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CONCEPTUAL DESIGN APPROACH FOR BIOVENTING FOR THE SLUDGE DRYING BED AREA NS MAYPORT

9/20/1996

BATTELLE

CONCEPTUAL DESIGN APPROACH FOR BIOVENTING FOR THE SLUDGE DRYING BED AREA AT NAVAL STATION MAYPORT, FLORIDA

ADDENDUM TO THE CONCEPTUAL BIOSLURPING DESIGN REPORT

Prepared by

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September 20, 1996

CONTENTS

FIGURES

TABLES

ACRONYMS AND ABBREVIATIONS

bgs	below ground surface
BTEX	benzene, toluene, ethylbenzene, and xylenes
F.A.C.	Florida Administrative Code
FDEP	Florida Department of Environmental Protection
I.D.	inside diameter
JP	jet propulsion (fuel)
MP	monitoring point
MPT	male pipe thread
MW	monitoring well
NAVSTA	Naval Station
O&M	operations and maintenance
OVA	organic vapor analyzer
PVC	polyvinyl chloride
S/S	stainless steel
SWMU	solid waste management unit
TPH	total petroleum hydrocarbons
U.S. EPA	United States Environmental Protection Agency
VW	vent well

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September 20, 1996

Section 1.0 INTRODUCTION

1.1 Scope. This addendum to the Full-Scale Conceptual Design of the Bioslurper System for SWMU7 at Naval Station Mayport, Florida (Battelle, 1996 [draft main report]) describes a conceptual approach for implementing a full-scale bioventing system inside the Sludge Drying Bed area, Solid Waste Management Unit 7 (SWMU7) at Naval Station (NAVSTA) Mayport. It is recommended that a pilot-scale test be performed prior to installing the full-scale system. This design is conservative; associated installation and operation costs should be used solely for budgeting purposes. Information from pilot testing will allow the design to be optimized to reduce both installation and operations costs.

1.2 Overview of Bioventing Technology. Bioventing is the process of aerating subsurface soils to stimulate soil-indigenous microorganisms to aerobically metabolize fuel hydrocarbons in unsaturated soils. Application of bioventing has been tested extensively by Battelle at a number of sites contaminated with fuel hydrocarbons. Bioventing is similar in design to soil venting (a.k.a. soil vacuum extraction, soil-gas extraction, or in situ soil stripping). The significant difference is that soil venting is designed and operated to maximize volatilization of low-molecular-weight compounds. Some biodegradation occurs in most soil venting remediation. In contrast, bioventing attempts to maximize biodegradation of aerobically biodegradable compounds, regardless of molecular weight. The significant difference is that the objective of soil venting is to volatilize compounds, and the main objective of bioventing is to enhance biodegradation. Although these technologies both involve venting air through the vadose zone, the differences in objectives result in significantly different designs and operation of the remedial systems.

Petroleum distillate fuel hydrocarbons such as JP-5 and JP-8 jet fuel generally are biodegradable if naturally occurring microorganisms are provided an adequate supply of oxygen and basic nutrients (Atlas, 1981). Natural biodegradation does occur at many sites and eventually may mineralize most fuel contamination. However, the process is dependent on the natural oxygen diffusion rate at the site (Ostendorf and Kampbell, 1989), which frequently is too slow to support effective biodegradation. At such sites, acceleration of the oxygen transport process via (bio)venting may prove to be the most effective way to enhance bioremediation and remediate the site.

The significant features of bioventing technology include the following:

- Optimizing air flow to minimize volatilization while maintaining aerobic conditions for biodegradation
- Monitoring local soil-gas conditions to ensure that aerobic conditions exist (not just monitoring vent gas composition)

- Conducting in situ respiration tests that provide for the effective measurement of continued contaminant biodegradation

- Manipulating the water table as required for air/contaminant contact.

1.3 **Site Description.** The site description is provided in Section 2 of the Full-Scale Conceptual Design of the Bioslurper System for SWMU7 at Naval Station Mayport, Florida (Battelle, 1996 [draft main report]).

1.4 **Report Organization.** Section 2 of this report describes the limited characterization activities in the Sludge Drying Bed that Battelle performed during the bioslurping pilot test at SWMU7. Section 3 recommends that a pilot test be implemented and briefly describes the associated tasks. A full-scale conceptual design is presented in Section 4; Section 5 describes the costs associated with both pilot-scale and full-scale implementation.

Section 2.0 CHARACTERIZATION ACTIVITIES PERFORMED BY BATTELLE

2.1 Characterization Activities. Battelle installed two 2-inch-diameter monitoring piezometers in SWMU7 using a hollow-stem auger drill rig. These piezometers were labeled MW1 and MW2. MW1 was installed in the northern portion of the central drying bed and MW2 was installed in the northern portion of the easternmost drying bed (see Figure 1). Both wells were located within the delineated plume. Each piezometer was installed to a depth of 13 feet beneath ground surface (bgs) and was screened from 3 to 13 feet bgs. The piezometer completion drawings are included in Appendix A of this document.

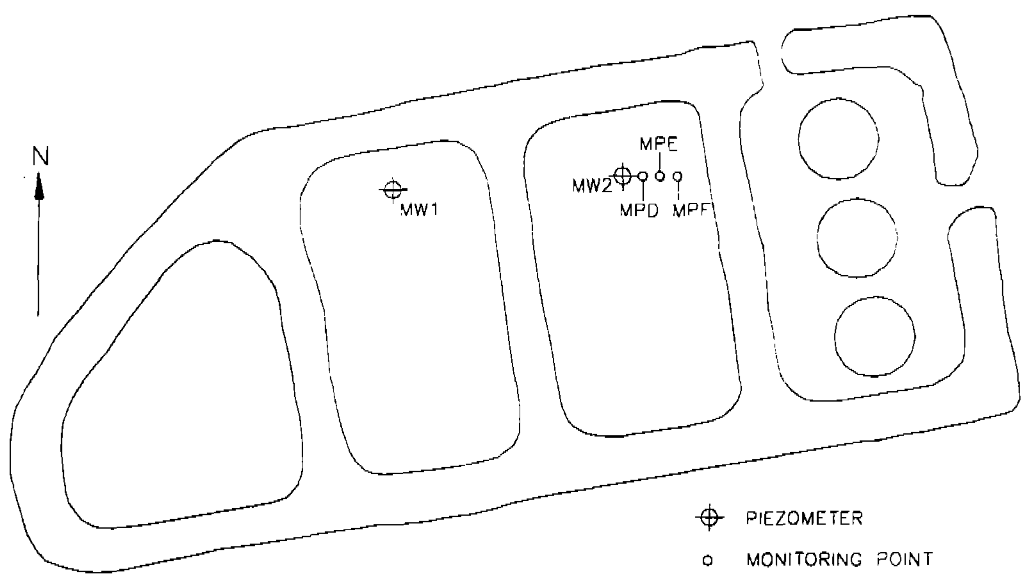

Figure 1. Existing Piezometer and Monitoring Point Locations

During the installation of the piezometers, a split spoon was used to collect soil samples at depths of about 1 to 9 feet bgs. The soil samples were dark gray in color and had a petroleum odor. A headspace analysis was performed on the soil samples in accordance with the method specified in the Florida Department of Environmental Protection (FDEP) "Guidelines for Assessment of Remediation of Petroleum Contaminated Soil" (FDEP, 1994). The method requires each sample to be placed in a 16-oz jar and to be half-filled with the sample and covered with foil. Within 5 minutes of obtaining the sample or bringing the soil sample to a temperature between 20°C and 30°C, the gas in the headspace above the soil is analyzed using an organic vapor analyzer (OVA). The samples were analyzed both with and without a charcoal filter that is designed to adsorb organic vapors other than methane. The reading due to petroleum volatile organic vapors is obtained by subtracting the filtered reading from the unfiltered reading. The results are presented in Table 1.

In addition to installing the piezometers, three soil-gas monitoring points were installed using a 3-inch-diameter bucket auger. The monitoring points, designated as MPD, MPE, and MPF, were placed 10, 20, and 30 feet east of MW2, respectively. Each monitoring point contains one

Table 1. Headspace Analysis Results

Sample Location	Sample Depth (ft bgs)	Hydrocarbon Concentration (ppm)
MW1	0-2	105
	2-4	140
	4-6	80
MW2	0-1	0
	1-2	4
	2-3	120
	3-4	95
	4-5	580

1-inch-diameter by 6-inch-long suction filter screen filled with gravel and was placed about 3 feet bgs. Nylon tubing was connected to each filter screen. The tubing was extended to the surface and attached to a quick-connect coupler. The monitoring point was packed with a 12-inch-thick sand pack. The interval between the sand pack and the surface was sealed with bentonite.

MW1 and MW2 were monitored over a 1-week period. During this time, free product was not observed in either piezometer. Groundwater elevation measurements ranged from 5.3 to 5.5 feet bgs in MW1 and from 4.5 to 4.8 feet bgs in MW2. Groundwater samples removed from the well had a yellow tint. There was no hydrocarbon odor associated with these samples.

Soil gas was analyzed for oxygen, carbon dioxide, and total petroleum hydrocarbon (TPH) concentrations in the previously installed soil-gas monitoring points. The results are presented in Table 2. The decrease in oxygen concentrations and increase in carbon dioxide concentrations with time indicate the potential aerobic microbial biodegradation activity at these locations.

2.2 Recommendations. Based on the limited characterization results, it appears that free product may not be present in the Sludge Drying Bed. It may be necessary to perform additional

Table 2. Soil-Gas Analysis at SWMU7

Monitoring Point	Parameter	Date				
		7/18/96	7/19/96	7/19/96	7/21/96	7/23/96
MPD	Oxygen (%)	18	18	20	5	11
	Carbon Dioxide (%)	1.5	3.5	1	11	6.5
	TPH (ppm)	160	300	230	800	200
MPE	Oxygen (%)	17	18.5	19	6	2
	Carbon Dioxide (%)	2.5	3	1.8	10	13
	TPH (ppm)	200	280	180	2000	1000
MPF	Oxygen (%)	17	20	18	8	0.5
	Carbon Dioxide (%)	2.5	1.5	2.8	8.5	14
	TPH (ppm)	380	200	320	940	2000

characterization to confirm that there is no free product in the Sludge Drying Bed area. If additional characterization confirms that there is no free product, it is not necessary to implement a free-product recovery technology inside the drying bed. However, the headspace analysis indicates that some form of treatment may be required to remediate the petroleum-contaminated vadose zone soils inside the bed. Further characterization is required to establish baseline conditions and to identify the areas that need further treatment.

The FDEP considers soil to be "excessively contaminated" if soil headspace analyses (for diesel and similar less volatile fuels) indicate concentrations of total organic vapor (excluding methane) greater than 50 ppm according to Rule 17-770-200(2) in the Florida Administrative Code (F.A.C.). If this rule is applicable to the Sludge Drying Bed, a bioventing system can be designed and implemented for areas with high contamination to reduce the total organic vapor levels in soil gas to below 50 ppm. Bioventing is a relatively low-cost in situ technology that has been proven to be effective at remediating petroleum-contaminated sites. However, additional information should be gathered prior to designing and installing a full-scale bioventing system. For example, the soil-gas radius of influence and biodegradation rates should be determined for an optimal design. Although the radius of influence and biodegradation rates were determined for soils located beyond the Sludge Drying Bed during pilot-scale bioslurper testing, these values cannot be used to accurately design a bioventing system inside the drying bed. For example, the fact that the groundwater table elevation is significantly higher in the Sludge Drying Bed area potentially could affect the radius of influence. Differing fill material in the drying bed and in the soil beyond the drying bed would be another factor affecting the design. It is recommended that these important design parameters be determined prior to designing and installing the full-scale system.

Section 3.0 PILOT-SCALE IMPLEMENTATION

To design a full-scale bioventing system, it is extremely important to conduct a pilot-scale study. The parameters addressed in the pilot-scale study are important in determining well spacing, cleanup time estimates, blower sizing, and optional parameters such as airflow injection rates.

3.1 **Soil and Soil-Gas Characterization.** It appears from the initial site characterization that bioventing is a feasible method for remediation of the Sludge Drying Bed area. However, the Sludge Drying Bed area needs to be further characterized to determine what portion of the vadose zone is oxygen-limited and to determine the locations of the most contaminated areas. This typically is accomplished by a soil-gas survey, which can be performed with a GeoProbe™. The GeoProbe™ is a quick and relatively inexpensive hydraulic probing machine that is well suited for soil-gas surveys. A hand-held electric hammer also can be used to perform the soil-gas survey.

3.2 **Well Installations.** A typical pilot-scale installation consists of one vent well (VW) and three soil-gas monitoring points (MPs) that are located based on the data obtained in the soil gas survey. The monitoring points should be constructed in the same way as MPD, MPE, and MPF described in Section 2.0. In fact, these three monitoring points could be used for the pilot-scale test assuming that a vent well is located approximately 10 feet east of MPF. A typical monitoring point construction diagram is presented in Figure 2.

3.3 **In Situ Respiration Testing.** Although in situ respiration tests have been performed during bioslurping tests outside of the Sludge Drying Bed area, it is still necessary to conduct respiration tests inside the area due to geologic differences. The data collected during the in situ respiration test is used to determine an oxygen utilization rate and subsequent biodegradation rate.

3.4 **Radius of Influence and Soil Gas Permeability.** The radius of influence test is performed to determine the lateral distance air can be moved physically. In practice, the radius of influence is estimated by measuring a pressure radius of influence. The pressure radius of influence is the maximum distance from a vent well where pressure change can be measured. Usually, 0.1 inch of water is the cutoff pressure. Past experience indicates that when design procedures are followed, the radius of influence is larger than the measured pressure radius of influence, making the pressure radius of influence a reasonably conservative, rapid method for estimating the true radius of influence.

In general, the soil permeability must be sufficiently high to allow movement of oxygen from the vent well in a reasonable time frame (1 to 10 days). If such a flowrate cannot be achieved, oxygen cannot be supplied at a rate to match its demand. If either the soil-gas permeability or the radius of influence is high ($>$ 0.01 darcy or radius of influence greater than the screened interval of the vent well), this is a good indicator that bioventing is feasible at the site and that it is appropriate to proceed to full-scale design. If either the soil gas permeability or radius of influence is low (permeability $<$0.01 darcy or a radius of influence less than the screened interval of the vent well), bioventing may not be feasible. In this situation, it is necessary to evaluate the cost effectiveness of bioventing over other alternative technologies for site remediation. The cost of installing a bioventing system at a low-permeability site will be driven primarily by the need to install more vent wells, use a blower with a higher delivery pressure, or install horizontal wells.

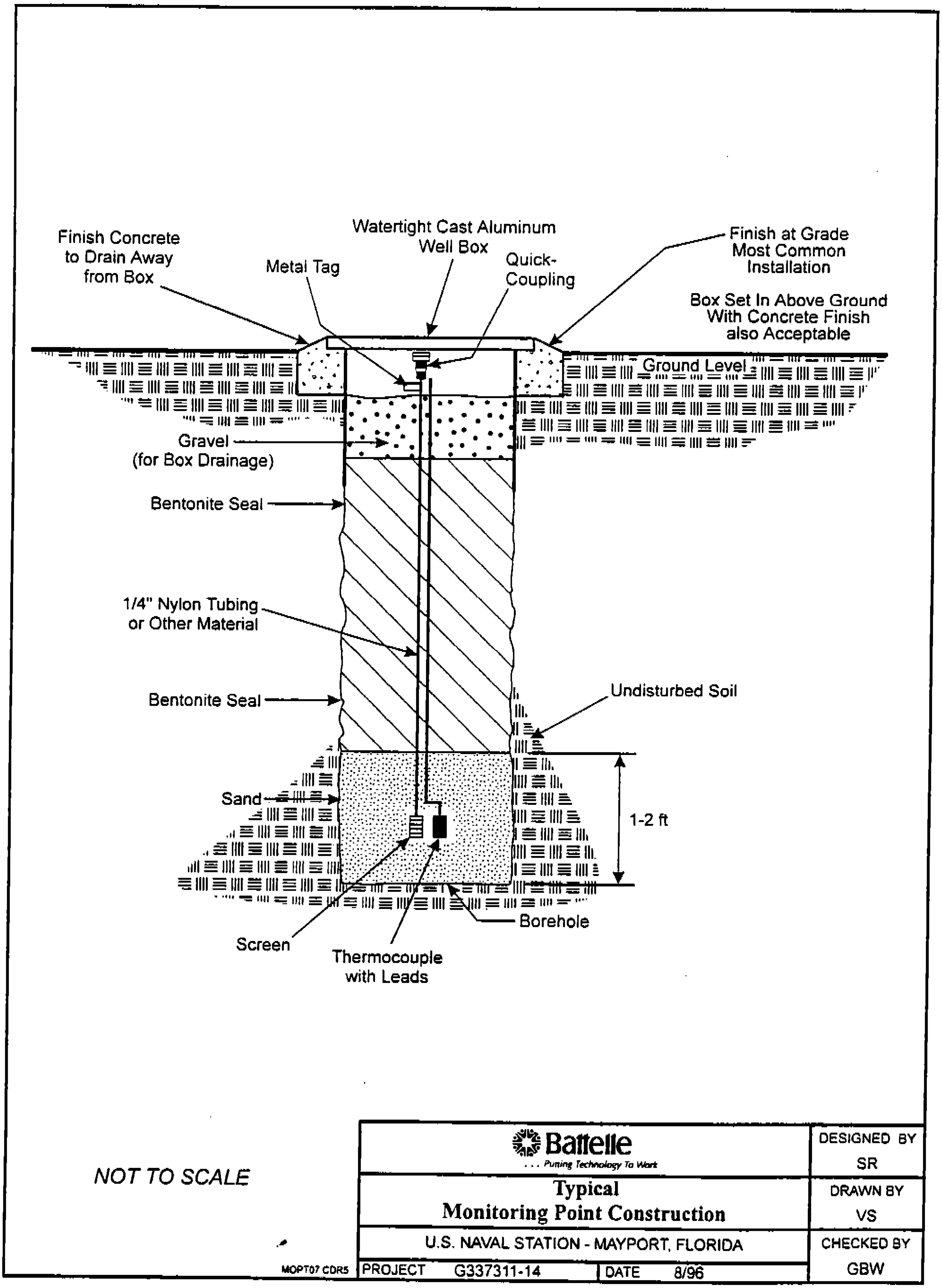

Figure 2. Typical Monitoring Point Construction

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3.5 **Surface Emissions Monitoring.** Surface emissions typically do not occur or are very low at bioventing sites due to low air flowrates. However, surface emissions often are a regulatory concern and surface emission rates may need to be quantified to obtain regulatory approval for bioventing.

Section 4.0 FULL-SCALE CONCEPTUAL DESIGN

In order to develop cost estimates for the Sludge Drying Bed area (SWMU7) at NAVSTA Mayport, a full-scale conceptual design needs to be developed. It is important to note that the design is not based on site-specific data generated from pilot tests. This section presents the assumptions and preliminary calculations associated with the full-scale conceptual design.

4.1 Air Flow System. It is assumed that the bioventing system will operate in air injection mode due to the absence of nearby structures and the cost benefits resulting from not treating the off-gas. Thus, for design purposes, the air injection flowrate needs to be calculated. The flowrate required to operate the bioventing system is dependent on the oxygen demand of the indigenous microorganisms. Oxygen demand is determined from maximum oxygen utilization rates measured during an in situ respiration test. Equation (1) is used to estimate the required air flowrate:

$$Q = \frac{k_o V \theta_a}{(20.9\% - 5\%) \times 60 \frac{\text{min}}{\text{hr}}} \tag{1}$$

where:
Q = flowrate (ft^3/min)
k_o = oxygen utilization rate (%/hr)
V = volume of contaminated soil (ft^3)
θ_a = gas-filled porosity (fraction)

Because the oxygen utilization rate, volume of contaminated soil, and gas-filled porosity have not yet been determined, the values will be approximated based on both past experience and what was learned about the site from the bioslurping pilot test. The oxygen utilization rates obtained during the bioslurping pilot test ranged from 0.170 to 0.215%/hr. A rate of 0.20%/hr was chosen as a reasonable approximation. The volume of contaminated soil was estimated by multiplying the entire Sludge Drying Bed surface area times the depth to the groundwater (approximately 4 feet). The gas-filled porosity was estimated at 0.25 based on previous experience. Finally, based on these assumptions and Equation (1), the required flowrate, Q, was calculated to be 19. Table 3 summarizes the assumptions and resulting flowrate.

Table 3. Estimated Values for Determining Flowrate

Parameter	Value
k_o = oxygen utilization rate (%/hr)	0.20
V = volume of contaminated soil (ft^3)	370,000
θ_a = gas-filled porosity (fraction)	0.25
Q = flowrate (ft^3/min)	19

4.2 Well Placement. To determine the required number of wells and their appropriate spacing, an estimate of the radius of influence is necessary. Because the radius of influence cannot be known until the pilot test has been performed, it is difficult to determine the well spacing. However, during the bioslurping pilot test performed outside the Sludge Drying Bed area, a radius of influence of 30 feet was achieved at an extraction pressure of 20 inches of H_2O. The radius of influence in the Sludge Drying Bed area probably will be less than that observed in the bioslurping pilot test due to the shallow depth to groundwater. Also, based on the lithology data collected during the installation of piezometers MW1 and MW2, air channel formation is possible which would further limit the radius of influence. These concerns can be addressed by placing impermeable plastic liners on the ground surrounding the vent wells, forcing the radius of influence to increase. For conceptual design purposes, it will be assumed that the Sludge Drying Bed area has a radius of influence of 25 feet.

An overlapping layout for locating vent wells is proposed so that nearly all of the contaminated areas are within the radius of influence of at least one vent well. Figure 3 presents the conceptual vent well layout. The circles surrounding each vent well in Figure 3 represent the estimated 25-foot radius of influence.

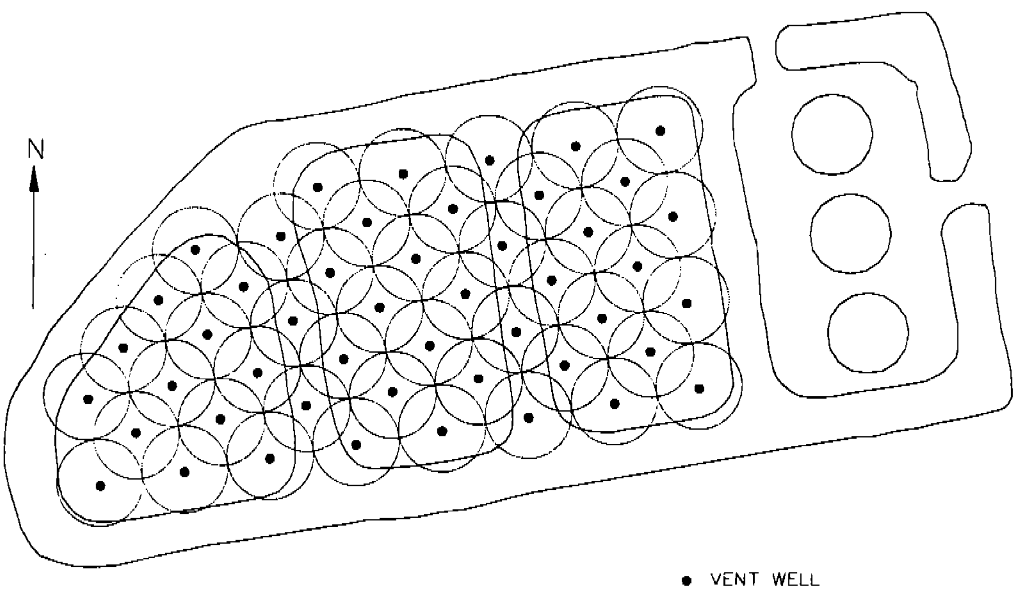

Figure 3. Conceptual Vent Well Layout

4.3 Well Installations. Based on the assumed 25-foot radius of influence and the contaminated area of 2.11 acres, approximately 47 more vent wells would need to be installed, assuming the pilot test vent wells could be used. To effectively monitor these vent wells, at least 13 strategically placed soil-gas monitoring points with one sampling section would need to be installed. Figure 4 presents a conceptual drawing of how the vent wells and monitoring points would be placed.

4.4 Equipment. The major pieces of equipment and materials that will be necessary for full-scale implementation of bioventing at the Sludge Drying Bed area (SWMU7) are listed below:

- 16 soil gas monitoring points.
- 48 vent wells.
- GasTech 3250X CO_2/O_2 detector (or similar detector).
- GasTech GT105 TPH detector (or similar detector).

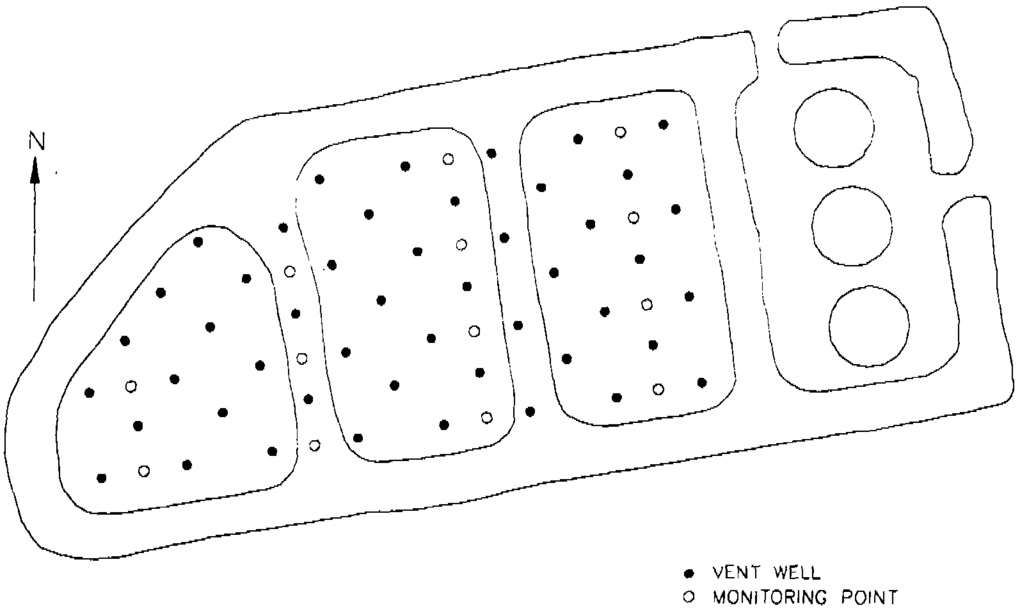

Figure 4. Vent Well and Monitoring Point Layout

- Two 2.0-HP regenerative blowers manufactured by Gast (or equivalent).
- Approximately 1,850 feet schedule 40 polyvinyl chloride (PVC) piping.
- Schedule 40 PVC valves, elbows, etc.
- Helium source for tracer test.
- Type J thermocouples.
- Mark Products, Inc. Model 9821 helium detector (or similar detector).
- Decontamination (deionized) water and Alconox™ (or equivalent) detergent.
- Safety equipment.

4.5 Blowers and Piping. Using the air injection flowrate calculated in Section 4.2 and the number of vent wells stated in Section 4.4, the assumption was made that two 2.0-hp regenerative blowers could effectively vent the area. Gast manufactures a single-phase 2.0-hp regenerative blower that can deliver a maximum of 100 cfm of air flow at 50 inches of H_2O. Therefore, the calculated airflow requirements for the site could be obtained within a reasonable range of the blower capacity. Under the current conceptual design, one blower would serve the easternmost 25 wells and one blower would serve the remaining 23 wells. The blowers would be equipped with relief valves that could bypass excess air. Appendix B presents the manufacturer's literature on the 2.0-hp Gast regenerative blower.

Because there is no vehicle traffic within the Sludge Drying Bed area, it is assumed the piping that connects the blowers to the vent wells can be placed above ground. The piping should be installed in such a way that if one blower needs to be serviced, the other blower could vent the entire site. Figure 5 shows the conceptual blower locations and piping layout design.

4.6 Operations and Monitoring. Bioventing systems are very simple, with minimal mechanical and electrical parts. If the system is operated in the injection mode, a simple visual system check to ensure that the blower is operating within its intended flowrate pressure and temperature range is

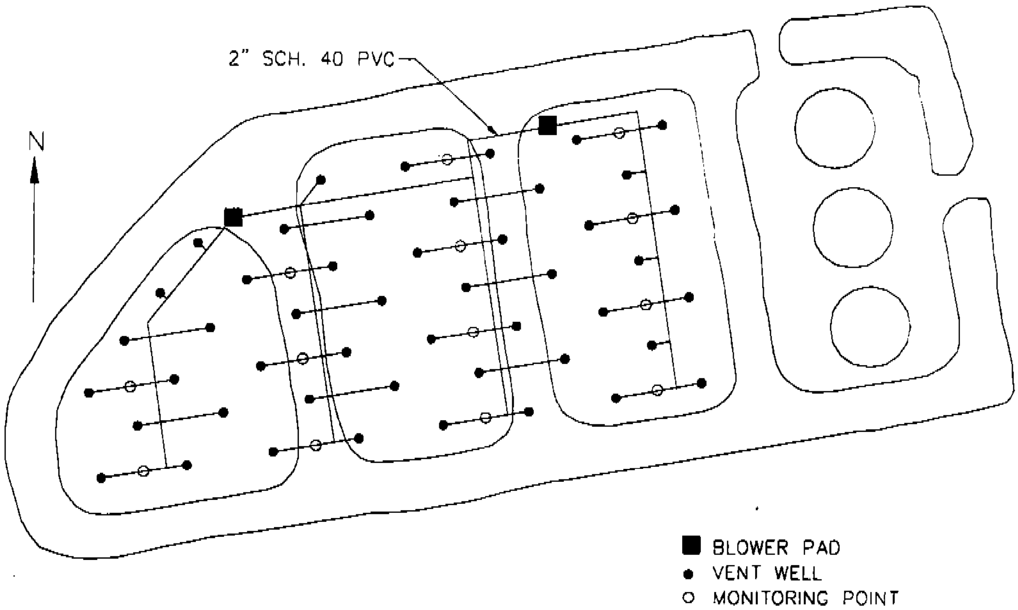

Figure 5. Conceptual Blower Locations and Piping Layout

required. Periodic soil gas monitoring should be conducted to ensure that the bioventing site is well-oxygenated. Also, surface emission levels need to be considered. Refer to Appendix C for bioventing system operation, monitoring, and maintenance guidelines.

4.7 **Closure Requirements.** Cleanup criteria at the site according to Florida State regulatory requirements mandate that soils contain less than 100 ppb of total volatile organic aromatics and that total recoverable petroleum hydrocarbon concentrations be below 10 ppm (FDEP, 1994). The site should have a final sampling event to demonstrate that the contaminant concentrations are below the regulatory levels.

Section 5.0 BIOVENTING COST ANALYSIS

The estimated cost for pilot testing, full-scale installation, and 3 years of operation and maintenance (O&M) have been determined based on the available site information and the proposed conceptual design. Pilot testing costs include labor and materials needed to install 1 vent well, 3 soil-gas monitoring points, and a blower as well as to perform a soil-gas survey. Pilot testing costs also include soil analysis, a helium tracer test, a soil-gas permeability test, and a soil-gas respiration test. Costs for the full-scale system include labor and materials needed to install 47 additional vent wells, 13 additional soil-gas monitoring points, an additional blower, and approximately 1,850 feet of 2-inch schedule 40 PVC piping. Annual O&M costs include materials and labor to conduct routine operation of the bioventing system and the power requirements needed to operate two 2.0-hp blowers. A contingency cost of 10% also is included to account for unforeseeable circumstances that may add to the total cost of the system. Estimated labor costs include general and administration charges, overhead, and fee charges. It is also assumed that the purchase of all meters, detectors, probes, and Magnehelic™ gauges is accounted for in the full-scale bioslurping design. Because each contracting company applies these charges to different categories of project costs at different rates, application of these costs should be computed according to contractor-specific methods.

Documentation preparation, site closure, and design costs are not included in this estimate. These costs will be determined by both Florida regulatory agency requirements and the contractor experience with designing and installing full-scale bioventing systems. Also, the cost estimate does not include travel or per diem expenses.

The cost to conduct the pilot-scale testing and a soil gas survey is estimated to be $41,000. Well installation, soil analysis, and testing activities account for $28,000 and the soil gas survey accounts for the remaining $13,000. The full-scale system estimated costs include $21,000 to install the vent wells, $12,000 to install the soil gas monitoring points, and $7,500 to install the blower and piping. The total annual O&M cost is estimated to be $9,000, which based on 3 years of operation and a 3.5% inflation rate, equates to $27,450. Additional fixed costs account for $2,000. Assuming a 10% contingency, the total project cost for installation and operation for 3 years is approximately $122,000. Appendix D presents detailed cost analysis sheets for the conceptual bioventing system.

Section 6.0 REFERENCES

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Ostendorf, D.W., and D.H. Kampbell. 1989. "Vertical Profiles and Near Surface Traps for Field Measurement of Volatile Pollution in the Subsurface Environment." In: *Proceedings of the NWWA Conference on New Techniques for Quantifying the Physical and Chemical Properties of Heterogeneous Aquifers*, Dallas, Texas. ISBN 389432-009-5. Westarp Wiss. Essen, Germany, pp. 475-485.

APPENDIX A

Piezometer Completion Diagrams

ATTACHMENT 2

PIEZOMETER AS BUILT DRAWING

CLIENT: Battelle

PROJECT: Mayport, FL

PIEZOMETER NO.: MW2

FILE NO.: 96-1080

DATE INSTALLED: 7/17/96

GROUND ELEVATION: UNKNOWN

PIEZOMETER TOP ELEV: UNKNOWN

PIEZOMETER LOCATION: APPROXIMATE CENTER OF NORTH HALF OF EAST SLUDGE DRYING POND

REMARKS: DRAWING NOT TO SCALE. WATER TABLE AT TIME OF DRILLING APPROX. 3.5'

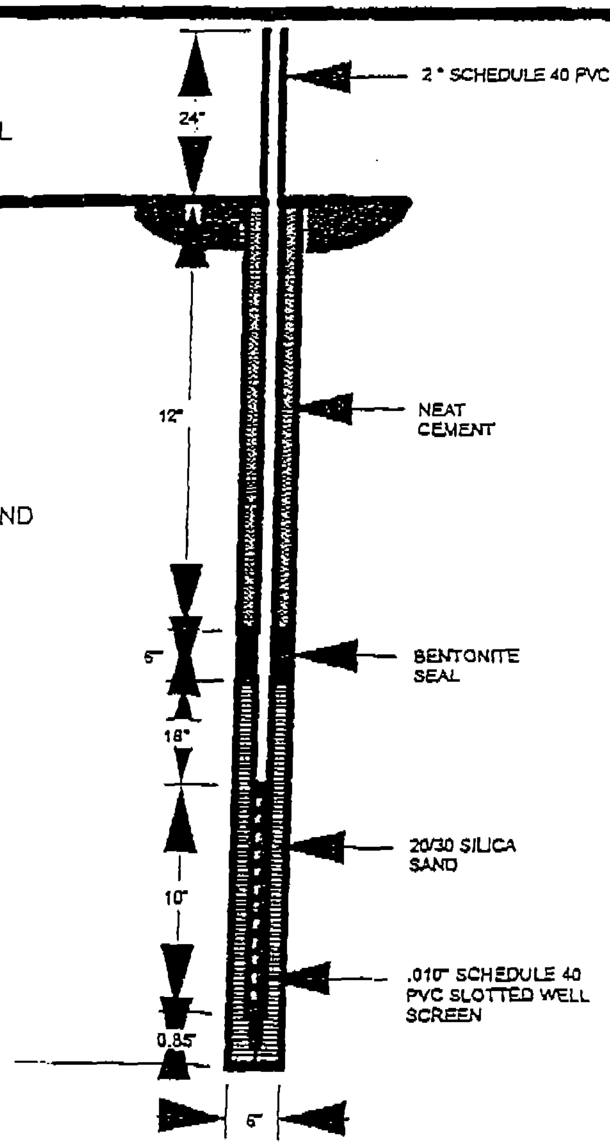
SOIL DESCRIPTION AND UNIFIED SOIL CLASSIFICATION

0 - 7" LIGHT BROWN FINE SAND WITH SHELL FRAGMENTS (SP)

7- 9" VERY DARK BROWN SILTY FINE SAND WITH ORGANICS (SM)

9" - 8' DARK GRAY (STAINED) FINE SAND WITH SHELL FRAGMENTS (SP)

8 - 13' LIGHT GRAY FINE SAND WITH SHELL FRAGMENTS (SP)



Geotechnical Professional Associates, Inc.

ATTACHMENT 2

PIEZOMETER AS BUILT DRAWING

CLIENT: Battelle

PROJECT: Mayport, FL

PIEZOMETER NO.: MW1

FILE NO.: 96-1080

DATE INSTALLED: 7/17/96

GROUND ELEVATION: UNKNOWN

PIEZOMETER TOP ELEV: UNKNOWN

PIEZOMETER LOCATION: NORTHWEST CORNER OF WEST SLUDGE DRYING POND

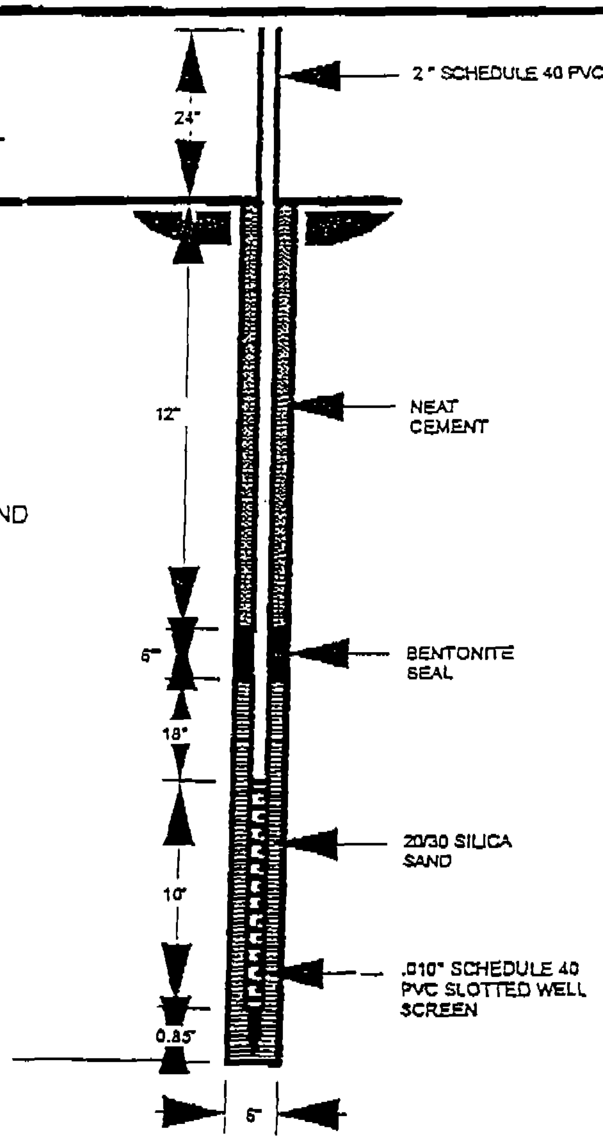
REMARKS: DRAWING NOT TO SCALE. WATER TABLE AT TIME OF DRILLING APPROX. 4.0'

SOIL DESCRIPTION AND UNIFIED SOIL CLASSIFICATION

0 - 4 " LIGHT BROWN FINE SAND WITH SHELL FRAGMENTS (SP)

4" - 9' DARK GRAY (STAINED) FINE SAND WITH SHELL FRAGMENTS (SP)

9 - 13' LIGHT BROWN FINE SAND WITH SHELL FRAGMENTS (SP)



Geotechnical Professional Associates, Inc.

APPENDIX B

Manufacturer's Documentation

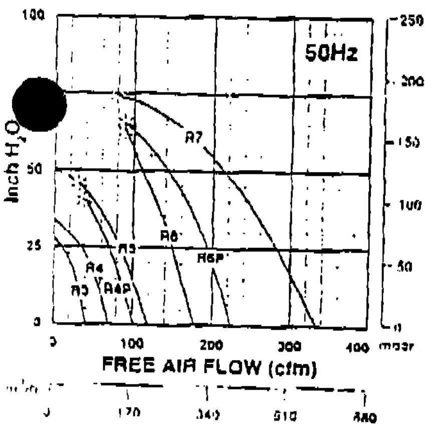
SOIL VAPOR EXTRACTION PUMPS - REGENERATIVE BLOWERS

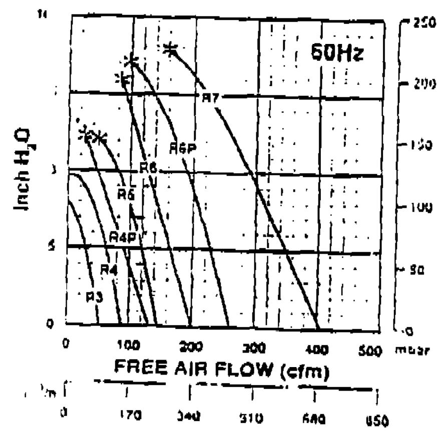
Product Specifications

Model Number	Phase	Hz	Motor Specification Voltages	HP	Full Load Amps	Max Vac "H_2O	Max Vac mbar	Max Pressure "H_2O	Max Pressure mbar	Max Flow cfm	Max Flow m^3h	Net. Wt. lbs	Net. Wt. kg
R3105N-50	Single	50	110/220-240	.33	3-8/1.9-2.0	28	70	31	77	43	73	52	24
		60	115/208-230	0.5	5.2/2.9-2.6	40	100	43	107	53	90		
R4110N-50	Single	50	110/220-240	0.6	9.2/5.2-4.6	35	87	38	95	74	126	60	28
		60	115/208-230	1.0	11.4/6.2-5.6	48	120	51	127	92	156		
R4310P-50	Three	50	220/380	0.6	3.2/1.6	35	87	38	95	74	126	68	27
		60	208-230/460	1.0	3.4-3.3/1.65	48	120	51	127	92	156		
R4P115N-50	Single	50	110/220-240	1.0	15.2/7.6-8	40	100	45	112	112	190	79	36
		60	115/208-230	1.5	18.2/9.7-9.1	60	149	65	162	133	226		
→ R5125Q-50	Single	60	115/230	2.0	25/12.5	60	149	55	137	160	272	77	35
R5325R-50	Three	50	190-220/380-415	1.5	5.0-4.4/2.5-2.6	47	117	50	125	133	226	75	34
		60	208-230/460	2.0	6.0-5.6/2.8	60	149	65	162	160	272		
R6130Q-50	Single	50	220-240	2.5	14.7-13.5	65	162	75	187	182	309	129	59
		60	230	3.0	16.3	70	174	60	149	215	365		
R6340R-50	Three	50	190-220/380-415	3.0	14.4-13.4/7.2-6.8	65	162	75	187	180	306	112	51
		60	208-230/460	4.0	13-12/6	80	199	100	249	215	365		
R6P155Q-50	Single	50	220-240	4.0	20.8-19.1	65	162	80	199	235	399	243	110
		60	230	5.5	29.9	85	212	95	237	280	476		
R6P355R-50	Three	50	190-220/380-415	4.5	14.9-11/7.45-5.8	65	162	80	199	232	394	233	105
		60	208-230/460	6.0	20-18/9	85	212	100	249	280	476		
R7100R-50	Three	50	190-220/380-415	8.0	20.8-18.9/10.4-9.5	72	179	80	199	350	595	297	134
		60	208-230/460	10.	26.5-24/12	90	224	90	224	420	714		

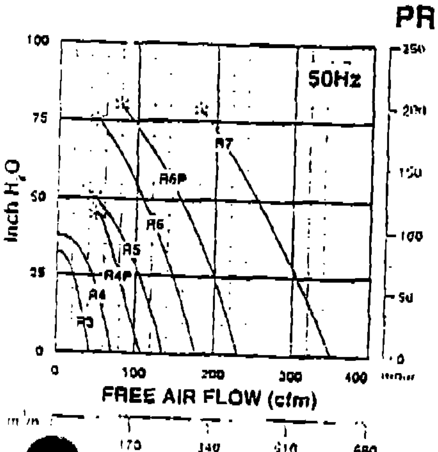
NOTICE: Performance specifications subject to change without notice.

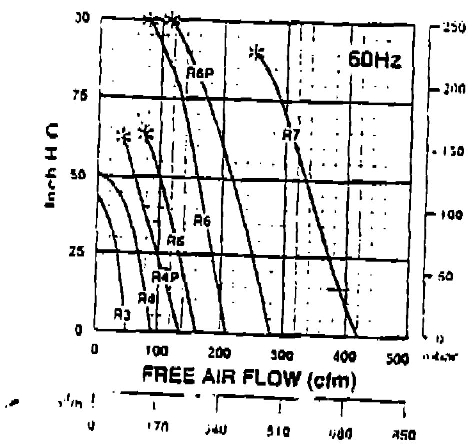
VACUUM





PRESSURE





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APPENDIX C

Bioventing System Operation, Monitoring, and Maintenance

Appendix C BIOVENTING SYSTEM OPERATION, MONITORING, AND MAINTENANCE GUIDELINES

The conceptual design report for a full-scale bioventing system at the Sludge Drying Beds area (SWMU7) at NAVSTA Mayport describes the requirements to remediate approximately 2.11 acres. The design consists of 48 vent wells, 16 monitoring points, two 2.0-hp regenerative blowers, and approximately 1,850 feet of schedule 40 polyvinyl chloride (PVC) piping. This appendix describes the operation, monitoring, and maintenance requirements for the full-scale installation.

C.1 System Startup and Shutdown. Bioventing systems are very easy to operate. System startup consists of obtaining electrical power for the blower and turning it on. A relief valve located near the exhaust of the blower is adjusted to ensure that an appropriate airflow is being delivered to the system. System shutdown consists only of turning the blower off.

C.2 Soil-Gas Monitoring. Collection of soil-gas samples before, during, and after termination of air injection is important to determine the effectiveness of a bioventing system. As part of the monitoring plan established at the site, soil-gas measurements will be taken on an as-needed basis (i.e., air permeability testing, respiration testing, etc.). Soil-gas samples will be collected with a soil-gas sampling pump system. Oxygen and carbon dioxide concentrations in the soil gas are measured with a direct-reading GasTech 3250X O_2/CO_2 detector (or equivalent detector). Concentrations of TPH are measured with a direct-reading GasTech GT105 total petroleum hydrocarbon (TPH) detector (or similar detector). Each field analytical instrument will be calibrated daily with calibration standards prior to use.

C.3 In Situ Respiration Testing. Following startup of the bioventing system, in situ respiration tests should be conducted after 3 months, 6 months, 9 months, 1 year, 2 years, and 3 years. In situ respiration testing consists of turning off the system to measure oxygen utilization rates. All monitoring points and thermocouples will be monitored during these tests. Once air injection is turned off, the soil gas will be measured for oxygen, carbon dioxide, and TPH as described in Section C.2. Typically, measurement of the soil gas will be conducted at 2, 4, 6, and 8 hours and then every 4 to 12 hours depending on the rate at which the oxygen is utilized. If oxygen uptake is rapid, more frequent monitoring will be required. If it is slower, less frequent readings are acceptable. Table C-1 summarizes the various parameters that will be measured and the frequency of measurement for each.

The test will be terminated when the oxygen concentration of the soil gas decreases to approximately 5% or after 5 days of sampling. At this time, the bioventing system will be turned back on. The oxygen consumption and carbon dioxide production measurements will be used to determine the oxygen utilization and biodegradation rates.

C.4 Surface Emissions Monitoring. At bioventing sites where surface emissions have been measured, surface emissions rates of benzene, toluene, ethylbenzene, and xylenes (BTEX) and TPH have been several orders of magnitude below regulatory levels. It should be noted that, according to the U.S. EPA document *Estimation of Air Impacts for Bioventing Systems Used at Superfund Sites* (U.S. EPA, 1993, EPA 451/R-93-003), emissions from bioventing sites operating in the injection mode are thought to be minimal. Therefore, it is assumed that surface emissions need not be monitored.

Table C-1. Parameters To Be Measured

Parameter/Media	Method	Frequency	Accuracy
CO_2/Soil Gas	Infrared adsorption method, field instrument (0 to 5% and 0 to 25% CO_2)	Initial soil gas sample before pumping air or at blower shutdown, then at 2, 4, 6, 8 hours, then every 4 to 12 hours	±10%
O_2/Soil Gas	Electrochemical cell method, field instrument (0 to 25% O_2)	Initial soil gas sample before pumping air or at blower shutdown, then at 2, 4, 6, 8 hours, then every 4 to 12 hours	±10%
TPH/Soil Gas	Hydrocarbon detector, field instrument (ppm TPH)	Initial soil gas sample before pumping air or at blower shutdown, then at 2, 4, 6, 8 hours, then every 4 to 12 hours	±5%
Pressure	Pressure gauge (0 to 15 psia)	Reading taken during air injection	0.5 psia
Flowrate/Air	Flowmeter	Reading taken during air injection	±5 cfh

C.5 Process Evaluation and Site Closure. In situ respiration testing should be used as the primary indicator for site closure. As site remediation progresses and contaminants are degraded, biodegradation rates will approach the background levels. Therefore, when the in situ respiration tests show that the biodegradation rates in the contaminated areas approximately equal the rates in the uncontaminated areas, the site is assumed to be remediated and final soil sampling can be conducted.

Soil sampling should not be used as a process-monitoring technique. In order to obtain meaningful results, extensive soil sampling must be conducted which has a tremendous impact on project costs. With bioventing systems, in situ respiration testing should be used to monitor remediation and keep project costs down. In situ respiration testing also indicates when final soil sampling should be conducted. Regulatory issues will determine the number of final soil samples required for site closure.

C.6 Maintenance Guidelines. On-site personnel will be responsible for visually inspecting and making any necessary repairs once every week while the bioventing system is in operation. Typically, routine repairs to a bioventing system will include:

- Replacing any damaged quick-disconnect couplings on the soil-gas monitoring points
- Replacing any damaged air delivery piping
- Replacing the inlet filter on the blower
- Replacing any other damaged instrumentation (i.e. flowmeter, temperature gauge, etc.)

- Making any necessary repairs to the analytical instruments used at the site
- Keeping the blower area and site, in general, clear of dust and debris.

C.7 Health and Safety Requirements. Health and safety requirements for the Sludge Drying Bed area are the same as those presented in Section 6 of the Operations and Maintenance Manual for a Full-Scale Bioslurper System at SWMU7 at Naval Station Mayport, Florida (Battelle, 1996 [draft main report]).

C.8 Troubleshooting. Bioventing systems are very easy to troubleshoot. The only mechanical part in the bioventing system that could be of concern is the blower. Blowers used in bioventing systems typically last for several years and should not need replacement. If problems do occur with the blower, refer to the manufacturer's literature.

C.9 Reference. U.S. Environmental Protection Agency. 1993. *Estimation of Air Impacts for Bioventing Systems Used at Superfund Sites*. EPA 451/R-93-003.

APPENDIX D

Cost Analysis Information

Bioventing Cost Summary

Pilot Test		
Soil-Gas Survey	$12,943.22	
Pilot Testing	$28,307.91	
TOTAL PILOT TEST COSTS		$41,251.13
Full-Scale System Installation		
Vent Well Installation	$21,198.87	
Soil-Gas Monitoring Point Well Installation	$11,873.56	
Blower System Installation	$7,482.55	
TOTAL FULL-SCALE INSTALLATION COSTS		$40,554.98
O&M for 3 Years		
Annual System Operation and Maintenance	$8,739.68	
TOTAL O&M FOR 3 YEARS WITH 3.5% INFLATION		$27,147.42
TOTAL FIXED COSTS		$1,948.70
TOTAL COST ESTIMATE WITH 10% CONTINGENCY		$121,992.45

Pilot Test

Pilot Scale Installation:

Item	Unit	Unit Cost	Number	Cost	Vendor/source
Driller Mobilization/Demobilization	mile	$3.00	100	$300.00	Layne Env Services
Driller travel	crew hr	$60.00	2	$120.00	Layne Env Services
Driller Per diem, per crew	crew day	$140.00	1	$140.00	Layne Env Services
Driller charge rate (labor & equip)	hour	$210.00	8	$1,680.00	Layne Env Services
3-1/4 in Environmental soil sampling kit	ea	$1,394.00	1	$1,394.00	EnviroTech
Soil-cuttings disposal	yd^3	$172.00	1	$172.00	Estimate
Explosion-proof regenerative blower	ea	$1,019.15	1	$1,019.15	Isaacs
Blower inlet filter with filter cover	ea	$115.00	1	$115.00	Grainger
Electrical parts/set-up	total	$200.00	1	$200.00	Estimate
Miscellaneous PVC piping, fittings, etc.	total	$500.00	1	$500.00	U.S. Plastics
Magnehelic gauge 0 - 10 in H_2O	ea	$47.00	1	$47.00	Dwyer
Magnehelic gauge 0 - 100 in H_2O	ea	$49.00	1	$49.00	Dwyer
Bentonite chips (assumed 0.75 ft^3)	bag	$10.16	2	$20.32	Unitek
Plastic cable ties 8 in long	100/bag	$6.00	2	$12.00	Instrmnt Lab Estimate
PVC 2-in sch 40 screen 5 ft	ea	$12.25	1	$12.25	Boundary Waters
PVC 2-in sch 40 casing 5 ft	ea	$7.75	1	$7.75	Boundary Waters
Quikrete ready mix, 80-lb bags	ea	$3.69	4	$14.76	Columbus Hardware
Silica sand, 1 ft^3/bag	bag	$11.86	3	$35.58	Unitek
Std brass valve tags 1.5 in natural	ea (1-99)	$1.30	15	$19.50	Seton
Al flush mount well cover (8 in solid)	ea	$98.42	4	$393.68	Global Drilling
Mini male thermocouple plug	ea	$3.18	8	$25.44	Instrmnt Lab Estimate
Thermocouple wire (type K) 125 ft	roll	$62.83	1	$62.83	L.H. Marshall
MPT male connector 3/8 in X 1/4 in tube	ea	$1.31	2	$2.62	NewAge Industries
Nylon tubing 1/4 in	50 ft pk	$19.25	1	$19.25	Cole-Parmer
Qck-cnct F X 1/4 in tube 4Z-Q4CN-BBP	ea	$12.10	4	$48.40	Forberg Scientific
Qck-cnct protector CP-Q4C-BB	ea	$5.01	4	$20.04	Forberg Scientific
Std brass valve tags 1.5 in natural	ea	$1.30	4	$5.20	Seton
Suction strainer (monitoring pt) 3/4 in	ea	$6.72	4	$26.88	Grainger
Gravel for suction screen 50 lbs	bag	$20.00	1	$20.00	Estimate
Misc. Safety	set	$500.00	1	$500.00	Estimate
Shipping	ea	$50.00	5	$250.00	Estimate
Labor	hr	$60.00	160	$9,600.00	Estimate
Installation Total				$16,832.65	

Soil Analysis:

Item	Unit	Unit Cost	Number	Cost	Vendor/source
Analysis - TPH and BTEX (soil)	ea	$75.00	4	$300.00	Alpha Analytical Inc.
Analysis - Bulk density (soil)	ea	$10.00	4	$40.00	Alpha Analytical Inc.
Analysis - Grain size (soil)	ea	$50.00	4	$200.00	Alpha Analytical Inc.
Analysis - Particle density (soil)	ea	$50.00	4	$200.00	Alpha Analytical Inc.
Analysis - Total porosity (soil)	ea	$7.00	4	$28.00	Alpha Analytical Inc.
Soil Analysis Total				$768.00	

Helium Tracer Test:

Item	Unit	Unit Cost	Number	Cost	Vendor/source
Helium gas cylinder	ea	$100.00	2	$200.00	Liquid Carbonic
Regulator CGA 590	ea	$245.00	2	$490.00	Liquid Carbonic Ind.
Flowmeter model VFB	ea	$28.90	2	$57.80	Dwyer
Male connector 4MSC4N-B	ea	$1.52	12	$18.24	Forberg Scientific
Nylon tubing 1/4 in (natural)	50 ft pk	$19.25	3	$57.75	Cole-Parmer

PVC pipe, 1 in	20 ft	$14.03	1	$14.03	U.S. Plastics
PVC end cap, 1 in	ea	$3.23	2	$6.46	U.S. Plastics
1/4 in tube x 1/4 in MPT connector	ea	$1.52	10	$15.20	Forberg
Labor	hr	$60.00	4	$240.00	
Helium Tracer Test Total				$1,099.48	

Permeability Test:

Item	*Unit*	*Unit Cost*	*Number*	*Cost*	*Vendor/source*
Stopwatch	ea	$39.95	1	$39.95	Cole-Parmer
Nylon tubing 1/4 in (natural)	50 ft pk	$19.25	1	$19.25	Cole-Parmer
Labor	hr	$60.00	48	$2,880.00	
Permeability Test Total				$2,939.20	

Respiration Test:

Item	*Unit*	*Unit Cost*	*Number*	*Cost*	*Vendor/source*
Latex tubing 3/16 in I.D.	100 ft	$52.58	1	$52.58	NewAge Industries
Tedlar bags	10/box	$82.00	4	$328.00	SKC
Carbon dioxide, size s3 10% bal N_2	ea	$124.00	4	$496.00	Scott Specialty Gases
Hexane, size s3 4800 in air	ea	$124.00	4	$496.00	Scott Specialty Gases
Oxygen, size s3 10% balance N_2	ea	$124.00	4	$496.00	Scott Specialty Gases
Labor	hr	$60.00	80	$4,800.00	
Respiration Test Total				$6,668.58	

TOTAL PILOT TEST COSTS $28,307.91

Soil-Gas Survey

Soil-Gas Survey Item & Cost:

Item	*Unit*	*Unit Cost*	*Number*	*Cost*	*Vendor/source*
Carbon dioxide, size s3 10% bal N_2	ea	$124.00	3	$372.00	Scott Specialty Gases
Hexane, size s3 4800 in air	ea	$124.00	3	$372.00	Scott Specialty Gases
Oxygen, size s3 10% balance N_2	ea	$124.00	3	$372.00	Scott Specialty Gases
Demolition electric hammer	ea	$1,600.00	1	$1,600.00	KVA Associates
Demolition hammer adaptor	ea	$288.00	2	$576.00	KVA Associates
Intercnctng nipple hollow Ni plated	ea	$23.00	4	$92.00	KVA Associates
Intercnctng nipple solid S/S	ea	$18.00	13	$234.00	KVA Associates
Latex tubing 3/16 in I.D.	100 ft	$52.58	1	$52.58	NewAge Industries
Nylon tubing 1/4 in (natural)	50 ft pk	$19.25	1	$19.25	Cole-Parmer
Plastic flasks 250 mL	12/case	$6.27	7	$43.89	U.S. Plastics
Soil gas probe shaft section 2.5 ft	ea	$255.00	3	$765.00	KVA Associates
Soil probe jack adapter (special made)	ea	$200.00	2	$400.00	
Tedlar bags	10/box	$82.00	5	$410.00	SKC
Utility Jack	ea	$100.25	2	$200.50	Grainger
Well pt slotted intake assy 3 ft	ea	$478.00	3	$1,434.00	KVA Associates
Labor	hr	$60.00	100	$6,000.00	
Soil-Gas Survey Total				$12,943.22	

Vent Well Installation

Vent Well Installation Item & Cost:

Item	*Unit*	*Unit Cost*	*Number*	*Cost*	*Vendor/source*
Driller Mobilization/Demobilization	mile	$3.00	100	$300.00	Layne Env Services
Driller travel	crew hr	$60.00	2	$120.00	Layne Env Services
Driller Per diem, per crew	crew day	$140.00	5	$700.00	Layne Env Services
Driller charge rate (labor & equip)	hour	$210.00	40	$8,400.00	Layne Env Services
3-1/4-in Environmental soil sampling kit	ea	$1,394.00	1	$1,394.00	EnviroTech
Soil-cuttings disposal	yd^3	$172.00	2	$344.00	Estimate
Misc. Safety	set	$500.00	3	$1,500.00	Estimate
shipping	ea	$50.00	12	$600.00	Estimate
Bentonite chips (assumed 0.75 ft^3)	bag	$10.16	50	$508.00	Unitek
Plastic cable ties 8 in long	100/bag	$6.00	2	$12.00	Instrmnt Lab Estimt
PVC 2 in sch 40 screen 5 ft	ea	$12.25	47	$575.75	Boundary Waters
PVC 2 in sch 40 casing 5 ft	ea	$7.75	47	$364.25	Boundary Waters
Ball valve, 2 in	ea	$20.74	47	$974.78	Pipe Valves
Quikrete ready mix, 80 lb bags	ea	$3.69	47	$173.43	Columbus Hardware
Silica sand, ft^3/bag	bag	$11.86	31	$367.66	Unitek
Std brass valve tags 1.5 in natural	ea (1-99)	$1.30	50	$65.00	Seton
Labor	hr	$60.00	80	$4,800.00	Estimate
Total				$21,198.87	

SG Monitoring Point Installation

Soil Gas Monitoring Point Item & Cost:

Item	*Unit*	*Unit Cost*	*Number*	*Cost*	*Vendor/source*
Driller per diem, per crew	crew day	$140.00	2	$280.00	Layne Env Services
Driller charge rate (labor & equip)	hour	$210.00	10	$2,100.00	Layne Env Services
3-1/4-in Environmental soil sampling kit	ea	$1,394.00	1	$1,394.00	EnviroTech
Soil-cuttings disposal	yd^3	$172.00	1	$172.00	Estimate
Misc. Safety	set	$500.00	3	$1,500.00	Estimate
Shipping	ea	$50.00	12	$600.00	Estimate
Al flush-mount well cover (8 in solid)	ea	$98.42	13	$1,279.46	Global Drilling
Bentonite chips (assumed 0.75 ft^3)	bag	$10.16	4	$40.64	Unitek
Quikrete ready mix, 80 lb bags	ea	$3.69	13	$47.97	Columbus Hardware
Silica sand (assumed 3/4 ft^3)	bag	$11.86	1	$11.86	Unitek
Mini male thermocouple plug	ea	$3.18	15	$47.70	Instrmnt Lab Estimt
Thermocouple wire (type K) 125 ft	roll	$62.83	1	$62.83	L.H. Marshall
MPT male connector 3/8 in X 1/4 in tub	ea	$1.31	15	$19.65	NewAge Industries
Nylon tubing 1/4 in	50 ft pk	$19.25	2	$38.50	Cole-Parmer
Plastic cable ties 8 in long	100/bag	$6.00	7	$42.00	Instrmnt Lab Estimt
Qck-cnct F X 1/4 in tube 4Z-Q4CN-BBP	ea	$12.10	15	$181.50	Forberg Scientific
Qck-cnct protector CP-Q4C-BB	ea	$5.01	15	$75.15	Forberg Scientific
Std brass valve tags 1.5 in natural	ea	$1.30	15	$19.50	Seton
Suction strainer (monitoring pt) 3/4 in	ea	$6.72	15	$100.80	Grainger
Gravel for suction screen 50 lb	bag	$20.00	1	$20.00	Estimate
Labor	hr	$60.00	64	$3,840.00	
Total				$11,873.56	

Blower System Installation

Blower System Installation Item & Cost:

Item	*Unit*	*Unit Cost*	*Number*	*Cost*	*Vendor/source*
Explosion-proof regenerative blower	ea	$1,019.15	1	$1,019.15	Isaacs
Blower inlet filter with filter cover	ea	$115.00	1	$115.00	Grainger
Electrical parts/set-up	total	$200.00	1	$200.00	Estimate
Miscellaneous PVC piping, fittings, etc.	ea	$400.00	1	$400.00	U.S. Plastics
Magnehelic gauge 0 - 10 in H_2O	ea	$47.00	1	$47.00	Dwyer
Magnehelic gauge 0 - 100 in H_2O	ea	$49.00	1	$49.00	Dwyer
Anemometer, hot wire	ea	$795.00	1	$795.00	TSI Inc
PVC cement	quart	$12.32	5	$61.60	U.S. Plastics
PVC primer	quart	$9.56	5	$47.80	U.S. Plastics
PVC 2 in sch 40 pipe	20 ft	$23.48	100	$2,348.00	U.S. Plastics
Labor	hr	$60.00	40	$2,400.00	
Total				$7,482.55	

Operation and Maintenance

Operation & Maintenance Item & Cost:

Item	*Unit*	*Unit Cost*	*Number*	*Cost*	*Vendor/source*
Filter cover replacement	ea	$13.75	5	$68.75	Grainger
Carbon dioxide, size s3 10% bal N_2	ea	$124.00	4	$496.00	Scott Specialty Gases
Hexane, size s3 4800 in air	ea	$124.00	4	$496.00	Scott Specialty Gases
Oxygen, size s3 10% balance N_2	ea	$124.00	4	$496.00	Scott Specialty Gases
Tedlar bags	10/box	$82.00	6	$492.00	SKC
Std brass valve tags 1.5 in natural	ea	$1.30	60	$78.00	Seton
Miscellaneous replacement parts	ea	$1,000.00	1	$1,000.00	
Power	kW-h	$0.10	26129	$2,612.93	
Labor	hr	$60.00	50	$3,000.00	
Total				$8,739.68	

Fixed Costs

Fixed Costs Independent of Site Size:

Item	*Unit*	*Unit Cost*	*Number*	*Cost*	*Vendor/source*
Valve tag stamps numbers 1/4 in	ea	$21.70	1	$21.70	Seton
Valve tag stamps letters 1/4 in	ea	$56.20	1	$56.20	Seton
OVA Rental	daily	$85.00	10	$850.00	Hazco
Diluter kit OVA purchase	ea	$750.00	1	$750.00	Hazco
Flowmeter, K72-05-0171	ea	$135.40	2	$270.80	King Instruments
Total				$1,948.70	