee of $220 for the Model V3, plus transportation and per diem (if applicable), VR Systems will perform the routine monthly engine maintenance.

VR Systems recommends the following maintenance schedule:

Figure 3.4
Cost Per Kilogram of BTEX and TVH Destroyed
at 80 SCFM Flow Rate



MAINTENANCE SCHEDULE

Initial Startup Sequence[a/]	Operation	Every 720 HRS[b/]	Every 1440 HRS
1	Set Up Supplemental Fuel Schedule With Vendor[c/]		
2	Oil, Check Level	X	
3	Coolant, Check Level	X	
4	Oil & Coolant Leaks, Check	X	
	Oil, Change	X	
	Oil Filter, Replace	X	
5	Air Cleaner, Replace[d/]	X	
6	Well Gas Element, Replace		X
7	Battery, Check Charge		X
	Battery Cables, Clean		X
8	Water Pump & Alternator Belts Check & Adjust		X
9	Spark Plugs, Replace		X
10	Filters, Check/Replace		X
11	Transporter Tires, Check Pressure & Condition		X
12	All Bolts & Nuts, Check for Tightness & Hose Clamps		X

[a/] Also use for startup after storage.

[b/] Intervals are established on approximate monthly runs. Do not exceed these limits. Service sooner if necessary or under severe conditions.

[c/] Scheduling of supplemental fuel is necessary prior to initial startup of the system.

[d/] More often if in dusty atmosphere.

SECTION 4

SUMMARY

4.1 TECHNOLOGY PERFORMANCE

4.1.1 Destruction Efficiency

During the 3-month Patrick AFB test, soil gas TVH concentrations were reduced from 26,800 to 1,600 ppmv and BTEX concentrations were reduced from 230 ppmv to 44 ppmv (Figure 3.2). Throughout the test period, greater than 99-percent destruction of BTEX was achieved by the ICE. TVH destruction ranged from 96 to 99+ percent. The 4-percent loss in TVH destruction efficiency occurred when worn engine rings and valves allowed unburned propane (supplemental fuel) to pass through the unit. When a newer ICE replaced the worn unit, TVH destruction efficiencies returned to greater than 99 percent.

4.1.2 Reliability

Following an initial week of system startup and optimization, the VR System unit operated with minimum interruptions. During the 3-month test, the unit experienced four unscheduled shutdowns accounting for 12 percent of the 2,160 available operating hours. Two of the unscheduled shutdowns were associated with repairs to the engine rings and valve assembly and ICE replacement, which were required to maintain a 99-percent destruction efficiency, and two shutdowns were due to a high water table condition at the site resulting in the need for installing a water knock-out drum before the unit. A factory representative completed the engine repairs at no additional cost to the Air Force.

Based on this test, weekly influent and effluent TVH sampling is recommended to verify system performance and to identify potential VOC pass through resulting from worn engine parts. This sampling can be accomplished with handheld instruments which are capable of detecting unburned propane as well as other fuel hydrocarbons.

The reliability of ICE systems also depends on the engineered elimination of condensate from the extracted soil vapor. The VR System unit is equipped with a water sensor which will automatically shut down the system when water approaches the carburetor intake. A water knockout drum is recommended for all applications, but is particularly important on sites with shallow aquifers where groundwater can be pulled into the vapor extraction system. At the Patrick AFB site, flow rates were reduced and a knockout drum was placed in front of the ICE to prevent ICE shutdown during seasonally high water table conditions.

4.1.3 Maintainability

Proper maintenance of ICE units is important to ensure that destruction efficiencies remain high and supplemental fuel use is minimized. Because these vapor treatment units are simply modified automobile engines, maintenance is virtually identical. Based on experience at the Patrick AFB test site, it may be advantageous to pay the additional maintenance fee and have a factory representative conduct monthly maintenance on the unit to ensure it is operating at peak efficiency. Although the onboard computer provides a straight forward diagnostic printout of the engine vital signs, corrections of problems are best left to experts who have full responsibility for the performance of the unit. One exception would be when a qualified engine mechanic from the base motor pool could be specifically assigned for unit maintenance. This could result in significant savings, particularly if the ICE operation exceeds 3 months.

In addition to routine maintenance, supplemental fuel must be supplied to the unit. If a natural gas line near the site can be inexpensively tapped, operation costs will be approximately 60 percent of the cost of using propane as a supplemental fuel. Propane also requires additional time to ensure that deliveries are completed.

4.2 COST

4.2.1 Purchase or Rental

The decision to purchase or rent an ICE depends on the number of months of operation expected at the site or sites. Purchase prices range from $40,450 for Model V2C to $98,880 for Model V4 (1994 prices). Although each ICE vendor has a different pricing schedule, it will almost always be more economical to rent a unit if the total period of operation will not exceed 10 months. Rental also places greater responsibility on the vendor to ensure proper unit operation. Also, if rented, major maintenance remains the responsibility of the vendor. If units are purchased, many manufacturers offer a monthly maintenance and service agreement. The VR System maintenance agreement costs $220/month for Models V2C and V3, and $374/month for the Model V4, plus travel and per diem. Maintenance agreements may be needed if the base is unable to provide necessary maintenance. Factors such as the level of contamination, size of the site, and degree of vapor treatment will determine the number of months of ICE operation. Air Force bases (or MAJCOMs) with three or more gasoline-contaminated sites may find it economically advantageous to purchase one of these units and move it from site to site.

4.2.2 Operating Costs

The cost of operating an ICE will increase over time as soil vapor VOCs are reduced and additional supplemental fuel is required. Based on the Patrick AFB test, daily operating costs of $74 to $107 per day were estimated. Propane accounted for $24 to $57 of the daily operating costs, and 1 hour of contract labor to check and monitor the unit was estimated at $50 per day. To reduce labor costs, every attempt should be made to use base personnel for system monitoring and basic maintenance.

4.2.3 Cost Per Kilogram of TVH/BTEX

The unit cost for each kg of TVH (including BTEX) or specifically for BTEX destroyed is a convenient way of comparing different vapor treatment technologies. The ICE system used at the Patrick AFB site was oversized, and unit costs derived from this test are considered conservative. During the initial days of operation when VOC concentrations were high, TVH treatment costs as low as $0.48 per kilogram were achieved. During the final days of operation, TVH treatment costs had increased to $15.40 per kilogram. BTEX treatment costs ranged from $49 to $550 per kilogram (Figure 3.4). These costs are site specific and were inflated at the Patrick AFB BX Site due the low BTEX content of the soil gas.

4.3 Integration With *In Situ* Bioventing

At sites with high levels (>10,000 ppmv) of soil gas TVH, it may be necessary to extract these vapors before long-term air injection/bioventing can begin. Of particular concern are sites with gasoline- or light-distillate-contaminated soils and sites near buildings and utility corridors which could be adversely impacted by vapor migration caused by air injection.

Based on both vendor information and Patrick AFB tests, the ICE technology is an effective method of controlling vapor emissions and destroying contaminants. These units are most effective when initial soil gas TVH is greater than 40,000 ppmv. At these high concentrations, the ICE will operate without supplemental fuel. ICE units come in a variety of sizes and can be optimized based on the desired soil vapor extraction rate and site-specific soil gas permeability.

The length of ICE operation at each site will depend on several factors. The decision to begin air injection bioventing must be based on the potential risk of vapor migration into buildings and utility corridors and the ability of soil bacteria to biodegrade mobilized VOCs. Biodegradation rates established during bioventing pilot tests can be used to determine the approximate mass of soil "biofilter" required to biodegrade a known mass of migrating hydrocarbons. By minimizing air flow rates to just satisfy *in situ* oxygen demand, the flux of volatile hydrocarbons to the atmosphere from the contaminated soil will also be minimized.

4.4 Future Work

Other *ex situ* vapor treatment technologies have been evaluated including the Biocube® and PURUS PADRE®. Reports similar to this will be provided on each technology. A summary report will compare cost and performance of each and assist in remedial design decisions.

REFERENCES

Engineering Science, Inc. 1993. *Interim Test Results Report for Bioventing at the Patrick AFB BX Service Station.* Report provided to the Air Force Center for Environmental Excellence (AFCEE/ERT).

APPENDIX A

5.02 FLAME ARRESTER

A 3" Flame Arrester shall be included to protect the well gas source from any "Flash Back" from the engine.

5.03 GROUNDING

A 50' Static Line and Reel shall be included.

5.04 AUTOMATIC ENGINE SHUT DOWN

The system shall be protected by automatic shut down under the following conditions:

Overspeed
High Coolant Temperature
High Oil Temperature
Low Oil Pressure
Fire
High Water Level (Well Gas Filter)

The computer shall be programmed to store and report the reason for the automatic engine shut down.

5.05 FUEL SHUT OFF

Means shall be included to shut off the fuel supply should the engine shut down for any reason.

5.06 LABEL AND INSTRUCTIONS

An Operation and Maintenance Manual shall be included establishing safe operation and required maintenance together with pertinent Material Safety Data Sheets from various suppliers. Safety and warning labels shall be appropriately affixed to the unit according to accepted standards. Safety and Operation instructions shall be conspicuously posted at the operation console within easy view of the operator.

6.00 TRANSPORTATION AND INSTALLATION

Included as part of the package shall be a transporter to safely move the unit from one site to another. Also, a stand shall be available and means supplied to slide the unit off of the transporter and onto the stand (and vice versa).

7.00 GENERAL APPROVAL

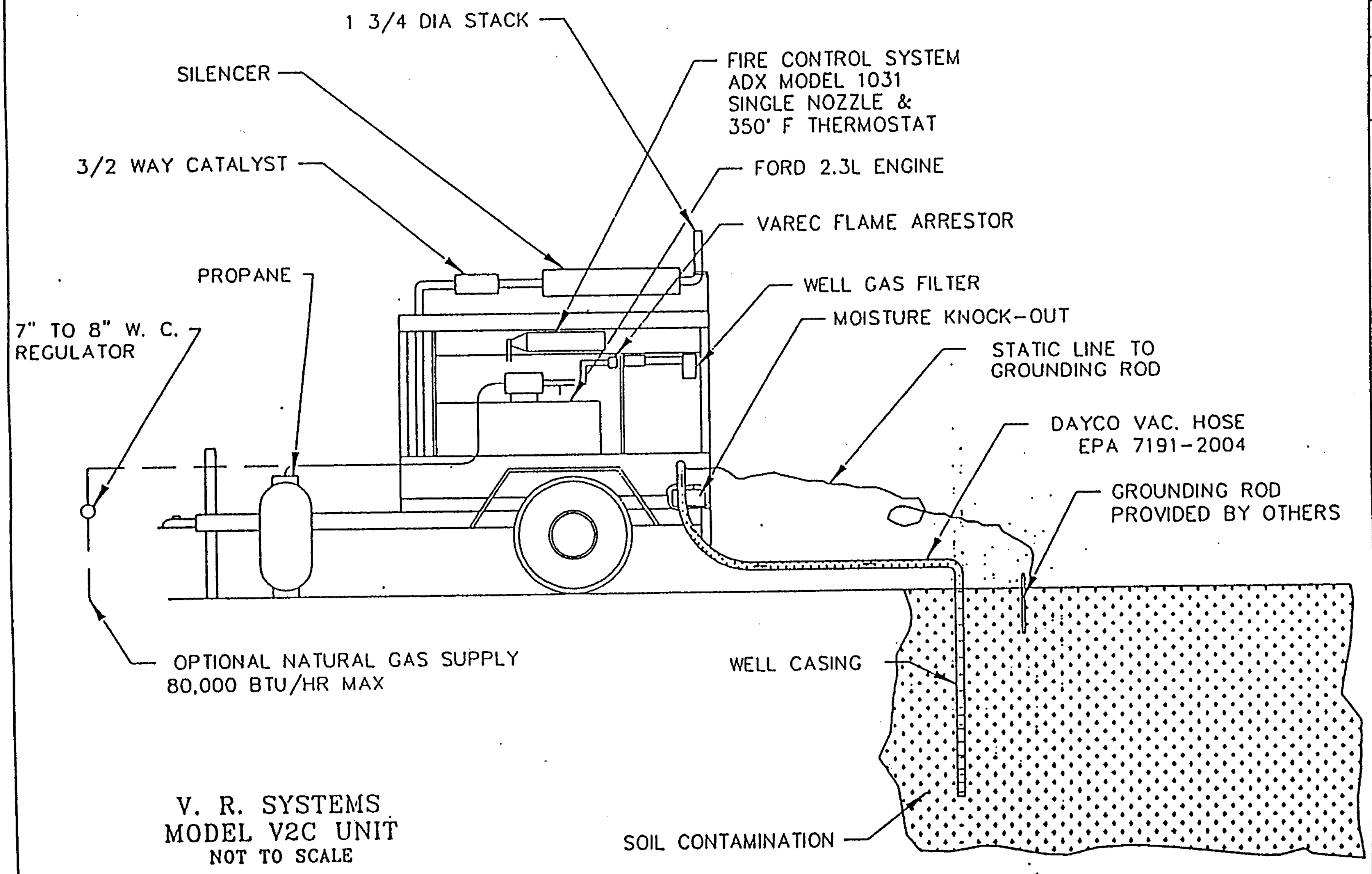
The system shall have an approval by a registered third party testing laboratory for safety and operations.

8.00 WARRANTY

The system shall carry a one-year warranty on all items manufactured by the sellers and the seller will pass on the guarantee of the manufacturer of purchased parts installed on the unit.

MATL	FINISH	DESC.	SHEET	ITEM NO.
		V2C SYSTEM SCHEMATIC	OF	EC3D029

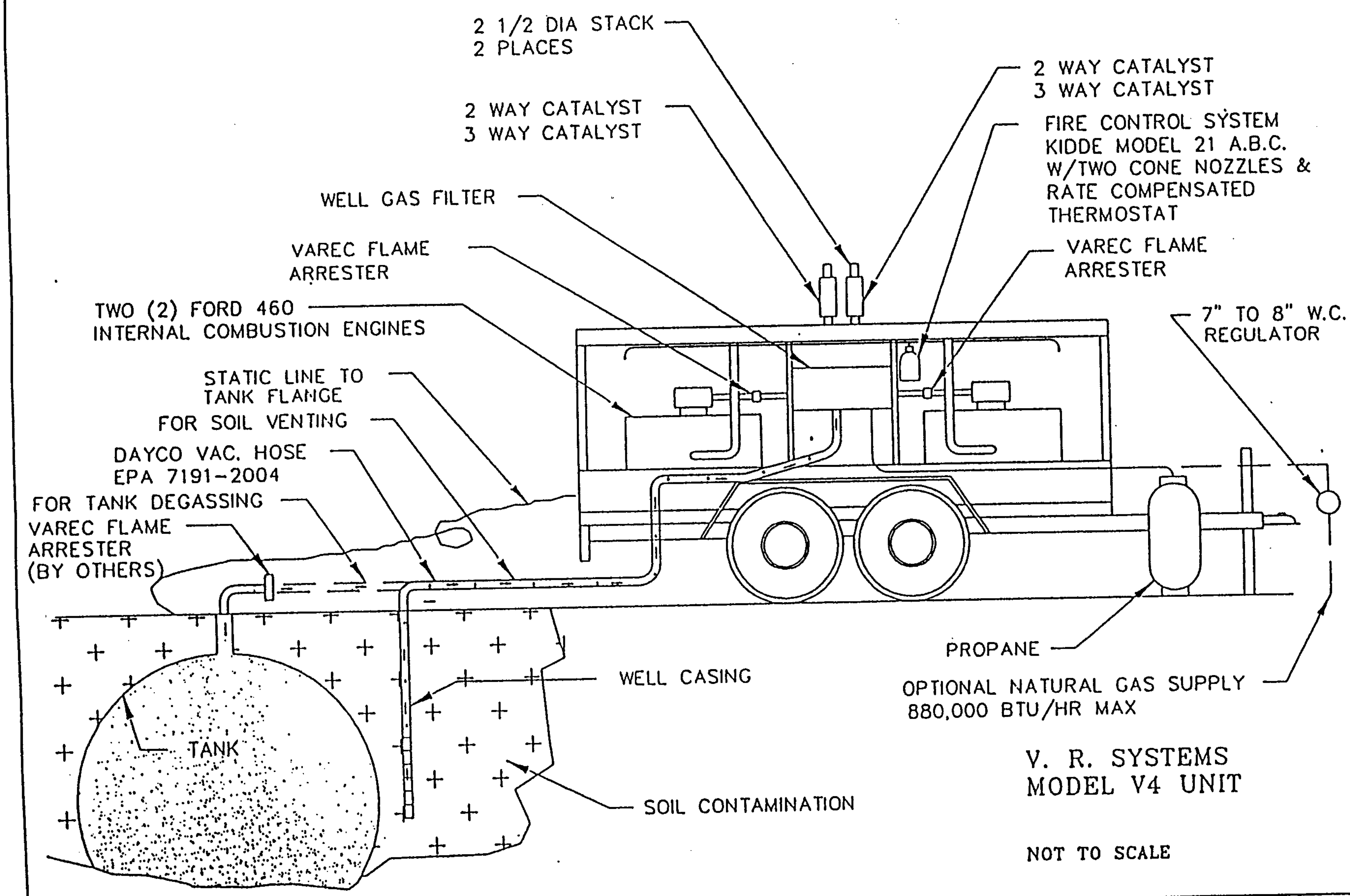
DATE
2/92
REV DATE
A 12/93
B 2/94



DRAWN BY: DBG	DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED. TOLERANCES UNLESS OTHERWISE SPECIFIED ARE AS FOLLOWS: ANGLES: ±1° FRACTIONS ±1/16 .XX ±.01 .XXX ±.001	VR SYSTEMS ANAHEIM, CA.
SCALE: NONE		

MATL	FINISH	DESC.	SHEET	ITEM NO.
		V4 SYSTEM SCHEMATIC	OF	EC2H020

DATE	REV DATE	A	B
2-92	2-92	6-93	12-93



V. R. SYSTEMS
MODEL V4 UNIT

NOT TO SCALE

DRAWN BY: DBG
SCALE: NONE

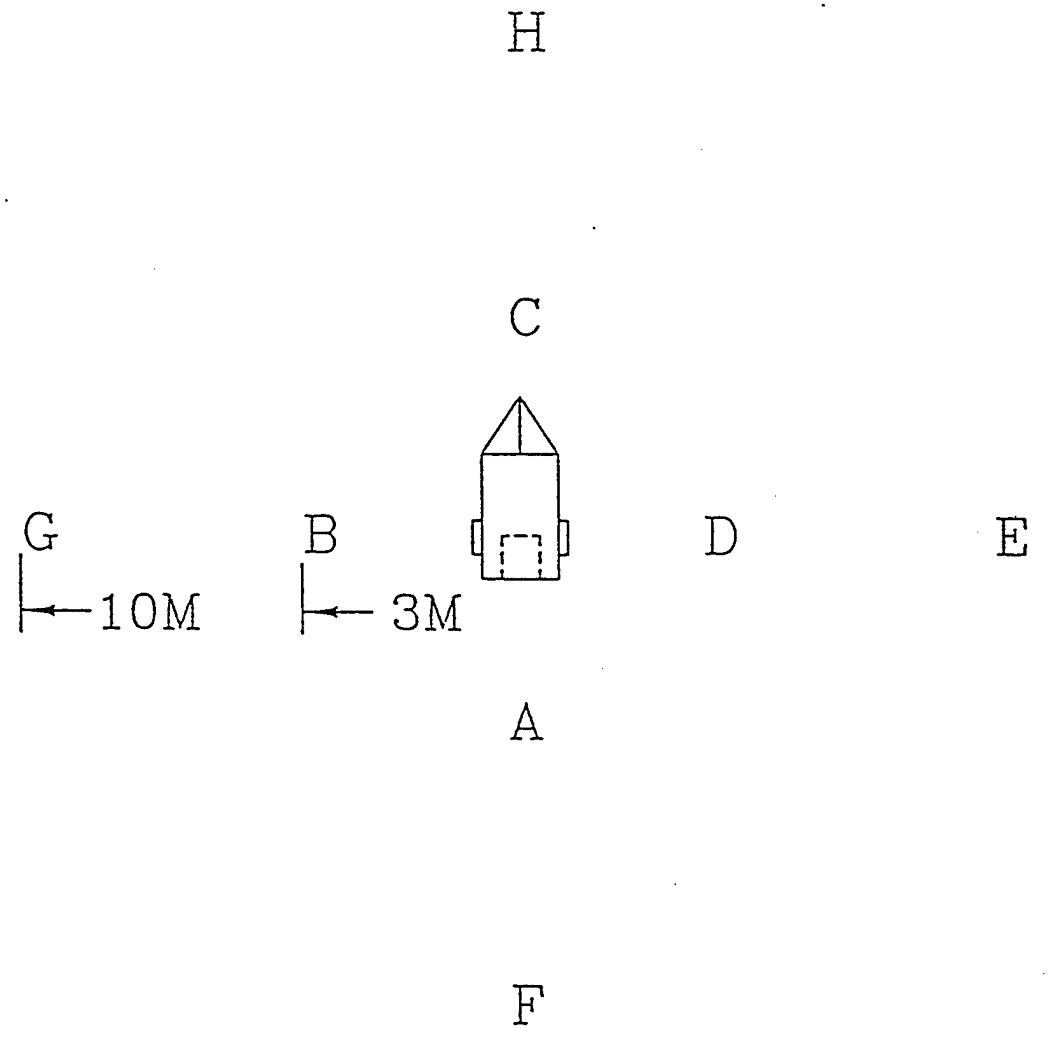
DIMENSIONS ARE IN INCHES UNLESS OTHERWISE SPECIFIED.
TOLERANCES UNLESS OTHERWISE SPECIFIED ARE AS FOLLOWS:
ANGLES: ±1° FRACTIONS ±1/16 .XX ±.01 .XXX ±.001

VR SYSTEMS
ANAHEIM, CA.

VRsystems inc.

Technology In Support of the Environment.

NOISE TEST 4/9/91
MODEL V3 STD S/N 11
ON HARD PACKED DIRT dBA SLOW RESPONSE



	3MTRS				10MTRS			
RPM	A	B	C	D	E	F	G	H
AMBIENT	50–52	52	50–52	50–52	50–52	52	50–52	50
1800	81.5	77.5	77	77	69.5	72.75	71	69.5
2200	88	81.5	79.5	81	76	78.75	77	76
2750	91	88	86.5	87	79	83.5	82	79

VR systems inc.

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V2C STANDARD FEATURES

- "QUIET RUN" PACKAGE
- FIRE CONTROL SYSTEM
- INPUT FLAME ARRESTER
- AUTO SHUT DOWN
    - High Water Temperature
    - High Oil Temperature
    - Low Oil Level
- AUTOMATIC OIL LEVEL REGULATOR
- WELL GAS FLOW METER
- EASILY TRANSPORTED - ONE MAN SETUP
- SHUTDOWN/CALL-UP CAPABILITY
- PERMITTABILITY IN SCAQMD
    - Soil Remediation (Various Locations)
- 20 MINUTE INSTALLATION CAPABILITY
- SLIDE IN/SLIDE OUT ENGINE PACKAGE
- PERMANENT STAND OR TRANSPORTABILITY
- 15' X 1 1/2" INTERNALLY GROUNDED VAPOR HOSE
- 50' STATIC REEL
- LCD MONITOR W/16 ITEM READOUT & DISC DRIVE
    - For Report Accumulation
- INVERTER PACKAGE
    - For "Stand Alone" Capability

AVAILABLE OPTIONS

- MONITORING BY MODEM
- KIT FOR NATURAL GAS OPERATION

10/19/93

SPECIFICATIONS - MODEL V2C

1.00 GENERAL

It is the intent of these specifications to describe a "State of the Art" Soil Remediation System including an internal combustion engine capable of extracting hydrocarbon vapors from contaminated soil or storage tanks without the use of a compressor or pump, and destruct such vapors as fuel in a controlled manner by the use of an on-board computer system.

2.00 DETAILED DESCRIPTION

System shall conform to the following minimum requirements:

2.01 ENGINE

The engine shall be a Ford, liquid cooled, 140 C.I.D., Model LSG-423. The engine shall be totally controlled by the computer system described below and shall be capable of operating three weeks without need of servicing. The engine shall be equipped with an automatic oil level device together with one (1) automotive type cartridge filter. The engine serves as both a vacuum pump and as a means of destroying hydrocarbon vapors removed from the soil. Engine cooling shall be by means of an oversized radiator.

2.02 FUEL CONTROL SYSTEM

Supplemental fuel, as may be required for proper combustion, shall be either Propane (LPG) or Natural Gas. The control of the fuel to the engine shall be by the means of an electro/mechanical system including a Master Control Unit (MCU). The MCU shall adjust the supplemental fuel flow to compensate for changing influent hydrocarbon concentrations and maintain an air/fuel ratio at stoichiometric.

2.03 IGNITION SYSTEM

The Ignition System shall be an electronic type, automatically adjusted by commands from the computer.

2.04 ELECTRICAL POWER

Electrical power required shall be supplied by an on-board 12 volt DC battery for "stand-alone" operation. This battery also provides power for starting the engine and is charged by the engine's alternator. An internal DC to DC converter provides the necessary +5, +12 and -12 volts required to power the control system.

2.05 ON-BOARD COMPUTER CONTROL

The system shall include a "State of the Art" Data Acquisition System for monitoring the engine control.

2.06 MONITORING

Monitoring shall include a 16 channel data reporting system on engine vital signs and operation. Reporting can be on regular intervals (every hour or half hour) or manually at the discretion of the operator, or stored (30 days max.) for future retrieval. Remote monitoring by hardwire or cellular shall also be available.

2.07 WELL GAS FILTER

The system shall include a Well Gas Filter and moisture knock out. A Transducer shall be included to indicate well gas vacuum levels.

2.08 EXHAUST SYSTEM

The Exhaust System shall include a dual NOx reduction monolith and a dual HC/CO monolith. The oxygen supply to the NOx reduction unit shall be controlled at all times at 0.5% to 0.7% as read by an O_2 sensor in the exhaust manifold.

2.09 QUIET RUN

The system shall be capable of operating at a noise level of 55db measured at 10 meters without additional noise screening.

3.00 OPERATION

The operation of the system shall be automatic (except for start up, shut down and RPM set point) and shall not require manual adjustment of influent gas, supplemental fuel or combustion air.

4.00 CAPACITIES

4.01 VACUUM AND FLOW

The system shall be capable of developing up to 18" Hg at the well gas inlet. Flow rates shall be from 0 to 65 CFM. These conditions will depend on soil conditions, hydrocarbon concentrations and level of inerts encountered.

4.02 HYDROCARBON REMOVAL

The system shall be capable of removing up to 15 lbs/hr of hydrocarbons at a total destruction efficiency of 99.97%.

5.00 SAFETY FEATURES

5.01 FIRE CONTROL SYSTEM

A Fire Control System shall be included as an integral part of the unit. This system consists of a ADX 1021 dry chemical automatic package utilizing a fusible link type actuator and 8 lbs. of dry chemical with 20 sq. feet of coverage.

5.02 FLAME ARRESTER

A 3" Flame Arrester shall be included to protect the well gas source from any "Flash Back" from the engine.

5.03 GROUNDING

A 50' Static Line and Reel shall be included.

5.04 AUTOMATIC ENGINE SHUT DOWN

The system shall be protected by automatic shut down under the following conditions:

Overspeed
High Coolant Temperature
High Oil Temperature
Low Oil Pressure
Fire
High Water Level (Well Gas Filter)

The computer shall be programmed to store and report the reason for the automatic engine shut down.

5.05 FUEL SHUT OFF

Means shall be included to shut off the fuel supply should the engine shut down for any reason.

5.06 LABEL AND INSTRUCTIONS

An Operation and Maintenance Manual shall be included, establishing safe operation and required maintenance, together with pertinent Material Safety Data Sheets from various suppliers. Safety and Warning Labels shall be appropriately affixed to the unit according to accepted standards. Safety and Operation instructions shall be conspicuously posted at the operation console within easy view of the operator.

6.00 TRANSPORTATION AND INSTALLATION

A transporter, to safely move the unit from one site to another, shall be included as part of the package. Also, a stand shall be available and means supplied to slide the unit off of the transporter onto the stand (and vice versa) as a one-man operation.

7.00 GENERAL APPROVAL

The system shall have an approval by a registered third party testing laboratory for safety and operations.

8.00 WARRANTY

The system shall carry a one-year warranty on all items manufactured by the seller and the seller will pass on the guarantee of the manufacturer of purchased parts installed on the unit.

9.00 MANUFACTURE

The unit shall be manufactured in the United States of America and the supplier shall hold the owner and/or its various departments free and harmless from any patent infringement suit arising out of the purchase of this Soil Venting System.

VR systems inc.
Technology In Support of the Environment.

V4 STANDARD FEATURES

- * FIRE CONTROL SYSTEM
- * INPUT FLAME ARRESTER
- * AUTO SHUT DOWN
    - High Water Temperature
    - High Oil Temperature
    - Low Oil Level
- * AUTOMATIC OIL LEVEL REGULATOR
- * "0" PRESSURE COOLANT SYSTEM
    - (Safety & Long Life)
- * WELL GAS FLOW METER
- * EASILY TRANSPORTED - ONE MAN SETUP
- * SHUTDOWN/CALL-UP CAPABILITY
- * PERMITTABILITY IN SCAQMD
    - Soil Remediation (Various Locations)
    - Underground Tank Degassing (Various Locations)
    - Above Ground Tank Degassing (In Progress)
- * L.A. CITY FIRE DEPARTMENT
    - General Approval
- * SANTA ANA FIRE DEPARTMENT
    - General Approval
- * 20 MINUTE INSTALLATION CAPABILITY
- * SLIDE IN/SLIDE OUT ENGINE PACKAGE
- * LARGE SERVICE DOORS
- * PERMANENT STAND OR TRANSPORTABILITY
- * 15' x 3" INTERNALLY GROUNDED VAPOR HOSE
- * 50' STATIC REELS
- * LCD MONITOR W/16 ITEM READOUT & DISC DRIVE
    - For Report Accumulation
- * INVERTER PACKAGE
    - For "Stand Alone" Capability

AVAILABLE OPTIONS

- * MONITORING BY MODEM
- * FOXBORO OVA
- * KIT FOR NATURAL GAS OPERATION
- * LONG RUN OIL TANK

4/27/93

VRsystems inc.

Technology In Support of the Environment.

SPECIFICATIONS - MODEL V4

1.00 GENERAL

It is the intent of these specifications to describe a "State of the Art" Soil Remediation and Tank Degassing System including internal combustion engines capable of extracting hydrocarbon vapors from contaminated soil or storage tanks without the use of a compressor or pump, and destruct such vapors as fuel in a controlled manner by the use of an on-board computer system.

2.00 DETAILED DESCRIPTION

System shall conform to the following minimum requirements:

2.01 ENGINE

These VR Systems engines have been re-configured to design specification exclusive to VR Systems Vapor Extraction Equipment using a Ford Motor Company 460 C.I.D. engine block, heads and accessories. The engine shall be totally controlled by the computer system described below and shall be capable of operating one month without need of servicing. The engine shall be equipped with an automatic oil level device together with three (3) automotive type cartridge filters. The engine serves as both a vacuum pump and as a means of destroying hydrocarbon vapors removed from the soil. Engine cooling shall be by means of an oversized radiator and zero-pressure coolant system to insure safety and long life.

2.02 FUEL CONTROL SYSTEM

Supplemental fuel, as may be required for proper combustion, shall be either Propane (LPG) or Natural Gas. The control of the fuel to the engine shall be by the means of an electro/mechanical system including a Master Control Unit (MCU). The MCU shall adjust the supplemental fuel flow to compensate for changing influent hydrocarbon concentrations and maintain an air/fuel ratio at stoichiometric.

2.03 IGNITION SYSTEM

The Ignition System shall be an electronic type, automatically adjusted by commands from the computer.

2.04 ELECTRICAL POWER

Not required.

2.05 ON-BOARD COMPUTER CONTROL

The system shall include a "State of the Art" Data Acquisition System for monitoring and engine control.

2.06 MONITORING

Monitoring shall include a 36 channel data reporting system on engine vital signs and operation. An LCD monitor shall be supplied to continuously view the operational data. Also supplied shall be a 720K, 3.5 inch floppy drive, for data storage. Remote monitoring by modem shall also be available.

2.07 WELL GAS HOSE

A hose assembly w/sampling port is supplied for ease of hook up out either side of the housing. An internally grounded 15' main well gas vacuum hose is also supplied.

2.08 WELL GAS FILTER

The system shall include a Well Gas Filter and moisture knock out. A transducer shall be included to indicate well gas vacuum levels.

2.09 EXHAUST SYSTEM

The Exhaust System shall include a dual NOx reduction monolith and a dual HC/CO monolith. The oxygen supply to the NOx reduction unit shall be controlled at all times at 0.5% to 0.7% as read by an O_2 sensor in the exhaust manifold.

3.00 OPERATION

The operation of the system shall be automatic (except for start up, shut down and RPM set point) and shall not require manual adjustment of influent gas, supplemental fuel or combustion air.

4.00 CAPACITIES

4.01 VACUUM AND FLOW

The system shall be capable of developing up to 18" Hg at the well gas inlet. Flow rates shall be from 0 to 500 CFM. These conditions will depend on soil conditions, hydrocarbon concentrations and level of inerts encountered.

4.02 HYDROCARBON REMOVAL

The system shall be capable of removing up to 110 lbs/hr of hydrocarbons at a total destruction efficiency of 99.97%.

5.00 SAFETY FEATURES

5.01 FIRE CONTROL SYSTEM

A Fire Control System shall be included as an integral part of the unit and consists of a Kidde 21# dry chemical automatic package with dual "Rate of Rise" temperature probes and a manual emergency override.

9.00 MANUFACTURE

The unit shall be manufactured in the United States of American and the supplier shall hold the owner and/or its various departments free and harmless from any patent infringement suit arising out of the purchase of this Soil Venting System.

APPENDIX B

LABORATORY ANALYTICAL REPORTS

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
(702) 355-1044
FAX: 702-355-0406
1-800-283-1183

Boise, Idaho
(208) 336-4145

Las Vegas, Nevada
(702) 386-6747

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: 90106/6462201-30D0401
Phone: (614) 424-3753
Attn: Al Pollack

Sampled: 02/07/96 Received: 02/10/96 Analyzed: 02/13/96

Matrix: [X] Soil [ ] Water [ ] Waste

Analysis Requested: TPH - Total Petroleum Hydrocarbons-Purgeable Quantitated As Gasoline
BTEX - Benzene,Toluene,Ethylbenzene,Xylenes

Methodology: TPH - Modified 8015/DHS LUFT Manual/BLS-191
BTEX - Method 624/8240

Results:

Client ID/ Lab ID	Parameter	Concentration	Detection Limit	
MAR-MPA- 35.0-35.5 /BMI021096-05	TPH (Purgeable)	ND	10	mg/Kg
	Benzene	28	20	ug/Kg
	Toluene	ND	20	ug/Kg
	Ethylbenzene	ND	20	ug/Kg
	Total Xylenes	ND	20	ug/Kg
MAR-MPA- 35.5-36.0 /BMI021096-06	TPH (Purgeable)	ND	10	mg/Kg
	Benzene	110	20	ug/Kg
	Toluene	57	20	ug/Kg
	Ethylbenzene	ND	20	ug/Kg
	Total Xylenes	ND	20	ug/Kg

ND - Not Detected

Approved by: Roger L. Scholl Date: 2/20/96
Roger L. Scholl, Ph.D.
Laboratory Director

Laboratory Analysis Report

Sierra
Environmental
Monitoring, Inc.

ALPHA ANALYTICAL
255 GLENDALE AVENUE, SUITE 21
SPARKS NV 89431

Date : 2/27/96
Client : ALP-855
Taken by: CLIENT
Report : 15581
PO# :

Page: 1

ample	Collected Date	Time	MOISTURE CONTENT %	DENSITY G/CM3	POROSITY %	PARTICLE SIZE DISTRIBUTION FRACTION %		
BMI021096-07-MAP-MPA-32.0-35.0	2/07/96	:	15.5	1.02	61.5	SEE REPORT		

Approved By:

Sierra
Environmental
Monitoring, Inc.

February 27, 1996

TO: Alpha Analytical

FROM: Sierra Environmental Monitoring, Inc.

RE: Particle Size Distribution Analysis for Sample:

SEM 9602-0202 BMI 021096-07-MAP-MPA-32.0-35.0

As per your request, we have performed particle size analysis on the samples submitted to our laboratory. Test results are as follows:

Clay: 8.6 % **Silt: 25.9 %** **Sand: 65.5 %**

The sample was passed through a #10 sieve prior to analysis as per procedure. All results are based on oven dry sample weights.

We appreciate this opportunity to provide our laboratory testing services. If you have any questions or require further testing, please feel free to contact us at your convenience.

Sincerely,
SIERRA ENVIRONMENTAL MONITORING, INC.

John Seher
Laboratory Manager

William F. Pillsbury
President

1135 Financial Blvd.
Reno, NV 89502
Phone (702) 857-2400
FAX (702) 857-2404

John C. Seher
Manager

PO. 90/00

Battelle
Columbus Laboratories

CHAIN OF CUSTODY RECORD

Form No. 001

Proj. No. 6462201-30D0401	Project Title MARCH AFB BiosIURPiNG

SAMPLERS: (Signature)

DATE	TIME	SAMPLE I.D.	SAMPLE TYPE (✓) BTEX/TPH (JP4)	PARTicle Size Dist	Bulk Density	Porosity	Moisture Content										Container No.	Number of Containers	Remarks
07FEB96	1400	MAR-MPA-35.0-35.5	X															1	
07FEB96	1430	MAR-MPA-35.5-36.0	X															1	
07FEB96	1300	MAP-MPA-32.0-35.0		X	X	X	X											2	2 tubES

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
	07FEB96 0920				

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)

Relinquished by: (Signature)	Date/Time	Received for Laboratory by: (Signature)	Date/Time	Remarks
			2/10/96 1105	QuEStions: Contact Al Pollack (614) 424-3753

Page 1 of 1

Bi[redacted]Info[redacted]tion

Name
Address
City, State, Zip
Phone Number

A[redacted]An[redacted]tical, [redacted]
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
Phone (702) 355-1044
Fax (702) 355-0406

BB# 64-02201-30D0401.

Page # 1 of 1

Client Name	Battelle	P.O. #	90106
Address		Phone #	(614) 424-3753
City, State, Zip		Report Attention	AL Pollack
Sampled by			

Analyses Required

Time Sampled	Date Sampled	Type* See Key Below	Lab ID Number	Sample Description	Number of Containers	TPH (Gas)	BTX	Particle Size	Bulk Density	Porosity	Moisture Content			Remarks
	2/7	SO	BMI021096-05	MAR-MPA-35.0-35.5	1	X	X							Plastic tubing
	✓	✓	06	MAR-MPA-35.5-36.0	1	X	X							
	✓	✓	07	MAP-MPA-32.0-35.0	2			X	X	X	X			Composite
														Both tubes
														per AL Pollack
														2/12/96

	Signature	Print Name	Company	Date	Time
Relinquished by					
Received by	Tammy Brace	TAMMY BRACE	Alpha Analytical	2/10/96	1 20
Relinquished by	Tammy Brace	TAMMY BRACE	Alpha Analytical	2/12/96	1505
Received by		R Pruitt	SCo.	2/12/96	1505
Relinquished by					
Received by					

NOTE: Samples are discarded 60 days after results are reported unless other arrangements are made. Hazardous samples will be returned to client or disposed of at client expense.

*Key: AQ - Aqueous SO - Soil WA - Waste OT - Other

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
(702) 355-1044
FAX: 702-355-0406
1-800-283-1183

Boise, Idaho
(208) 336-4145

Las Vegas, Nevada
(702) 386-6747

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: 90106
Phone: (614) 424-3343
Attn: Jeff Kittel

Sampled: 02/13/96 Received: 02/20/96 Analyzed: 02/22/96

Matrix: [ ] Soil [ ] Water [X] Other

Analysis Requested: BTEX - Benzene,Toluene,Xylenes,Ethylbenzene

Methodology: BTEX - EPA Method 624/8240

Results:

Client ID/ Lab ID	Parameter	Concentration mg/Kg	Detection Limit mg/Kg
MAFB-F-01 /BMI022096-01	Benzene	1,300	530
	Toluene	2,100	530
	Ethylbenzene	2,000	530
	Total Xylenes	26,000	530

ND - Not Detected

Approved by: Roger L. Scholl Date: 2/22/96
Roger L. Scholl, Ph.D.
Laboratory Director

[redacted] **Bil[redacted]Info[redacted]on:**[redacted]

Name
Address
City, State, Zip
Phone Number

Al[redacted]Ana[redacted]cal, [redacted]
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
Phone (702) 355-1044
Fax (702) 355-0406

Page # 1 of 1

Client Name Battelle
Address
City, State, Zip
P.O. # 90106
Phone # (614) 4243343
Report Attention Jeff Kittel
Sampled by Client

Time Sampled	Date Sampled	Type* See Key Below	Lab ID Number	Sample Description	Number of Containers	BTEX	TPH								Remarks
	2/13	OT	BMIC2209601	MAFB-F-01	1	X									Fuel Sample

	Signature	Print Name	Company	Date	Time
Relinquished by					
Received by		Linda Bydairk	MAZ	2/20/96	1000
Relinquished by					
Received by					
Relinquished by					
Received by					

NOTE: Samples are discarded 60 days after results are reported unless other arrangements are made. Hazardous samples will be returned to client or disposed of at client expense.

*Key: AQ - Aqueous SO - Soil WA - Waste OT - Other

@ AIR TOXICS LTD.

AN ENVIRONMENTAL ANALYTICAL LABORATORY

WORK ORDER #: 9602166

Work Order Summary

CLIENT: Mr. Jeff Kittel
Battelle Memorial Institute
505 King Avenue
Columbus, OH 43201

BILL TO: Same

PHONE: 614-424-6122
FAX: 614-424-3667
DATE RECEIVED: 2/20/96
DATE COMPLETED: 2/29/96

INVOICE # 9747
P.O. # 91221
PROJECT # March AFB/Bioslurping
AMOUNT$: $693.22

FRACTION #	NAME	TEST	RECEIPT VAC./PRES.	PRICE
01A	MAR-SL-01	TO-3	2.5 "Hg	$120.00
02A	MAR-ICE-01	TO-3	1.5 "Hg	$120.00
03A	STACK-02	TO-3	2.5 "Hg	$120.00
04A	MAR-SL-02	TO-3	1.5 "Hg	$120.00
05A	MAR-ICE-02	TO-3	3.0 "Hg	$120.00
06A	Lab Blank	TO-3	NA	NC

Misc. Charges	1 Liter Summa Canister Preparation (5) @ $10.00 each.	$50.00
	Shipping (2/2/96)	$43.22

CERTIFIED BY: Linda L Freeman
Laboratory Director

DATE: 2/29/96

Seal tank headspace
MW-4

AIR TOXICS LTD.

SAMPLE NAME: MAR-SL-01
ID#: 9602166-01A

EPA METHOD TO-3
(Aromatic Volatile Organics in Air)

GC/PID

File Name:	**6022813**	**Date of Collection: 2/15/96**
Dil. Factor:	**2200**	**Date of Analysis: 2/28/96**

Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
Benzene	2.2	7.1	460	1500
Toluene	2.2	8.4	460	1800
Ethyl Benzene	2.2	9.7	69	300
Total Xylenes	2.2	9.7	340	1500

TOTAL PETROLEUM HYDROCARBONS
GC/FID
(Quantitated as Jet Fuel)

File Name:	**6022813**	**Date of Collection: 2/15/96**
Dil. Factor:	**2200**	**Date of Analysis: 2/28/96**

Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
TPH* (C5+ Hydrocarbons)	22	140	5900	38000
C2 - C4** Hydrocarbons	22	40	550	1000

*TPH referenced to Jet Fuel (MW=156)
**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

Ice off-gas
MW-4

AIR TOXICS LTD.

SAMPLE NAME: MAR-ICE-01
ID#: 9602166-02A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name:	6022814		Date of Collection: 2/15/96	
Dil. Factor:	2.13		Date of Analysis: 2/28/96	
Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
Benzene	0.002	0.007	0.047	0.15
Toluene	0.002	0.008	0.055	0.21
Ethyl Benzene	0.002	0.009	0.016	0.071
Total Xylenes	0.002	0.009	0.072	0.32

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as Jet Fuel)

File Name:	6022814		Date of Collection: 2/15/96	
Dil. Factor:	2.13		Date of Analysis: 2/28/96	
Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
TPH* (C5+ Hydrocarbons)	0.021	0.14	34	220
C2 - C4** Hydrocarbons	0.021	0.039	3.7	6.8

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

Vapor Sample of SVE

AIR TOXICS LTD.

SAMPLE NAME: STACK-02
ID#: 9602166-03A

EPA METHOD TO-3
(Aromatic Volatile Organics in Air)

GC/PID

File Name:	6022818	Date of Collection:	2/16/96
Dil. Factor:	11000	Date of Analysis:	2/28/96

Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
Benzene	11	36	1600	5200
Toluene	11	42	3100	12000
Ethyl Benzene	11	49	110	480
Total Xylenes	11	49	340	1500

TOTAL PETROLEUM HYDROCARBONS
GC/FID
(Quantitated as Jet Fuel)

File Name:	6022818	Date of Collection:	2/16/96
Dil. Factor:	11000	Date of Analysis:	2/28/96

Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
TPH* (C5+ Hydrocarbons)	110	710	100000	650000
C2 - C4** Hydrocarbons	110	200	15000	27000

*TPH referenced to Jet Fuel (MW=156)
**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

Seal Water
Tank
MW03

AIR TOXICS LTD.

SAMPLE NAME: MAR-SL-02
ID#: 9602166-04A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name:	6022815		**Date of Collection:** 2/18/96	
Dil. Factor:	5320		**Date of Analysis:** 2/28/96	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
Benzene	5.3	17	590	1900
Toluene	5.3	20	1400	5400
Ethyl Benzene	5.3	23	170	750
Total Xylenes	5.3	23	660	2900

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as Jet Fuel)

File Name:	6022815		**Date of Collection:** 2/18/96	
Dil. Factor:	5320		**Date of Analysis:** 2/28/96	
Compound	**Det. Limit (ppmv)**	**Det. Limit (uG/L)**	**Amount (ppmv)**	**Amount (uG/L)**
TPH* (C5+ Hydrocarbons)	53	350	48000	310000
C2 - C4** Hydrocarbons	53	97	9900	18000

*TPH referenced to Jet Fuel (MW=156)

**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

ICE
MW-03

AIR TOXICS LTD.

SAMPLE NAME: MAR-ICE-02
ID#: 9602166-05A

EPA METHOD TO-3
(Aromatic Volatile Organics in Air)

GC/PID

File Name: 6022816 **Date of Collection:** 2/18/96
Dil. Factor: 2.24 **Date of Analysis:** 2/28/96

Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
Benzene	0.002	0.007	Not Detected	Not Detected
Toluene	0.002	0.009	Not Detected	Not Detected
Ethyl Benzene	0.002	0.010	Not Detected	Not Detected
Total Xylenes	0.002	0.010	Not Detected	Not Detected

TOTAL PETROLEUM HYDROCARBONS
GC/FID
(Quantitated as Jet Fuel)

File Name: 6022816 **Date of Collection:** 2/18/96
Dil. Factor: 2.24 **Date of Analysis:** 2/28/96

Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
TPH* (C5+ Hydrocarbons)	0.022	0.15	0.28	1.8
C2 - C4** Hydrocarbons	0.022	0.041	1.0	1.8

*TPH referenced to Jet Fuel (MW=156)
**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: 1 Liter Summa Canister

AIR TOXICS LTD.

SAMPLE NAME: Lab Blank
ID#: 9602166-06A

EPA METHOD TO-3
(Aromatic Volatile Organics in Air)

GC/PID

File Name:	6022806		Date of Collection: NA	
Dil. Factor:	1.00		Date of Analysis: 2/28/96	

Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
Benzene	0.001	0.003	Not Detected	Not Detected
Toluene	0.001	0.004	Not Detected	Not Detected
Ethyl Benzene	0.001	0.004	Not Detected	Not Detected
Total Xylenes	0.001	0.004	Not Detected	Not Detected

TOTAL PETROLEUM HYDROCARBONS
GC/FID
(Quantitated as Jet Fuel)

File Name:	6022806		Date of Collection: NA	
Dil. Factor:	1.00		Date of Analysis: 2/28/96	

Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
TPH* (C5+ Hydrocarbons)	0.010	0.065	Not Detected	Not Detected
C2 - C4** Hydrocarbons	0.010	0.018	Not Detected	Not Detected

*TPH referenced to Jet Fuel (MW=156)
**C2 - C4 Hydrocarbons referenced to Propane (MW=44)

Container Type: NA

Battelle
Columbus Laboratories

9602166

CHAIN OF CUSTODY RECORD

Form No. 1

Proj. No.

Project Title: MARCH AFB/BIOSLURPING

SAMPLERS: (Signature) Jon T Eastep

	DATE	TIME	SAMPLE I.D.	SAMPLE TYPE (√) BTEX	TPH	vac press	Container No.	Number of Containers	Remarks
01A	02-15-96	0840	MAR-SL-01	X	X	2.5"Hg	1	1	VAPOR
02A	"	0900	MAR-ICE-01	X	X	1.5"Hg	1	1	"
03A	02-16-96	1400	STACK-02	X	X	2.5"Hg	1	1	"
04A	02-18-96	1143	MAR-SL-02	X	X	1.5"Hg	1	1	"
05A	02-18-96	1119	MAR-ICE-02	X	X	3.0"Hg	1	1	"
	←		1 CAN UNUSED			→			
						2/20/96			

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)
Jon T Eastep	02-18-96 1150				

Relinquished by: (Signature)	Date/Time	Received by: (Signature)	Relinquished by: (Signature)	Date/Time	Received by: (Signature)

Relinquished by: (Signature)	Date/Time	Received for Laboratory by: (Signature)	Date/Time	Remarks
			2/20/96 930	SEND RESULTS TO: JEFF KITTEL 505 KING AVE COLUMBUS OHIO 4320

Custody Seal intact? Y N None   Temp. Ambient   Condition when received: good

Page 1 of 1

Battelle
Columbus Laboratories

CHAIN OF CUSTODY RECORD

Form No. /

Proj. No.

Project Title: BIOSLURPING, MARCH AFB

SAMPLERS: (Signature) for J Eastep

DATE	TIME	SAMPLE I.D.	SAMPLE TYPE (√) BTEX	TPH	Container No.	Number of Containers	Remarks
[illegible] 96	1211	MAR-GW5-01	X	X	1	1	WATER
[illegible] 96	1211	MAR-CA5-01	X	X	1	1	
17 FEB 96	1124	MARCH-W-03	X	X	1	1	″
17 FEB 96	1124	MARCH-W-04	X	X	1	1	″

Relinquished by: (Signature)	Date/Time		Received by: (Signature)	Relinquished by: (Signature)	Date/Time		Received by: (Signature)
J Eastep	18 FEB 96	1053					
Relinquished by: (Signature)	Date/Time		Received by: (Signature)	Relinquished by: (Signature)	Date/Time		Received by: (Signature)
Relinquished by: (Signature)	Date/Time		Received for Laboratory by: (Signature)	Date/Time		Remarks	
						SEND RESULTS TO: JEFF KITTEL 505 KING AVE COLUMBUS, OHIO	

Page 1 of 1

APPENDIX C

SYSTEM CHECKLIST

Checklist for System Shakedown

Site: MARCH AFB, CA.

Date: 08 FEB 96

Operator's Initials: DH

Equipment	Check if Okay	Comments
Liquid Ring Pump	✓	10 HP Atlantic Fluidics, 460 Volt, 3 Ø
Aqueous Effluent Transfer Pump	✓	2 EA.
Oil/Water Separator	✓	megator 10 GPM separator
Vapor Flowmeter		
Fuel Flowmeter	✓	mechanical
Water Flowmeter	✓	Electronic
Emergency Shut off Float Switch	✓	High level/Low level
Effluent Transfer Tank	✓	water tank 325 gAL
Analytical Field Instrumentation		
GasTector™ O_2/CO_2 Analyzer	✓	model 3252 OX and GT-105
TraceTector™ Hydrocarbon Analyzer	✓	GT-105
Oil/Water Interface Probe	✓	2 EA
Magnehelic Boards	✓	4 EA
Thermocouple Thermometer	✓	Fluke

APPENDIX D

DATA SHEETS FROM THE SHORT-TERM PILOT TEST

Baildown Test Record Sheet

Site: MARCH AFB

Well Identification: MW-4

Well Diameter (OD/ID): 4" SCH 80 PVC

Date at Start of Test: 05 FEB 96

Sampler's Initials: DH

Time at Start of Test: 1545 HRS.

Initial Readings

Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)	Total Volume Bailed (L
35,73'	35,0'	0,73'	1.2 liter

Test Data

Sample Collection Time	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
05 FEB/1615/T=0	35.46	35,09	0.37'
05 FEB/1617/T=2 min	35.46	35.07	0,39'
05 FEB/1620/T=5 min	35.48	35.06	0,42'
05 FEB/1715/T=60M	35.47	35.04	0.43'
06 FEB/0740/T=925m	35.47	35.03	0.44'
07 FEB/0845/T=2430	35.33	34.90	0.43'

ATMOSPHERIC OBSERVATIONS

Site: MARCH AFB

Operators: HEADINGTON/EASTER

Date/Time	Ambient Temperature	Relative Humidity	Barometric Pressure
09FEB96/0830	67.2°	37%	—
09FEB 96 /1805	61.5°	71%	—
10FEB96/0715	52.3°	88%	—
11 FEB96/0740	53°	84%	30.01" Hg
12 FEB96/1400	67°	34%	29.90" Hg
13 FEB96/ 0700	56°	61%	30.06" Hg
14 FEB96/0938	62°	64%	30.10" Hg
15 FEB96/ 0800	64°	62%	30.12" Hg

WELL CHARACTERistics
~~ATMOSPHERIC OBSERVATIONS~~

Site: MARCH AFB, CA.

Operators: DH/JE

DATE: 12 FEB 96

WELL ID:	DEPTH TO LNAPL	DEPTH TO WATER	LNAPL LAYER
MW-01	36.56	37.16	
TF-03	36.08	36.55	
PZ-2B	35.99	35.995	0.005
TF-08	sheen	37.57	sheen
SVE-IA	36.30	36.35	0.05
TF-07	NA	36.50	NA
TF-05	NA	38.09	NA
EX-01	NA	37.35	NA
EX-04	confined	SPACE no data	
FP-01	37.25	37.25	sheen
MW-03	confined	SPACE	

PANERO SYSTEM OPERATIONAL WELLS

MW-03 — Collects only fuel (skimmer pump)

EX 2 } Collects fuel and water.
EX 4 }

water PRODUCTION IS APPROX 5-6 GPM.

FUEL RECOVERY FROM these 3 WELLS = 40-50 GAL PER WEEK

Bioslurping Pilot Test
(Data Sheet 2)
Pilot Test Pumping Data

Page ___ of ___

Site: MARCH AFB, CA.

Operators: HEADINGTON / EASTEP

Test Type: Skimmer

Depth to Groundwater: 35.47

Depth to Fuel: 35.04

Start Date: 09 FEB 96

Start Time: 0830

Well ID: MW-4

Depth of Tube: 35.47

Date/Time	Run Time	Vapor Extraction			Pump Stack Temp (°C)	Pump Head Vacuum (in. Hg)	Extraction Well Vacuum (in. H_2O)
		MAKE UP AIR (scfm)	ICE INTAKE AIR (scfm)	WELL Flowrate (scfm)			
09 FEB/0830	0	34	123	89	56.6	22	Atmospheric
09 FEB/1205	3.6 HR	35-40	139	101.5	67.9	20"	Atmospheric
09 FEB/1805	9.6 HR	33	122	89	49.2	21"	Atmospheric
10 FEB/0715	22.8 HR	32	122	90	55	21"	Atmospheric
10 FEB/1700	32.5 HR	38.5	132	93.5	69	20"	Atmospheric
11 FEB/0740	47.2 HR	34	128	94	65	20"	Atmospheric

PILOT TEST PUMPING DATA

Site: MARCH AFB, CA.

Operators: HEADINGton / EASTEP

Test Type: SLURPING

Depth to Groundwater: 35.32 GRAD
36.42 (TOP OF Adaptor)

Depth to Fuel: ——

Start Date: 11 FEB 96

Start Time: 1010

Well ID: MW-4

Depth of Tube: 36.17 (GRAD)
37.27' (TOP OF Adaptor)

Date/Time	Run Time	Vapor Extraction			Pump Stack Temp (°C)	Pump Head Vacuum (in Hg)	Comments
		MAKE UP AIR (scfm)	~~ICE~~ INTAKE AIR (SCFM)	Flowrate (scfm)			
11 FEB / 1010	0	—	—	—	—	—	HOURMETER = 48.6
11 FEB / 1110	1.0 HR	41	116	75	33°	24	HOURMETER = 49.6
11 FEB / 1335	3.4	43	116	73	38°		
11 FEB / 1410	4.0	OFF					
12 FEB / 0900	NOTE:	Depth	to water	= 36.31 —	NO FUEL	RECHARGE,	SYSTEM OFF FOR 19 HRS.
12 FEB / 1400	0	33	121	88	23.6	23	
12 FEB / 1640	2.4 HR	43	120	77		23"	
13 FEB / 0700	17 HR	43	115	72	26°	22"	Stopped 0723
		Total	slurping	time	Approx	21	Hours

Page 1 of 1

Bioslurper Pilot Test Monitoring Well Data Sheet

Site: MARCH AFB, CA.   MW-04

Test Type (Skimmer, Bioslurper Vacuum Extraction, Drawdown): Skimmer

Depth to Groundwater: 35.47'   Depth to Fuel: 35.04'   Depth of Slurper Tube: 35.47'

Date at Start of Test: 09 FEB 96

Time at Start of Test: 0830   Operator's Initials: AH

Time	Vapor Extraction Flow		LNAPL Totalizer (gal)	Groundwater Totalizer (gal)	Well-Head Vacuum (in H_2O)	Comments (include samples collection/analysis information)
	MAKE UP FLOW ~~Pressure (in H_2O)~~	Flowrate WELL (scfm)				
T=0	0	0	0	0	Atms.	
T=9.6HR	35-40 scfm	89	0	302 GAL	Atms.	METER READING = 59 GALLONS WATER, PUMP VAC = 21" Hg
T=22.8	32 scfm	90	0	548 GAL	Atms.	water meter = 304.9 GAL / RATE = 0.2 GPM
T=32.5	38.5	132	0	560 GAL	Atms.	Water Rate 0.08 GPM
T=47.2	34	128	0	690 GAL	Atms.	OFF at 47.5 HR RUN TIME

Figure 14. Typical Record Sheets for Bioslurper Pilot Testing (continued)

Bioslurping Pilot Test
(Data Sheet 3)
Fuel and Water Recovery Data

Page 1 of 1

Site: MARCH AFB, CA. / MW-04

Start Date: 09 FEB 96

Test Type: SKimmER

Operators: Hadyta/Eastep

Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
0830	T=0	0	0
	T=9.6	0	302 GAL
	T=22.8	0	548 GAL
	T=32.5	0	560 GAL
	T=47.2	0	690 GAL
		OFF AT 47.5 HOURS	

Page 1 of 1

Bioslurper Pilot Test Monitoring Well Data Sheet

MW-04

Site: MARCH AFB, CA,

Test Type (Skimmer, Bioslurper Vacuum Extraction, Drawdown): BIOSLURPER

Depth to Groundwater: 35.32', GRAD / 36.42' (Top of Adaptor)

Depth to Fuel: —

Depth of Slurper Tube: 36.17' (GRAD) / 37.27' (TOP OF Adaptor)

Date at Start of Test: 11FEB96

Time at Start of Test: 1010

Operator's Initials: DH

Time	Vapor Extraction Flow		LNAPL Totalizer (gal)	Groundwater Totalizer (gal)	Well-Head Vacuum (in H_2O)	Comments (include samples collection/analysis information)
	MAKE UP AIR FLOW (scfm)	WELL Flowrate (scfm)				
T=0	—	—	0		—	— Hour meter = 48.6 HR
T=1 HR	41	75	0	Rate = 3.6 GPM	21" H_2O	
T=3.4	43	73	0	Rate = 5.53 GPM	22"	
T=4.0	- - - - OFF	- - -	- - -	- - -	- - -	HAVING TROUBLE PUMPING WATER TO THE PANERO PLANT
T=0	33	88 cfm	0	502.6 GAL	23"	12 FEB/1400 HRS / HOUR METER 52.7 HRS. WATER RATE = 3.48 GPM TUBE SET 37.2'
T=1.8 HR	—	—	0	825 GAL	17"	1548 HRS WATER = 3.0 GPM
T=2.4 HR	43	77	0	1029 GAL	18"	HOUR METER = 55.1 WATER RATE = 3.34 GPM OFF GAS = 1260 PPM TPH O_2 = 20.8 %
T=17 HR	43	72	0	3825		HOUR METER 69.7 3.3 GPM WATER OFF GAS = 1000 PPM TPH O_2 = 20.9 %
		Stopped	SLURPING	total	time	= ~21 HRS SLURPING
						DTW MW 4 = 37.11' Top of Adaptor Well EX03 (DTW = 36.84' (VAC = 0.005" H_2O)

Figure 14. Typical Record Sheets for Bioslurper Pilot Testing (continued)

Bioslurping Pilot Test
(Data Sheet 3)
Fuel and Water Recovery Data

Page 1 of 1

Site: MARCH AFB, CA. MW-04

Start Date: 11 FEB 96

Test Type: Bioslurper

Operators: SE/GH

Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
1010 HR	T=0	0	0
	T=1	0	water Rate = 3.6 GPM
	T=3.4	0	Water Rate = 5.53 GPM
	T=4.0	System off	HAVING PROBlems Pumping water to PANERO PLANT
12FEB 1400	T=0	0	502.6 GAL
	T=1.8	0	825 GAL
	T=2.4	0	1029 GAL
	T=17	0	3825 GAL
		OFF, total of 21 HRS	slurping
		with no fuel recovery.	

Page 1 of 2

Bioslurper Pilot Test Monitoring Well Data Sheet

Site: MARCH AFB, CA. MW-04

Test Type (Skimmer, Bioslurper Vacuum Extraction, Drawdown): DRAWDOWN (TRY TO DEWATER WELL AS MUCH AS POSSIBLE)

Depth to Groundwater: 37.11 (Top of Adaptor) Depth to Fuel: NO FUEL

Depth of Slurper Tube: Slowly moved tube to 37.8' (Top of Adap)
Total Liquid pulling a height of 47.25' (Hose/pipe Above GRAD)
Adjusted total tube length to 42.4' JH

Date at Start of Test: 13 FEB 96

Time at Start of Test: 0800 HRS.
well Adaptor = 1.1' Above GRAD

Operator's Initials: JE

Time	Vapor Extraction Flow		LNAPL Totalizer (gal)	Groundwater Totalizer (gal)	Well-Head Vacuum (in H_2O)	Comments (include samples collection/analysis information)
	MAKE UP AIR (scfm)	WELL Flowrate (scfm)				
T=0			0	3825	Atms.	Start 0800 HR. HR METER = 70.4 HOURS
T= 1.5 HR			0	4110	Atm.	HOUR meter = 71.9 HOUR
T=2.2			0	4187	Atm.	1010 HRS Hour meter = 72.6 HOUR / RATE = 77 GAL/40 MIN 1.93 GPM
T=3.1			0	3.18 GPM	Atm.	1102 HRS, WATER RATE = 3.18 GPM (73.5 = HOUR METER)
T= 3.6			0	2.6 GPM	Atm	1130 HRS, HOUR METER = ~74 HRS water RATE = 2.6 GPM
T= 5.3			0	2.7 GPM	Atm.	1317 HOURS, HR meter = 75.7 HR WATER RATE = 2.7 GPM
T= 6.3			0	4.7 GPM	Atms.	1418 HOUR, HR meter 76.7 HR WATER RATE = 4.7 GPM
T= 7.4			0	5127 GALLONS 3.6 GPM	Atms	1525 HOURS HOUR meter 77.8 HR WATER RATE = 3.6 GPM
T=9.8			0	5401 GAL	Atms.	1805 HOURS, HOUR METER 80.2 HRS
T=16.8				6100 GAL	Atms.	14 FEB 96 0100 HRS. / Note: system stopped pulling / draw tube dropped down into WELL

Page 2 of 2

Bioslurper Pilot Test Monitoring Well Data Sheet

Site: MARCH AFB, CA.

Test Type (Skimmer, Bioslurper Vacuum Extraction, Drawdown): Drawdown/Skimm

Depth to Groundwater: 37.11 Depth to Fuel: — Depth of Slurper Tube: ______

Date at Start of Test: 13 FEB 96

Time at Start of Test: See first PAGE Operator's Initials: DE Att

Time	Vapor Extraction Flow		LNAPL Totalizer (gal)	Groundwater Totalizer (gal)	Well-Head Vacuum (in H_2O)	Comments (include samples collection/analysis information)
	Pressure (in H_2O)	Flowrate (scfm)				
T=0	—	—	—	—	—	Restart system 0930 HRS / 14 FEB 96 2.92 GPM
				6428		0938 HRS.
T=17.1	—	—	—	—	—	0945 HR. PUMP HR METER = 96.2 HR 1025 HR tube SET AT 39.0' (Top of Adaptor)
T=18.0			0	RATE 3.8 GPM	—	1040 HR. WATER RATE 3.8 GPM
T=23.4				7547 GAL	HR METER 102.5 HR	1600 HR. STOP DRAWDOWN/SKimm switch over to slurping.
						Total WAtER RECOVERED = 3722 GAL
						Approx 160 Gallons PER HOUR

Figure 14. Typical Record Sheets for Bioslurper Pilot Testing (continued)

Bioslurping Pilot Test
(Data Sheet 3)
Fuel and Water Recovery Data

Page 1 of 1

Site: March AFB, CA. MW-04

Start Date: 13 FEB 96

Test Type: Dewatering/Drawdown

Operators: JE/GH

Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
13 FEB 0800	T=0	0	3825 meter reading
	T=1.5	0	4110 GAL
	T=2.2	0	4187 GAL
	T=3.1	0	Rate (3.18 GPM)
	T=3.6	0	Rate (2.6 GPM)
	T-5.3	0	Rate (2.7 GPM)
	T=6.3	0	Rate (4.7 GPM)
	T=7.4	0	5127 GAL
	T=9.8	0	5401 GAL
	T=16.8	0	6100 GAL
	T=17.1	0	—
	T=18.0	0	Rate (3.8 GPM)
	T=23.4	0	7547 GAllons
		Water Generation is	159 GAllons PER Hour

Page 1 of 1

Bioslurper Pilot Test Monitoring Well Data Sheet

Site: MARCH AFB, CA. MW-04

Test Type (Skimmer, Bioslurper Vacuum Extraction, Drawdown): Bioslurping (drawndown)

Depth to Groundwater: ______ Depth to Fuel: ______ Depth of Slurper Tube: 39.0' Top of Adaptor (1.1')

Date at Start of Test: 14 FEB 96

Time at Start of Test: 1600 HR

Operator's Initials: JE GH

Time	Vapor Extraction Flow		LNAPL Totalizer (gal)	Groundwater Totalizer (gal)	Well-Head Vacuum (in H_2O)	Comments (include samples collection/analysis information)
	OFF GAS TPH	WELL Flowrate (scfm)				
T=0	—	|	0	7547 GAL	—	1600 HRS, HOUR METER = 102.5 HRS WATER RATE = 5.34 GPM
T=50min	—	|	0	7685 GAL	—	1650 HRS 2.76 GPM / SEPERATOR RATE 3.1 GPM
T=1.9HR	4300 ppm	|	0	8046 GAL	18"	1755 HRS, HR METER 104.4 RATE = 5.6 GPM
T=16HR	4300 ppm	75 cfm	0	11808 GAL	32"	15 FEB 96 / 0800 HR HR METER = 118.5 HR | 0825 HR RATE 4.5 GPM
T=18.7	—	—	0	12543	35"	1045 HR HR METER = 121.2 | WATER RATE 4.5 GPM

Figure 14. Typical Record Sheets for Bioslurper Pilot Testing (continued)

Bioslurping Pilot Test
(Data Sheet 3)
Fuel and Water Recovery Data

Page 1 of 1

Site: MARCH AFB, CA. MW-04

Start Date: 14 FEB 96

Test Type: Bioslurping (Drawdown)

Operators: JE / GH

Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
14FEB/1600	T=0	0	7547 GAL
	T=50 min	0	7685 GAL
	T=1.9	0	8046 GAL
	T=16	0	11808 GAL
	T=18.7	0	12543 GAL
		Water generated = Average	267 Gallons per Hour
			4.4 GPM

Baildown Test Record Sheet

Site: MARCH AFB, CA. BAILDOWN

Well Identification: MW-03

Well Diameter (OD/ID): 4" Stainless Steel

Date at Start of Test: 15 FEB 96

Sampler's Initials: JE ~~OH~~

Time at Start of Test: 1416 HRS

REMOVED PANERO System skimmer pump which

Initial Readings WAS OPERATING and gauged well for fuel LAYER changes.

Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)	Total Volume Bailed (L)
37.02	36.78	0.24'	——

Test Data

Sample Collection Time	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
1416	37.02	36.78	0.24
1430	36.98	36.715	0.265
1500	36.95	36.71	0.24'
1510	36.98	36.72	0.26
1527	36.97	36.71	0.26

Page 1 of 2

Bioslurper Pilot Test Monitoring Well Data Sheet

Site: MARCH AFB, CA.

MW-03
4" Stainless steel well

Test Type (Skimmer, Bioslurper Vacuum Extraction, Drawdown): Low VACUUM Slurping / High Vacuum Slurping

Depth to Groundwater: 36.97 Depth to Fuel: 36.71 Depth of Slurper Tube: 37.25

Date at Start of Test: 15 FEB 96

Time at Start of Test: 1730 HRS. Operator's Initials: JE GH

well head - 6.0' Below ground in concrete vault.

Time	Vapor Extraction Flow		LNAPL Totalizer (gal)	Groundwater Totalizer (gal)	PUMP Head Vacuum (in Hg)	Comments (include samples collection/analysis information)
	WELL Pressure (in H_2O)	WELL GAS TPH				
T=0	—— initi	A/S ——	0	12551	——	1730 HRS HOUR METER 123.0 HRS
T=43min	7.5"	16,000 ppm	PULLED A slug	12672	22"	1813 HRS PUMP VAC = 22" Hg
T=1.25HR	7.5"	16,000	——	12723	22"	1844 HRS water RATE 1.64 GPM HR METER 124.3
T=13.7	8.5"	10,500	1.3 GAL	13,500	22"	16FEB96 / 0715 / HR meter = 136.7 HRS water Rate = 1.6 GPM
T=15.45	8.5"	——	——	13661	22"	0900 HRS WATER RATE = 1.5 GPM
T=19.5	——	——	0850-1252 700 ml	13920	21"	HR METER = 142.5 HR ~13:00 FUEL RATE 0850-1252-700cc.
T=20.1	9.5"	——	1100 ml	~13967	21"	1330 HRS. 1431 - HR meter Collected ~ 1.8 GAL Fuel this test
		Switch to higher VACUUM				Close air by-pass VALVE
T=0	22"	——	~~1.5 GAL~~ 0	13967	21"	1339 HR
T=0.9HR	——	——	RATE 0.03 GPM	Rate = 2.12 GPM	25"	1427 HRS / HR METER READING 144 HRS.

Figure 14. Typical Record Sheets for Bioslurper Pilot Testing (continued)

Page 2 of 2

Bioslurper Pilot Test Monitoring Well Data Sheet

MW-03

Site: MARCH AFB, CA.

Test Type (Skimmer, Bioslurper Vacuum Extraction, Drawdown): High Vacuum Slurping

Depth to Groundwater: 36.97 Depth to Fuel: 36.71 Depth of Slurper Tube: 37.25

Date at Start of Test: 15 FEB 96

Time at Start of Test: 1730 HRS

Operator's Initials: JE GH

Time	Vapor Extraction Flow		LNAPL Totalizer (gal)	Groundwater Totalizer (gal)	PUMP Head Vacuum (in Hg)	Comments (include samples collection/analysis information)
	WELL Pressure (in H_2O)	WELL GAS TPH				
T=2.4	25"	—	2.75 GAL	14,271	25"	1557 HR 16FEB96 HOURMETER 145.5 WATER RATE 3.5 GPM
T=3.5	26"	—	4.35	14,426	24"	HR METER 146.6 HR WATER RATE 2.14 GPM
T=7.7	27"	—	7.05	15040	25"	HR METER 150.8 WATER RATE = 2.4 GPM
T=18.2	29"	—	11.45	16479	24.5"	17FEB96 FUEL RATE = 0.16 GPH 0747 HRS/METER 161.3 WATER RATE = 2.3 GPM
T=21.3	29"	—	12.25	16873	24.5"	FUEL RATE = 800 cc/HR HRmeter 164.4 water RATE 2.12 GPM
T=27.8	30"	—	13.25	17730	24"	HOUR meter 170.9 HR WATER RATE 2.2 GPM
T=42.7	29"	—	16.75	19668	24.5"	0800/18FEB96 Hour meter = 185.8 Fuel RATE = 0.23 GPH WATER RATE = 2.2 GPM
T=47.4	30"	—	17.75	20479	24"	Fuel Rate = 0.21 GPH HOUR METER = 190.5 WATER RATE 2.9 GPM
		END		TEST		
	Note: Cleaning system/		separator ect,	recovered	Addition	4 Gallons of fuel (Low VAC test High VAC test) total

Also recovered approx 15 gallons of emulsion (fuel, sediment, water mixed)

Figure 14. Typical Record Sheets for Bioslurper Pilot Testing (continued)

Bioslurping Pilot Test
(Data Sheet 3)
Fuel and Water Recovery Data

Page 1 of 1

Site: MARCH AFB, CA. (MW-03)

Start Date: 16 FEB 96

Test Type: Higher VAcuum SlurPing

Operators: JL

Date/Time	Run Time	Total LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
16 FEB / 1339	T=0	0	13967 GAL
	T=2.4	2.75 GAL	14271 GAL
	T=3.5	4.35 GAL	14426 GAL
	T=7.7	7.05 GAL	15040 GAL
17 FEB 96	T=18.2	11.45 GAL	16479 GAL
	T=21.3	12.25 GAL	16873 GAL
	T=27.8	13.25 GAL	17730 GAL
FEB 18/96	T=42.7	16.75	19668 GAL
	T=47.4	17.75	20479 GAL

END OF TEST – Recovered an additional 4 gAllons of fuel and approx 15 gAllons of emulsion*

Total fuel collected ≈ ~~[illegible]~~ 20 gAllons fuel

Total water recovered this test = 6512 gAllons OR 137.4 GPH

SLURPPT.DS3 (G462201-1001 DISK)

Bioslurping Pilot Test
(Data Sheet 3)
Fuel and Water Recovery Data

Page 1 of 1

Site: MARCH AFB, CA. (MW-03)

Start Date: 15 FEB 96

Test Type: Low Vacuum Slurping

Operators: JE

Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
15FEB/1730	T=0	0	12551 GAL
	T=0.7	pulled slug from well	12672 GAL
	T=1.25	0	12723 GAL
	T=13.7	1.3 GAL	13500 GAL
	T=15.45	0	13661 GAL
	T=19.5	700 ml	13920 GAL
	T=20.1	1.1 Liter	13967 GAL
		Total water generated =	1416 Gallons or 70.4 GPH
		Total fuel recovered =	1.8 Gallons

APPENDIX E

SOIL GAS PERMEABILITY TEST RESULTS

MW-04

Record Sheet for Air Permeability Test

Site MARCH AFB	**Monitoring Point** A
Blower Type 10 HP	**Distance from Vent Well** 10'
Depth of Point 15'-25'-35'	**Recorded by** JE GH

Time	G ~~MP1~~	B ~~MP2~~	R ~~MP3~~	Time	G ~~MP1~~	B ~~MP2~~	R ~~MP3~~
INITIAL	0	0	0				
2min	(-)0.01	(-)0.01	(-)0.01				
4 min	-0.01	-0.01	-0.01				
6 min	0.0	0.0	0.0				
8 min	-0.005	-0.01	-0.007				
12min	-0.03	-0.03	-0.03				
14min	-0.01	-0.003	0.0				
16 min	-0.002	-0.003	(-)0.01				
19min	(-)0.03	(-)0.03	(-)0.032				
22 min	(-)0.035	-0.035	(-)0.032				
44 min	(-)0.07	(-)0.065	(-)0.065				
82min	(-)0.085	(-)0.075"	(-) 0.067				

(-) Neg readings indicate positive pressure.

MW-04

Record Sheet for Air Permeability Test

Site MARCH AFB

Monitoring Point B

Blower Type 10 HP

Distance from Vent Well 22'

Depth of Point 15'-25'-34'

Recorded by JE GH

B

Time	G ~~MP1~~	B ~~MP2~~	R ~~MP3~~	Time	G ~~MP1~~	B ~~MP2~~	R ~~MP3~~
INITIAL	0	0	0				
2min	(-)0.015	(-)0.02	(-)0.02				
4 min	-0.01	-0.01	0.0				
6 min	(-)0.005	(-)0.005	0.0				
8 min	(-)0.007	-0.005	(-)0.002				
10 min	(-)0.025	-0.025	-0.005				
13min	(-) 0.025	-0.035	-0.025"				
15min	(-)0.00	0.0	+0.001				
17min	(-)0.03	-0.032	-0.005				
20min	(-)0.055	(-)0.05	(-)0.005				
23min	(-)0.055	(-)0.048	(-)0.005				
42min	(-)0.085	(-)0.085	(-)0.005				
85min	(-)0.125	(-)0.137"	(-) 0.015"				

(-) Neg readings indicate positive pressure.

MW-04

Record Sheet for Air Permeability Test

Site MARCH AFB	**Monitoring Point** C
Blower Type 10 HP	**Distance from Vent Well** 40'
Depth of Point 15'-25'-34'	**Recorded by** JE GH

Time	G ~~MP1~~	B ~~MP2~~	R ~~MP3~~	Time	G ~~MP1~~	B ~~MP2~~	R ~~MP3~~
INITIAL	0	0	0				
1 MIN	<0	<0	<0				
2 MIN	<0	<0	<0				
3 MIN	-.01	-.01	-.015				
4 MIN	-.005	-.005	-.01				
5 MIN	0	0	0				
7 MIN	0	0	0				
10 MIN	-.025	-.025	-.030				
12 MIN	-.025	-.025	-.030				
14 MIN	-.01	-.01	-.015				
16 MIN	-.005	-.005	-.015				
18 MIN	-.025	-.025	-.035				
20 MIN	-.03	-.03	-.04				
22 MIN	-.04	-.04	-.05				
24 MIN	-.04	-.04	-.05				
44 MIN	-.075	-.075	-.085				
82 MIN	-.10	-.10	-.15				

WELL HEAD 12.5" H_2O 7 MIN.
19.0" H_2O 19 MIN.
21.0" H_2O 47 MIN.
21.0" H_2O 83 MIN.