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SITE-SPECIFIC TECHNICAL REPORT FOR BIOSLURPER TESTING AT SITE ST-04, K.I. SAWYER AFB, MICHIGAN

DRAFT

PREPARED FOR:

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

AND

K.I. SAWYER AFB, MI

18 OCTOBER 1996

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SITE-SPECIFIC TECHNICAL REPORT (A003)

for

FREE-PRODUCT RECOVERY TESTING AT K.I. SAWYER AFB, MICHIGAN

by

A. Leeson, M. Place, M. Graves, and J. Kramer

for

Mr. Patrick Haas
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Brooks AFB, Texas 78235-5357

October 18, 1996

Battelle
505 King Avenue
Columbus, Ohio 43201-2693

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ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
AFCEE	U.S. Air Force Center for Environmental Excellence
bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
ft/ft	foot per foot
HC1	hydrochloric acid
LNAPL	light-nonaqueous-phase liquid
MW	monitoring well
POL	petroleum, oils, and lubricants
ppmv	part(s) per million by volume
PVC	polyvinyl chloride
scfm	standard cubic foot (feet) per minute
TPH	total petroleum hydrocarbon
VOC	volatile organic compound

EXECUTIVE SUMMARY

This report summarizes the field activities conducted at K.I. Sawyer Air Force Base (AFB) for a short-term field pilot test to compare vacuum-enhanced free-product recovery (bioslurping) to traditional free-product recovery techniques used to remove light, nonaqueous-phase.liquid (LNAPL) from subsurface soils and aquifers. The field testing at K.I. Sawyer 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 K.I. Sawyer 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 K.I. Sawyer AFB were skimmer pumping, bioslurping, and drawdown pumping.

Bioslurper pilot test activities were conducted at two monitoring wells at the POL Bulk Fuel Storage Area (Site ST-04): (1) monitoring well RW-2, and (2) monitoring well K30S. 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 RW-2, pilot tests for skimmer pumping, bioslurping, and drawdown pumping were conducted. The LNAPL recovery testing was conducted in the following sequence at monitoring well RW-2: 46.75 hr in the skimmer configuration, approximately 47 hr in the bioslurper configuration, an additional 8 hr in the skimmer configuration, and 61.25 hr in the drawdown configuration.

After the drawdown pump test at RW-2, LNAPL recovery testing was conducted in the following sequence at K30S: 8 hr in the skimmer configuration, followed by 37.5 hr in the bioslurper configuration.

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.

Approximately 60 gallons of LNAPL were recovered during the series of pump tests at monitoring well RW-2. Groundwater was extracted at rates ranging from 640 gallons/day during the initial skimmer pump test up to 1,000 gallons/day during the bioslurper pump test. In general, fuel recovery rates decreased with time, with the highest rates during the initial skimmer pump test. There appeared to be little difference in recovery rates based on the configuration of the system. This may be due to the inability to achieve high vacuum during the bioslurper pump test due to the well construction and water table depth. It is possible that greater fuel recovery could have been achieved with higher well vacuums.

Soil gas concentrations were measured at monitoring points during the bioslurper pump test at monitoring well RW-2 determine whether the vadose zone was being oxygenated. Oxygen concentrations increased at all monitoring points by the completion of the test. These results demonstrated that the oxygen radius of influence was slightly larger than the pressure radius of influence measured during the soil gas permeability test.

During the pump tests conducted at K30S, free-product recovery rates were significantly different between skimming and bioslurping, with higher recovery rates achieved during bioslurping. However, fuel recovery rates were still relatively low. During the bioslurper pump test, the average fuel recovery rate was approximately 8.7 gallons/day. Groundwater recovery rates over the 37-hour test averaged 450 gallons/day. Free product recovery at this monitoring well was fairly similar to that observed at monitoring well RW-2, although groundwater recovery was significantly less at this monitoring well. The inability to achieve a high vacuum on either well may have limited recovery rates.

Based on the results at monitoring wells RW-2 and K30S, implementation of bioslurping at Site ST-04 is unlikely to facilitate enhanced recovery of LNAPL from the water table. Different well construction which would allow for higher vacuums on the wells may facilitate improved free product removal via bioslurping; however, it should be noted that free product rates were low at this site and even with different well construction, it's possible that there is not sufficient quantities of mobile free product to recover. In situ biological activity is fairly low; therefore, bioslurping would be unlikely to enhance microbial degradation rates in the vadose zone.

DRAFT SITE-SPECIFIC TECHNICAL REPORT (A003)

for

FREE-PRODUCT RECOVERY TESTING AT K.I. SAWYER AFB, MICHIGAN

October 18, 1996

1.0 INTRODUCTION

This report describes activities performed and data collected during field tests at K.I. Sawyer Air Force Base (AFB), Michigan 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 K.I. Sawyer 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 K.I. Sawyer 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 K.I. Sawyer 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 K.I. Sawyer AFB were skimmer pumping, bioslurping, and drawdown pumping. The specific test objectives, methods, and results for the K.I. Sawyer AFB test program are discussed in the following sections.

1.2 Testing Approach

Bioslurper pilot test activities were conducted at two monitoring wells at the POL Bulk Fuel Storage Area (Site ST-04): (1) monitoring well RW-2, and (2) monitoring well K30S. 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 RW-2, pilot tests for skimmer pumping, bioslurping, and drawdown pumping were conducted. The LNAPL recovery testing was conducted in the following sequence at monitoring well RW-2: 46.75 hr in the skimmer configuration, approximately 47 hr in the bioslurper configuration, an additional 8 hr in the skimmer configuration, and 61.25 hr in the drawdown configuration.

After the drawdown pump test at RW-2, LNAPL recovery testing was conducted in the following sequence at K30S: 8 hr in the skimmer configuration, followed by 37.5 hr in the bioslurper configuration.

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.

2.0 SITE DESCRIPTION

The information presented in this section was obtained from site-specific information received by Battelle from K.I. Sawyer AFB and a document entitled *Bioventing Pilot Test Work Plan for*

Installation Restoration Program: Site ST-04 POL Bulk Fuel Storage Area, K.I. Sawyer AFB, Michigan (Engineering-Science, Inc. 1992)

K.I. Sawyer AFB is located in Marquette, Michigan, which is in the north-central portion of Michigan's Upper Peninsula. Site ST-04 is located on the south-central part of the base, and is bounded on the east and west by Avenues D and H, respectively, and on the north and south by First Street and Avenue A, respectively (Figure 1). Site ST-04 is approximately 500 ft by 500 ft in size. There are five aboveground jet fuel storage tanks and a vapor sphere. The fuel tanks have the following capacities: one each at 37,500, 20,000, 10,000 gallons, and two at 5,000 gallons. The vapor sphere has a capacity of 10,000 ft^3. Each tank is contained in a diked area with concrete walls and base. A truck loading/unloading and tank car unloading area is located along the east side of Site ST-04.

Air Force records show that five spills have been documented at the site since 1970, including a single spill of 40,000 gallons between tank No. 5 and Avenue D, of which only about 8,000 gallons were recovered. The total volume of JP-4 estimated to have been spilled is between 65,000 and 74,000 gallons; however, the actual volume may be significantly greater due to undocumented spills before 1970. Long-term Base employees indicate that in the past, fuel was transferred by train cars, and spills were common.

An oval-shaped free-product plume is located to the southeast of Site ST-04. The plume is approximately 950 ft by 500 ft. Groundwater depth appears to be approximately 72 ft below ground surface (bgs) and flows in a southeasterly direction across the site at a gradient of approximately 0.01 foot per foot (ft/ft). In July, 1996, groundwater depth was measured at approximately 67 ft bgs. The site is upgradient from an alternative Base drinking water supply well and Silver Lead Creek, located approximately 1,700 feet east of the site. A previous study of the area showed that a plume of contaminated groundwater originated in Site ST-04 and extended under Silver Lead Creek. Site ST-04 soils are glacial deposits of sand with some gravel and silt overlying relatively impermeable bedrock at a depth of approximately 100 ft.

A soil vapor survey indicated that the highest levels of contamination occur along the southeastern edge of Site ST-04. A total aromatic volatile organic compound (VOC) concentration was reported at 292,000 mg/kg. Total petroleum hydrocarbon (TPH) concentrations were measured in excess of 7,000 mg/kg at a depth of approximately 15 ft. Groundwater analyses from 1988 through 1990 indicate the presence of benzene (up to 5,200 μg/L), ethylbenzene (up to 630 μg/L), total xylenes (up to 1,000 μg/L), and toluene (up to 4,400 μg/L).

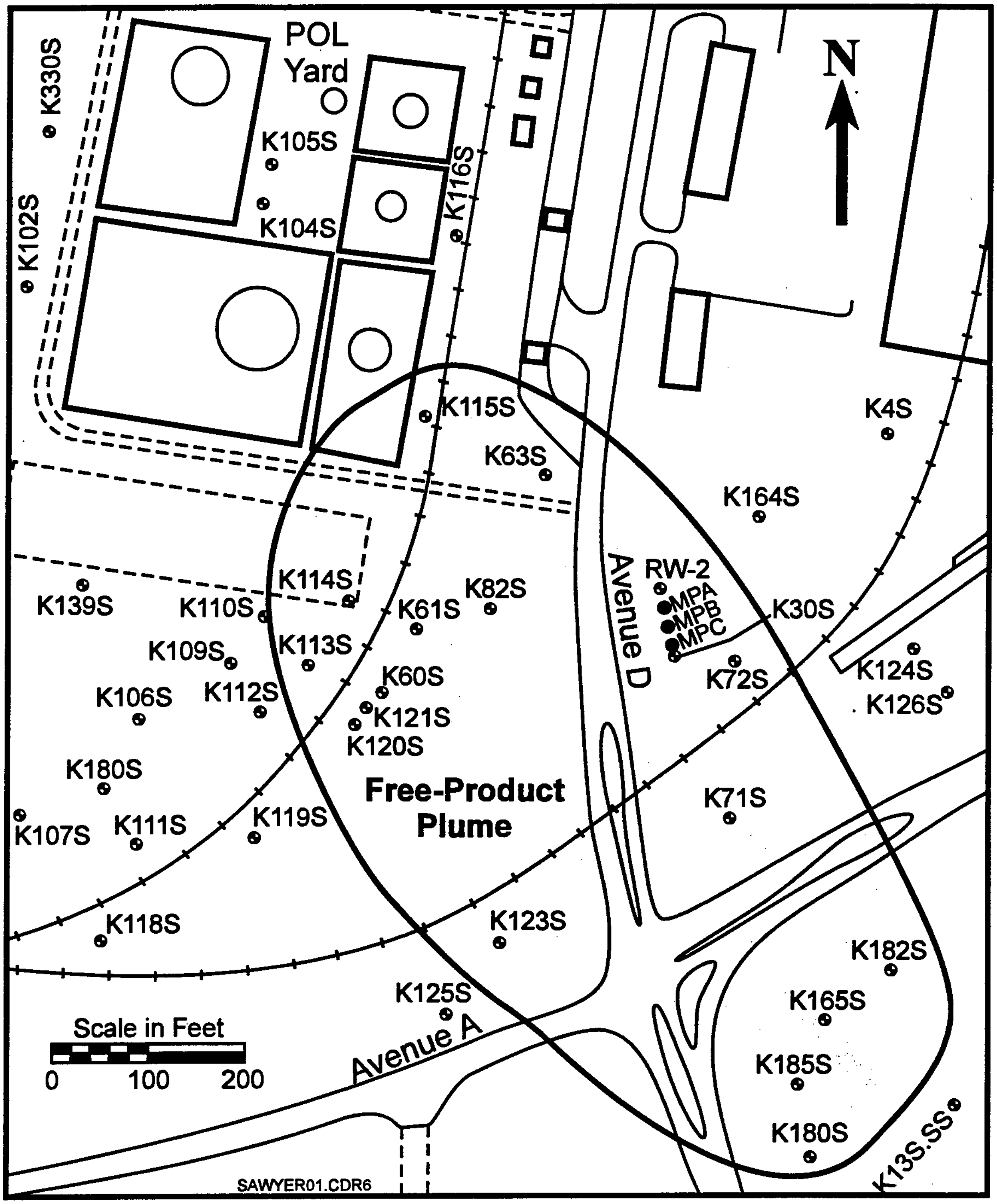

Figure 1. Schematic Diagram Showing Locations of Monitoring Wells and Monitoring Points at Site ST-04, K.I. Sawyer AFB, MI

A bioventing pilot test was performed at Site ST-04 in September 1992. The radius of influence was determined to exceed 60 ft at depths down to 60 ft bgs. A subsequent 1-year bioventing test demonstrated sizable reductions in soil concentrations of benzene, toluene, ethylbenzene, and xylenes (BTEX) indicating that fuel biodegradation progressed at a significant rate.

A free-product recovery system was installed at Site ST-04 in March 1995. Six extraction wells were installed as part of the recovery system. The system was not successful in extracting recoverable floating product. In May 1996, monitoring well measurements were taken and baildown tests were performed to provide data to review and possibly reengineer the free-product recovery system.

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 K.I. Sawyer.

3.1 Initial LNAPL/Groundwater Measurements and Baildown Testing

Monitoring wells RW-2 and K30S 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 21 hr at monitoring well RW-2 and for approximately 3.5 hr at monitoring well K30S.

An LNAPL sample was collected from monitoring well RW-2 for analysis of BTEX and for boiling point fractionation. The sample was sent to Alpha Analytical, Inc., in Sparks, Nevada for analysis.

3.2 Well Construction Details

Short-term bioslurper pump tests were conducted at existing monitoring well RW-2 and at monitoring well K30S. Monitoring well RW-2 is constructed of 6-inch-diameter, schedule 40 PVC with a total depth of 82 ft bgs and 25 ft long section of screen. Monitoring well K30S is constructed of 4-inch-diameter, schedule 40 polyvinyl chloride (PVC) with a total depth of 74 ft bgs and an 8-ft long section of screen. A schematic diagram illustrating well construction details for monitoring wells RW-2 and K30S is provided in Figure 2. There was some uncertainty regarding the construction details of the wells at Site ST-04, due to some inconsistency and incompleteness in the information provided. These completion details were a compilation of several sources provided by the Base.

3.3 Soil Gas Monitoring Point Installation

Three monitoring points were installed and labeled MPA, MPB, and MPC. The locations of the monitoring points are illustrated in Figure 1 and construction details are provided in Figure 2.

The monitoring points consisted of ¼-inch tubing, with 1-inch-diameter, 6-inch-long screened areas. The screened lengths were positioned at depths of 15, 25, 35, 45, 55 and 65 ft bgs, and the annular space corresponding to the screened length was filled with silica sand. The interval from the top of the screened length to the bottom of the next screened length, as well as the interval from the ground surface to the top of the first screened length, was filled with bentonite clay chips. After placement, the bentonite clay was hydrated with water to expand the chips and provide a seal.

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 concentrations observed at the monitoring points ranged from 3.0 to 19.5%, with the lowest concentrations corresponding with the deeper depths (Table 1).

3.4 Soil Sampling and Analysis

Two soil samples were collected during the installation of monitoring point MPB and were labeled KIS-S-1 and KIS-S-2. The samples were taken from 60 to 62 ft bgs using a split spoon sampler with brass sleeves. 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. Samples were analyzed for BTEX, bulk density, moisture content, particle size, porosity, and TPH-purgeable. The laboratory analytical report is provided in Appendix B.

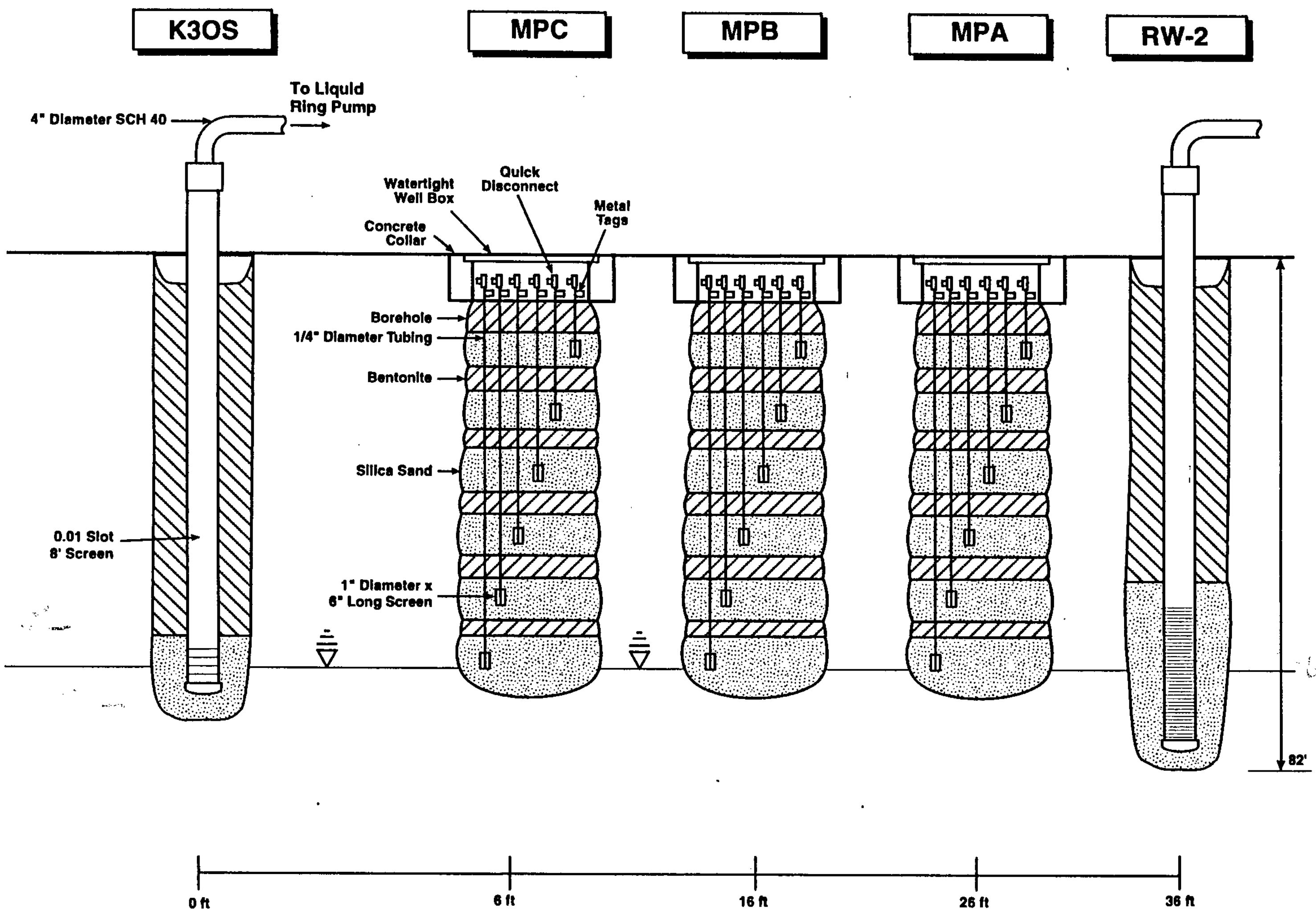

Figure 2. Construction Details of Monitoring Well RW-2 and K30S, and Soil Gas Monitoring Points at K.I. Sawyer AFB, MI

Table 1. Initial Soil Gas Composition at K.I. Sawyer AFB, MI

Monitoring Point	Depth (ft)	Oxygen (%)	Carbon Dioxide (%)	TPH (ppmv)
MPA	15	19.5	0.8	58
	25	19.0	0.7	150
	35	18.0	0.7	53
	45	17.0	1.3	14
	55	16.0	1.5	430
	65	6.0	7.0	>20,000
MPB	15	18.5	1.0	58
	25	18.0	0.8	44
	35	18.0	0.8	36
	45	17.0	1.2	80
	55	17.0	1.5	180
	65	3.0	7.0	16,500
MPC	15	18.0	0.8	66
	25	18.0	0.8	70
	35	18.0	0.8	112
	45	16	2.0	215
	55	LP*	LP*	LP*
	65	16	2.5	16,400

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 well seal was placed on 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 well seal 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 recovered fluid through a filter tank, an oil/water separator, and allowing it to settle in a 325-gallon tank. The groundwater was discharged into the base sanitary sewer system using a ¾-hp sump pump located inside the 325-gallon storage tank.

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 Skimmer Pump Test

Two skimmer pump test were conducted: one at monitoring well RW-2 and one at monitoring well K30S. Details of the tests are described in the following sections.

3.5.2.1 Monitoring Well RW-2. 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. The drop tube was held in position by the well seal, and was positioned to leave the wellhead vented to the atmosphere (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 totalizer for the LNAPL and aqueous effluent were zeroed, and the liquid ring pump was started on July 30, 1996 to begin the skimmer pump test. The test was operated continuously for approximately 46.75 hr. The LNAPL and groundwater extraction rates

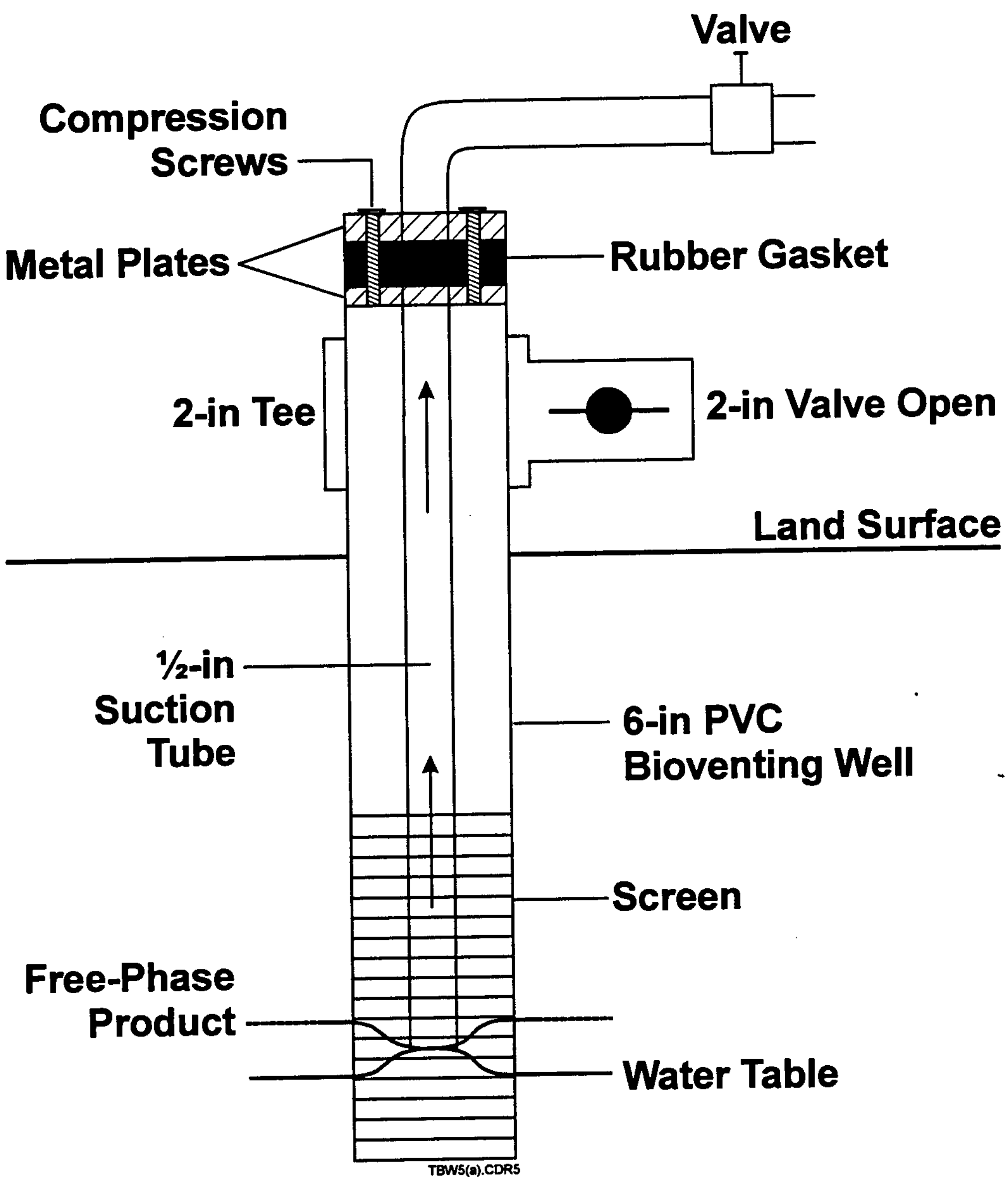

Figure 3. Slurper Tube Placement and Valve Position for the Skimmer Pump Test

were monitored throughout the test, as were all other relevant data for the skimmer pump test. Test data sheets are provided in Appendix D.

3.5.2.2 Monitoring Well K30S. Upon completion of the drawdown pump test at monitoring well RW-2, preparations were made to begin the skimmer pump test at monitoring well K30S. Depths to LNAPL and groundwater were measured. The system was configured as described in Section 3.5.2.1. The liquid ring pump was started on August 6, 1996 to begin the skimmer pump test. The test was operated continuously for approximately 8 hr. 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

Two bioslurper pump test were conducted: one at monitoring well RW-2 and one at monitoring well K30S. Details of the tests are described in the following sections.

3.5.3.1 Monitoring Well RW-2

Upon completion of the skimmer pump test, preparations were made to begin the bioslurper pump test. The slurper tube was set at the LNAPL/groundwater interface. The LNAPL and groundwater depth were measured prior to any recovery testing. The sanitary well seal was positioned inside the well, 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 was started on August 1, 1996 to begin the bioslurper pump test. The test was initiated approximately 2 hr after the skimmer pump test on RW-2 and was operated for approximately 46.75 hr. The LNAPL and groundwater extraction rates were monitored throughout the test, as were all other relevant data for the bioslurper pump test. The data sheets are provided in Appendix D.

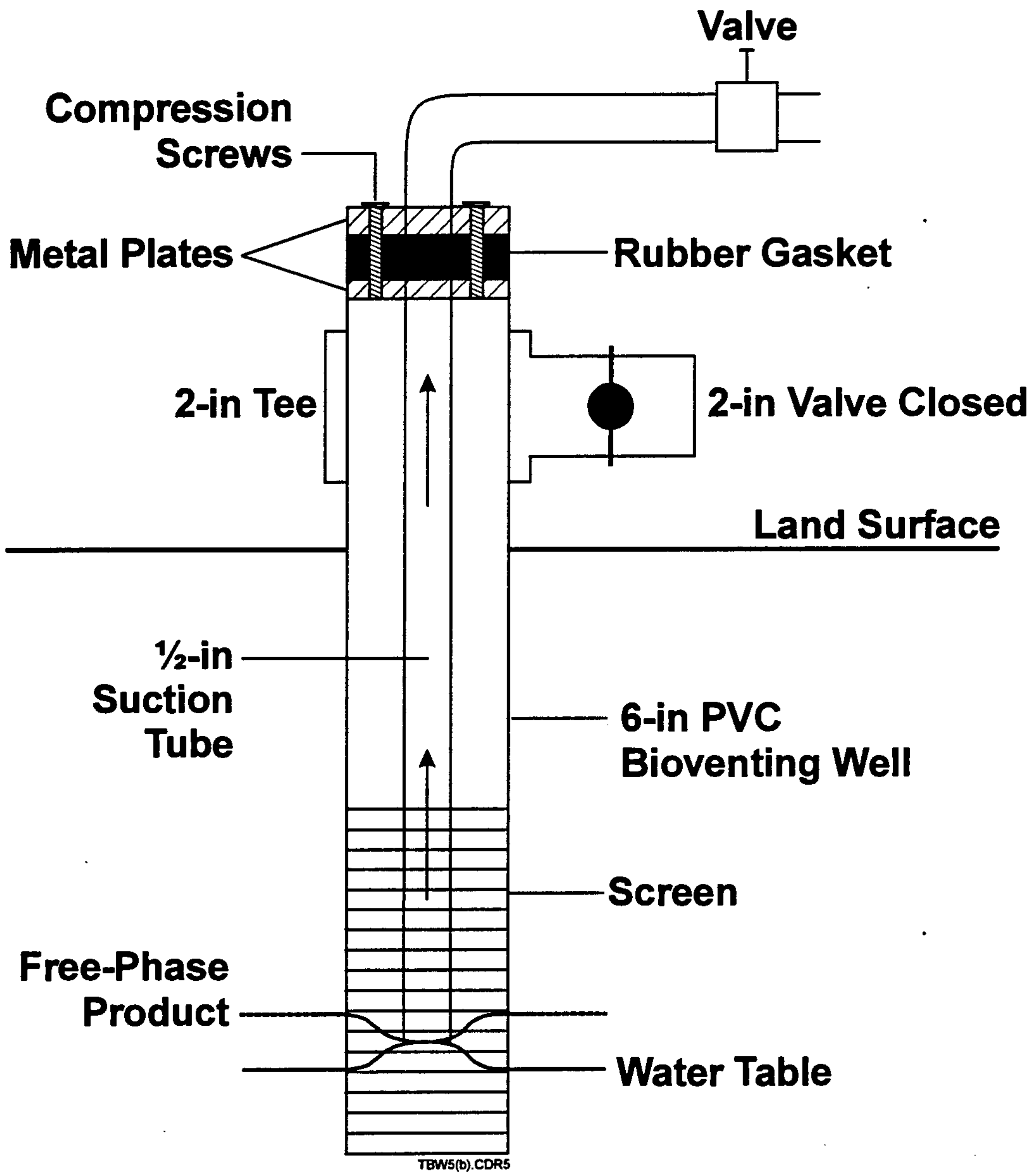

Figure 4. Slurper Tube Placement for the Bioslurper Pump Test

3.5.3.2 Monitoring Well K30S

System setup at K30S was modified due to there having been inadequate information about the well construction. A 3-inch well casing, not secured to the bottom of the well, was positioned inside a stable 4-inch casing. A sanitary well seal was used to seal off the 4-inch well to ensure vacuum was not lost between the two casings. The liquid ring pump was started on August 6, 1996 to begin the bioslurper pump test. The test was initiated approximately 5 minutes after termination of the skimmer pump test at K30S. 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.

3.5.4 Second Skimmer Test

Upon completion of the bioslurper pump test at RW-2, a second skimmer test was performed on the well. The bioslurper system was configured as described in Section 3.5.2. The liquid ring pump was started on August 3, 1996 approximately 15 minutes after completion of the bioslurper pump test and was operated continuously for 8 hr. The LNAPL and groundwater extraction rates were monitored throughout the test, as well as all other relevant data for the bioslurper pump test. Test sheets are provided in Appendix D.

3.5.5 Drawdown Pump Test

Upon completion of the second skimmer pump test at RW-2, preparations were made to begin the drawdown pump test. The slurper tube was positioned 4 inches below the initial LNAPL/water interface measured prior to any recovery pump testing (Figure 5). The liquid ring pump was started on August 3, 1996 to begin the drawdown pump test at RW-2. The test was initiated approximately 15 minutes after the second skimmer pump test was completed and was operated continuously for 61.25 hr. 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.

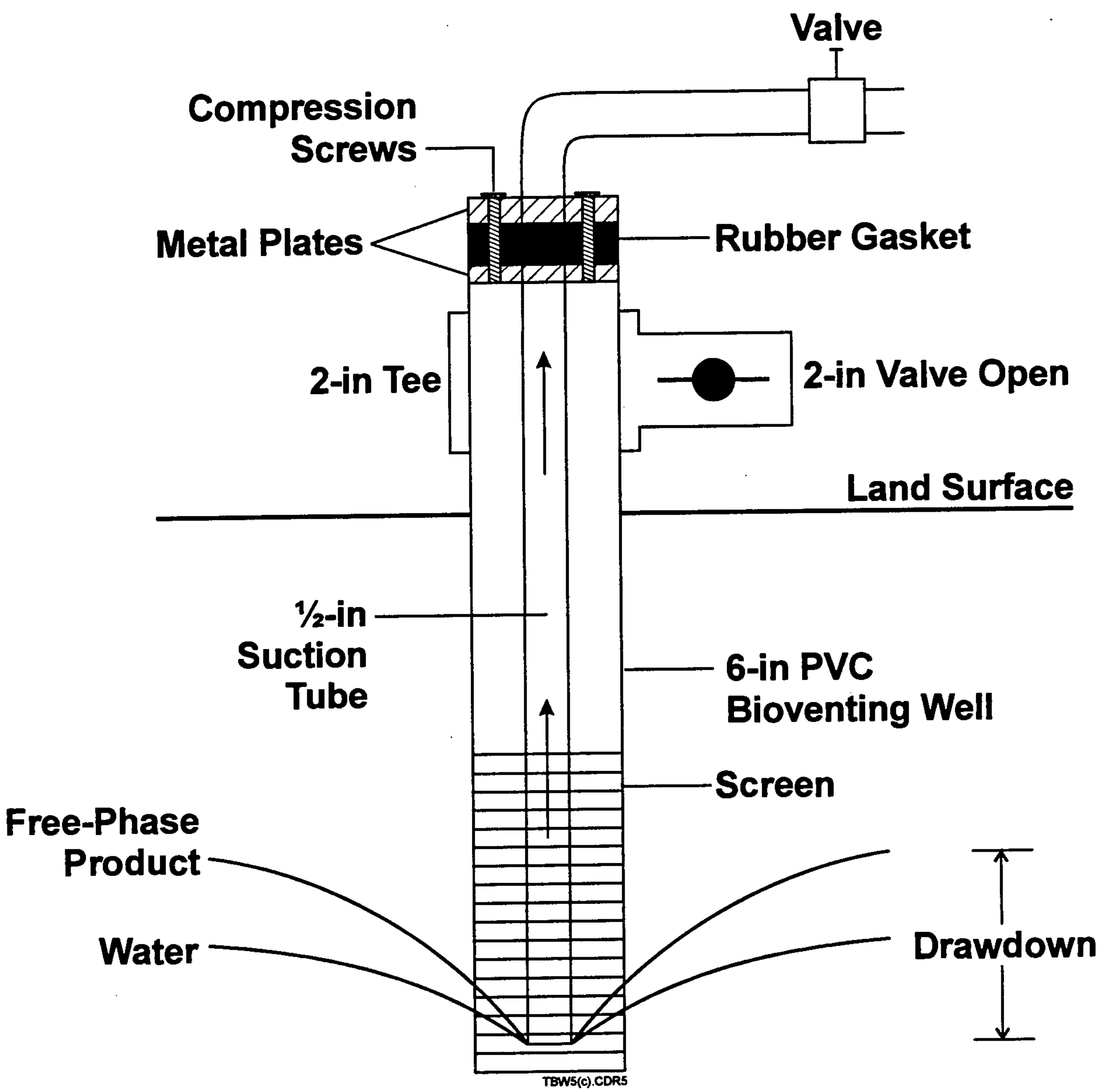

Figure 5. Slurper Tube Placement for Drawdown Pump Test

3.6 Off-Gas Sampling and Analysis

Two soil gas samples were collected during the bioslurper pump tests. Samples KIS-OGS-1 and KIS-OGS-2 were collected from the bioslurper off-gas during the bioslurper pump test at monitoring well RW-2. Sample KIS-OGS-1 was collected following approximately 45 hr of operation, and Sample KIS-OGS-2 was collected after approximately 47 hr of operation. The samples were collected in Summa™ canisters. The samples were sent under chain of custody to Air Toxics, Ltd., in Folsom, California, for analyses of BTEX and TPH, using EPA Method TO-3.

3.7 Groundwater Sampling and Analysis

Two groundwater samples were collected during the bioslurper pump test at RW-2 and were labeled KIS-DW-1 and KIS-DW-2. Each sample was collected from the point of discharge into the base sanitary sewer system, after approximately 45 and 47 hrs of operation, respectively. Samples were collected in 40-mL septa vials containing hydrochloric acid (HC1) 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 (purgeable).

3.8 Soil Gas Permeability Testing

The soil gas permeability test data were collected during the bioslurper pump test at monitoring well K30S. Before a vacuum was established in the extraction well, the initial soil gas pressures at the three installed monitoring points were recorded. The start of the bioslurper pump test created a steep pressure drop in the extraction well which was the starting point for the soil gas permeability testing. Soil gas pressures were measured at each of the three monitoring points at all depths to track the rate of outward propagation of the pressure drop in the extraction well. Soil gas pressure data were collected frequently during the first 20 minutes of the test. The soil gas pressures were recorded throughout the bioslurper pump test to determine the bioventing radius of influence. Test data are provided in Appendix E.

3.9 In Situ Respiration Testing

Air containing approximately 2% helium was injected into three monitoring points for approximately 24 hr beginning on August 3, 1996. The setup for the in situ respiration test is described in the *Test Plan and Technical Protocol a Field Treatability Test for Bioventing* (Hinchee et al., 1992). A ½-hp diaphragm pump was used for air and helium injection. Air and helium were injected through monitoring points MPA-65′, MPB-65′, and MPC-65′. After the air/helium injection was terminated, soil gas concentrations of oxygen, carbon dioxide, TPH, and helium were monitored periodically. The in situ respiration test was terminated on August 6, 1996. Oxygen utilization and biodegradation rates were calculated as described in Hinchee et al. (1992). Raw data for these tests are presented in Appendix F.

Helium concentrations were measured during the in situ respiration test to quantify helium leakage to or from the surface around the monitoring points. Helium loss over time is attributable to either diffusion through the soil or leakage. A rapid drop in helium concentration usually indicates leakage. A gradual loss of helium along with a first-order curve generally indicates diffusion. As a rough estimate, the diffusion of gas molecules is inversely proportional to the square root of the molecular weight of the gas. Based on molecular weights of 4 for helium and 32 for oxygen, helium diffuses approximately 2.8 times faster than oxygen, or the diffusion of oxygen is 0.35 times the rate of helium diffusion. As a general rule, we have found that if helium concentrations at test completion are at least 50 to 60% of the initial levels, measured oxygen uptake rates are representative. Greater helium loss indicates a problem, and oxygen utilization rates are not considered representative.

4.0 RESULTS

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

4.1 Baildown Test Results

Results from the baildown test in monitoring well RW-2 are presented in Table 2. A total volume of 5 L was removed by hand-bailing from monitoring well RW-2. The LNAPL thickness

Table 2. Baildown Test Record at RW-2, K.I. Sawyer AFB, MI

Monitoring Well	Sample Collection Time	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
RW-2	Initial Reading 7/29/96-1030	67.47	66.69	0.78
	7/29/96-1125	69.14	68.82	0.32
	7/29/96-1126	69.16	68.72	0.44
	7/29/96-1129	69.20	68.73	0.47
	7/29/96-1131	69.20	68.73	0.47
	7/29/96-1137	69.27	68.70	0.57
	7/29/96-1154	69.33	68.68	0.65
	7/29/96-1325	69.39	68.68	0.71
	7/29/96-1448	69.40	68.65	0.75
	7/30/96-0835	69.43	68.65	0.78
K30S	7/29/96-1335	69.55	69.09	0.46
	7/29/96-1338	69.36	69.29	0.07
	7/29/96-1339	69.30	69.21	0.09
	7/29/96-1342	69.30	69.18	0.12
	7/29/96-1349	69.30	69.17	0.13
	7/29/96-1357	69.31	69.17	0.14
	7/29/96-1415	69.35	69.16	0.19
	7/29/96-1445	69.38	69.15	0.23

recovered to approximately 99% of initial levels by the end of the 21-hour test period. The results of these tests indicate that this well may be suitable for bioslurping.

A baildown test was also performed on monitoring well K30S (Table 2). A total of 0.65 L of LNAPL was removed. Fuel recovery into this well was significantly slower than that observed in monitoring well RW-2. Therefore, monitoring well RW-2 appeared to be the most suitable for bioslurping.

4.2 Soil Sample Analyses

Table 3 shows the TPH and BTEX concentrations measured in soil samples collected from Site ST-04. TPH and BTEX concentrations varied between the two samples. TPH concentration in KIS-S-1 was 110 mg/kg, while in KIS-S-2, the concentration of TPH was 1,000 mg/kg. BTEX concentrations also varied between the two samples. Concentrations ranged from 0.18 mg/kg (ethylbenzene) to 1.0 mg/kg (toluene) in KIS-S-1. In contrast, all BTEX components were below detection limits in KIS-S-2. The results of the physical characterization and inorganic analysis of the soil are presented in Table 4.

4.3 LNAPL Pump Test Results

4.3.1 Initial Skimmer Pump Test Results

4.3.1.1 Monitoring Well RW-2

A total of 35 gallons of LNAPL was recovered during this test, with an average recovery rate of 19 gallons/day (Table 5). A total of 1,200 gallons of groundwater was extracted with an average extraction rate of 640 gallons/day (Table 5). Results of LNAPL recovery versus time are shown in Figure 6.

4.3.1.2 Monitoring Well K30S

A total of 0.9 gallons of LNAPL was recovered during this test, with an average recovery rate of 2.7 gallons/day (Table 6). A total of 14.4 gallons of groundwater was extracted with an average

Table 3. **TPH and BTEX Concentrations in Soil Samples for Site ST-04, K.I. Sawyer AFB, MI**

Parameter	Concentration (mg/kg)	
	KIS-S-1	KIS-S-2
TPH as diesel	110	1,000
Benzene	0.48	<1.0
Toluene	1.0	<1.0
Ethylbenzene	0.18	<1.0
Xylenes	0.69	<1.0

Table 4. **Physical Characterization and Inorganic Analyses of Soil from Site ST-04, K.I. Sawyer AFB, MI**

Parameter		Sample	
		KIS-S-1	KIS-S-2
Moisture Content (%)		15.1	9.9
Porosity (%)		27.6	28.3
Density (g/cm^3)		1.92	1.90
Particle Size	Sand	98.3	98.3
	Silt	0.0	0.0
	Clay	1.7	1.7

Table 5. Pump Test Results at Monitoring Well RW-2, Site ST-04, K.I. Sawyer AFB, MI

Time (days)	Recovery Rate (gal/day)							
	Initial Skimmer Pump Test		Bioslurper Pump Test		Second Skimmer Pump Test		Drawdown Pump Test	
	LNAPL	Groundwater	LNAPL	Groundwater	LNAPL	Groundwater	LNAPL	Groundwater
1	23.14	754	9.48	441	6.0	544.8	3.3	1,161
2	14.15	521	4.98	1,611	NA	NA	4.9	741
3	NA	NA	NA	NA	NA	NA	6.18	738
Average	18.6	637.5	7.23	1,026	6.0	544.8	4.7	880
Total Recovery (gal)	34.75	1,234	12.8	1,974	2.5	227	10.4	2,172

NA = Not applicable.

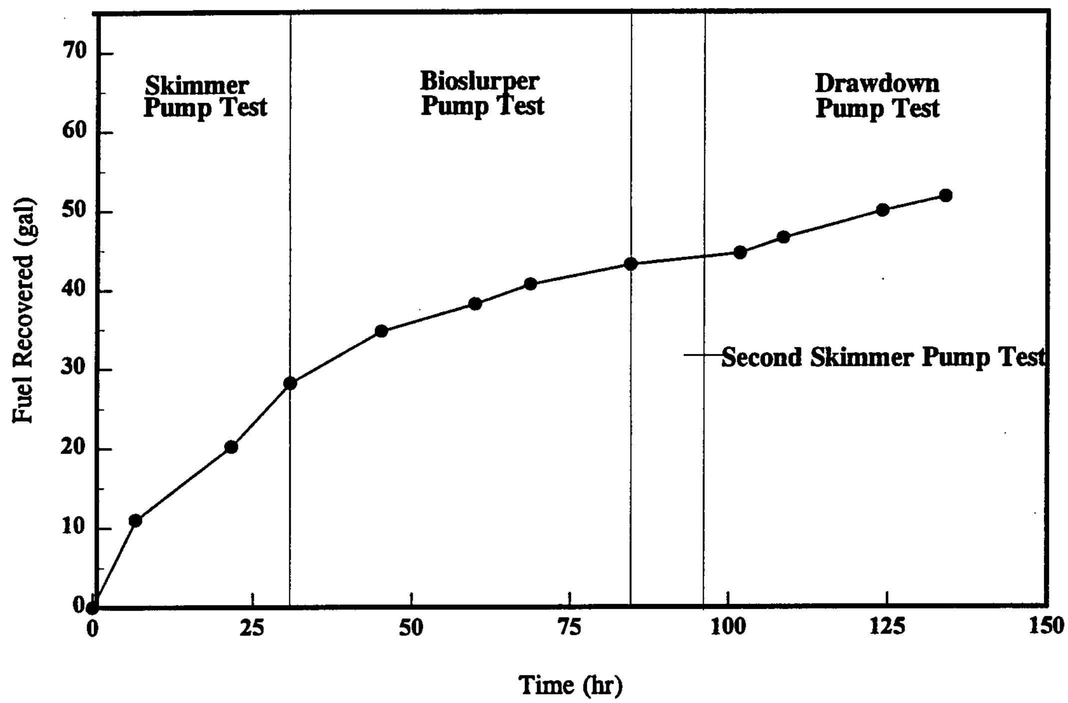

Figure 6. Fuel Recovery Versus Time During Each Pump Test in Monitoring Well RW-2

Table 6. Bioslurper Pump Test Results at Monitoring Well K30S, Site ST-04, K.I. Sawyer AFB, MI

Time (Days)	Recovery Rate (gal/day)			
	Skimmer Pump Test		Bioslurper Pump Test	
	LNAPL	Groundwater	LNAPL	Groundwater
1	2.7	43.2	7.6	798
2	NA	NA	4.6	311
Average	2.7	43.2	6.1	554.5
Total Recovery (gal)	0.9	14.4	8.9	765

extraction rate of 43 gallons/day (Table 6). Results of LNAPL recovery versus time are shown in Figure 7. Total fuel recovered and recovery rates were significantly lower at this monitoring well than those measured under the skimmer configuration at monitoring well RW-2.

4.3.2 Bioslurper Pump Test Results

4.3.2.1 Monitoring Well RW-2

LNAPL recovery rates decreased during the bioslurper pump test compared to the initial skimmer pump test (Figure 6). A total of 13 gallons of LNAPL and 2,000 gallons of groundwater was extracted during the bioslurper pump test, with daily average recovery rates of 7.2 gallons/day for LNAPL and 1,000 gallons/day for groundwater (Table 5). The LNAPL recovery rate versus time is shown in Figure 8. The vacuum-exerted wellhead pressure on monitoring well RW-2 was kept relatively constant throughout the bioslurper pump test at approximately 0.05 inches of water. Due to the well construction and the water table depth, it was difficult to exert significant vacuum on the well. Higher vacuums may have resulted in improved free product recovery rates.

Soil gas concentrations were measured at monitoring points during the bioslurper pump test to determine whether the vadose zone was being oxygenated. Oxygen concentrations increased at all monitoring points by the completion of the test (Table 7). These results demonstrate that the oxygen

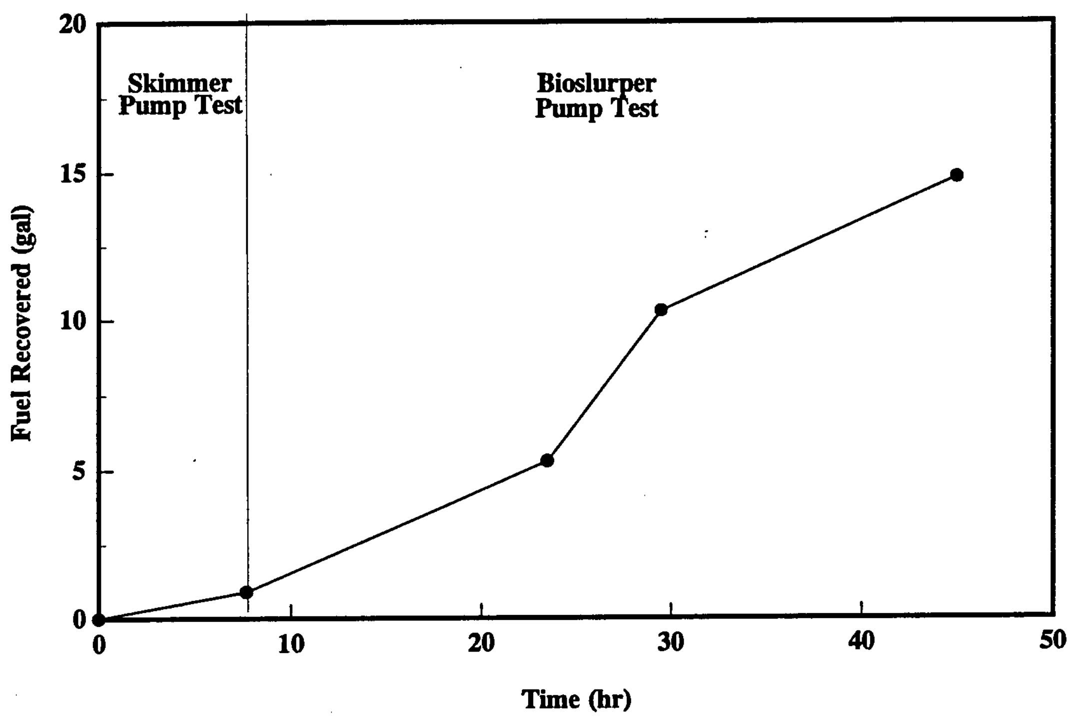

Figure 7. Fuel Recovery Versus Time During Each Pump Test in Monitoring Well K30S

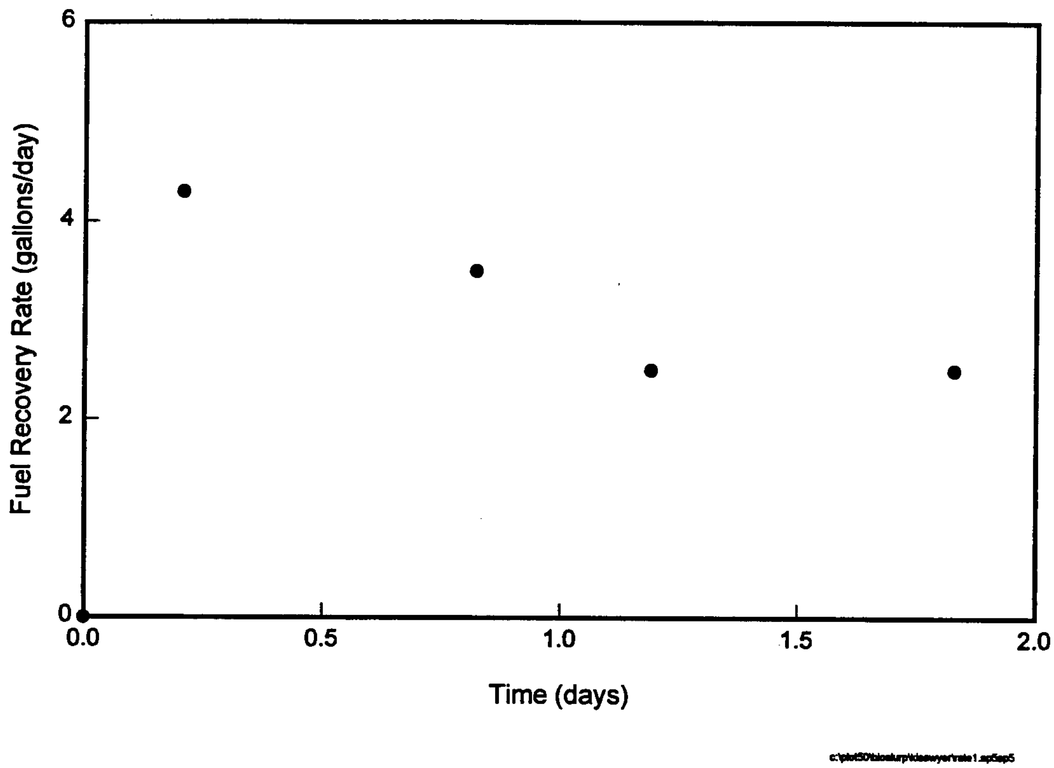

Figure 8. LNAPL Recovery Rate Versus Time During the Bioslurper Pump Test at Monitoring Well RW-2

Table 7. Oxygen Concentrations During the Bioslurper Pump Test at RW-2, Site ST-04, K.I. Sawyer, MI

Monitoring Point	Oxygen Concentrations (%) Versus Time (hr)				
	0	5	20	28	44
MPA-65	6.0	6.9	8.0	5.2	12.1
MPB-65	3.0	4.0	4.0	5.0	17.0
MPC-65	10.0	10.0	20.0	10.0	19.5

radius of influence is slightly larger than the pressure radius of influence measured during the soil gas permeability test.

4.3.2.2 Monitoring Well K30S

Totals of 8.9 gallons of LNAPL and 770 gallons of groundwater were recovered during the bioslurper pump test, with daily average recovery rates of 6.1 gallons/day for LNAPL and 550 gallons/day for groundwater (Table 6). Fuel recovery was significantly greater during the bioslurper pump test in monitoring well K30S than that observed during the skimmer pump test in the same well. Compared to results at monitoring well RW-2, fuel recovery rates were comparable, although groundwater recovery was substantially less. Fuel recovery versus time is shown in Figure 7.

4.3.3 Second Skimmer Pump Test Results

A total of 2.5 gallons of LNAPL was recovered during this test, with an average recovery rate of 6.0 gallons/day (Table 5). A total of 230 gallons of groundwater was extracted with an average extraction rate of 540 gallons/day (Table 5). Fuel recovery rates were significantly less than during the initial skimmer pump test, although groundwater recovery rates were similar. The fuel recovery rate also decreased slightly from that measured during the bioslurper pump test.

4.3.4 Drawdown Pump Test

The free product recovery rate continued to drop during the drawdown pump test. Totals of 10 gallons of LNAPL and 2,200 gallons of groundwater were recovered during the drawdown pump test, with daily average recovery rates of 4.7 gallons/day for LNAPL and 880 gallons/day for groundwater (Table 5).

4.3.5 Extracted Groundwater, LNAPL, and Off-Gas Analyses

Results of groundwater analyses are shown in Table 8. Contaminant concentrations were similar between the two samples, with average TPH and total BTEX concentrations of 6.4 mg/L and 2.7 mg/L, respectively (Table 8).

The results from the off-gas analyses are presented in Table 9. Given a vapor discharge rate of 5 scfm and using a concentration of 88,000 ppmv TPH and 170 ppmv benzene, approximately 260 lb/day of TPH and 0.25 lb/day benzene were emitted to the air during the bioslurper pump test.

The composition of LNAPL is shown in Table 10 and 11 in terms of BTEX concentrations and distribution of C-range compounds, respectively. The distribution of C-range compounds also is shown graphically in Figure 9.

4.4 Bioventing Analyses

4.4.1 Soil Gas Permeability and Radius of Influence

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. Based on this definition, the radius of influence during the bioslurper pump test at monitoring well K30S was approximately 18 ft (Figure 10).

Table 8. BTEX and TPH Concentrations in Extracted Groundwater During the Bioslurper Pump Test at Site ST-04, K.I. Sawyer AFB, MI

Parameter	Concentration (mg/L)	
	KIS-DW-1	KIS-DW-2
TPH	6.3	6.5
Benzene	0.37	0.37
Toluene	1.3	1.3
Ethylbenzene	0.17	0.17
Total Xylenes	0.87	0.89

Table 9. BTEX and TPH Concentrations in Off-Gas During the Bioslurper Pump Test at K.I. Sawyer AFB, MI

Parameter	Concentration (ppmv)	
	KIS-OSG-1	KIS-OGS-2
TPH	98,000	78,000
Benzene	180	160
Toluene	600	460
Ethylbenzene	170	120
Total Xylenes	620	460

Table 10. BTEX Concentrations in LNAPL from K.I. Sawyer AFB, MI

Compound	Concentrations (mg/kg)
Benzene	680
Toluene	5,600
Ethylbenzene	1,800
Total Xylenes	7,400

Table 11. C-Range Compounds in LNAPL from Site ST-04, K.I. Sawyer, MI

C-Range Compounds	Percentage of Total
<C8	50.75
C9	9.58
C10	11.05
C11	10.70
C12	6.72
C13	4.78
C14	2.40
C15	1.43
C16	0.81
C17	0.58
>C18	1.18

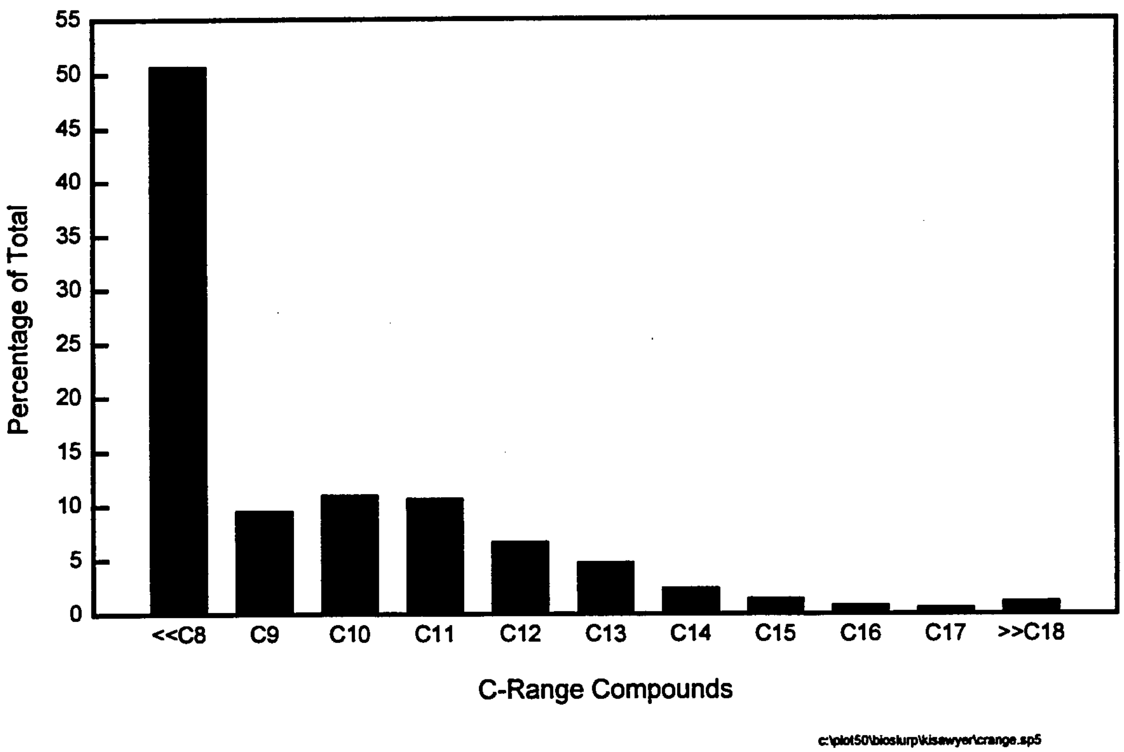

Figure 9. Distribution of C-Range Compounds in Extracted LNAPL at Site ST-04, K.I. Sawyer AFB, MI

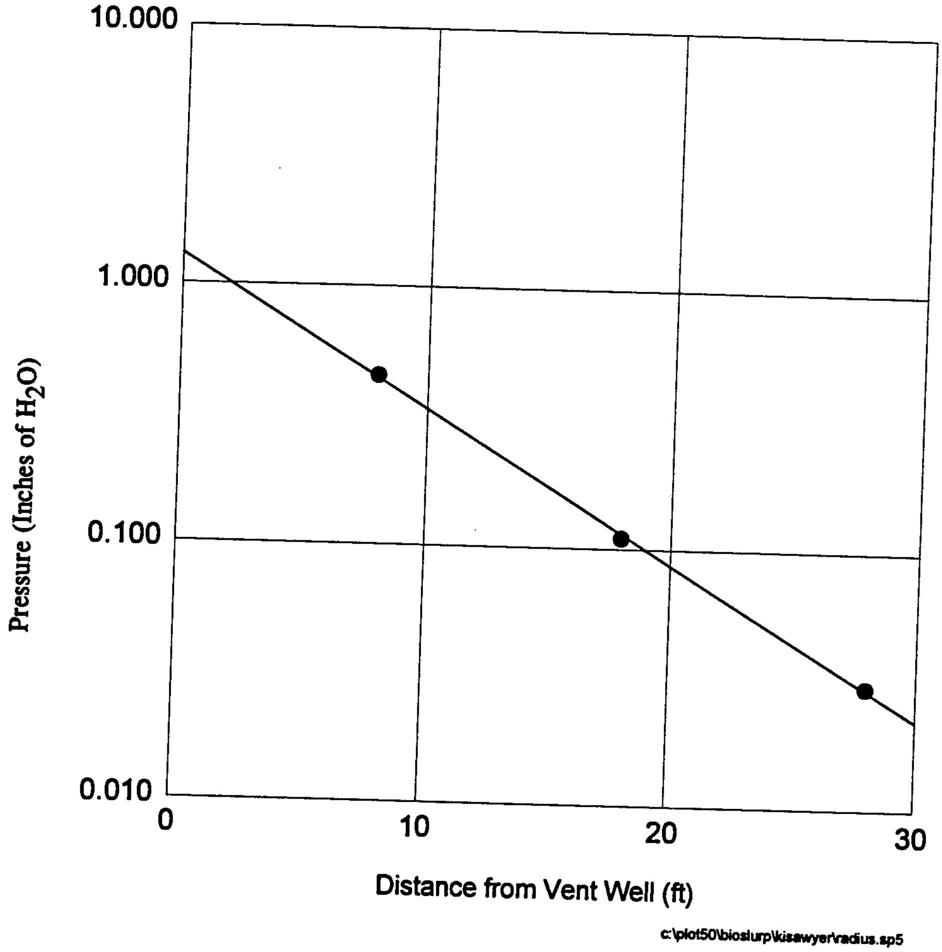

Figure 10. Soil Gas Pressure Change as a Function of Distance During the Soil Gas Permeability Test at Monitoring Well K30S

4.4.2 In Situ Respiration Test Results

Results from the in situ respiration test are presented in Table 12. Oxygen utilization rates were relatively low, ranging from 0.020 to 0.029 $\%O_2$/hr. Biodegradation rates ranged from 0.33 to 0.47 mg/kg-day. The helium concentration gradually decreased by as much as 34%, indicating that diffusion was possible. These results indicate that biodegradation in these locations is quite low.

Table 12. In Situ Respiration Test Results at Site RW-2, K.I. Sawyer AFB, MI

Monitoring Point	Oxygen Utilization Rate (%/hr)	Biodegradation Rate (mg/kg-day)
MPA-65′	0.020	0.33
MPB-65′	0.026	0.42
MPC-65′	0.029	0.47

5.0 DISCUSSION

Approximately 60 gallons of LNAPL were recovered during the series of pump tests at monitoring well RW-2. Groundwater was extracted at rates ranging from 640 gallons/day during the initial skimmer pump test up to 1,000 gallons/day during the bioslurper pump test. In general, fuel recovery rates decreased with time, with the highest rates during the initial skimmer pump test. There appeared to be little difference in recovery rates based on the configuration of the system. This may be due to the inability to achieve high vacuum during the bioslurper pump test due to the well construction and water table depth. It is possible that greater fuel recovery could have been achieved with higher well vacuums.

Soil gas concentrations were measured at monitoring points during the bioslurper pump test at monitoring well RW-2 determine whether the vadose zone was being oxygenated. Oxygen concentrations increased at all monitoring points by the completion of the test. These results demonstrated that the oxygen radius of influence was slightly larger than the pressure radius of influence measured during the soil gas permeability test.

During the pump tests conducted at K30S, free-product recovery rates were significantly different between skimming and bioslurping, with higher recovery rates achieved during bioslurping. However, fuel recovery rates were still relatively low. During the bioslurper pump test, the average fuel recovery rate was approximately 8.7 gallons/day. Groundwater recovery rates over the 37-hour test averaged 450 gallons/day. Free product recovery at this monitoring well was fairly similar to that observed at monitoring well RW-2, although groundwater recovery was significantly less at this monitoring well. The inability to achieve a high vacuum on either well may have limited recovery rates.

Based on the results at monitoring wells RW-2 and K30S, implementation of bioslurping at Site ST-04 is unlikely to facilitate enhanced recovery of LNAPL from the water table. Different well construction which would allow for higher vacuums on the wells may facilitate improved free product removal via bioslurping; however, it should be noted that free product rates were low at this site and even with different well construction, it's possible that there is not sufficient quantities of mobile free product to recover. In situ biological activity is fairly low; therefore, bioslurping would be unlikely to enhance microbial degradation rates in the vadose zone.

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.

Engineering-Science, Inc. 1992. *Bioventing Pilot Test Work Plan for Installation Restoration Program: Site ST-04 POL Bulk Fuel Storage Area, K.I. Sawyer AFB, Michigan.*

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 K.I. SAWYER AFB, MICHIGAN

SITE-SPECIFIC TEST PLAN FOR BIOSLURPER TESTING AT K.I. SAWYER AIR FORCE BASE, MICHIGAN

FINAL

PREPARED FOR:

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

AND

K.I. SAWYER AFB, MICHIGAN

19 JULY 1996

SITE-SPECIFIC TEST PLAN FOR BIOSLURPER TESTING AT K.I. SAWYER AIR FORCE BASE, MICHIGAN CONTRACT NO. F41624-94-C-8012

FINAL

to

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

and

K.I. Sawyer Air Force Base, Michigan

19 July 1996

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505 King Avenue
Columbus, Ohio 43201-2693

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ACRONYMS AND ABBREVIATIONS

AFB	Air Force Base
AFCEE	Air Force Center for Environmental Excellence
BTEX	benzene, toluene, ethylbenzene, and xylenes
bgs	below ground surface
ft/ft	foot per foot; feet per feet
IRP	Installation Restoration Program
JP	jet propulsion (fuel)
LNAPL	light, nonaqueous-phase liquid
POC	Point of Contact
POL	Petroleum, Oils, and Lubricants
TPH	total petroleum hydrocarbons
VOC	volatile organic compound

SITE-SPECIFIC TEST PLAN FOR BIOSLURPER TESTING AT K.I. SAWYER AIR FORCE BASE, MICHIGAN

FINAL

to

Air Force Center for Environmental Excellence
Technology Transfer Division
(AFCEE/ERT)
Brooks AFB, Texas 78235-5357

19 July 1996

1.0 INTRODUCTION

The U.S. 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 technologies tested in the Bioslurper Initiative include vacuum-enhanced free-product recovery/bioremediation (bioslurping) as well as traditional skimmer and groundwater depression approaches. The field test and evaluation are intended to demonstrate the feasibility of free-product recovery by measuring system performance in the field. 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 geologic 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 entitled *Test Plan and Technical Protocol for Bioslurping* (Battelle, 1995). The overall plan is supplemented by plans specific to each test site. The concise site-specific plans effectively communicate planned site activities and operational parameters.

The overall Test Plan and Technical Protocol was developed as a generic plan for the Bioslurper Initiative to improve the accuracy and efficiency of site-specific Test Plan preparation. The field program involves 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 report is the site-specific Test Plan for application of bioslurping at K.I. Sawyer Air Force Base (AFB), Marquette, Michigan. It was prepared based on site-specific information received by Battelle from K.I. Sawyer AFB and other pertinent site-specific information to support the overall Test Plan and Technical Protocol.

Site-specific information for K.I. Sawyer AFB has identified subsurface hydrocarbon contamination at the Installation Restoration Program (IRP) Site ST-04, Petroleum, Oils, and Lubricants (POL) Bulk Fuel Storage Area. The contamination at the POL Area is primarily associated with JP-4 jet fuel. Free product, as light, nonaqueous-phase liquid (LNAPL), has been found in various well locations at the site. In field activities conducted in May 1996, 32 monitoring wells were measured for static groundwater and free product elevations. Free product was detected in 21 wells with thicknesses ranging from 0.14 ft to 2.41 ft. Based on initial free product and recovery data, monitoring wells K30S and RW2 are possible candidates for conducting the bioslurper demonstration.

2.0 SITE DESCRIPTION

The information presented in this section was obtained from site-specific information received by Battelle from K.I. Sawyer AFB and a document entitled *Bioventing Pilot Test Work Plan for Installation Restoration Program: Site ST-04 POL Bulk Fuel Storage Area, K.I. Sawyer AFB, Michigan* (Engineering-Science Inc. 1992).

K.I. Sawyer AFB is located in Marquette, Michigan, which is in the north-central portion of Michigan's Upper Peninsula. The POL Area is located on the south-central part of the base, and is bounded on the east and west by Avenues D and H, respectively, and on the north and south by First Street and Avenue A, respectively (Figure 1). The POL Area is approximately 500 ft by 500 ft in size. There are five aboveground jet fuel storage tanks and a vapor sphere. The fuel tanks have the following capacities: one each at 37,500 gal, 20,000 gal, 10,000 gal, and two at 5,000 gal. The vapor sphere has a capacity of 10,000 ft^3. Each tank is contained in a diked area with concrete walls and base. A truck loading/unloading and tank car unloading area is located along the east side of the POL Area.

Air Force records show that five spills have been documented at the site since 1970, including a single spill of 40,000 gal between tank No. 5 and Avenue D, of which only about 8,000 gal were recovered. The total volume of JP-4 estimated to have been spilled is between 65,000 and 74,000 gal; however, the actual volume may be significantly greater due to undocumented spills before 1970. Long-term Base employees indicate that in the past fuel was transferred by train cars, and spills were common.

An oval-shaped free-product plume is located to the southeast of the POL Area. The plume is approximately 950 ft by 500 ft (Figure 2). Groundwater depth appears to be approximately 72 ft below ground surface (bgs) and flows in a southeasterly direction across the site at a gradient of approximately 0.01 foot per foot (ft/ft). The site is upgradient from an alternative Base drinking water supply well and Silver Lead Creek, located approximately 1,700 feet east of the site. A previous study of the area showed that a plume of contaminated groundwater originated in the POL Area and extended under Silver Lead Creek. The POL Area soils are glacial deposits of sand with some gravel and silt overlying relatively impermeable bedrock at a depth of approximately 100 ft. Figure 3 shows a hydrogeologic cross section of the site.

A soil vapor survey indicated that the highest levels of contamination occur along the southeastern edge of the POL Area. A total aromatic volatile organic compound (VOC) concentration was reported at 292,000 mg/kg. Total petroleum hydrocarbon (TPH) concentrations were measured

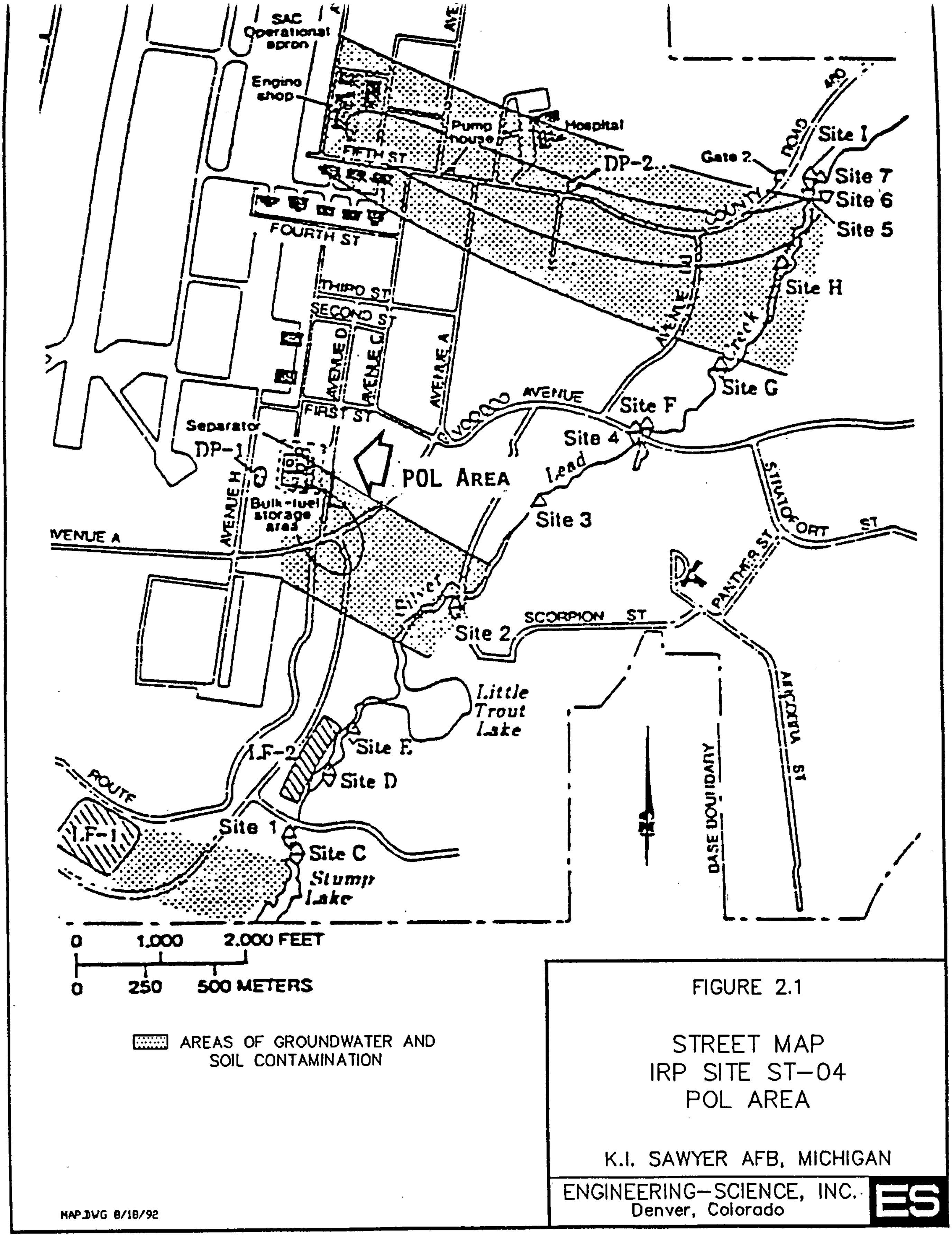

Figure 1. Location of IRP Site at K.I. Sawyer AFB, Michigan

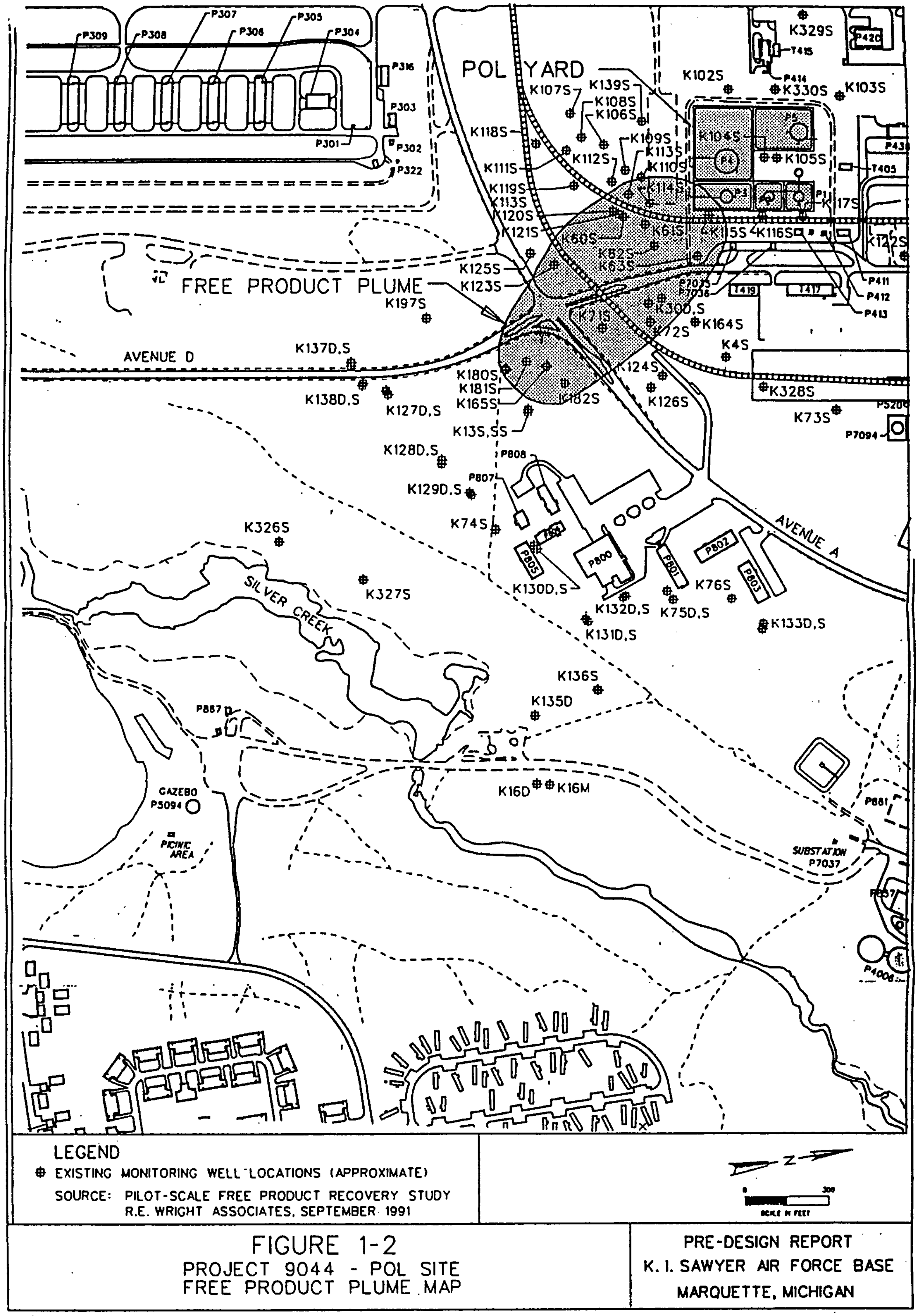

Figure 2. Free-Product Plume at POL Area, K.I. Sawyer AFB, Michigan

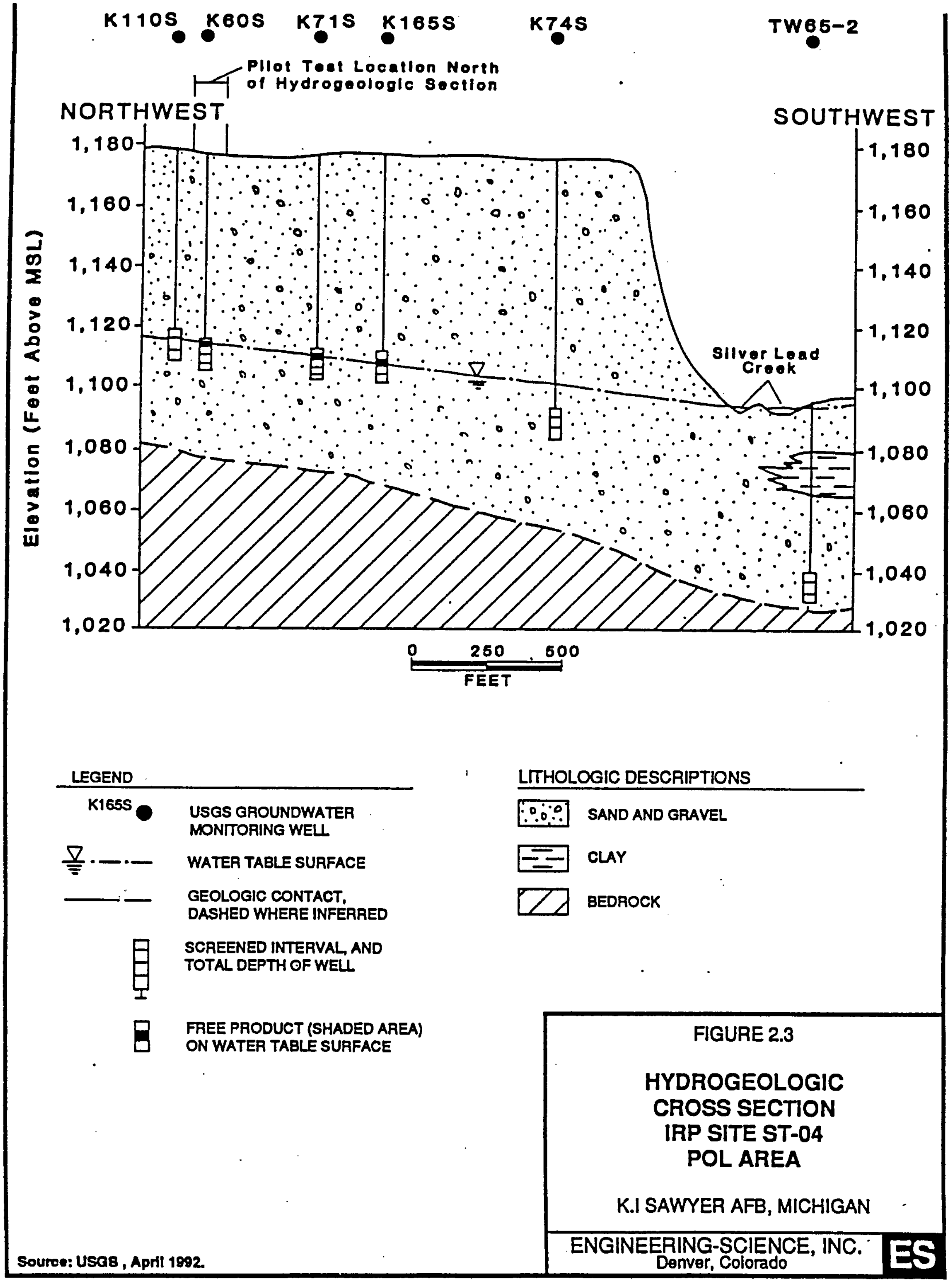

Figure 3. Hydrogeologic Cross Section, IRP Site ST-04, POL Area (from Engineering Science, Inc., 1992)

in excess of 7,000 mg/kg at a depth of approximately 15 ft. Groundwater analyses from 1988 through 1990 indicate the presence of benzene [up to 5,200 μg/L], ethylbenzene (up to 630 μg/L), total xylenes (up to 1,000 μg/L), and toluene (up to 4,400 μg/L).

A bioventing pilot test was performed at the POL Area in September 1992. The radius of influence was determined to exceed 60 ft at depths down to 60 ft bgs. A subsequent 1-year bioventing test demonstrated sizable reductions in soil concentrations of BTEX indicating that fuel biodegradation progressed at a significant rate.

A free-product recovery system was installed at the POL Area in March of 1995. Six extraction wells were installed as part of the recovery system. The system was not successful in extracting recoverable floating product. In May of 1996 monitoring well measurements were taken and baildown tests were performed to provide data to review and possibly reengineer the free-product recovery system. Appendices A and B give a summary of these test results.

3.0 PROJECT ACTIVITIES

The field activities discussed in the following sections are planned for the bioslurper pilot test at K.I. Sawyer 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 1 presents the schedule of activities for the Bioslurper Initiative at K.I. Sawyer 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 K.I. Sawyer AFB prior to staff arrival. The Base Point of Contact (POC) will have been 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 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 confirmation that the shipped equipment has been received by K.I. Sawyer AFB. If the existing free-product removal system is operating, it will need to be turned off 1 week before Battelle is to mobilizes to the site.

Table 1. Schedule of Bioslurper Pilot Test Activities

Pilot Test Activity	Schedule
Mobilization	Days 1-2
Site Characterization	Days 2-3
LNAPL/Groundwater Interface Monitoring and Baildown Tests	
Soil Gas Survey (Limited)	
Monitoring Point Installation (3 monitoring points)	
Soil Sampling (BTEX, TPH, physical characteristics)	
System Installation	Days 2-3
Test Startup	Day 4
Skimmer Pump Test (2 days)	Days 4-5
Bioslurper Pump Test (4 days)	Days 5-8
Soil Gas Permeability Testing	Day 5
Skimmer Pump Test (continued)	Day 9
In Situ Respiration Test - Air/Helium Injection	Day 9
In Situ Respiration Test - Monitoring	Days 10-13
Drawdown Pump Test (2 days)	Days 10-11
Demobilization/Mobilization	Days 12-13

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 also are useful for evaluating actual versus apparent free-product thicknesses. 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 LNAPL will be collected at this point for analyses of boiling point distribution and concentrations of benzene, toluene, ethylbenzene, and xylenes (BTEX). Detailed procedures for the baildown tests are provided in Section 5.6 of the overall Test Plan and Technical Protocol (Battelle, 1995).

3.2.2 Monitoring Point Installation

Monitoring points must 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 initial soil gas survey and baildown tests, at least three soil gas monitoring points will be installed (unless existing monitoring points are available for use) to measure soil gas changes that occur during bioslurper operation. These 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 monitoring point is shown in Figure 5. Information on monitoring point installation can be found in Section 4.2.1 of the overall Test Plan and Technical Protocol (Battelle, 1995).

3.2.3 Soil Sampling

Soil samples will be collected from each boring 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 chosen for the bioslurper test. Generally, samples will be collected from the capillary fringe over the free product.

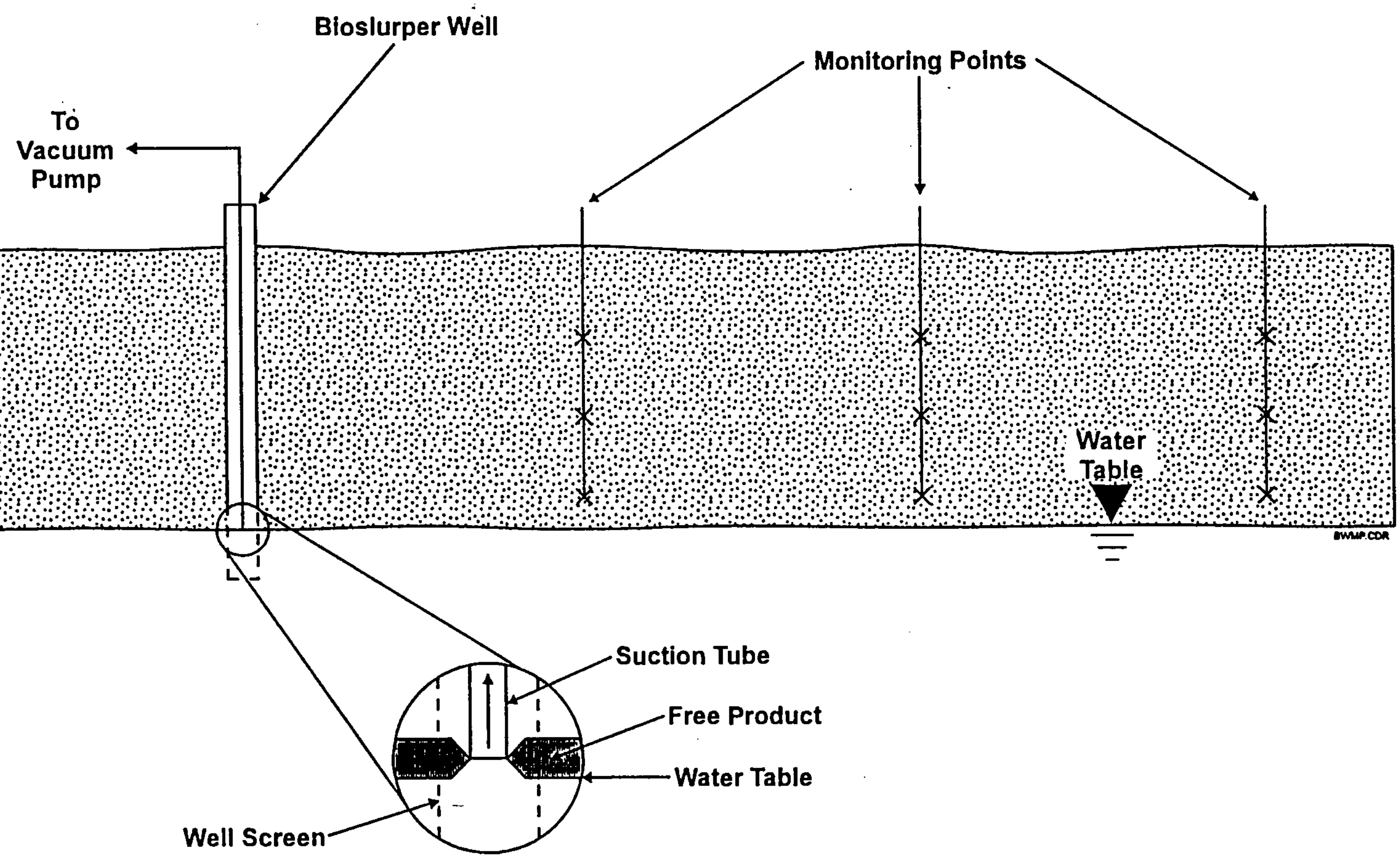

Figure 4. General Bioslurper Well and Monitoring Point Arrangement

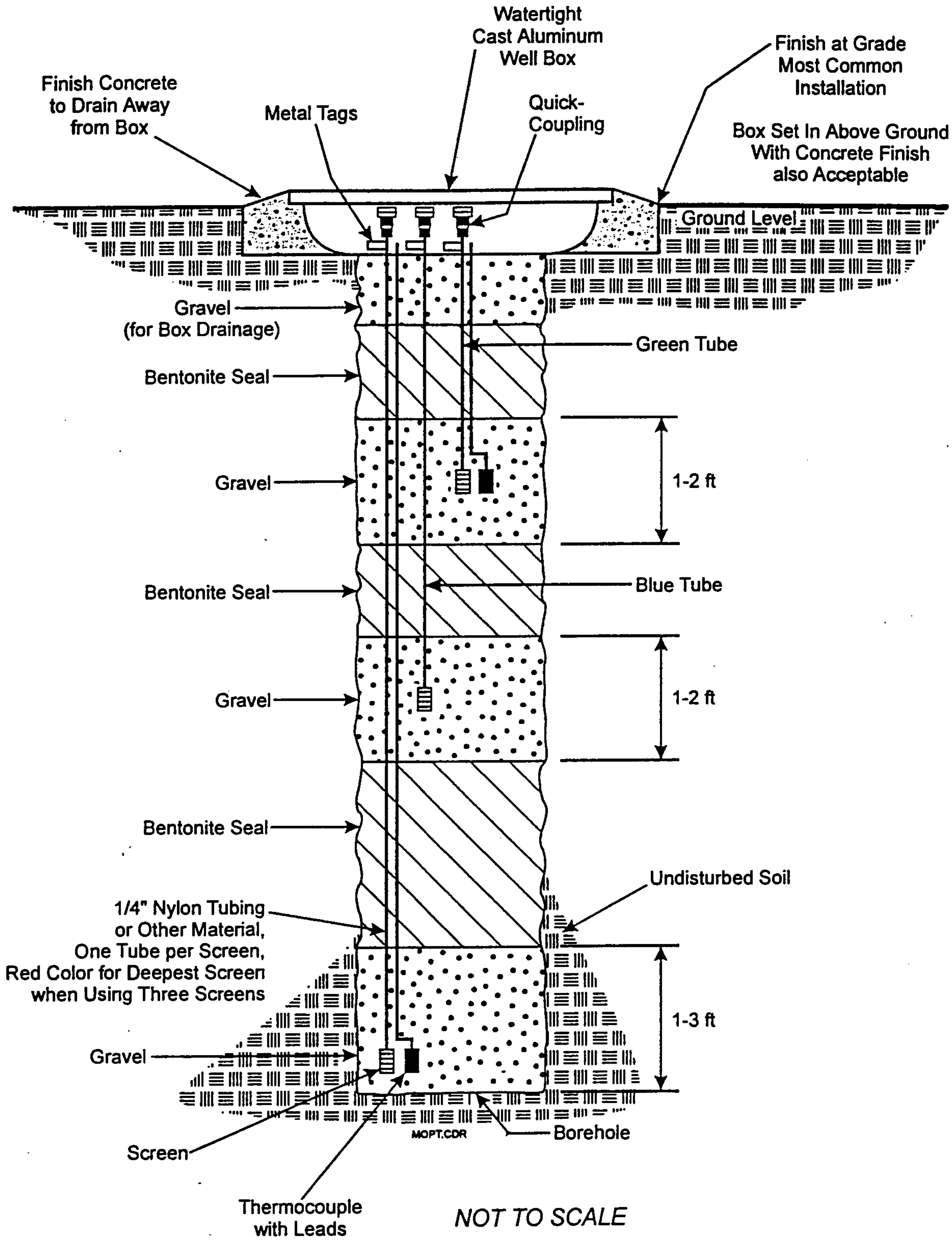

Figure 5. Schematic Diagram of a Typical Monitoring Point

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 (Battelle, 1995) contains additional information on field measurements and sample collection procedures for soil sampling.

3.3 Bioslurper System Installation and Operation

Once the well to be used for the bioslurper test installation at K.I. Sawyer AFB has been identified, the bioslurper pump and support equipment will be installed and pilot testing will be initiated.

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 illustrates a typical bioslurper well that will be used at K.I. Sawyer 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, 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-ft 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.

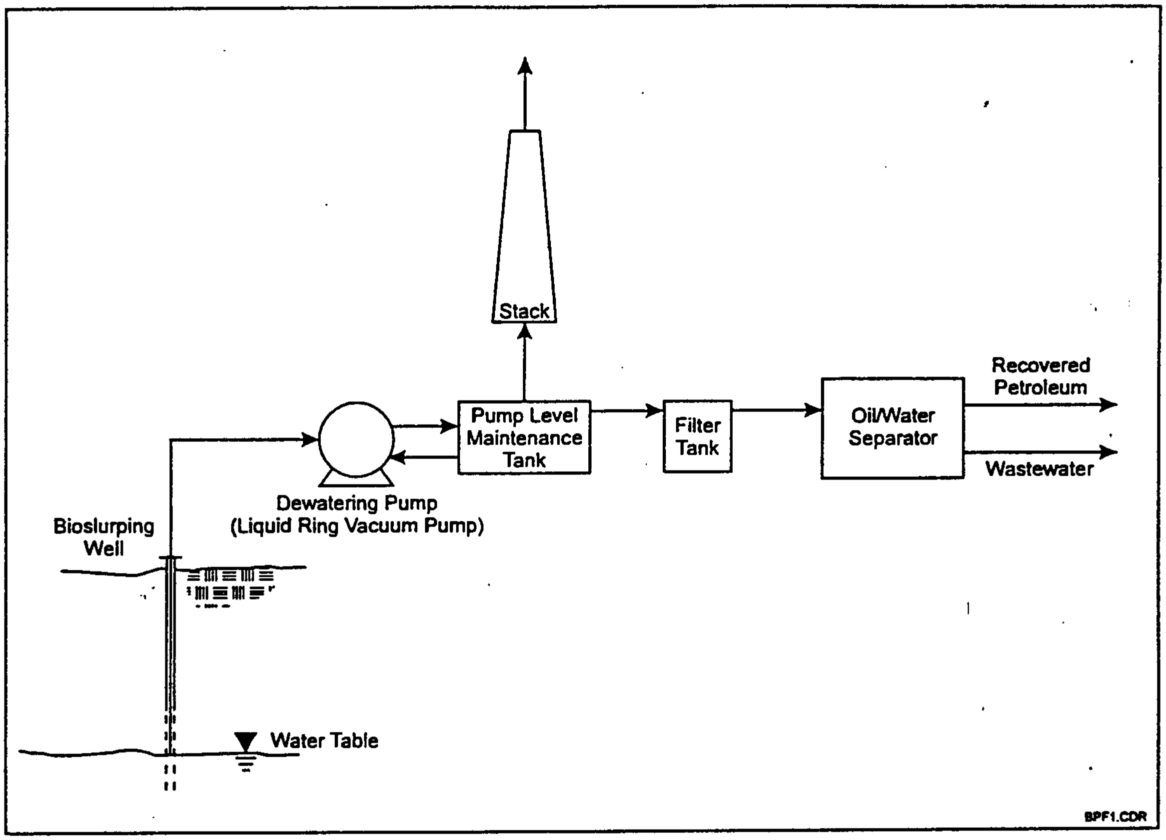

Figure 6. Bioslurper Process Flow at K.I. Sawyer AFB, Michigan

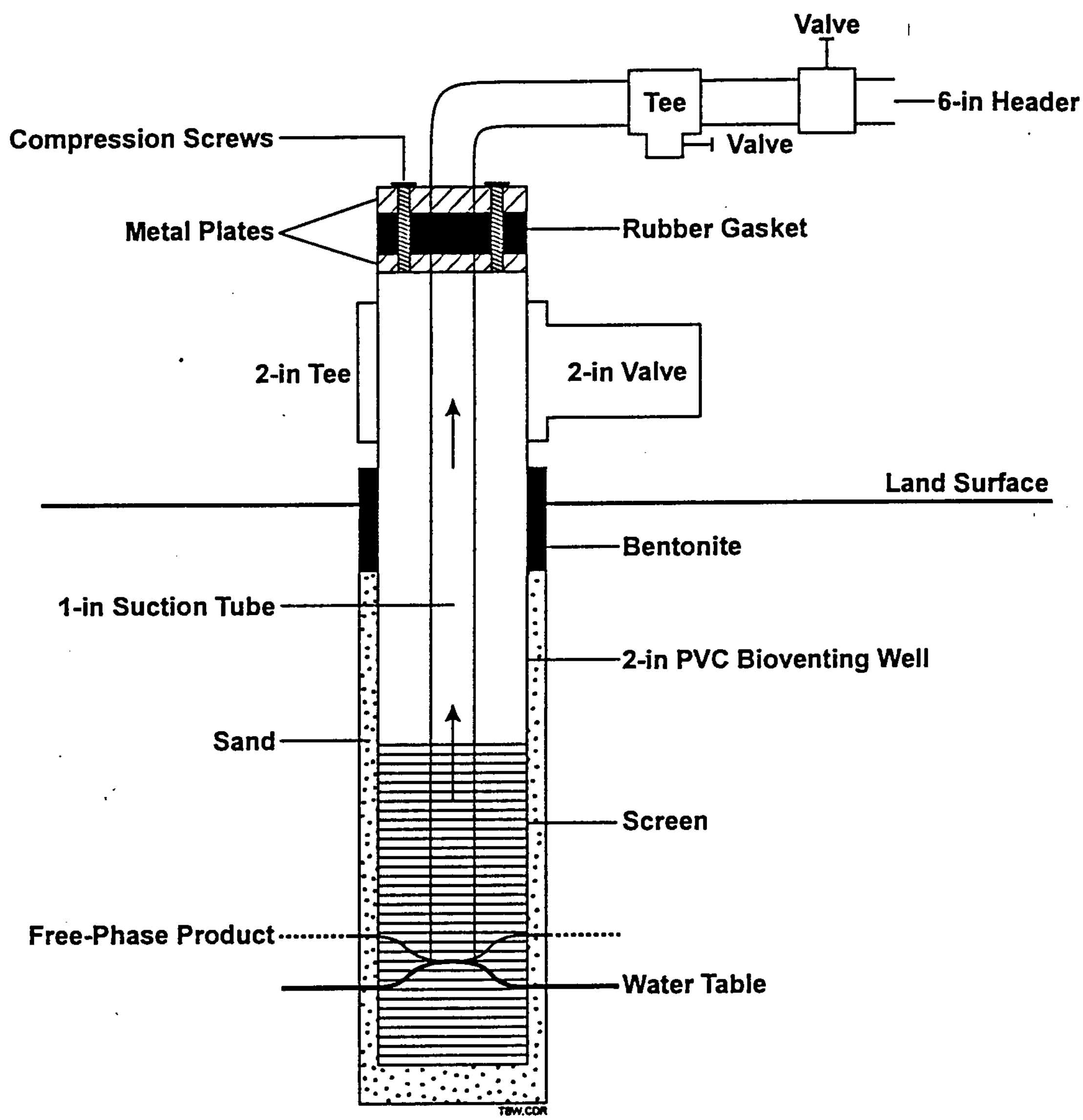

Figure 7. Schematic Diagram of a Typical Bioslurper Well

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 test technology relative to conventional gravity-driven LNAPL recovery technologies. The Bioslurper Initiative includes three separate LNAPL recovery tests: (1) a skimmer pump test, (2) a bioslurper pump test, and (3) a 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 detailed laboratory analysis. 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 (Battelle, 1995) 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.

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 (Battelle, 1995).

3.3.6 LNAPL and Groundwater Level Monitoring

During the bioslurper pump test, the LNAPL and groundwater 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 so the subsurface vacuum will be contained. Additional information for the monitoring of fluid levels is provided in Section 4.3.4 of the overall Test Plan and Technical Protocol (Battelle, 1995).

3.3.7 In Situ Respiration Test

An in situ respiration test will be conducted after completion of the bioslurper pilot tests. The in situ respiration test will involve injection of air and helium into selected soil gas monitoring points followed by monitoring changes in concentrations 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. The timing of the tests will be adjusted based on the 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 of the in situ respiration test is provided in Section 5.8 of the overall Test Plan and Technical Protocol (Battelle, 1995).

3.4 Demobilization

Once all necessary tests have been completed at the K.I. Sawyer AFB site, the equipment will be disassembled by Battelle staff. The equipment then 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 leaving K.I. Sawyer AFB.

4.0 BIOSLURPER SYSTEM DISCHARGE

4.1 Vapor Discharge Disposition

Battelle expects that the operation of the bioslurper test system at K.I. Sawyer AFB will not require a waiver or a point source air release registration per a conversation with Brian Brady, Marquette District Supervisor MI DEQ/AQD (Appendix C). It can be estimated that the concentrations of TPH released to the atmosphere will be approximately 60 lb/day and benzene will be <1.0 lb/day without treatment. This value is based on the average discharge rates at three bioslurper test sites (Warner Robins AFB, Travis AFB, and Wright-Patterson AFB) that are contaminated with a type of fuel similar to that found at the POL Area. 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 eight previous bioslurper sites are presented in Table 2.

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 air flow 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 3 presents information typically required to complete an air release registration form.

Table 2. 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
Bolling AFB, Site 1	No. 2 Fuel Oil	4.0	0.20	153	0.00030	0.0090
Bolling AFB, Site 2	Gasoline	21	370	70,000	2.3	470
Johnston Atoll	JP-5 Jet Fuel	10	0.60	975	0.0017	5.7
Warner Robins AFB, UST 70/72	JP-4 Jet Fuel	5	515	37,000	0.74	110
Warner Robins AFB, SS010	JP-4 Jet Fuel	5.5	13	680	0.021	2.2
Travis AFB	JP-4 Jet Fuel	20	100	10,800	0.58	130
Wright-Patterson AFB	JP-4 Jet Fuel	3.0	ND	595	0	1.0

ND = Not detected.

Table 3. 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 VOC level in air	~60 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 10 gpm. TPH concentrations in the discharge water are expected to be less than 50 mg/L based on data from past bioslurper tests conducted at Wright-Patterson AFB, Warner Robins AFB, Travis AFB, McGuire AFB, and Dover AFB. These sites are contaminated with a similar type of fuel as that found at the POL Area. It may be necessary in Michigan to obtain a groundwater pumping waiver or registration permit. If one is required, the Base POC will inform Battelle of the necessary steps in obtaining the waiver or permit. Battelle intends to release the recovered groundwater to the local sanitary sewer at the point of discharge of the current treatment system. An on-site water treatment plant does exist; however, it is not currently functioning.

4.3 Free-Product Recovery Disposition

The bioslurper system will recover free-phase product from the pilot tests performed at K.I. Sawyer AFB. Recovered free product will be turned over to the Base for disposal and/or recycling. The volume of free product recovered from the Base will not be known until the tests have been performed. The maximum recovery rate for this system is 10 gpm, but the actual rate of LNAPL recovery likely will be much lower.

5.0 SCHEDULE

The schedule for the bioslurper fieldwork at K.I. Sawyer 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 K.I. Sawyer AFB, all staff will return their Base passes. Battelle staff will 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, K.I. Sawyer AFB, and AFCEE during the bioslurper field test.

6.1 Battelle Activities

The obligations of Battelle in the Bioslurper Initiative at K.I. Sawyer 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 K.I. Sawyer AFB Support Activities

To support the necessary field tests at K.I. Sawyer AFB, the Base must be able to provide the following:

a. Any digging permits and utility clearances that 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 local sanitary sewer must be furnished so that Battelle staff can discharge the bioslurper aqueous effluent directly to the Base treatment facility.

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 not likely that a waiver or permit to allow air releases or a point source air release registration will be required for emissions of approximately 60 lb/day of TPH and <1.0 lb/day benzene without treatment. A waiver for pumping and discharging groundwater at a rate of 10 gpm may be required. 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 also 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 4 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 K.I. Sawyer 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.

Table 4. Health and Safety Information Checklist

Emergency Contacts	Name	Telephone Number
Hospital		
Fire Department	Emergency Switchboard	911
Ambulance and Paramedics	Emergency Switchboard	911
Police Department	Emergency Switchboard	911
EPA Emergency Response Team	Switchboard	(800) 424-8802
Program Contacts		
Air Force	Patrick Haas	(210) 536-4314
Battelle	Jeff Kittel	(614) 424-6122
K.I. Sawyer AFB	Gary Koski/Mark Hansen	
Other		
Emergency Routes		
Hospital ______		
Other ______		

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

Battelle POCs	Jeff Kittel	(614) 424-6122
AFCEE POC	Patrick Haas	(210) 536-4314
K.I. Sawyer AFB POC	Gary Koski/Mark Hansen	
Regulatory POCs	Diane Maley	
	Mark A. Petrie	

7.0 REFERENCES

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.

Bioventing Pilot Test Work Plan for Installation Restoration Program Site ST-04 POL Bulk Fuel Storage Area, K.I. Sawyer AFB, Michigan. Engineering-Science, Inc. 1992. Prepared for the U.S. Air Force Center for Environmental Excellence, Brooks Air Force Base, Texas and 410th Support Group, K.I. Sawyer AFB, Michigan, November.

APPENDIX A

**FREE-PRODUCT THICKNESSES AT POL AREA
K.I. SAWYER AFB, MICHIGAN**

Table 1
Free-Phase Product Thicknesses (Pre-Baildown Static Levels)
Site ST-04
KI Sawyer AFB, MI

Location ID	Depth to LNAPL (ft)	Depth to Water (ft)	Thickness of LNAPL (ft)	Remarks	Date
K30S*	70.03	72.03	2.00	3-inch ID PVC	5/14/96
K72S	72.5	74.14	1.64	4-inch ID Carbon Steel	5/14/96
K4S	73.79	74.22	0.43	4-inch ID Carbon Steel	5/14/96
K124S*	74.8	76.59	1.79	4-inch ID Carbon Steel	5/14/96
K126S	ND	75.66	ND	4-inch ID Carbon Steel	5/14/96
K182S*	74.89	77.15	2.26	4-inch ID Carbon Steel	5/14/96
K165S	74.54	75.81	1.27	4-inch ID Carbon Steel	5/14/96
K13SS	ND	77.11	ND	4-inch ID Carbon Steel	5/14/96
K13S	ND	77	ND	4-inch ID Carbon Steel	5/14/96
K180S	74.28	75.73	1.45	4-inch ID Carbon Steel	5/14/96
K181S*	73.36	75.61	2.25	4-inch ID Carbon Steel	5/14/96
K71S	72.25	73.69	1.44	4-inch ID Carbon Steel	5/14/96
K123S	71.16	71.63	0.47	4-inch ID Carbon Steel	5/14/96
K62S	69.76	70.59	0.83	2-inch ID Carbon Steel	5/14/96
K63S*	70.49	72.9	2.41	2-inch ID Carbon Steel	5/14/96
K114S	68.64	69.42	0.78	4-inch ID Carbon Steel	5/15/96
K110S	ND	68.21	ND	4-inch ID Carbon Steel	5/15/96
K109S	ND	67.95	ND	4-inch ID Carbon Steel	5/15/96
K113S	68.24	68.38	0.14	4-inch ID Carbon Steel	5/15/96
K112S	ND	68.1	ND	4-inch ID Carbon Steel	5/15/96
K61S*	68.31	69.32	1.01	2-inch ID Carbon Steel	5/15/96
K60S	67.37	68.36	0.99	2-inch ID Carbon Steel	5/15/96
K121S	68.06	68.95	0.89	4-inch ID Carbon Steel	5/15/96
K120S	67.74	68.28	0.54	4-inch ID Carbon Steel	5/15/96
K119S[1]	ND	66.95	ND	4-inch ID Carbon Steel	5/15/96
K127S[1]	74.62	75.97	1.35	4-inch ID Carbon Steel	5/15/96
K128S[1]	ND	75.9	ND	4-inch ID Carbon Steel	5/15/96
K129S[1]	ND	76.46	ND	4-inch ID Carbon Steel	5/15/96
K131S[1]	ND	74.1	ND	4-inch ID Carbon Steel	5/15/96
K197S[1]	ND	72.44	ND	4-inch ID Carbon Steel	5/15/96
K115S*	69.95	71.43	1.48	4-inch ID Carbon Steel	5/16/96
RW-2*[1]	70.89	72.46	1.57	6-inch PVC	5/16/96

Notes:
* Baildown test conducted
[1] Additional wells used to determine plume boundary

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APPENDIX B

BAILDOWN TEST RESULTS

Baildown Test Record Form
Site ST-04, KI Sawyer AFB, MI

Location ID: K30S	Date (mm-dd-yy): 5-15-1996 @17:17
Well Diameter (inch): 3 ; PVC	Conducted By: M. Kesebir, M. Goydas
INITIAL (Pre-Baildown Test)	**FINAL (Post-Baildown Test)**
PID Reading at well head (ppm):	PID Reading at well head (ppm):
Depth to LNAPL (ft. below TOC): 70.03	Depth to LNAPL (ft. below TOC): 70.06
Depth to water (ft. below TOC): 71.99	Depth to water (ft. below TOC): 71.84
Thickness of LNAPL (feet): 1.96	Thickness of LNAPL (feet): 1.78

BAILING OUT LNAPL

Volume (ml)	Depth to LNAPL (ft. below TOC)	Depth to Water (ft. below TOC)	Thickness of LNAPL (feet)	Remarks
4,000	Not measured	Not measured	Not measured	
6,600	70.4	70.91	0.51	1,000 ml water purged

BAILDOWN TEST

Time (HH:MM:SS)	Elapsed Time (minute)	Depth to LNAPL (ft. below TOC)	Depth to Water (ft. below TOC)	LNAPL Thickness (feet)	Remarks
17:34:15	0:00:00	70.4	70.91	0.51	
17:35:15	0:01:00	70.35	70.93	0.58	
17:35:30	0:01:15	70.32	70.94	0.62	
17:35:45	0:01:30	70.29	70.93	0.64	
17:36:00	0:01:45	70.26	70.95	0.69	
17:36:15	0:02:00	70.26	70.96	0.7	
17:36:45	0:02:30	70.24	70.99	0.75	
17:37:15	0:03:00	70.23	71.02	0.79	
17:37:45	0:03:30	70.22	71.05	0.83	
17:38:15	0:04:00	70.21	71.09	0.88	
17:38:45	0:04:30	70.2	71.11	0.91	
17:39:15	0:05:00	70.19	71.14	0.95	
17:40:15	0:06:00	70.18	71.19	1.01	
17:41:15	0:07:00	70.17	71.24	1.07	
17:42:15	0:08:00	70.16	71.28	1.12	
17:43:15	0:09:00	70.15	71.32	1.17	
17:44:15	0:10:00	70.14	71.38	1.24	
17:45:15	0:11:00	70.13	71.4	1.27	
17:46:15	0:12:00	70.13	71.44	1.31	
17:47:15	0:13:00	70.13	71.47	1.34	
17:48:15	0:14:00	70.12	71.5	1.38	
17:49:15	0:15:00	70.11	71.52	1.41	
17:54:15	0:20:00	70.09	71.63	1.54	
17:59:15	0:25:00	70.08	71.71	1.63	
18:04:15	0:30:00	70.08	71.76	1.68	
18:09:15	0:35:00	70.07	71.8	1.73	
18:14:15	0:40:00	70.06	71.84	1.78	

Baildown Test Record Form
Site ST-04, KI Sawyer AFB, MI

Location ID: K63S	Date (mm-dd-yy): 5-16-1996 @16:14
Well Diameter (inch): 2 ; Carbon Steel	Conducted By: M. Kesebir, M. Goydas

INITIAL (Pre-Baildown Test)		FINAL (Post-Baildown Test)	
PID Reading at well head (ppm):	50	PID Reading at well head (ppm):	
Depth to LNAPL (ft. below TOC):	70.46	Depth to LNAPL (ft. below TOC):	70.48
Depth to water (ft. below TOC):	72.79	Depth to water (ft. below TOC):	72.61
Thickness of LNAPL (feet):	2.33	Thickness of LNAPL (feet):	2.13

BAILING OUT LNAPL

Volume (ml)	Depth to LNAPL (ft. below TOC)	Depth to Water (ft. below TOC)	Thickness of LNAPL (feet)	Remarks
4,100	70.92	71.25	0.33	100 ml water purged

BAILDOWN TEST

Time (HH:MM:SS)	Elapsed Time (minute)	Depth to LNAPL (ft. below TOC)	Depth to Water (ft. below TOC)	LNAPL Thickness (feet)	Remarks
16:24:00	0:00:00	70.92	71.25	0.33	
16:25:00	0:01:00	70.90	71.25	0.35	
16:25:15	0:01:15	70.88	71.26	0.38	
16:25:30	0:01:30	70.85	71.27	0.42	
16:25:45	0:01:45	70.85	71.28	0.43	
16:26:00	0:02:00	70.83	71.28	0.45	
16:26:15	0:02:15	70.82	71.29	0.47	
16:26:30	0:02:30	70.80	71.31	0.51	
16:26:45	0:02:45	70.80	71.32	0.52	
16:27:00	0:03:00	70.79	71.33	0.54	
16:27:15	0:03:15	70.78	71.35	0.57	
16:27:30	0:03:30	70.77	71.36	0.59	
16:27:45	0:03:45	70.77	71.37	0.6	
16:28:00	0:04:00	70.75	71.39	0.64	
16:28:30	0:04:30	70.74	71.41	0.67	
16:29:00	0:05:00	70.72	71.43	0.71	
16:29:30	0:05:30	70.72	71.46	0.74	
16:30:00	0:06:00	70.71	71.48	0.77	
16:30:30	0:06:30	70.70	71.51	0.81	
16:31:00	0:07:00	70.69	71.53	0.84	
16:32:00	0:08:00	70.67	71.59	0.92	
16:33:00	0:09:00	70.66	71.64	0.98	
16:34:00	0:10:00	70.65	71.69	1.04	
16:35:00	0:11:00	70.64	71.73	1.09	
16:36:00	0:12:00	70.63	71.77	1.14	
16:41:00	0:17:00	70.60	71.95	1.35	
16:46:00	0:22:00	70.57	72.08	1.51	
16:52:00	0:28:00	70.57	72.2	1.63	
16:56:00	0:32:00	70.55	72.27	1.72	
17:01:00	0:37:00	70.54	72.31	1.77	
17:11:00	0:47:00	70.53	72.4	1.87	
17:21:00	0:57:00	70.51	72.46	1.95	
17:31:00	1:07:00	70.51	72.5	1.99	

Baildown Test Record Form
Site ST-04, KI Sawyer AFB, MI

Location ID: K181S	Date (mm-dd-yy): 5-15-1996 @15:36
Well Diameter (inch): 4 ; Carbon Steel	Conducted By: M. Kesebir, M. Goydas

INITIAL (Pre-Baildown Test)		FINAL (Post-Baildown Test)	
PID Reading at well head (ppm):		PID Reading at well head (ppm):	3.6
Depth to LNAPL (ft. below TOC):	73.42	Depth to LNAPL (ft. below TOC):	73.41
Depth to water (ft. below TOC):	75.67	Depth to water (ft. below TOC):	75.41
Thickness of LNAPL (feet):	2.25	Thickness of LNAPL (feet):	2.00

BAILING OUT LNAPL

Volume (ml)	Depth to LNAPL (ft. below TOC)	Depth to Water (ft. below TOC)	Thickness of LNAPL (feet)	Remarks
3,000	73.75	74.45	0.7	450 ml water purged

BAILDOWN TEST

Time (HH:MM:SS)	Elapsed Time (minute)	Depth to LNAPL (ft. below TOC)	Depth to Water (ft. below TOC)	LNAPL Thickness (feet)	Remarks
15:50:30	0:00:00	71.08	72.04	0.96	
15:52:00	0:01:30	71.08	72.08	1	
15:52:30	0:02:00	71.06	72.04	0.98	
15:53:00	0:02:30	71.05	72.05	1	
15:53:30	0:03:00	71.05	72.03	0.98	
15:54:00	0:03:30	71.04	72.05	1.01	
15:55:00	0:04:30	71.04	72.06	1.02	
15:56:00	0:05:30	71.05	72.07	1.02	
15:57:00	0:06:30	71.04	72.08	1.04	
15:58:00	0:07:30	71.03	72.07	1.04	
15:59:00	0:08:30	71.03	72.09	1.06	
16:00:00	0:09:30	71.02	72.09	1.07	
16:01:00	0:10:30	71.02	72.09	1.07	
16:06:00	0:15:30	71.01	72.09	1.08	
16:11:00	0:20:30	71.01	72.12	1.11	
16:16:00	0:25:30	71.01	72.11	1.1	
16:21:00	0:30:30	71.01	72.12	1.11	
16:31:00	0:40:30	71.01	72.16	1.15	
17:01:00	1:10:30	71.00	72.16	1.16	
18:03:00	2:12:30	71.00	72.19	1.19	

APPENDIX C

CONVERSATION CONFIRMER BETWEEN PATRICK HAAS (AFCEE) AND BRIAN BRADY (MI DEQ/AQD)

AFCEE TECHNOLOGY TRANSFER DIVISION

TECHNOLOGY PROJECT MANAGER CONVERSATION CONFIRMER

Date: 01 July 1996
Time:
Organization: MI DEQ/AQD
Project: Free Product Recovery Pilot Test
Contract #:
File #:
Conversation with: Brian Brady
By: Patrick E. Haas P.E.H. 01Jul96
Media: ✓ Telephone / Office Meeting / Other ( )
cc: Gary Koski, Dean Dunn, Jeff Kittel

SUBJECT: Vapor Discharge Waiver for Free Product Recovery Activities at K.I. Sawyer AFB MI.

Mr. Brian Brady is the Marquette District Supervisor of the MI DEQ/AQD

The activities and equipment items related to the planned AFCEE/ERT Pilot test at K.I Sawyer AFB MI were discussed in detail. The testing sequence involving skimmer pump testing, followed by vacuum enhanced, followed by drawdown were discussed. Vapor emissions from vacuum pumps were designated to last approximately 8 days.

An exclusion for direct discharge of entrained vapors was requested. Mr. Brady identified that he understood the nature of the testing and granted a waiver to conduct direct discharge without vapor treatment.

I asked if any rule or specific exclusion need be cited. Mr. Brady stated that this telephone contact would be sufficient to proceed with the planned direct discharge. I identified that this conversation confirmer would be developed to serve as a record of his concurrence. He agreed.

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

2505 Chandler Avenue, Suite 1
Las Vegas, Nevada 89120
(702) 498-3312
FAX: 702-736-7523
1-800-283-1183

ALPHA ANALYTICAL FAX COVER SHEET

DATE: __________

TIME: __________

FROM: Gary

TO: Melody Grails

NUMBER OF PAGES TO FOLLOW: 6

COMMENTS: __________

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

e-mail: alpha@powernet.net
http//www.powernet.net/~alpha

2505 Chandler Avenue, Suite 1
Las Vegas, Nevada 89120
(702) 498-3312
FAX: 702-736-7523
1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: G462201-30B2101
Phone: (614) 424-6199
Attn: Al Pollock

Sampled: 08/03/96 Received: 08/06/96 Analyzed: 08/08/96

Matrix: [ ] Soil [X] 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	
KIS-DW-1 /BMI080696-06	TPH (Purgeable)	6.3	5.0	mg/L
	Benzene	370	10	ug/L
	Toluene	1,300	10	ug/L
	Ethylbenzene	170	10	ug/L
	Total Xylenes	870	10	ug/L
KIS-DW-2 /BMI080696-07	TPH (Purgeable)	6.5	5.0	mg/L
	Benzene	370	10	ug/L
	Toluene	1,300	10	ug/L
	Ethylbenzene	170	10	ug/L
	Total Xylenes	890	10	ug/L

Approved by: *Roger L. Scholl* Date: *8/15/96*
Roger L. Scholl, Ph.D.
Laboratory Director

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
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Las Vegas, Nevada 89120
(702) 498-3312
FAX: 702-736-7523
1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: G462201-30B2101
Phone: (614) 424-6199
Attn: Al Pollock

Sampled: 07/30/96 Received: 08/06/96 Analyzed: 08/08-09/96

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	
KIS-S-1 /BMI080696-08	TPH (Purgeable)	110	10	mg/Kg
	Benzene	480	20	ug/Kg
	Toluene	1,000	20	ug/Kg
	Ethylbenzene	180	20	ug/Kg
	Total Xylenes	690	20	ug/Kg
KIS-S-2 /BMI080696-09	TPH (Purgeable)	1,000	500	mg/Kg
	Benzene	ND	1,000	ug/Kg
	Toluene	ND	1,000	ug/Kg
	Ethylbenzene	ND	1,000	ug/Kg
	Total Xylenes	ND	1,000	ug/Kg

ND - Not Detected

Approved by: Roger L. Scholl Date: 8/15/96
Roger L. Scholl, Ph.D.
Laboratory Director

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
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2505 Chandler Avenue, Suite 1
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(702) 498-3312
FAX: 702-736-7523
1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: G462201-30B2101
Phone: (614) 424-6199
Attn: Al Pollock

Sampled: 08/05/96 Received: 08/06/96 Analyzed: 08/08/96

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

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

Methodology: BTEX - Method 624/8240

Results:

Client ID/ Lab ID	Parameter	Concentration	Detection Limit	
KIS-FP-1	Benzene	680	480	mg/Kg
/BMI080696-10	Toluene	5,600	480	mg/Kg
	Ethylbenzene	1,800	480	mg/Kg
	Total Xylenes	7,400	480	mg/Kg

Approved by: Roger L. Scholl Date: 8/15/96
Roger L. Scholl, Ph.D.
Laboratory Director

Alpha Analytical, Inc.
255 Glendale Avenue, Suite 21
Sparks, Nevada 89431
(702) 355-1044
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2505 Chandler Avenue, Suite 1
Las Vegas, Nevada 89120
(702) 498-3312
FAX: 702-736-7523
1-800-283-1183

ANALYTICAL REPORT

Battelle
505 King Ave
Columbus Ohio 43201

Job#: G462201-30b2101
Phone: (614) 424-6199
Attn: Al Pollook

Alpha Analytical Number: BMI0806796-10

Client I.D. Number: KIS-FP-1

Date Sampled: 08/05/96

Date Received: 09/04/96

C-range Compounds	Method	Percentage of Total	Detection Limit (Not Applicable)	Date Analyzed
<C08	GC/FID	50.75	NA	09/05/96
C09	GC/FID	9.58	NA	09/05/96
C10	GC/FID	11.05	NA	09/05/96
C11	GC/FID	10.70	NA	09/05/96
C12	GC/FID	6.72	NA	09/05/96
C13	GC/FID	4.78	NA	09/05/96
C14	GC/FID	2.40	NA	09/05/96
C15	GC/FID	1.43	NA	09/05/96
C16	GC/FID	0.81	NA	09/05/96
C17	GC/FID	0.58	NA	09/05/96
>C18	GC/FID	1.18	NA	09/05/96

Approved by: Roger L. Scholl Date: 9/5/96

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 : 9/09/96
Client : ALP-855
Taken by: CLIENT
Report : 17333
PO# :

Page: 1

Sample	Collected Date	Collected Time	MOISTURE CONTENT %	DENSITY G/CM3	PARTICLE SIZE DISTIBUTION FRACTION %	POROSITY		
BMI080696-08 - KIS-S-1	7/30/96	:	15.1	1.92	REPORT	27.6		
BMI080696-09 - KIS-S-2	7/30/96	:	9.9	1.90	REPORT	28.3		

Approved By: ____________

This report is applicable only to the sample received by the laboratory. The liability of the laboratory is limited to the amount p[aid] for this report. This report is for the exclusive use of the client to whom it is addressed and upon the condition that the client assumes all liability for the further distribution of the report or its contents.

William F. Pillsbury
President

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

John C. Seher
Manager

AIR TOXICS LTD.

AN ENVIRONMENTAL ANALYTICAL LABORATORY

180 BLUE RAVINE ROAD
Suite B
Folsom, CA 95630

Phone (916) 985-1000
FAX (916) 985-1020
Hours 8:00 A.M. to 6:00 P.M. Pacific

COMPANY: Battelle

ATTENTION: Amanda Bush

FAX #: 614-424-3667

FROM: AR

PAGES (Including cover) 5

COMMENTS: WO# 9608061

WORK ORDER #: 9608061

Work Order Summary

CLIENT: Ms. Amanda Bush
Battelle Memorial Institute
505 King Avenue
Columbus, OH 43201-2693

BILL TO: Same

PHONE: 614-424-4996
FAX: 614-424-3667
DATE RECEIVED: 8/6/96
DATE COMPLETED:

INVOICE #
P.O. #
PROJECT # G462201-30B1301 Bioslurper
AMOUNT$: $303.69

FRACTION #	NAME	TEST	RECEIPT VAC./PRES.	PRICE
01A	KIS-OGS-1	TO-3	1.5 "Hg	$120.00
02A	KIS-OGS-2	TO-3	1.0 "Hg	$120.00
03A	Lab Blank	TO-3	NA	NC

Misc. Charges	1 Liter Summa Canister Preparation (2) @ $15.00 each.	$30.00
	Shipping (7/30/96)	$33.69

PRELIMINARY

CERTIFIED BY: [signature]
Laboratory Director

DATE: 8-13-96

AIR TOXICS LTD.

SAMPLE NAME: KIS-OGS-1

ID#: 9608061-01A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name: 6081010 Date of Collection: 8/3/96

Dil. Factor: 5320 Date of Analysis: 8/10/96

Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
Benzene	5.3	17	180	580
Toluene	5.3	20	600	2300
Ethyl Benzene	5.3	23	170	750
Total Xylenes	5.3	23	620	2700

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as Jet Fuel)

File Name: [illegible] Date of Collection: 8/3/96

Dil. Factor: 5320 Date of Analysis: 8/10/96

Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
TPH* (C5+ Hydrocarbons)	53	350	98000	640000
C2 - C4** Hydrocarbons	53	97	6000	11000

*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: KIS-OGS-2

ID#: 9608061-02A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name: 6081011 Date of Collection: 8/3/96

Dil. Factor: 2610 Date of Analysis: 8/10/96

Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
Benzene	2.6	8.5	160	520
Toluene	2.6	10	460	1800
Ethyl Benzene	2.6	12	120	530
Total Xylenes	2.6	12	460	2000

TOTAL PETROLEUM HYDROCARBONS

GC/FID

(Quantitated as Jet Fuel)

File Name: 6081011 Date of Collection: 8/3/96

Dil. Factor: 2610 Date of Analysis: 8/10/96

Compound	Det. Limit (ppmv)	Det. Limit (uG/L)	Amount (ppmv)	Amount (uG/L)
TPH* (C5+ Hydrocarbons)	26	170	78000	500000
C2 - C4** Hydrocarbons	26	48	9600	18000

*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#: 9608061-03A

EPA METHOD TO-3

(Aromatic Volatile Organics in Air)

GC/PID

File Name: 6081005 Date of Collection: NA
Dil. Factor: 1.00 Date of Analysis: 8/10/96

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: 6081005 Date of Collection: NA
Dil. Factor: 1.00 Date of Analysis: 8/10/96

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

APPENDIX C

SYSTEM CHECKLIST

Checklist for System Shakedown

Site: ~~7-29~~ K. I. SAWYER AFB

Date: 7-29-96

Operator's Initials: MP

Equipment	Check if Okay	Comments
Liquid Ring Pump	✓	
Aqueous Effluent Transfer Pump	✓	
Annunciator Panel	NA	
Equalizing Tank	NA	
Heat Exchanger	NA	
Dehumidifier	NA	
Blower	NA	
Off-Gas Treatment System	NA	
Vapor Flow Meter	✓	
Water Flow Meter	✓	
Emergency Shut Off Float Switches	✓	
Analytical Field Instrumentation - GasTechtor O_2/CO_2 Analyzer - TraceTechtor Hydrocarbon Analyzer - Oil/Water Interface Probe - Magnehelic Boards - Thermocouple Thermometer	 ✓ ✓ ✓ ✓ ✓	

APPENDIX D

DATA SHEETS FROM THE SHORT-TERM PILOT TEST

ATMOSPHERIC OBSERVATIONS

Site: KI SAWYER AFB

Operators: M. PLACE & M. GRAVES

Date/Time	Ambient Temperature	Relative Humidity	Barometric Pressure
7/30/96 1755 HRS	63.0°F		
7/31/96 0855 HRS	61.0°F		
7/31/96 1810 HRS	64.0°F		
8/1/96 0830 HRS	65.0°F		
8/1/96 1815 HRS	75.8°F		
8/2/96 0900 HRS	66.4°F		
8/2/96 1745 HRS	80.6°F		
8/3/96 0936 HRS	70.0°F		
8/4/96 2115 HRS	64.4°F		
8/4/96 0330 HRS	76.0°F		
8/5/96 1204 HRS	70.9°F		
8/5/96 2201 HRS	79.0°F		
8/6/96 0724 HRS	74.4°F		
8/6/96 1730 HRS	84.8°F		
8/7/96 2340 HRS	76.2°F		
8/8/96 0715 HRS	MJG ~~76.2~~ 67.0°F		

Baildown Test Record Sheet

Site: KI SAWYER AFB

Well Identification: RW-2

Well Diameter (OD/ID): 6"

Date at Start of Test: 7/29/96

Sampler's Initials: MJA

Time at Start of Test: 1125 HRS

Initial Readings

Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)	Total Volume Bailed (L)
67.47	66.69	0.78	5.0

Test Data

Sample Collection Time	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
1125	69.14	68.82	0.32
1126	69.16	68.72	0.44
1129	69.20	68.73	0.47
1131	69.20	68.73	0.47
1137	69.27	68.70	0.57
1154	69.33	68.68	0.65
1325	69.39	68.68	0.71
1448	67.40	68.65	0.75
0835 (7/30)	69.43	68.65	0.78

Figure 9. Typical Baildown Test Record Sheet

Baildown Test Record Sheet

Site: KI SAWYER AFB

Well Identification: K30S

Well Diameter (OD/ID): 4"

Date at Start of Test: 7/29/96

Sampler's Initials: MJW

Time at Start of Test: 1338 HRS

Initial Readings

Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)	Total Volume Bailed (L)
69.55	69.09	0.46	.650

Test Data

Sample Collection Time	Depth to Groundwater (ft)	Depth to LNAPL (ft)	LNAPL Thickness (ft)
1338	69.36	69.29	0.07
1339	69.30	69.21	0.09
1342	69.30	69.18	0.12
1349	69.30	69.17	0.13
1357	69.31	69.17	0.14
1415	69.35	69.16	0.19
1445	69.38	69.15	0.23

Figure 9. Typical Baildown Test Record Sheet

Bioslurping Pilot Test
(Data Sheet 1)
Well Characteristics

Page ____ of ____

Site: K30S measured

Test Type (skimmer, bioslurper vacuum extraction, drawdown): RW2 extraction well

Depth to Groundwater: ________ Depth to Fuel: ________ Depth of Slurper Tube: ________

Date at Start of Test: ________

Time at Start of Test: ________

Operator's Initials: MJB/MP

Date/Time	Well ID: K-30S			Well ID:			Well ID:		
	LNAPL Level	Water Level	Pressure (in H_2O)	LNAPL Level	Water Level	Pressure (in H_2O)	LNAPL Level	Water Level	Pressure (in H_2O)
8/1/96	69.59	69.98							
8/2/96	69.60	69.94							
8/6/96	69.44	69.73							

Figure 11. Typical Record Sheets for Bioslurper Pilot Testing

Bioslurping Pilot Test
(Data Sheet 1)
Well Characteristics

Page ____ **of** ____

Site: RW2 Measured

Test Type (skimmer, bioslurper vacuum extraction, drawdown): K 30 S extration well

Depth to Groundwater: ________ **Depth to Fuel:** ________ **Depth of Slurper Tube:** ________

Date at Start of Test: ________

Time at Start of Test: ________

Operator's Initials: NWG/MP

Date/Time	Well ID: RW-2			Well ID:			Well ID:		
	LNAPL Level	Water Level	Pressure (in H_2O)	LNAPL Level	Water Level	Pressure (in H_2O)	LNAPL Level	Water Level	Pressure (in H_2O)
8/6/96	6648	66.77							
8/7/96	66.46	66.84							
8/8/96	66.47	66.85							

Figure 11. Typical Record Sheets for Bioslurper Pilot Testing

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

Site: K.I Sawyer AFB

Operators: M Place & M Graves

Test Type: Bioslurping

Depth to Groundwater: ________ Depth to Fuel: ________

Start Date: 8/1/96

Start Time: 1345

Well ID: RW-2

Depth of Tube: 67.20

Date/Time	Run Time	Vapor Extraction			Pump Stack Temp (°C)	Pump Head Vacuum (in. Hg)	Extraction Well Vacuum (in. H_2O)
		Stack Pressure (in. H_2O)	Carbon Drums (in. H_2O)	Flowrate (scfm)			
8/1/96 1815	5hrs	<0.005	–	<5	47.67	23	0.08
8/2/96 0900	19.75	0.005	–	5	40.78	23	0.22
8/2/96 1745	28.5	0.005	–	5	48.30	23	0.05
8/3/96 0936	43.85	0.005	–	5	54.70	21	0.70

Figure 11. Typical Record Sheets for Bioslurper Pilot Testing (Continued)

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

Page 1 of 1

Site: K.I. Sawyer AFB

Operators: M. Place & M. Graves

Test Type: Bioslurping

Depth to Groundwater: 69.73 Depth to Fuel: 69.44

Start Date: 8/6/96

Start Time: 1755

Well ID: K305

Depth of Tube: 69.73

Date/Time	Run Time	Vapor Extraction: Stack Pressure (in. H_2O)	Vapor Extraction: Carbon Drums (in. H_2O)	Vapor Extraction: Flowrate (scfm)	Pump Stack Temp (°C)	Pump Head Vacuum (in. Hg)	Extraction Well Vacuum (in. H_2O)
8/6/96 2340		0.015	–	8	46.33	22	3
8/7/96 0745		0.015	–	8	38.83	23	3.2
8/7/96 1540		0.005	–	5	47.22	22	3
8/8/96 0715		0.01	–	7	39.78	23	3.5

Figure 11. Typical Record Sheets for Bioslurper Pilot Testing (Continued)

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

Site: K.I. Sawyer AFB RW-2 Test Type: Skimmer

Start Date: 7/30/96 1115hrs Operators: M. Place & M. Graves

Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
7/30/96 1755	6.67hrs	11 gallons	200 gallons
7/31/96 0855	15/21 total	9.25	460
7/31/96 1810	9.25/30.92 total	8.0	480.9
8/1/96 0830	14.67/45.59 total	6.5	253.1

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

Site: K.I Sawyer AFB RW-2 Test Type: Bioslurping

Start Date: 8/1/96 1345 Operators: M. Place & M. Graves

Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
8/1/96 1815	5hrs	4.3 gallons	126 gallons
8/2/96 0900	14.75/19.75 total	3.5	MJG ~~363~~ 237
8/2/96 1745	8.75/28.5 total	2.5	377
8/3/96 0936	15.35/43.85 total	2.5	MJG ~~871~~ 1234

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

Site: K.I. Sawyer AFB RW-2 Test Type: Second Skimmer

Start Date: 8/3/96 1230 Operators: M. Place & M. Graves

Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
8/3/96 2220	9.83hrs	2.5 gallons	227 gallons

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

Site: K.I. Sawyer AFB RW-2 Test Type: Drawdown

Start Date: 8/3/96 2030 Operators: M. Place & M. Graves

Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
8/4/96 1340	17.17 hrs	1.4	715
8/4/96 2030	6.83/24 total	1.9	446
8/5/96 1204	15.43/39.43 total	3.4	513
8/5/96 2201	9.93/49.36 total	1.8	271
8/6/96 0724	7.38/56.74 total	1.9	227

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

Site: K.I. Sawyer AFB K 30S   Test Type: Skimmer/Bioslurper

Start Date: 8/6/96 0945   Operators: M. Place & M. Graves

	Date/Time	Run Time	LNAPL Recovery (volume collected in time period)	Groundwater Recovery (volume collected in time period)
skimmer	8/6/96 1730	8.25hrs	0.9 gallons	14 gallons
bio slurper	8/6/96 1755		begin bioslurping	
	8/7/96 0745	12.83hrs	4.4	460
	8/7/96 1540	7.92/20.75 total	5	223
	8/8/96 0715	15.83/36.58 total	4.5	88

APPENDIX E

SOIL GAS PERMEABILITY TEST RESULTS

BATTELLE	SOIL GAS SURVEY INFORMATION	DATE: 8/1/96
METERS (SERIAL NUMBERS): O_2 ______ CO_2 ______ TPH ______		SITE: KI SAWYER MP-A

POINT #	DEPTH (ft. & tenths) (e.g., 10.2')	READINGS O_2 (%)	CO_2 (%)	TPH (ppm)	PUMP PRESS (in Hg. Vac.)	Recorded by: M. Place & M. Graves Comments
MP-A	15'	19.5	0.8	58		8/1/96 0955 Initial Rd
"	25'	19.0	0.7	150		" " "
"	35'	18.0	0.7	53		" " "
"	45'	17.0	1.3	14		" " "
"	55'	16.0	1.5	430		" " "
"	65'	6.0	7.0	10,000+ (1:1)		" " "
"	15'	19.1	0.8	120		8/1/96 1820
"	25'	19.8	0.7	200		" "
"	35'	17.9	0.7	210		" "
"	45'	16.9	1.1	230		" "
"	55'	16.8	1.2	1800		" "
"	65'	6.9	5.2	8200 (1:1)		" "
"	15'	19.0	0.8	38		8/2/96 0930
"	25'	19.0	0.8	62		" "
"	35'	19.0	0.8	48		" "
"	45'	17.0	1.0	36		" "
"	55'	17.5	1.2	400		" "
"	65'	8.0	6.0	11,200		" "

BATTELLE		SOIL GAS SURVEY INFORMATION			DATE:	
METERS (SERIAL NUMBERS): O_2 ______ CO_2 ______ TPH ______					SITE: KI SAWYER MP-A cont.	
POINT #	DEPTH (ft. & tenths) (e.g., 10.2')	READINGS			PUMP PRESS (in Hg. Vac.)	Recorded by:
		O_2 (%)	CO_2 (%)	TPH (ppm)		Comments
MP-A	15'	19.2	0.8	43		8/2/96 1755
"	25'	19.7	0.7	30		" "
"	35'	17.9	0.7	27		" "
"	45'	16.6	1.0	35		" "
"	55'	16.5	1.1	3200		" "
"	65'	5.2	5.9	3000(1:1)		" "
"	15'	19.3	0.8	70		8/3/96 1030
"	25'	18.9	0.8	78		" "
"	35'	17.9	0.7	52		" "
"	45'	17.0	1.3	70		" "
"	55'	16.5	1.6	260		" "
"	65'	12.1	4.2	4800		" "

	BATTELLE		SOIL GAS SURVEY INFORMATION			DATE: 8/1/96	
	METERS (SERIAL NUMBERS): O_2 ______ CO_2 ______ TPH ______					SITE: MPB	

Recorded by: M. Place & M. Graves

	POINT #	DEPTH (ft. & tenths) (e.g., 10.2′)	READINGS O_2 (%)	READINGS CO_2 (%)	READINGS TPH (ppm)	PUMP PRESS (in Hg. Vac.)	Comments
8/1/96 0955	MP-B	15 ft	18.5	1.0	58		Initial Reading
"	MP-B	25 Ft	18.0	0.8	44		" "
"	MP-B	35 ft	18.0	0.8	36		" "
"	MP-B	45 ft	17.0	1.2	80		" "
"	MP-B	55 ft	17.0	1.5	180		" "
"	MP-B	65 ft	3.0	7.0	8250(1:1)		" "
/1/96 1820							
"	MP-B	15 ft	19.0	0.7	59		
"	MP-B	25 ft	18.2	0.7	52		
"	MP-B	35 ft	17.5	0.6	40		
"	MP-B	45 ft	16.5	0.9	94		
"	MP-B	55 ft	16.2	1.2	98		
"	MP-B	65 ft	4.0	1.2	5400(1:1)		
8/2/96 0930	MP-B	15 ft	19.5	1.0	40		
"	MP-B	25 ft	18.0	1.0	38		
"	MP-B	35 ft	18.0	0.8	22		
"	MP-B	45 ft	17.0	1.5	39		
"	MP-B	55 Ft	17.0	1.5	52		
"	MP-B	65 ft	4.0	5.0	10,800		

BATTELLE	SOIL GAS SURVEY INFORMATION				DATE: 8/2/96	
METERS (SERIAL NUMBERS): O_2 ______ CO_2 ______ TPH ______					SITE: KI SAWYER MP-B	
POINT #	DEPTH (ft. & tenths) (e.g., 10.2')	READINGS			PUMP PRESS (in Hg. Vac.)	Recorded by: M. Place & M. Graves
		O_2 (%)	CO_2 (%)	TPH (ppm)		Comments
MPB	15'	20.1	0.7	8		8/2/96 1755
"	25'	18.4	0.6	27		" "
"	35'	17.8	0.6	12		" "
"	45'	16.7	1.1	31		" "
"	55'	16.0	1.2	32		" "
"	65'	5.0	4.9	1200(1:1)		" "
"	15'	19.0	0.75	20		8/3/96 1030
"	25'	18.5	0.5	45		" "
"	35'	20.8	0	25		" "
"	45'	20.8	0	44		" "
"	55'	8.5	2.0	30(1:1)		" "
"	65'	17.0	2.5	1800		" "

	BATTELLE		SOIL GAS SURVEY INFORMATION			DATE: 8/1/96	
	METERS (SERIAL NUMBERS): O_2 ____ CO_2 ____ TPH ____					SITE: MP-C	
	POINT #	DEPTH (ft. & tenths) (e.g., 10.2′)	READINGS O_2 (%)	CO_2 (%)	TPH (ppm)	PUMP PRESS (in Hg. Vac.)	Recorded by: M. Pldle & M. Graves Comments
8/1/96 0955	MP-C	15 ft	18.0	0.8	60		Initial Reading
"	MP-C	25 ft	18.0	0.8	70		" "
"	MP-C	35 ft	18.0	0.8	112		" "
"	MP-C	45 ft	16.0	2.0	215		" "
"	MP-C	65 ft	16.0	2.5	8200 (1:1)		" "
8/1/96 1820							
"	MP-C	15 ft	19.2	0.7	46		
"	MP-C	25 ft	18.2	0.7	54		
"	MP-C	35 ft	17.9	0.7	94		
"	MP-C	45 ft	16.5	1.4	190		
"	MP-C	65 ft	10.0	3.0	2400 (1:1)		
~~"~~	~~MP-C~~ MJG						
8/2/96 0930	MP-C	15 ft	19.5	1.0	19		
"	MP-C	25 ft	19.5	0.5	20		
"	MP-C	35 ft	18.0	0.8	28		
"	MP-C	45 ft	16.5	2.0	54		
"	MP-C	65 ft	20.0	1.0	320		

BATTELLE		SOIL GAS SURVEY INFORMATION			DATE:	
METERS (SERIAL NUMBERS): O_2 ____ CO_2 ____ TPH ____					SITE: KI SAWYER MPC cont	
POINT #	DEPTH (ft. & tenths) (e.g., 10.2')	READINGS			PUMP PRESS (in Hg. Vac.)	Recorded by: M. Place & M. Graves
		O_2 (%)	CO_2 (%)	TPH (ppm)		Comments
MP-C	15'	19.0	0.7	22		8/2/96 1755
"	25'	18.2	0.7	22		" "
"	35'	17.9	0.6	25		" "
"	45'	16.0	1.4	54		" "
"	65'	20.0	6.7	580		" "
"	15'	19.3	0.8	30		8/3/96 1030
"	25'	18.5	0.9	32		" "
"	35'	18.0	0.7	28		" "
"	45'	16.5	1.6	58		" "
"	65'	19.0	0.6	140		" "

APPENDIX F

IN SITU RESPIRATION TEST RESULTS

Record Sheet for In Situ Respiration Test

Site	Monitoring Point MP-B 65'	
Shutdown Date	O_2/CO_2 Meter No.	TPH Meter No.
Shutdown Time	Recorded by M. Place & M. Graves	

Date	Time	O_2 (%)	CO_2 (%)	TPH (ppm)	He (%)	Temperature (°C)	Comments
8/4/96	1340	21.0	0	0	2.7		Initial Conc.
8/4/96	1456	21.0	0	0	1.5		
8/4/96	1646	20.5	0	0	1.6		
8/4/96	2030	20.5	0	20	1.6		
8/4/96	0340	20.5	0	16	1.6		
8/5/96	1225	20.0	0.2	44	1.5		
8/5/96	2140	20.0	0.2	240	1.3		
8/6/96	0724	19.75	0.2	200	1.3		

Record Sheet for In Situ Respiration Test

Site	Monitoring Point MP-C 65'
Shutdown Date	O_2/CO_2 Meter No. — TPH Meter No.
Shutdown Time	Recorded by M. Place & M. Graves

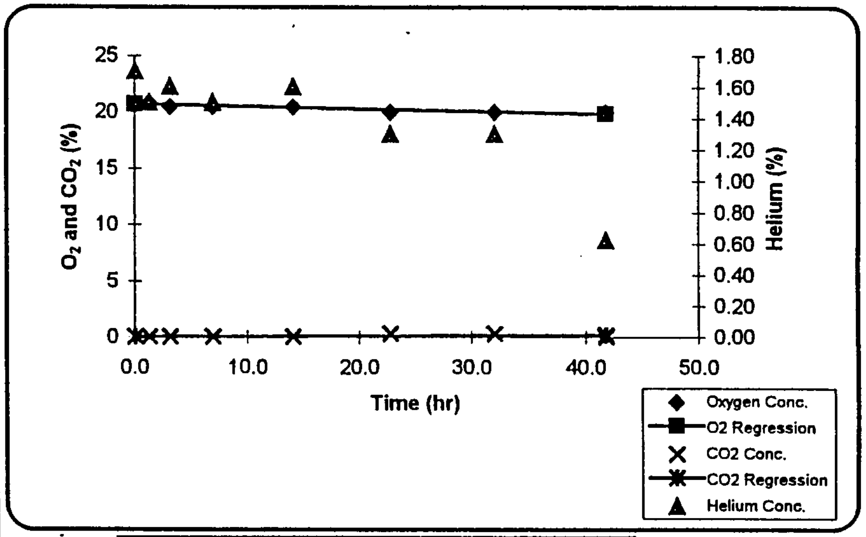
Date	Time	O_2 (%)	CO_2 (%)	TPH (ppm)	He (%)	Temperature (°C)	Comments
8/4/96	1340	21.0	0	0	1.9		
8/4/96	1456	21.0	0	0	1.2		
8/4/96	1646	20.5	0	30	1.3		
8/4/96	2030	20.5	0	200	1.3		
8/4/96	0340	20.5	0	240	1.3		
8/5/96	1225	19.75	0.3	1400	1.1		
8/5/96	2140	20.0	0.2	1180	0.96		
8/6/96	0724	19.75	0.2	280	0.65		

In Situ Respiration Test

Date: 8/4/96 **Site Name:** KI Sawyer AFB, MI

Monitoring Point: MP-A **Depth of M.P. (ft):** 65'

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)	Helium (%)
8/4/96 13:40	0.0	20.80	0.00	1.70
8/4/96 14:56	1.3	20.80	0.00	1.50
8/4/96 16:46	3.1	20.50	0.00	1.60
8/4/96 20:30	6.8	20.50	0.00	1.50
8/5/96 3:40	14.0	20.50	0.00	1.60
8/5/96 12:25	22.7	20.00	0.30	1.30
8/5/96 21:40	32.0	20.00	0.30	1.30
8/6/96 7:24	41.7	20.00	0.00	0.62



O_2 Utilization Rate

Ko	0.000	%/min
	0.020	%/hr
	0.486	%/day

Regression Lines	O_2	CO_2
Slope	-0.0203	0.0043
Intercept	20.6957	0.0092
Determination Coef.	0.8356	0.2340
No. of Data Points.	8	8

In Situ Respiration Test

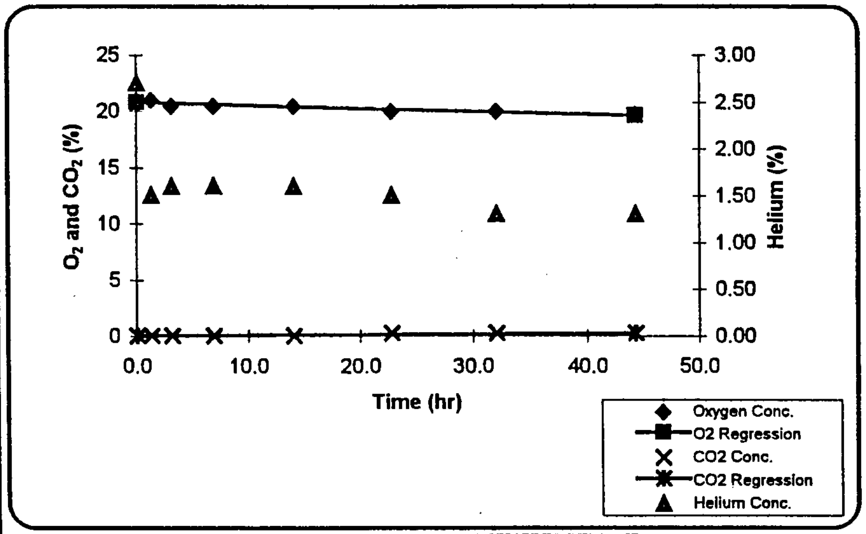
Date: 8/4/96

Site Name: KI Sawyer AFB, MI

Monitoring Point: MP-B

Depth of M.P. (ft): 65'

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)	Helium (%)
8/4/96 13:40	0.0	21.00	0.00	2.70
8/4/96 14:56	1.3	21.00	0.00	1.50
8/4/96 16:46	3.1	20.50	0.00	1.60
8/4/96 20:30	6.8	20.50	0.00	1.60
8/5/96 3:40	14.0	20.50	0.00	1.60
8/5/96 12:25	22.7	20.00	0.20	1.50
8/5/96 21:40	32.0	20.00	0.20	1.30
8/6/96 9:55	44.3	19.75	0.20	1.30



O_2 Utilization Rate

Ko	0.000	%/min
	0.026	%/hr
	0.635	%/day

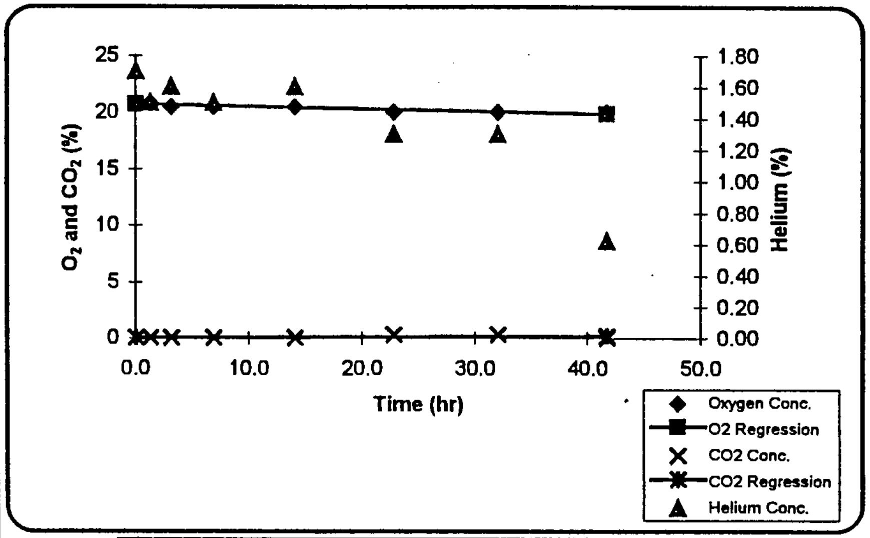
Regression Lines	O_2	CO_2
Slope	-0.0265	0.0057
Intercept	20.8169	-0.0142
Determination Coef.	0.8560	0.8030
No. of Data Points.	8	8

In Situ Respiration Test

Date: 8/4/96 **Site Name:** KI Sawyer AFB, MI

Monitoring Point: MP-C **Depth of M.P. (ft):** 65'

Date/Time (mm/dd/yr hr:min)	Time (hr)	Oxygen (%)	Carbon Dioxide (%)	Helium (%)
8/4/96 13:40	0.0	21.00	0.00	1.90
8/4/96 14:56	1.3	21.00	0.00	1.20
8/4/96 16:46	3.1	20.50	0.00	1.30
8/4/96 20:30	6.8	20.50	0.00	1.30
8/5/96 3:40	14.0	20.50	0.00	1.30
8/5/96 12:25	22.7	19.75	0.30	1.10
8/5/96 21:40	32.0	20.00	0.20	0.96
8/6/96 7:24	41.7	19.75	0.20	0.65



O_2 Utilization Rate

Ko	0.000	%/min
	0.029	%/hr
	0.691	%/day

Regression Lines	O_2	CO_2
Slope	-0.0288	0.0065
Intercept	20.8126	-0.0110
Determination Coef.	0.7977	0.6508
No. of Data Points.	8	8

* Stack CO_2, O_2 ✓
* Depth of soil samples = MPB 60 - 62' bgs
* Composition of LNAPL (mg/kg?); Include Trimethyl Benzenes
  Comparison to fresh product

* Stack gas emission during skimming vs bioslurping vs. draw down ✓

* Well construction details

* Was [illegible] being drawn [illegible] Yes; Drawdown [illegible]
  [illegible]

  [illegible] 1700
  [illegible] 1955

  [illegible]

* What was [illegible] during drawdown [illegible]

* Volume of LNAPL removed & comparison to void volume