DOWL/OGDEN
Joint Venture

FINAL DESIGN VERIFICATION STUDY REPORT FOR THE TREATMENT SYSTEM DEMONSTRATIONS AND DESIGN VERIFICATION STUDY RUFF ROAD FORT RICHARDSON, ALASKA

CONTRACT NO. DACA85-95-D-0008
DELIVERY ORDER NO. 0026

Prepared for:

U.S. Department of the Army
Corps of Engineers
Pacific Ocean Division, Alaska District
P.O. Box 898
Anchorage, Alaska 99506-0898

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Alaska District

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June 2001

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TABLE OF CONTENTS

Page

FIGURES

TABLES

APPENDICES

ACRONYMS

ADEC	Alaska Department of Environmental Conservation
Alaska District	Corps of Engineers, Pacific Ocean Division, Alaska District
bgs	below ground surface
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CoC	Contaminants of concern
DoD	Department of Defense
DPW	Department of Public Works
DRO	diesel range organics
EPA	Environmental Protection Agency
Fe^{3+}	iron
FFA	Federal Facility Agreement
GRO	gasoline range organics
LEL	lower explosive limit
NO_{3-}	nitrate
OU-4	Operable Unit 4
PID	photoionization detector
RI	Remedial Investigation
SP	Sample Port
SO_4^{2-}	sulfate
SOW	scope of work
SVE	soil vapor extraction
SVOC	semi-volatile organic compounds
TCE	trichloroethylene
VOC	volatile organic compounds

1.0 INTRODUCTION

1.1 Purpose

This Design Verification Study Report presents the field activities and evaluates the performance of the Ruff Road Fire Training Area Treatment System Demonstration. This soil vapor extraction (SVE) system was implemented by the DOWL/Ogden Joint Venture (DOWL/Ogden JV) in the summer of 1998 at the Ruff Road Fire Training Area located at Fort Richardson, Alaska as shown in Figure 1. The installation, operation, and monitoring of the treatment system demonstration was intended as a treatability study for the removal of volatile fuel and organic compounds from the soil at the former fire training area. This report provides system monitoring information and evaluation for the two periods of operation, specifically, September 15 through November 3, 1998 and May 3 through October 26, 1999.

1.2 Authorization and Objective

All work performed under this contract complies with the Comprehensive Environmental Response, Compensation, and Liability Act (CERCLA) and the Federal Facility Agreement (FFA) entered into in 1994 by the U.S. Department of the Army, the U.S. Environmental Protection Agency (EPA), the Alaska Department of Environmental Conservation (ADEC), and the U.S. Department of Defense (DoD). This report was prepared for the U.S. Army Corps of Engineers, Pacific Ocean Division, Alaska District (Alaska District) as authorized under Contract Number DACA85-95-D-0008, Delivery Order No. 0026.

The objective of the treatability study was to assess the effectiveness of the prescribed SVE system in reducing volatile organic compounds (VOCs) and semi-volatile organic compounds (SVOCs) by enhancing both the volatilization rate and biological degradation of the compounds in the treatment area. The desire was to determine whether short-term, enhanced biodegradation at this demonstration project could achieve final soil cleanup goals or whether long-term, natural attenuation or other processes might be necessary.

1.3 Scope

The scope of work (SOW) for the project is described in the Final Work Plan, Record of Decision, Remedial Action Design Study, Operable Unit 4 (OU-4), Fort Richardson, Alaska, prepared by DOWL/Ogden JV and dated March 1998.

Tasks completed to date include the design, installation, startup, testing, operation, maintenance, and first (1998) and second (1999) season monitoring of the prescribed treatment system at the Ruff Road Fire Training Area. This report summarizes findings to date, verifies the system design installed, and evaluates effectiveness of the treatability study conducted at the Ruff Road site.

1.4 Deviations from Work Plan

Minor changes to the Final Work Plan were made during the field phase of this project. Specific deviations are as follows:

- A 30-mil geomembrane was used to cap the treatment area rather than the 20-mil liner proposed in the Work Plan.

- Monitoring points and exhaust ports were monitored for O_2 and volatiles by photoionization detector (PID); however, CO_2 concentration was not consistently recorded at these points and therefore not presented in the reports.

- Although the system was designed to pulse air, experimentation with operation regimes early in the 1998 season proved a continuous vacuum was more effective. Thus, the blower was operated continually for the portion of the 1998 season during which average daytime temperatures remained above freezing and the entire 1999 season of operation.

- The work plan proposed a four-month season as the target duration of operation and monitoring. Due to delay in getting government-furnished power to the site, operation in 1998 did not begin until September 15. Despite the late start, the Department of Public Works (DPW) requested DOWL/Ogden JV to initiate the first season of operation. The first season was curtailed after two months of operation due to the onset of average daytime temperatures below freezing. The 1999 monitoring season began May 3 and extended to October 26.

2.0 BACKGROUND

2.1 Historical Use

Military fire response personnel trained at the Ruff Road Fire Training Area from the 1940s until 1980. Training exercises involved pouring combustible liquids into an unlined, water-saturated earthen pit and igniting them. Products burned included jet fuel, waste oil, diesel, brake fluid, and solvents. Residue from such activities contaminated near surface soil with flammable liquid intermediaries. Contaminants of concern (CoC) previously reported at the Ruff Road Fire Training area include diesel range organics (DRO), trichloroethylene (TCE), toluene, benzene, and gasoline range organics (GRO). The total volume of wastes burned and disposed of on site was previously approximated at 85,000 gallons. Charred debris was removed from the site in 1991. In 1994, the Fire Training Area was covered with approximately 18 inches of fill material and re-graded to provide a parking area for Alaska National Guard vehicles during the winter of 1994. The training area is located on the west side of Ruff Road as shown in Figure 2.

2.2 Geology

Fort Richardson lies within the upper Cook Inlet region, an area influenced by tectonic and glacial activity. Glacial events and corresponding sea level changes in the Pleistocene produced a large-scale inter-fingering of glacial deposits, marine, and alluvial sediments. Together, these deposits form a 300 to 400-foot layer over bedrock consisting of densely consolidated siltstone, sandstone, coal, and shale.

The Fire Training Area is near the southern margin of the terminal Elmendorf Moraine running northeast to southwest across the Base. This feature consists of unconsolidated glacial till with poorly sorted boulders, gravel, sand, and silt. Southeast of the moraine are alluvial and glacial deposits of the Naptowne outwash plain. Generalized geologic descriptions of the site indicate that the soil consists of dry, massive, well-graded gravel with minor silt and clay. However, geological descriptions specific to the site soil frequently estimate silt contents at 10 percent to 30 percent.

2.3 Surface and Groundwater

The north central section of Fort Richardson, where the site is located, features flat to gently rolling, wooded terrain. Numerous streams drain from the Chugach Mountains westward across the base into the Knik Arm of Cook Inlet. A former gravel pit is located approximately 0.6 mile south and hydraulically upgradient of the site. The pit has filled with water since abandonment. There is a small pond approximately 600 feet from the southwest corner of the former Fire Training Area. Groundwater occurs from 140 to 153 feet below ground surface (bgs) within an unconfined sandy gravel aquifer and flows westward at horizontal hydraulic gradient ranging from 0.018 to 0.023.

2.4 Contaminant Migration Pathways

Previous investigations detected contaminants in surface and subsurface soil. Off-site contaminant transport via surface runoff, and windblown particulate is possible but is not expected to transport a significant amount of contaminant from the site. The absence of site-related contaminants in the surface water and sediment samples collected at the nearby pond substantiates the conclusion that surface water runoff and particulate transport are not migration pathways of concern at the Fire Training Area. The Remedial Investigation (RI) included transport modeling of petroleum constituents in the subsurface soil. The model predicted that petroleum contaminants will migrate approximately 10 feet vertically from their present location over a 90-year period and that groundwater would not likely be impacted. Based on this result and the absence of contaminants in groundwater samples collected at the site, groundwater is not considered a transport medium.

3.0 REMEDIATION PROCESSES

Reduction of contaminants at the Ruff Road site is achieved through two dominant reactions. Concentrations of VOCs and SVOCs are reduced via volatilization and removal, whereas non-volatile, organic contaminants are ultimately transformed to carbon dioxide and water via biodegradation.

Volatilization is the transfer of chemicals in vadose zone soil or soil water from solids or liquids to the gaseous phase and is a function of the contaminant's vapor pressure. Vapor pressure is a compound-specific characteristic that directly relates to temperature. Thus, the volatilization rate of a treatment system increases with rising temperature. Evacuation rate of the resultant volatilized compounds from the subsurface increases with increasing airflow.

Biodegradation occurs when microorganisms use contaminants as a carbon and energy source for growth, motility, and reproduction. A fraction of the total carbon is incorporated as new cellular material, and the balance of the total carbon is oxidized to CO_2. Microorganisms gain energy by catalyzing energy-producing chemical reactions that involve breaking chemical bonds and transferring electrons away from the contaminant. Aerobic metabolism is expected to be the primary metabolic biodegradation pathway of organic contaminants such as those at the Ruff Road site. Under aerobic conditions, bacteria and/or fungi effect electron transfer from the hydrocarbon contaminant to the oxygen molecule O_2. While other molecules such as nitrate (NO_3^-), sulfate (SO_4^{2-}), or iron (Fe^{3+}) can take the place of oxygen as an electron acceptor in the bacterial metabolism, the greatest capture of energy is through aerobic metabolism with O_2 as the electron acceptor.

The rate of aerobic respiration and resulting contaminant biodegradation is dependent on many variables including the availability of the contaminant, appropriate transforming species, oxygen, and appropriate ranges of temperature, soil moisture, pH and nutrients. For the Ruff Road system, we assume contaminants are available. That is, they are not sorbed onto organic carbon or present in the non-aqueous liquid phase. Also assumed is the presence of appropriate transforming species, nutrients, and pH range. Based on these assumptions, variables such as temperature, soil moisture content, and percent oxygen may be manipulated to optimize system performance.

Increasing temperature results in a higher rate of biodegradation due to a reduction in activation energy required to mineralize a given contaminant (mineralization refers to the transformation of a contaminant into the ideal end-points of carbon dioxide and water). Limited provisions were made for monitoring and manipulating soil temperatures at this site. In flow and out flow exhaust temperatures were measured inline before entering and after exiting the blower. Results of these measurements are presented in Tables 10 and 11 and were utilized to determine when conditions warranted modification of the systems operation schedule or shutdown and winterization. For example, the system was reprogrammed to go off-line during nighttime hours to avoid circulating cold air which might have frozen the subsurface soil prematurely and was winterized when daytime subfreezing conditions prevailed. The system is also insulated and isolated by the geomembrane and overlying soil.

Sufficient water is vital to the life and productivity of the variety of microorganisms effecting biodegradation in a given system. Seven soil moisture indicators were installed in treatment area soils to track subsurface water availability. The four infiltration galleries allowed additional water to counteract any drying effects typical of SVE systems.

The SVE system at Ruff Road was designed to increase biological activity in the soil by increasing the amount of oxygen available to resident bacteria or fungi. When bacterial or fungicidal populations in soil or groundwater grow in response to the presence of contaminants, they can deplete the oxygen level in the vicinity of the contamination below atmospheric levels. When there is no air recharge in the soil, reduced oxygen levels limit aerobic respiration thereby shifting the balance towards anaerobic respiration which is characterized by slower metabolisms and lower population levels. The Ruff Road system placed air infiltration galleries adjacent to the horizontal wells to enhance movement of fresh air through the soil. Increased airflow through the subsurface simultaneously introduced atmospheric air with a high concentration of elemental oxygen while flushing volatile-laden stagnant air.

Lowered levels of oxygen in subsurface air are good indicators both of the presence of contaminants and of healthy biological action. When the percent O_2 in subsurface air is measured during respirometry testing, the reduction in O_2 levels is referred to as oxygen demand. Elevated oxygen demand results from elevated biological activity, which can be indicative of higher levels of contaminants. Thus, a net decrease in oxygen demand over the duration of system operation indicates a reduction of soil contaminant levels.

It is anticipated that even after system shutdown and site decommission, natural attenuation processes will continue to reduce site contaminant levels. Due to the predominance of organic contaminants at the Ruff Road site, natural attenuation processes will likely approximate those typical of enhanced aerobic metabolism. However, decreased airflow and oxygen availability will slow the comparative rate of biodegradation.

4.0 SYSTEM INSTALLATION, OPERATION AND MONITORING

4.1 Treatment System Installation and Configuration

The Ruff Road treatment system had the unique goal of facilitating natural attenuation processes rather than the direct remediation of contaminants. Three horizontal wells typical of standard SVE systems were installed at a depth of about five feet bgs and spaced 50 feet on center as shown on Figure 2. Additionally, to encourage natural attenuation processes, four passive air infiltration galleries were installed coplanar with, parallel to, and flanking the horizontal wells. These air infiltration galleries augmented the system by introducing a greater volume of air to the subsurface and by increasing the wells zone of influence. Also unique to the Ruff Road treatment system was the installation of a 30-mil geomembrane over the 175 by 190 feet (approximately 3/4 acre) site. The geomembrane prevented airflow decrease by infiltration of surface air. The geomembrane was covered by one foot of silty sand for protection purposes. Similar to other SVE systems, seven moisture sensors and 40 monitoring points are installed at the treatment area. The monitoring points are located at depths of two and one-half feet and five feet bgs in 20 separate locations.

Airflow to the system was provided by a Gardner Denver Sutorbuilt Legend blower, powered by a US Motors brand, 15 HP 3-phase electric motor. All machinery was located in the equipment enclosure. Blower operation following a pulsing regime was experimented with in the early stages of the 1998. Flow in each of the horizontal wells and dilution air for the system exhaust could be adjusted manually. The operation of the system could be programmed to run hourly, daily, or weekly with unique settings for each individual horizontal well. However, the blower appeared to be more effective when operated on a continuous basis. Thus, the blower applied continuous vacuum to all monitoring wells for the remainder of the 1998 season and the entire 1999 season. Blower action induced a vacuum in the three horizontal wells, which displaced accumulated volatile organics from the treatment area by pulling fresh air through the four passive air infiltration galleries. The contaminants removed by the vapor extraction portion of the system were discharged into the atmosphere at the site.

4.2 Operation

The system was completed on June 26, 1998 and tested September 11 immediately following installation of overhead power to the site by the DPW. The system was put into service on September 15, 1998. During the startup phase, vacuum in the three wells was equalized and the system was programmed for 24-hour operation. After a one month stabilization period, the system was shutdown by DOWL/Ogden JV personnel on October 14, 1998 to perform a respirometry test. The system was offline until October 15, 1998, a period of one day. On September 30, 1998, the system was reprogrammed to run from 9:00 a.m. to 7:00 p.m. daily. Nighttime closures were begun to prevent the subsurface from freezing prematurely due to the introduction of cold air into the treatment area soil. As the average daily temperature approached freezing, a decision was made to take the system offline, and on November 3, 1998, the system was winterized and shutdown for the season. Total operational time for 1998 was 49 days.

Minor mechanical adjustments and corrections were required from the equipment supplier during system startup. Some of the flow and vacuum meters originally installed were out of the operational range and were replaced. Subsequent system monitoring indicated the system was functioning as designed.

The following year's system startup was performed on May 3, 1999. The system was offline twice during the 1999 season of operation. The system was first shut down on May 18 for respirometry testing. The second shutdown occurred on October 8 and lasted for 12 days until the system was restarted on October 20. This shutdown occurred automatically as a result of a false positive lower explosive limit (LEL) warning. A flashing amber light on the exterior of the enclosure signaled the shutdown condition. After the alarm condition was noted by DOWL/Ogden JV personnel during an unscheduled site inspection, the LEL detector was reset and the system restarted. Down time for the system in 1999 totaled 13 days. Duration of operation for the system was 176 days; however, total operating time was limited to 163 days. The system operated until October 26, 1999 at which time the system was taken offline for the season and winterized.

4.3 Monitoring

Monitoring data was collected according to the Final Work Plan, Treatment System Demonstration and Design Verification Study, Ruff and Roosevelt Road, Fort Richardson, Alaska and is tabulated in Tables 1 through 11.

Individual system monitoring episodes varied slightly from case-to-case. Monitoring activities and data and samples collected during each monitoring episode included the following:

- Air samples were collected at the Sample Port (SP) in the equipment enclosure. This is the only air SP in the system and is located in-line before the vapor exhaust is discharged into the air. Air samples were collected into a clean summa canister, placed in a specialty container for shipment, and analyzed at the project laboratory using EPA Method TO-14. Table 1, provided at the end of this report, lists the reported analytes for EPA Method TO-14 and Tables 2 and 3 provide summaries of the analytical results of the sampling.

- Gauges in the equipment enclosure measured the airflow and vacuum of each horizontal well. Airflow data and vacuum data are presented in Tables 10 and 11.

- The vacuum, percent oxygen and PID readings within the treatment system were measured at the 20 monitoring points at depths of 2.5 and 5 feet bgs. Photoionization detection, percent oxygen and vacuum field data for the 1998 and 1999 seasons are provided in Tables 2, 3, 4, 5, 6, and 7, respectively.

- LEL readings within the equipment enclosure and the exhaust air stream were recorded while the system was operating. LEL readings are included in Tables 10 and 11.

- Temperature of the air flowing through the system was measured in-line before entering and after exiting the blower within the equipment enclosure. Temperature data is provided in Tables 10 and 11.

- Soil moisture was measured at each of the seven moisture sensors H-1 through H-7 prior to system startup to document natural moisture levels within the treatment area. Additional soil moisture monitoring was conducted at each sampling episode throughout the 1998 and 1999 operating seasons. Soil moisture data is provided in Tables 8 and 9.

5.0 FIELD INVESTIGATION ACTIVITIES

The 1998 and 1999 monitoring of the treatment system consisted of monitoring episodes and exhaust air sampling at four and eight hours after startup and during Days 1, 2, and 5; Weeks 2 and 3 and Months 1 and 2 of operation. 1999 monitoring included these same dates but also continued through the third, fourth, and fifth Months of operation. Monitoring of the system occurred September 15 through November 3, 1998 and May 3 through October 26, 1999.

Monitoring activities included recording vacuum and flow readings at each horizontal well, as well as recording temperature, PID, and LEL readings. During all monitoring episodes, PID readings recorded within the equipment enclosure and outdoors within the treatment area were non-detect. LEL readings in the enclosure were one percent or less of the LEL during all monitoring events. System monitoring and analytical air sample data are tabulated in Tables 1 through 11 and Appendix A provided at the end of this report.

In 1998, the vapor extraction system was operated at a calculated total airflow of about 300 scfm of which an estimated 85 percent was extracted from the ground and 15 percent from ambient air.

The combined airflow from the three SVE wells in 1999 was 252 scfm. This value represents the total airflow out of the ground. Because the SP is located after the three extraction wells have joined and after the addition of dilution air, the airflow at the sample port is necessarily greater than 252 scfm. However, the range of the current airflow meter at the SP only extends to 225 scfm. Installation of a higher range meter at the SP is needed to accurately estimate contaminant removal of the system. The airflow at the sampling point is therefore an estimated value. An addition of 20 percent dilution air was approximated by closing off the dilution air valve, reading the airflow in the extraction wells, and then opening the dilution valve until the airflow in the extraction wells dropped by 20 percent. The total airflow at the sampling point is estimated by this method at a minimum value of 315 scfm. Flow and vacuum readings from the three soil vapor extraction wells were collected during each monitoring episode.

6.0 SUMMARY OF RESULTS

6.1 Flow Rate and Vacuum

Flow rates measured during each monitoring episode at each horizontal well, averaged approximately 85 scfm in 1998 and 84 scfm in 1999. Vacuum, also measured during each monitoring episode at each horizontal well, averaged approximately two inches of water vacuum per well in 1998 and 1999. The average vacuum at the monitoring points within the treatment system area was 0.10 inches of water in 1998 and 0.11 inches of water in 1999. The vacuum at different locations within the treatment system area varied from 0.00 to 0.27 inches of water in 1998 as shown in Table 6 and from 0.00 to 0.53 inches of water in 1999 as shown in Table 7.

6.2 Respirometry Test

The respirometry tests conducted on October 14 and 15, 1998, May 18 and 19, and October 26 and 27, 1999 showed a rapid depletion of oxygen over a large part of the treatment system area. For both of the fall respirometry tests, the affected area showed a strong correlation with PID readings. Figures 3 and 5 show the average of the PID and percent oxygen results in 1998, respectively. Likewise, Figures 4 and 6 show the average of the PID and percent oxygen results in 1999, respectively. The decrease of oxygen from the beginning of respirometry to the 24-hour measurement indicates a high level of biological activity and likely biological degradation of contaminants.

6.3 Mass Removal Rate

Removal rate of total VOC mass peaked at 0.235 pounds per day (lbs./day) after two days of operation in 1998 and at 0.095 lbs./day after 35 days of operation in 1999 as shown in Figure 12. Because most of the contaminants, such as DRO and GRO, either have low volatility rates or are highly weathered, the total mass removal rate exhibited by the SVE system was low. After peaking, the mass removal rate decreased at a fairly constant rate in 1998 but fluctuated widely during the 1999 season of operation. Much of the decrease of the removal rate in October and November 1998 was due to the system operating only ten hours per day. Figure 7 presents the estimated total VOC concentration in air extracted from the system during the 1998 and 1999 seasons of operation, respectively. Figures 8 and 9 present the sampled benzene, toluene, ethylbenzene, and xylene (BTEX) concentration versus time for the 1998 and 1999 seasons, respectively. Figures 10 and 11 present the BTEX and total VOC mass removal rates for 1998 and 1999, respectively. Figure 13 presents the estimated cumulative total mass removal over time for both operating seasons.

6.4 Temperature

In 1998, the average temperature of air flowing into the blower was 54 degrees Fahrenheit (°F); the average temperature of air flowing out of the blower was 75°F. In 1999, the average temperature of in-flowing air was 47°F; the average temperature of out-flowing air was 72°F. Temperature data is present in Tables 10 and 11.

6.5 Soil Moisture

Average percent soil moisture saturation gradually decreased from 96.3 percent to 94.5 percent over the 1998 monitoring season. During the 1999 monitoring, the average percent soil moisture saturation gradually increased from 94.1 percent to a peak of 96.2 percent in month two and decreased to 93.6 percent at season end. Soil moisture data is presented in Tables 8 and 9.

7.0 DISCUSSION OF RESULTS

Results are based on the summation of data collected during the 1998 and 1999 monitoring and sampling episodes. Results for parameters monitored over the system's operational lifetime are discussed below.

7.1 Flow Rate

The flow rate in the three horizontal wells was constant during system operation and from year to year. Average flow rates during the 1998 and 1999 treatment periods were nearly identical at about 84 scfm and 85 scfm per well, respectively. At these flow rates, a complete air exchange within the treatment area is effected approximately every four to five hours, ensuring ample oxygen to maintain a high level of biological activity in the treatment area.

7.2 Vacuum Rate

The vacuum throughout the treatment area measured in inches of water was low indicating good soil permeability, which is affirmed by the above-discussed high flow rate. Vacuum potential at different monitoring points showed minimal variation and decreased with increasing distance from the horizontal wells. Vacuum in Line 3 was typically three times the amount of vacuum in Lines 1 and 2. Higher vacuum in Line 3 may relate to its position in the zone of highest contamination. Due to their occupancy of pore space, contaminants reduce permeability, which necessitates greater vacuum to move air through the zone of contamination. Permeability is enhanced by the presence of four air infiltration galleries placed between and flanking the three horizontal wells.

7.3 Respirometry Test Results

The respirometry tests performed over the 24-hour periods in 1998 and 1999 showed very good results. For each year, oxygen demand directly correlated with PID readings indicating healthy biological activity in the areas of highest contamination. At the east center of the treatment area, percent oxygen decreased to 0.0 percent 16 hours after the 1998 year-end shutdown and decreased to 10.4 percent 24 hours after 1999 year-end shutdown. The percent oxygen decrease exhibited on both occasions indicates high oxygen demand at the east center treatment area. Conversely, oxygen demand was limited to nonexistent each year towards the north, west, and south borders of the treatment area, indicating little or no contamination or biological activity in these areas. The reduced oxygen demand in the fall 1999 respirometry test compared to the 1998 test suggests a substantial reduction in site contamination.

7.4 Mass Removal Rate

The initial mass removal rate of total VOCs in 1998, as shown in Figure 10, was 0.17 lbs./day, peaking on day 2 at 0.24 lbs./day and declining quickly to a steady rate of approximately 0.018 lbs./day over the last month of operation. The initial mass removal rate of total VOCs during the system start up in 1999, as shown in Figure 11, was 0.0069 lbs./day and fluctuated between 0.0073 and 0.095 lbs./day for the remainder of the season of operation. Low daily recoveries may be attributed to the lack of volatile constituents in DRO, which is the primary CoC at the treatment area. It is likely that a large fraction of the most volatile compounds was removed during the 1998 operating season, and that during the 1999 season, the greatest reduction in contamination is achieved through enhanced biodegradation of the less volatile compounds. As shown in Figure 13, approximately 3.8 pounds of organic compounds were volatilized and purged during the 49 days of treatment system operation in 1998, equivalent to a removal rate of .078 pounds per day of system operation. Approximately seven pounds of organic compounds were volatilized and purged during the 163 days of operation in 1999, equivalent to a removal rate of .043 lbs./day of system operation. A total 10.8 pounds of organic compounds were purged over 212 days, which averages to .05 pounds of organic compounds purged per day of system operation.

Total VOC concentrations recorded during the 1999 monitoring are often greater than the last VOC concentration recorded in 1998. This may be attributable to interim volatilization and pore recharge of volatile components which are purged during the initial flushing phases of the succeeding year of system operation. This "stockpiling" of volatiles and their subsequent removal would result in elevated VOC concentrations. Additional factors which could augment initial 1999 biodegradation and volatilization rates compared to the initial 1998 season are a larger population of the appropriate bacteria and/or fungi, greater oxygen availability, higher temperatures, sufficient soil moisture, correct pH, and nutrient availability.

7.5 Temperature

Temperatures of air entering and exiting the blower were monitored to ensure circulating air was not below freezing. All temperatures recorded during each monitoring season were above 32°F.

7.6 Soil Moisture

Average soil moisture content remained above the maximum moisture content at which irrigation is needed for coarse soil, or 90 percent saturation, throughout the 1998 and 1999 seasons. Thus, no water was injected into the air infiltration galleries. It appears that sufficient moisture was introduced into the system due to natural infiltration events.

8.0 RECOMMENDATIONS

During the operation and maintenance of the system, air sampling was conducted to monitor the level of contaminants removed by the SVE system. However, soil sampling is necessary to confirm the decrease of contaminant levels resulting from both vapor extraction and enhanced biological activity. Soil sampling was not included in the SOW but was performed by the government after the fall 1999 shutdown. The results of the fall 1999 soil sampling have been made available to the DOWL/Ogden JV and are summarized in the following text.

The U.S. Army COE collected and screened soil samples from twenty locations within the treatment area at the surface and depths of five and ten feet bgs. Sample collection methodology consisted of piercing the geomembrane and extracting the soil with a mobile drill rig. Soil samples were analyzed for, GRO, DRO, residual range organics (RRO), and BTEX. Samples exhibiting signs of contamination were also tested for polyaromatic hydrocarbons (PAH).

Assuming migration to groundwater is not a pathway to any potential receptor, 18 AAC 75.341 Method 2 cleanup standards for inhalation and ingestion pathways may serve as regulatory limits for all detected compounds. On this basis, the site is eligible for closure as no contaminants detected at the project site currently exceed ingestion and inhalation cleanup standards. The expedient remediation of the site to accepted contaminant levels indicates that the treatment system selected was well suited to the site.

8.1 Recommended Changes to System and Monitoring Protocol

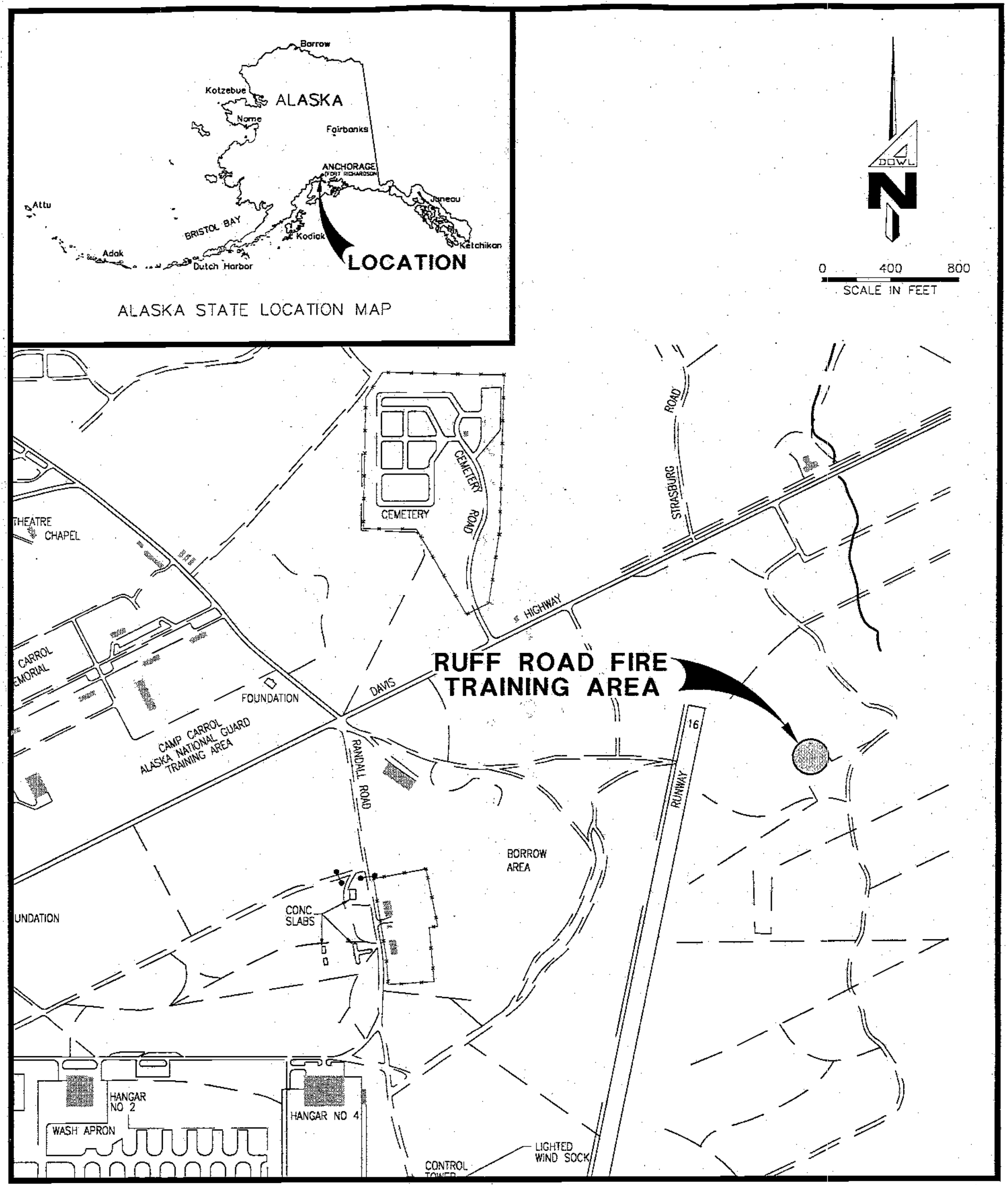
Overall, the treatment system's performance was satisfactory. Operation was as anticipated and monitoring activities were consistent in methodology and results. The following are suggestions for future use of this and/or other SVE systems.

- DPW representative, Kevin Gardner, recommended that for future projects the provision of electrical service to the system be the sole responsibility of the contractor rather than government-provided. Belated installation of the electrical service substantially delayed system startup in 1998.
- Installation of a higher range meter at the SP is necessary to accurately estimate contaminant removal of the system.
- Spring soil sampling is recommended to illustrate any change in contaminant concentrations during system down time and to provide a more accurate correlation between monitoring episodes.

9.0 DECOMMISSIONING

Decommissioning is limited to removal from the site of the aboveground portion of the system. Exposed pipes will be capped as appropriate and the subsurface portions will be abandoned in place according to contract negotiations. The SOW does not include well closure; however, wells will be marked per DPW request.

FIGURES



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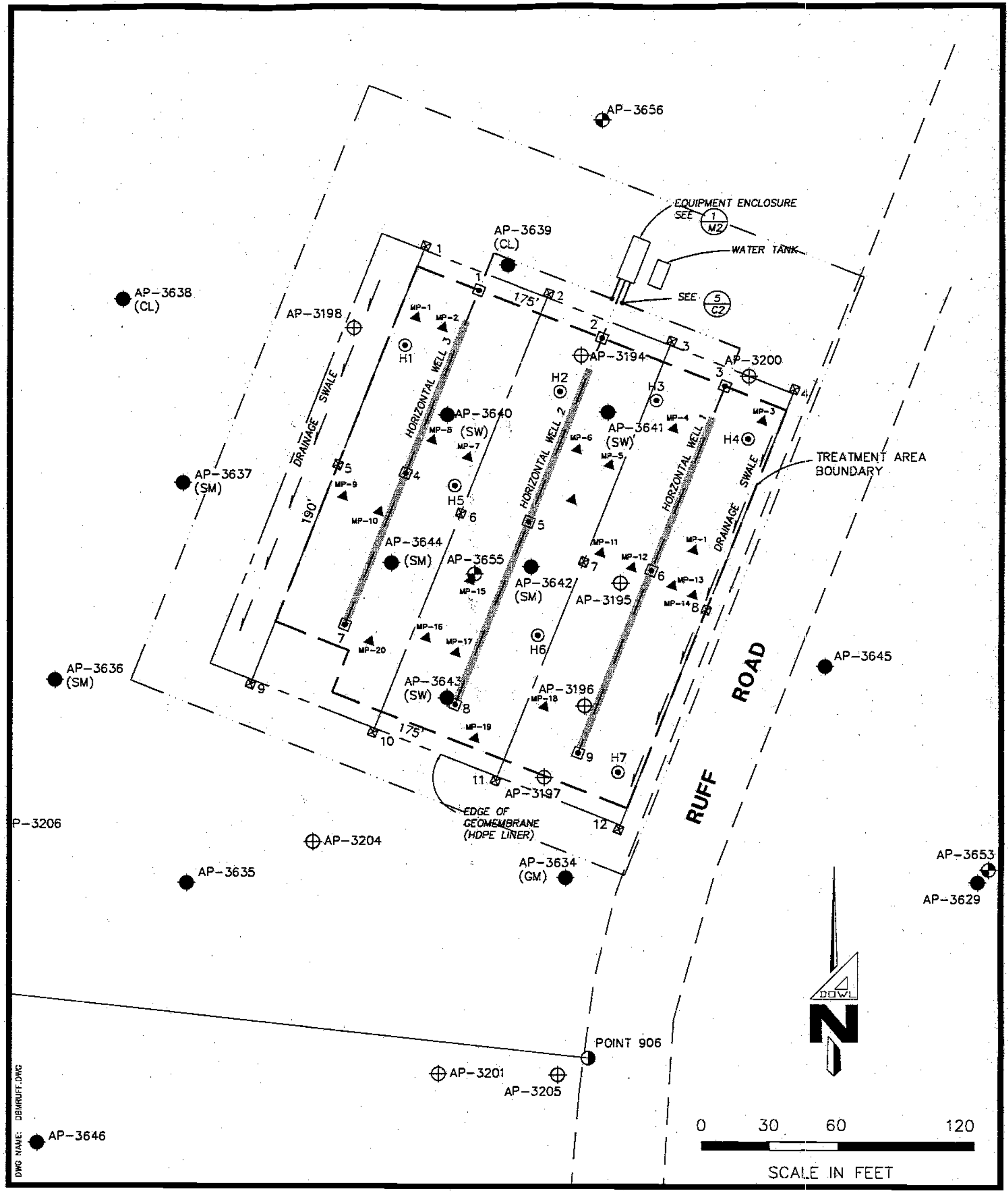
DOWL ENGINEERS

VICINITY MAP

RUFF ROAD FIRE TRAINING AREA
TREATMENT SYSTEM DEMONSTRATION
FORT RICHARDSON, ALASKA

Figure 1



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SCALE: 1"= 60'

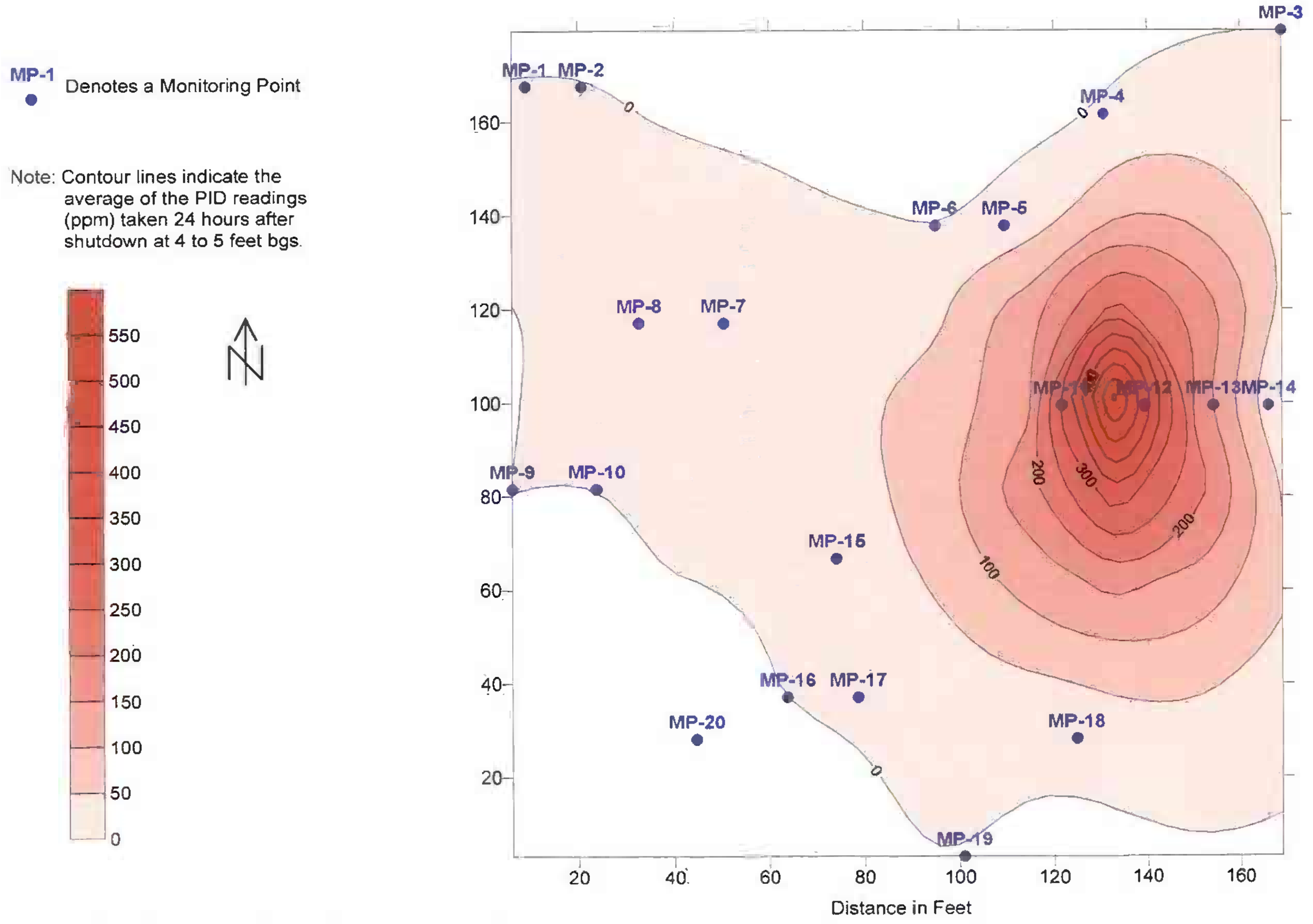
DOWL ENGINEERS

SITE MAP

RUFF ROAD FIRE TRAINING AREA
TREATMENT SYSTEM DEMONSTRATION
FORT RICHARDSON, ALASKA

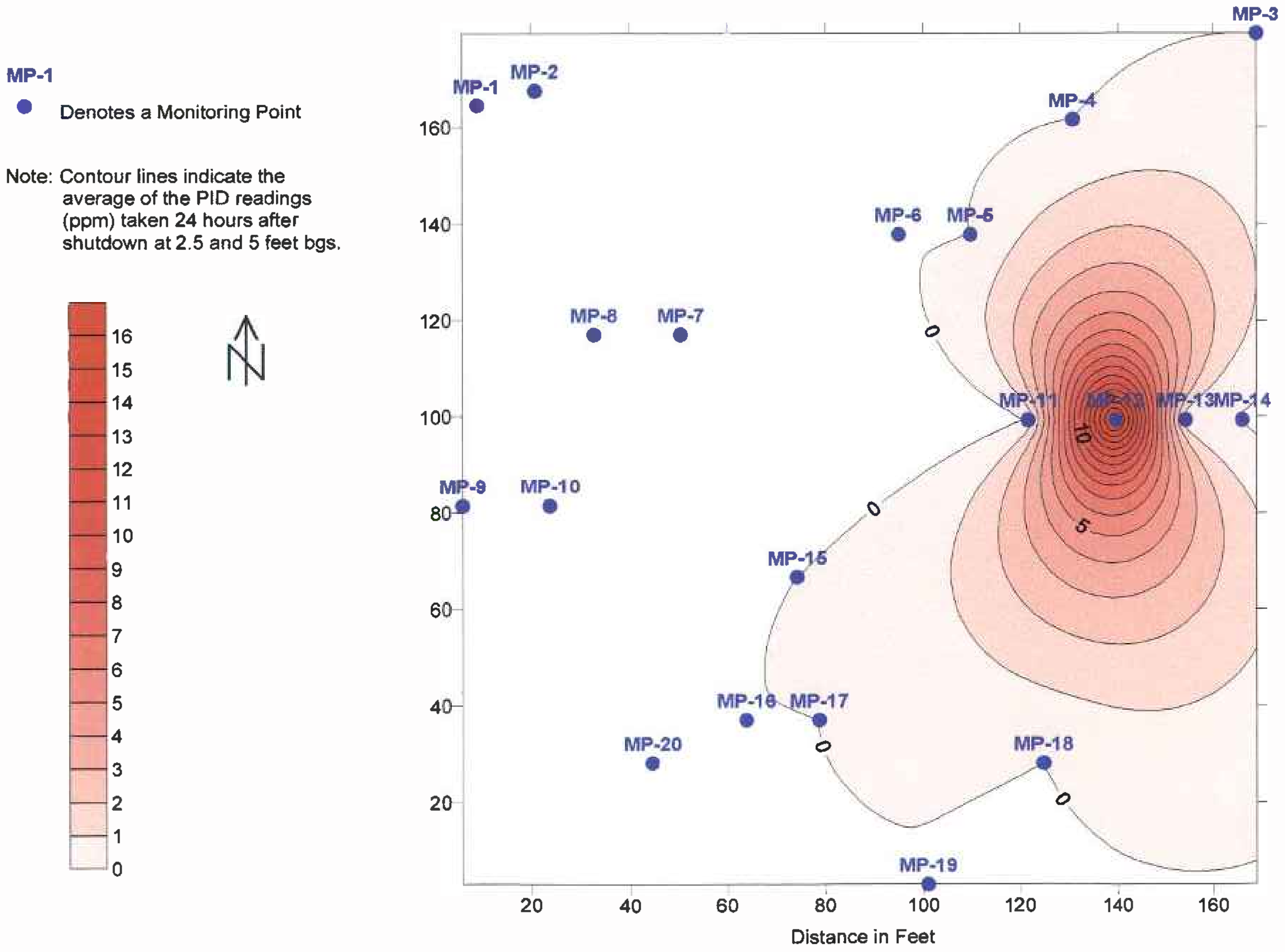
Figure 2

Figure: 3 PID Monitoring Field Data 1998
Ruff Road Fire Training Area Treatment System Demonstration



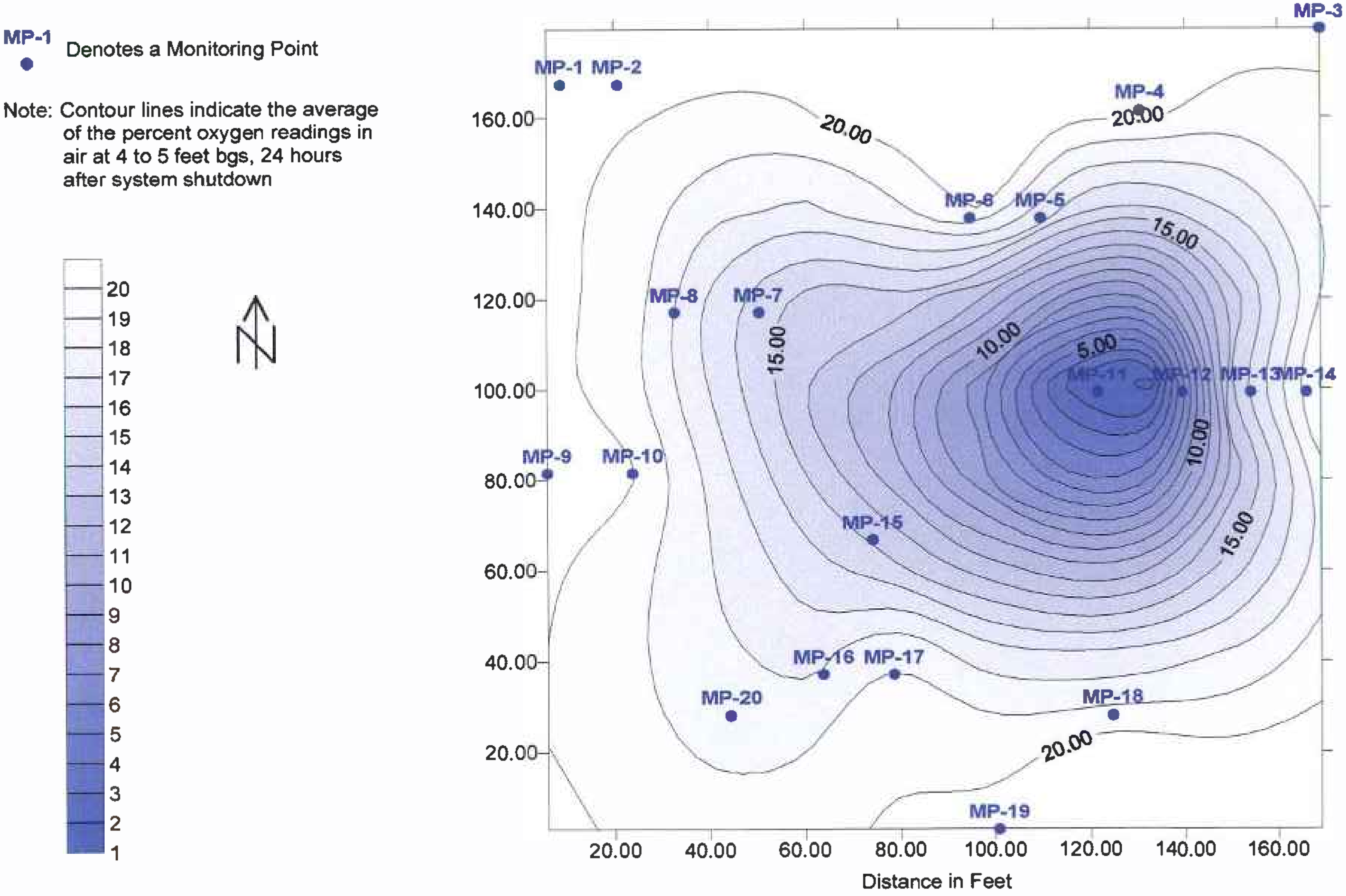
Note: Contour lines indicate the average of the PID readings (ppm) taken 24 hours after shutdown at 4 to 5 feet bgs.

Figure 4: PID Monitoring Field Data 1999
Ruff Road Fire Training Area Treatment System Demonstration



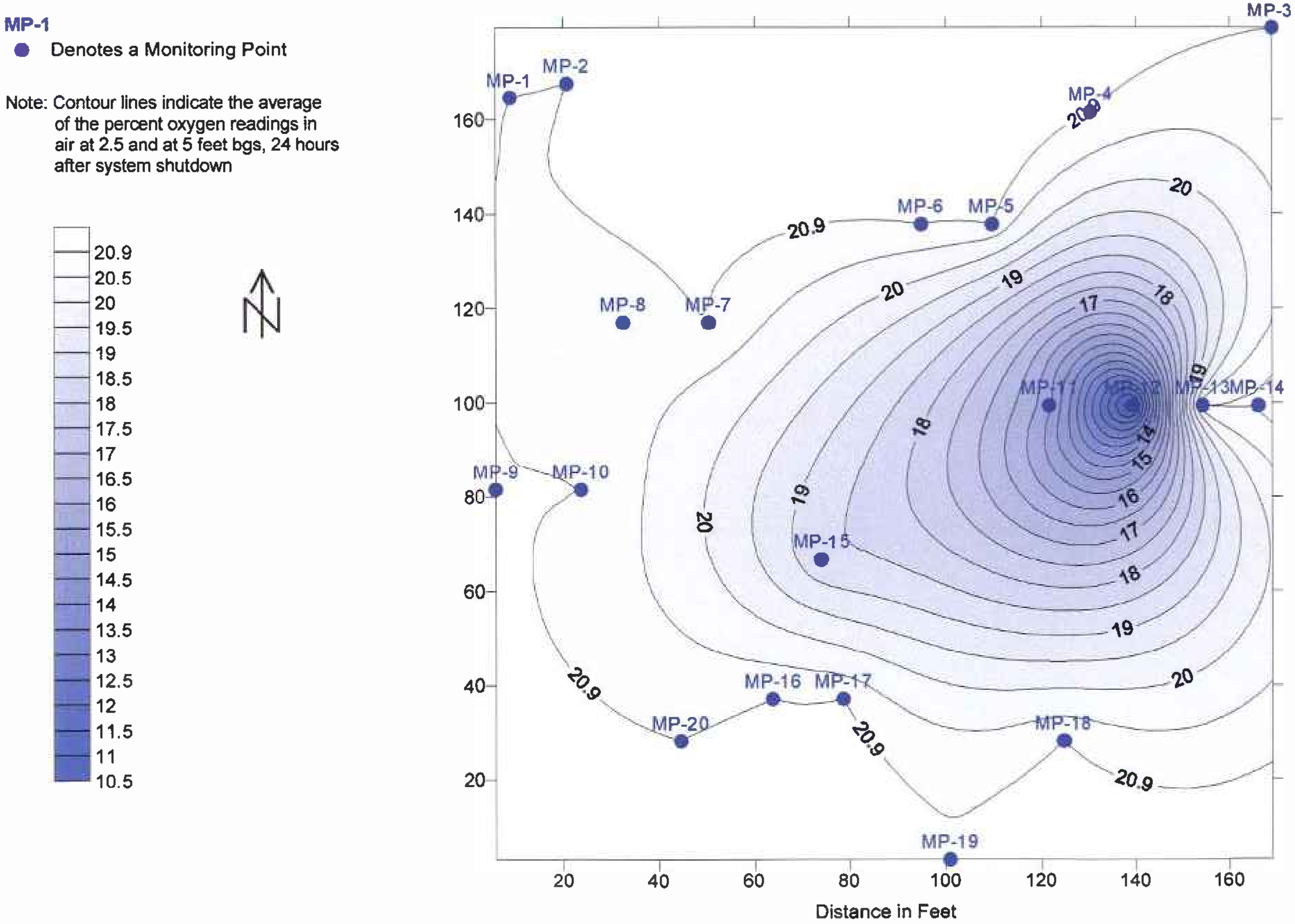
Note: Contour lines indicate the average of the PID readings (ppm) taken 24 hours after shutdown at 2.5 and 5 feet bgs.

Figure 5: Percent Oxygen in Soil 1998
Ruff Road Fire Training Area Treatment System Demonstration



Note: Contour lines indicate the average of the percent oxygen readings in air at 4 to 5 feet bgs, 24 hours after system shutdown

Figure 6:Percent Oxygen in Soil 1999
Ruff Road Fire Training Area Treatment System Demonstration



Note: Contour lines indicate the average of the percent oxygen readings in air at 2.5 and at 5 feet bgs, 24 hours after system shutdown

Figure 7: Total VOC Concentration in Air Extracted from Sample Port vs. Time 1998-1999

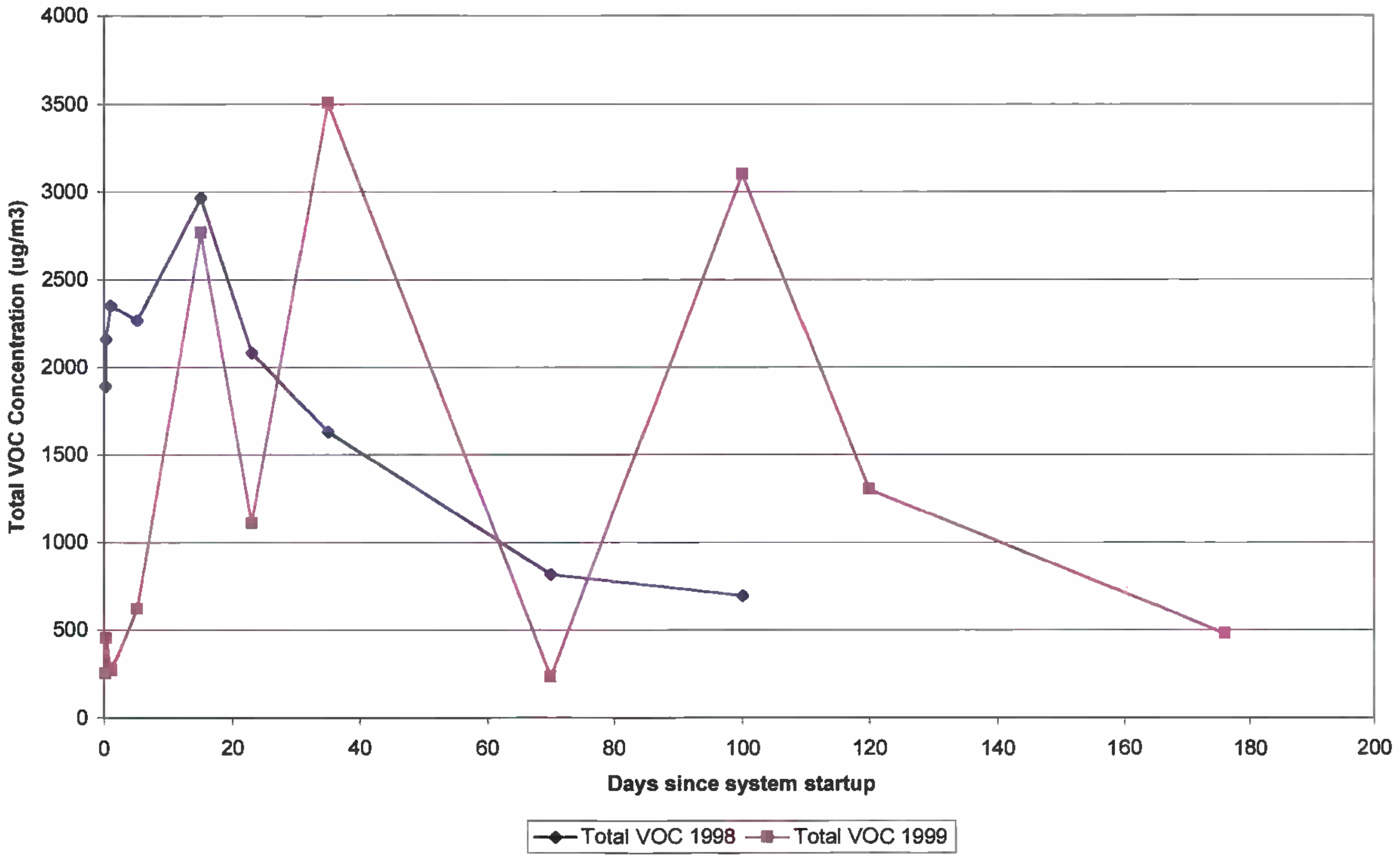


**Figure 8. BTEX Concentration in Air Extracted from Sample Port vs. Time
Ruff Road Fire Training Area - Treatment System Demonstration 1998**

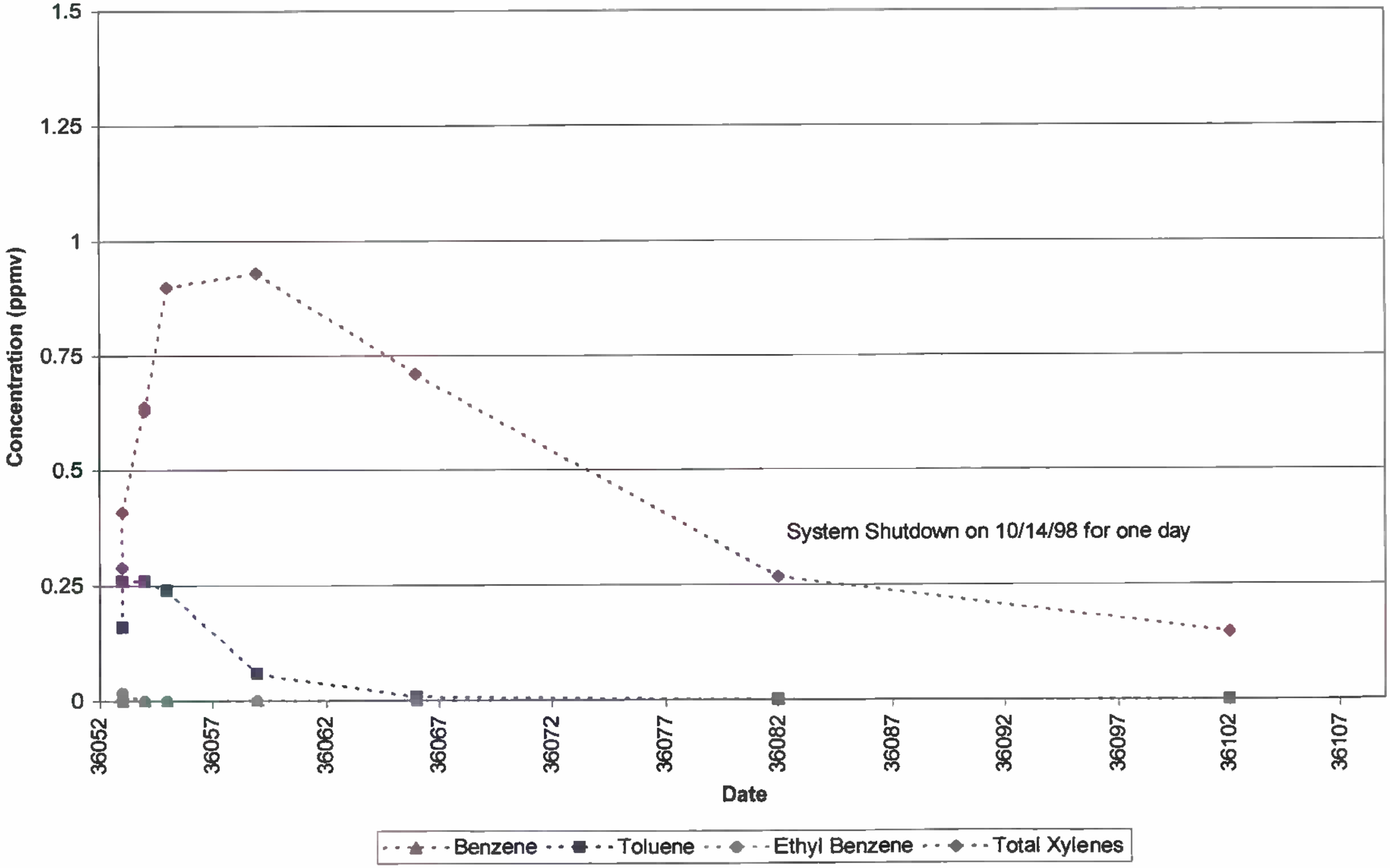


Figure 9. BTEX Concentration in Air Extracted form Sample Port vs. Time
Ruff Road Fire Training Area - Treatment System Demonstration 1999

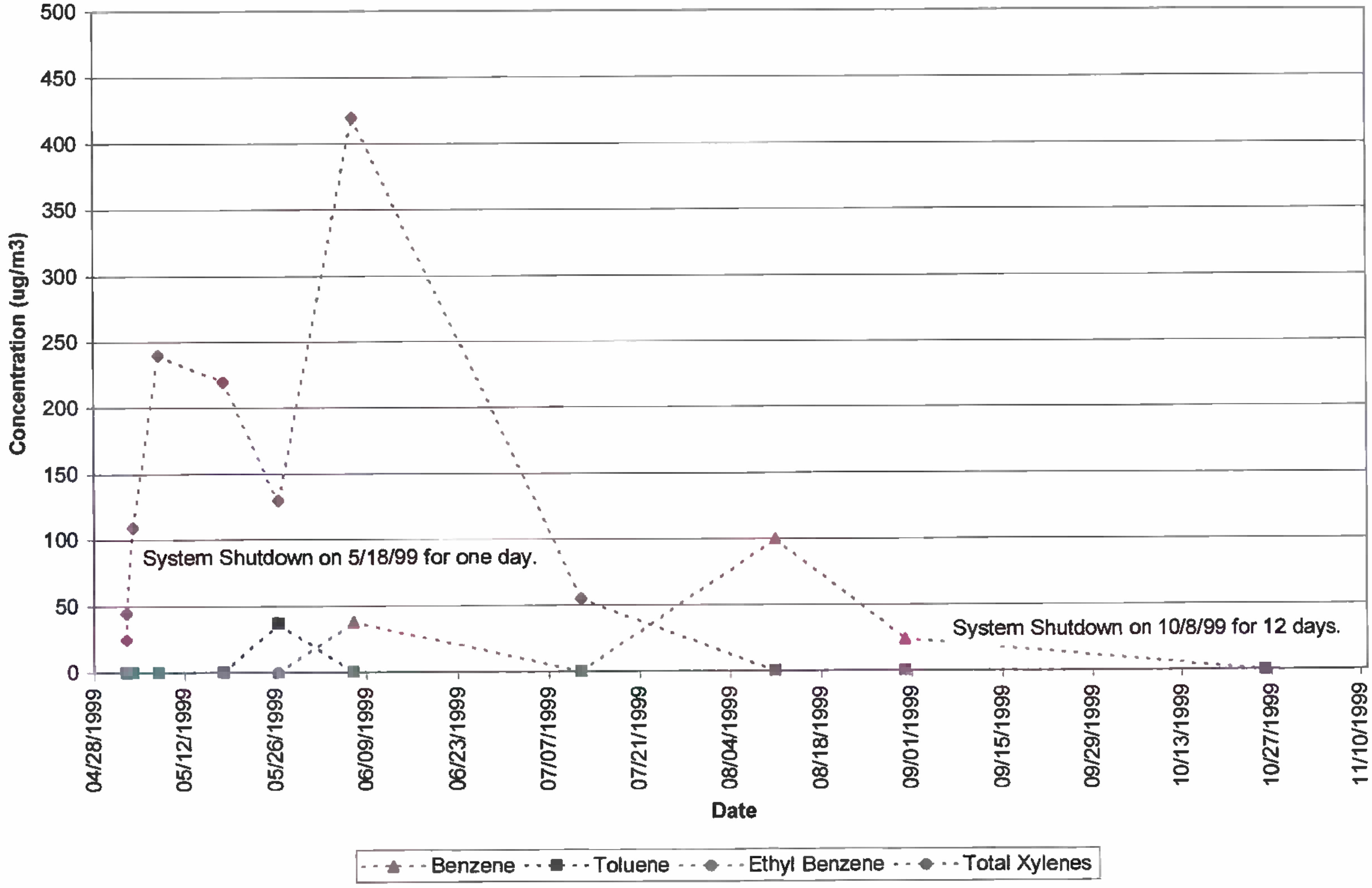


Figure 10. Mass Removal Rate of BTEX and Total VOC in Air Extracted from Sample Port vs. Time
Ruff Road Fire Training Area - Treatment System Demonstration 1998

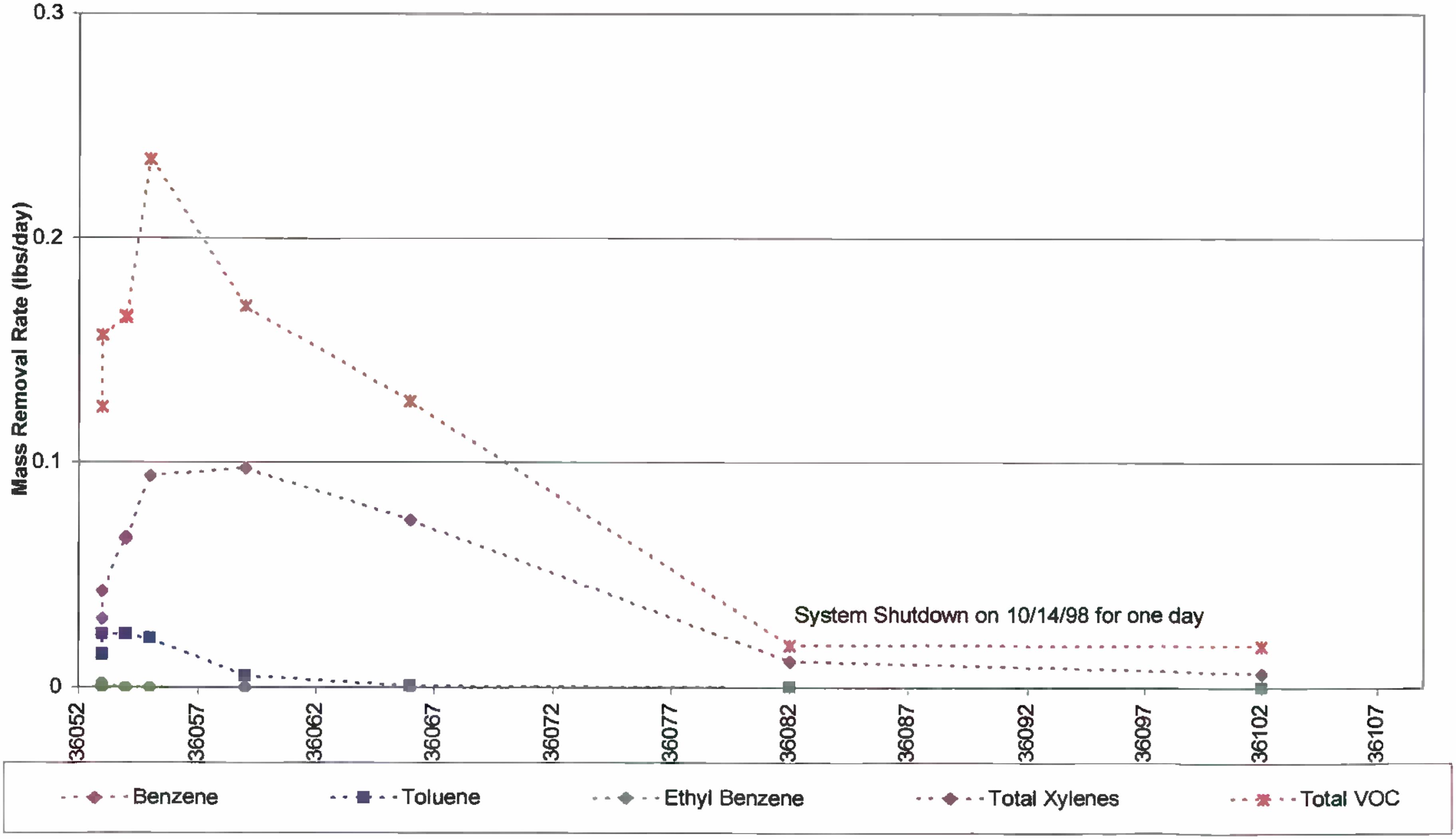


Figure 11: Mass Removal Rate of BTEX and Total VOC in Air Extracted from Sample Port vs. Time
Ruff Road Fire Training Area - Treatment System Demonstration 1999

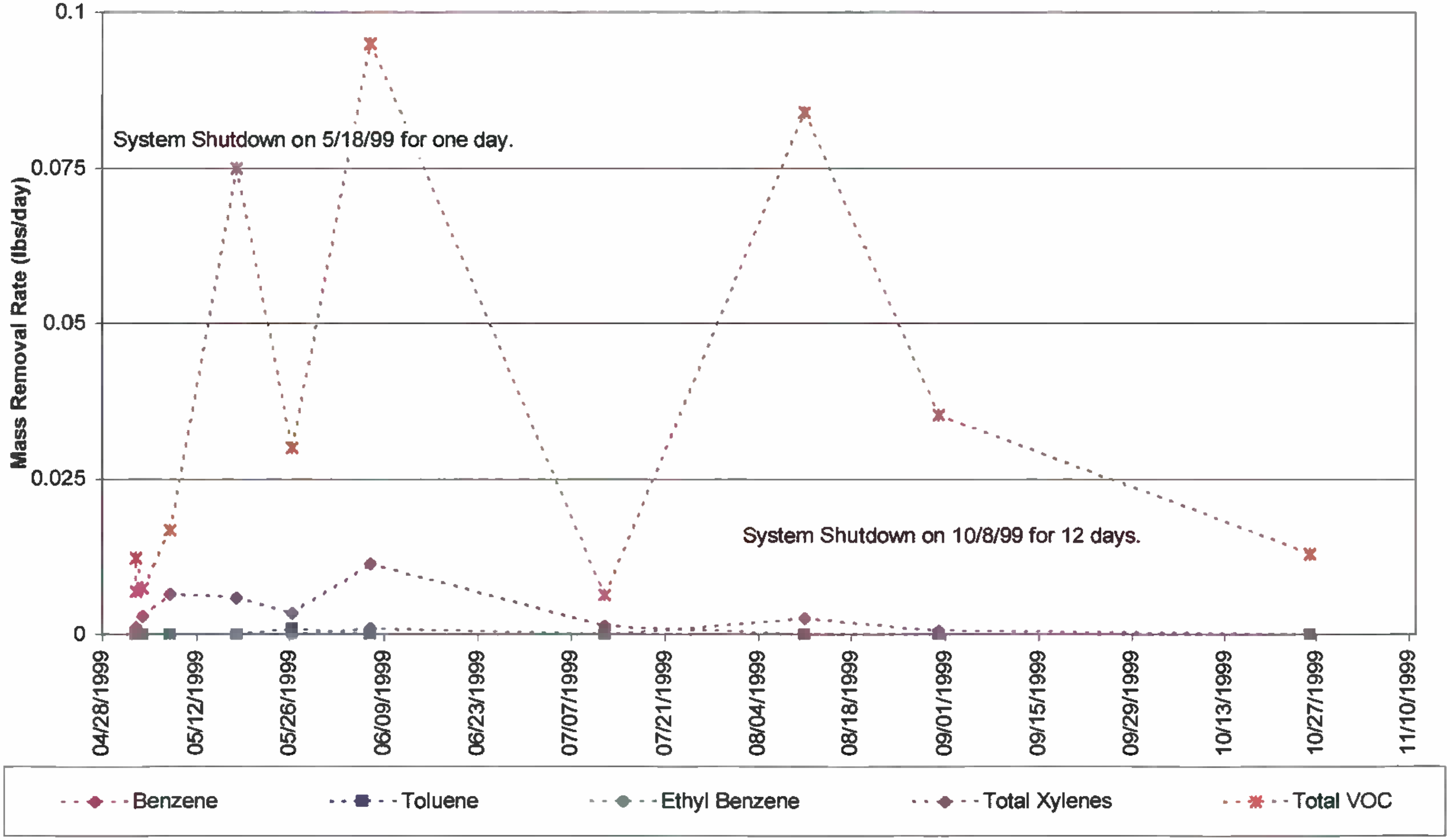


Figure 12: Mass Removal Rate of Total VOC in Air Extracted from Sample Port vs. Time
Ruff Road Fire Training Area - Treatment System Demonstration 1998-1999

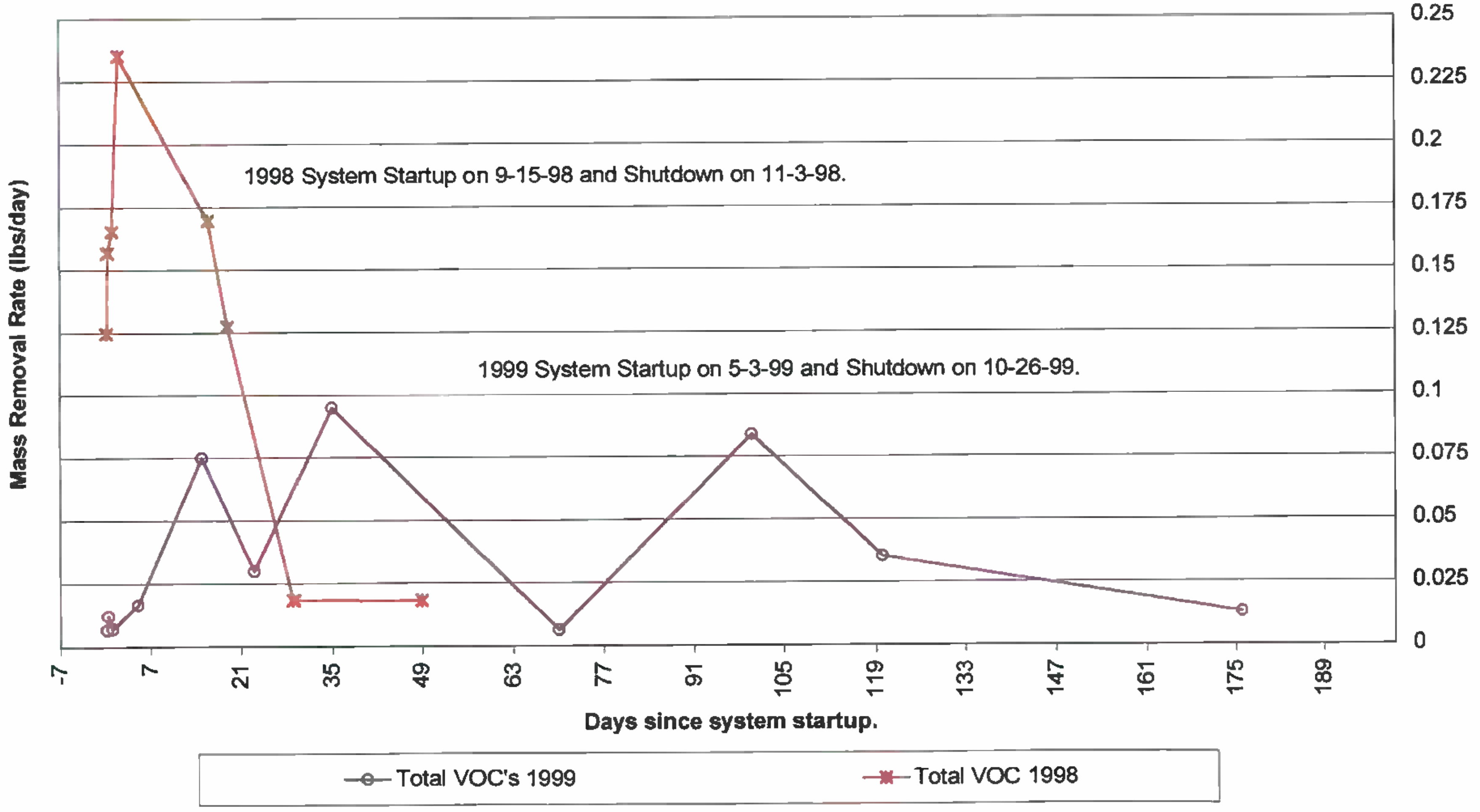
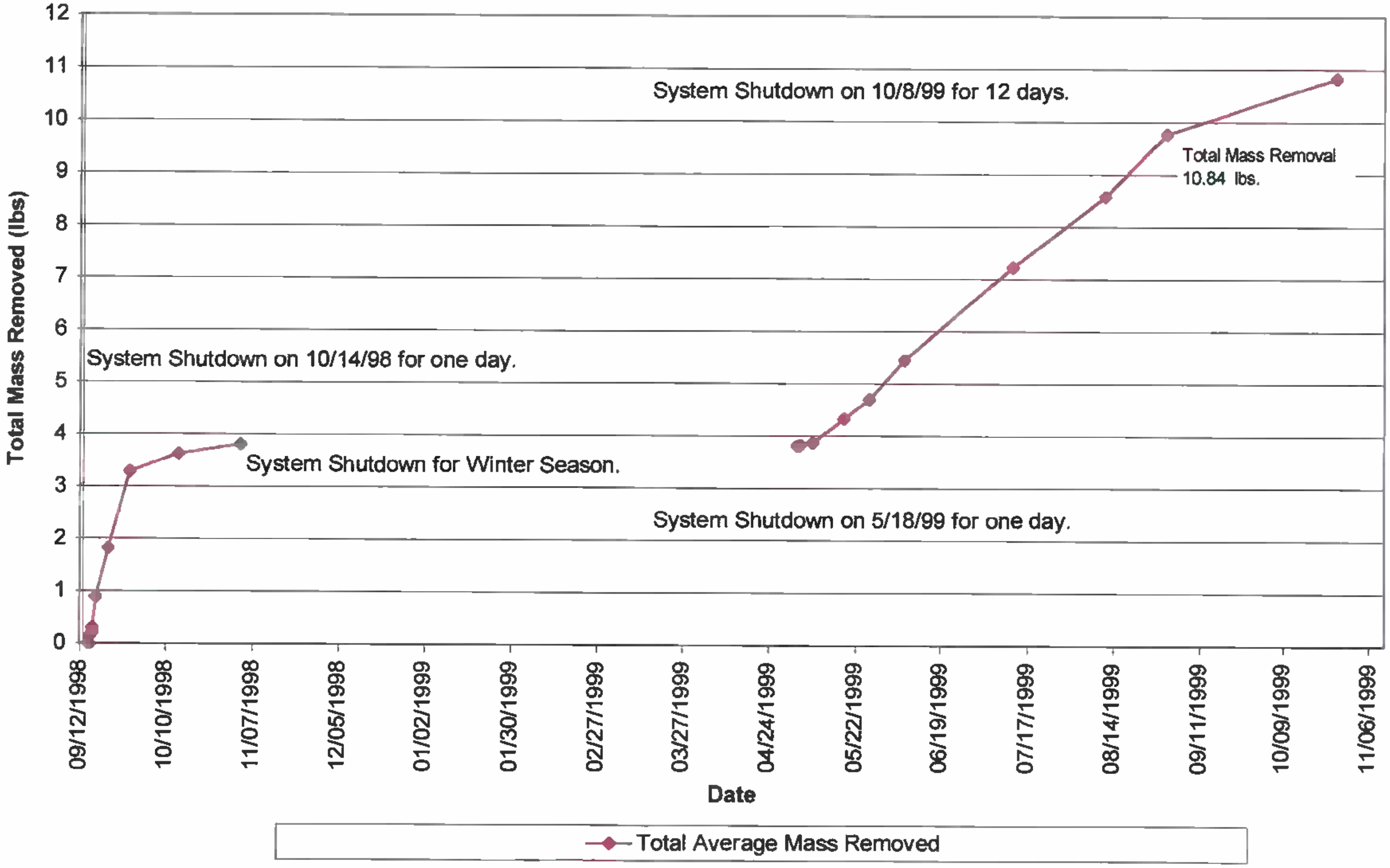


Figure 13. Total Cumulative Mass Removed in Air Extracted from Sample Port vs. Time
Ruff Road Fire Training Area - Treatment System Demonstration 1998-1999



TABLES

Table 1: EPA Method TO-14 Analytes

1,1,1-Trichloroethane
1,1,2,2-Tetrachloroethane
1,1,2-Trichloroethane
1,1-Dichloroethane
1,1-Dichloroethene
1,2,4-Trichlorobenzene
1,2,4-Trimethylbenzene
1,2-Dichlorobenzene
1,2-Dichloroethane
1,2-Dichloropropane
1,3,5-Trimethylbenzene
1,3-Butadiene
1,3-Dichlorobenzene
1,4-Dichlorobenzene
1,4-Dioxane
2-Butanone (Methyl Ethyl Ketone)
2-Hexanone
2-Propanol
4-Ethyltoluene
4-Methyl-2-pentanone
Acetone
Benzene
Bromemethane
Bromodichloromethane
Bromoform
Carbon Disulfide
Carbon Tetrachloride
Chlorobenzene
Chloroethane
Chloroform
Chloromethane
Chloroprene
Chlorotoluene
cis-1,2-Dichloroethene
cis-1,3-Dichloropropene
Cyclohexane
Dibromochloromethane
Ethanol
Ethlyene Dibromide
Ethyl Benzene
Freon 11
Freon 113
Freon 114
Freon 12
Heptane
Hexachlorobutadiene
Hexane
m,p-Xylene
Methyl tert-Butyl Ether
Methylene Chloride
o-Xylene
Propylene
Styrene
Tetrachloroethene
Tetrahydrofuran
Toluene
trans-1,2-Dichlorethene
trans-1,3-Dichloropropene
Trichloroethene
Vinyl Acetate
Vinyl Chloride

Table 2: Soil Vapor Extraction System Exhaust Sampling Data 1998
EPA Method TO-14 Analytical Laboratory Results

	EPISODE, DATE, and SAMPLING IDENTIFICATION NUMBER								
ANALYTES	**Hour 4** **9/15/98** 9839FR01051AI	**Hour 8** **9/15/98** 9839FR01052AI	**Day 1** **9/16/98** 9839FR01053AI	**Day 1** **9/16/98** 9839FR01053AI Dub	**Day 2** **9/17/98** 9839FR01054AI	**Day 5** **9/21/98** 9839FR01055AI	**Week 2** **9/28/98** 9839FR01056AI	**Month 1** **10/14/98** 9839FR01057AI	**Month 2** **11/3/98** 9839FR01058AI
Methylene Chloride	ND	ND	ND	ND	ND	ND	0.006	ND	ND
Chloroform	0.065	ND	ND	ND	ND	ND	ND	0.006	ND
cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	0.004	ND
1,1,1Trichloroeth.	ND	0.051J	0.046J	0.045J	0.043J	0.019J	0.023	ND	0.065
Benzene	ND	0.015J	ND	ND	ND	ND	ND	ND	ND
Trichloroethene	0.150	0.190	0.220	0.210	0.220	0.170	0.130	0.120	0.150
Toluene	0.160	0.260	0.260	0.260	0.240	0.058	0.007	ND	0.160
Tetrachloroethene	0.320	0.290	0.320	0.320	0.290	0.240	0.230	0.210	0.320
Ethyl Benzene	ND	0.018J	ND	ND	ND	ND	ND	ND	ND
m,p - Xylene	0.170	0.240	0.360	0.350	0.480	0.430	0.240	0.047	0.170
o-Xylene	0.120	0.170	0.280	0.280	0.420	0.500	0.470	0.220	0.120
1,3,5-Trimethylb.	0.016J	0.019J	0.040J	0.039J	0.058J	0.081	0.110	0.058	0.016J
1,2,4-Trimethylb	ND	ND	0.033J	0.032J	0.049J	0.067	0.074	0.013	ND
Propylene	ND	ND	ND	ND	ND	ND	ND	0.022	ND
Acetone	ND	ND	ND	ND	ND	ND	ND	0.019	ND
Hexane	ND	ND	0.070J	0.073J	0.180	ND	0.110	0.100	ND
Tetrahydrofuran	0.063J	ND	0.084J	ND	ND	ND	ND	ND	0.063J
Cyclohexane	0.270	0.330	0.260	0.270	0.440	0.230	0.190	ND	0.270
4-Ethyltoluene	ND	ND	ND	ND	ND	0.060J	0.042	ND	ND
Heptane	0.560	0.580	0.380	0.390	0.550	0.230	ND	ND	0.560

Notes to Table 2:

All concentrations presented as part per million volume (ppmv).
Analytes not detected during laboratory analysis are not presented.
Trimethylbenzene has been abbreviated to Trimethylb.
ND = Non Detect
J = Estimated value

Table 3: Soil Vapor Extraction System Exhaust Sampling Data 1999

EPA Method TO-14 Analytical Laboratory Results

	EPISODE AND DATE										
	Hour 4	Hour 8	Day 1	Day 5	Week 2	Week 3	Month 1	Month 2	Month 3	Month 4	Month 5
ANALYTES	5/3/99	5/3/99	5/4/99	5/8/99	5/18/99	5/26/99	6/7/99	7/12/99	8/11/99	8/31/99	10/26/99
1,1-Dichloroethane	ND	ND	ND	ND	ND	ND	ND	0.0036	ND	ND	ND
Methylene Chloride	0.0058	0.0066	0.0072	0.0076	0.0350	ND	ND	ND	ND	ND	ND
cis-1,2-Dichloroethene	ND	ND	ND	ND	ND	ND	ND	ND	ND	0.0049	0.0047
1,1,1-Trichloroethane	0.0780	0.0460	0.0280	0.0140	0.0210	ND	ND	0.0120	ND	0.0210	ND
Benzene	ND	ND	ND	ND	ND	ND	0.0120	ND	0.0320	0.0073	ND
Trichloroethene	0.0500	0.0590	0.0720	0.0640	0.0480	0.0250	0.0770	0.0620	0.0630	0.0790	0.0640
Tetrachloroethene	0.1100	0.1000	0.1100	0.0990	0.0640	0.0310	0.0880	0.0540	0.0440	0.0380	0.0320
Toluene	ND	ND	ND	ND	ND	0.0097	ND	ND	ND	ND	ND
o-Xylene	0.0056	0.0100	0.0250	0.0540	0.0500	0.0290	0.0950	0.0120	ND	ND	ND
1,3,5-Tmb*	ND	ND	0.0065	0.0120	ND	ND	0.0290	0.0100	ND	ND	ND
Propylene	ND	ND	ND	ND	ND	ND	0.0270	0.0180	ND	0.0210	ND
Acetone	ND	ND	ND	ND	ND	0.0330	ND	ND	ND	ND	ND
Hexane	0.0300	0.0640	ND	0.0360	0.3200	0.1200	0.4470	ND	0.5400	0.1900	0.0500
Cyclo-hexane	0.0360	0.0530	0.0370	0.0540	0.2400	0.0830	0.3400	0.0380	0.3100	0.1700	0.0860
Tetrahydrofuran	ND	ND	ND	ND	ND	ND	ND	ND	0.1500	ND	ND
Ethanol	ND	ND	ND	ND	ND	0.2600	ND	ND	ND	ND	ND
Heptane	ND	ND	ND	ND	ND	0.0500	ND	ND	ND	ND	ND

Notes to Table 3:

All concentrations presented as part per million volume (ppmv).
Analytes not detected during laboratory analysis are not presented.
Trimethylbenzene has been abbreviated to Tmb.
ND = Non Detect

Table 4: 1998 Percent Oxygen Monitoring Field Data

Measurements taken at 2.5 feet bgs

Monitoring Point	Week 3 10/5/98	Month1 10/14/98	Month 2 11/3/98
MP - 1	20.9	20.9	20.9
MP - 2	20.8	20.9	20.9
MP - 3	20.7	20.5	20.9
MP - 4	20.7	20.8	20.9
MP - 5	20.7	20.9	20.9
MP - 6	20.7	20.3	20.9
MP - 7	20.7	20.4	20.9
MP - 8	20.5	20.2	20.9
MP - 9	20.7	20.4	20.9
MP - 10	20.7	20.4	20.9
MP - 11	17.3	17.5	20.9
MP - 12	14.6	15.3	17.1
MP - 13	20.8	20.4	20.9
MP - 14	20.8	20.5	20.9
MP - 15	20.8	20.4	20.9
MP - 16	20.9	20.5	20.9
MP - 17	20.9	20.5	20.9
MP - 18	20.7	20.4	20.9
MP - 19	20.8	20.4	20.9
MP - 20	20.8	20.5	20.9

Measurements taken at 5 feet bgs

Monitoring Point	Week 3 10/5/98	Month1 10/14/98	Month 2 11/3/98
MP - 1	20.8	20.9	20.9
MP - 2	20.8	20.9	20.9
MP - 3	20.7	20.7	20.9
MP - 4	20.6	20.8	20.9
MP - 5	20.7	20.4	20.9
MP - 6	20.7	20.3	20.9
MP - 7	20.7	20.4	20.9
MP - 8	20.7	20.3	20.9
MP - 9	20.8	20.4	20.9
MP - 10	20.7	20.4	20.9
MP - 11	20.1	19.8	20.9
MP - 12	16.6	16.4	19.2
MP - 13	20.8	20.4	20.9
MP - 14	20.8	20.4	20.9
MP - 15	20.6	20.4	20.9
MP - 16	20.8	20.5	20.9
MP - 17	20.3	20.4	20.9
MP - 18	20.7	20.4	20.9
MP - 19	20.5	20.2	20.9
MP - 20	20.8	20.5	20.9

Table 5: 1999 Percent Oxygen Monitoring Field Data

Measurements taken at 2.5 feet bgs

Monitoring Point	Hour 4 5/3/99	Day5 5/8/99	Week 2 5/18/99	Week 3 5/26/99	Month1 6/7/99	Month 2 7/12/99	Month 3 8/11/99	Month 4 8/31/99	Month 5 10/26/99
MP - 1	20.9	20.4	20.9	20.9	20.9	20.7	10.8	20.9	20.9
MP - 2	20.9	20.4	20.2	20.9	20.9	20.2	20.7	20.9	20.9
MP - 3	20.9	20.4	20.9	20.9	20.9	20.9	20.9	20.9	20.9
MP - 4	F	20.5	20.9	20.9	20.9	20.9	20.9	20.9	F
MP - 5	F	20.5	20.8	20.9	20.9	20.9	20.9	20.9	20.9
MP - 6	F	20.5	20.6	20.9	20.9	20.9	20.7	20.9	20.9
MP - 7	20.8	20.5	20.7	20.9	20.9	20.9	20.9	20.9	F
MP - 8	19.5	20.5	20.9	20.9	20.9	20.9	20.9	20.9	20.8
MP - 9	20.8	20.2	20.9	20.9	20.8	20.8	20.9	20.9	20.5
MP - 10	17.7	20.2	20.9	20.9	20.7	20.7	20.9	20.8	F
MP - 11	16.6	19.8	20.2	19.8	19.6	19.5	20.3	20.2	20.9
MP - 12	13.7	18.7	18.3	18.4	18.5	18.7	18.1	18.7	19.7
MP - 13	20.5	20.5	20.9	20.9	20.5	20.1	20.9	20.9	20.9
MP - 14	20.9	20.4	20.9	20.9	20.9	20.9	20.9	20.9	20.9
MP - 15	20.7	20.3	20.9	20.8	20.8	20.8	20.9	20.8	20.8
MP - 16	20.3	20.2	20.9	20.9	20.9	20.9	20.9	20.9	20.9
MP - 17	F	20.2	20.9	20.9	20.9	20.9	20.9	20.9	20.9
MP - 18	18.4	20.2	20.9	20.9	20.9	20.9	20.9	20.9	20.9
MP - 19	20.2	20.1	20.9	20.9	20.9	20.9	20.9	20.9	20.9
MP - 20	17.7	20.2	20.9	20.9	20.9	20.9	20.9	20.9	20.9

Measurements taken at 5 feet bgs

Monitoring Point	Hour 4 5/3/99	Day5 5/8/99	Week 2 5/18/99	Week 3 5/26/99	Month1 6/7/99	Month 2 7/12/99	Month 3 8/11/99	Month 4 8/31/99	Month 5 10/26/99
MP - 1	20.9	20.5	20.9	20.9	20.5	20.5	20.8	20.9	20.9
MP - 2	20.9	20.4	19.9	20.9	20.1	20.0	20.5	20.9	20.9
MP - 3	20.8	20.4	20.9	20.9	20.9	20.9	20.9	20.9	20.9
MP - 4	20.9	20.5	20.9	20.9	20.9	20.9	20.9	20.9	20.9
MP - 5	20.9	20.5	20.8	20.9	20.9	20.9	20.9	20.9	20.9
MP - 6	20.9	20.5	20.6	20.9	20.8	20.8	20.4	20.9	20.9
MP - 7	20.8	20.5	20.6	20.9	20.9	20.9	20.8	20.9	F
MP - 8	20.3	20.5	20.7	20.9	20.9	20.9	20.9	20.9	20.9
MP - 9	20.8	20.2	20.9	20.9	20.9	20.9	20.9	20.9	F
MP - 10	20	20.3	20.9	20.9	20.8	20.8	20.9	20.9	F
MP - 11	20.5	20.4	20.9	20.8	20.7	20.6	20.9	20.8	20.9
MP - 12	11.7	19.4	19.8	18.9	18.3	18.3	19.3	19	19.8
MP - 13	19.7	20.4	20.9	20.9	20.8	20.8	20.8	20.7	20.9
MP - 14	20.9	20.4	20.9	20.9	20.9	20.9	20.9	20.9	20.9
MP - 15	20.7	20.3	20.9	20.9	20.8	20.8	20.9	20.9	F
MP - 16	20.5	20.2	20.9	20.9	20.9	20.9	20.9	20.9	20.9
MP - 17	F	19.9	19.8	20.5	20.9	20.9	20.9	20.8	20.9
MP - 18	F	2.2	20.9	20.9	20.9	20.9	20.9	20.9	20.9
MP - 19	17.1	19.9	20.9	20.9	20.9	20.9	20.9	20.9	20.9
MP - 20	F	F	20.9	20.9	20.9	20.9	20.9	20.9	20.9

F = Frozen Monitoring Point

Table 6: 1998 Vacuum Monitoring Field Data

Measurements taken at 2.5 feet bgs
Values measured in inches of water

Monitoring Point	Hour 4 9/15/98	Day 1 9/16/98	Day2 9/17/98	Day5 9/21/98	Week 2 9/28/98	Week 3 10/5/98	Month1 10/14/98	Month2 11/3/98	Normal Average
MP - 1	0.35	0.06	0.09	0.09	0.06	0.06	0.06	0.04	**0.07**
MP - 2	0.00	0.21	0.18	0.00	0.23	0.23	0.23	0.25	**0.18**
MP - 3	0.00	0.00	0.00	0.01	0.12	0.21	0.11	0.13	**0.06**
MP - 4	0.83	0.09	0.00	0.00	0.20	0.13	0.20	0.21	**0.14**
MP - 5	0.00	0.11	0.14	0.12	0.12	0.12	0.12	0.13	**0.12**
MP - 6	0.23	0.21	0.24	0.26	0.25	0.25	0.25	0.26	**0.25**
MP - 7	3.40	0.00	0.00	0.11	0.10	0.10	0.09	0.11	**0.09**
MP - 8	0.41	0.09	0.04	0.24	0.19	0.20	0.19	0.20	**0.19**
MP - 9	0.15	0.02	0.00	0.05	0.03	0.03	0.03	0.03	**0.03**
MP - 10	0.33	0.00	0.00	0.13	0.12	0.12	0.00	0.14	**0.09**
MP - 11	0.00	0.04	0.00	0.05	0.00	0.07	0.00	0.00	**0.02**
MP - 12	0.00	0.00	0.12	0.10	0.10	0.10	0.09	0.00	**0.07**
MP - 13	0.10	0.09	0.12	0.09	0.10	0.11	0.09	0.11	**0.10**
MP - 14	0.05	0.02	0.04	0.02	0.02	0.03	0.02	0.04	**0.03**
MP - 15	0.00	0.04	0.10	0.00	0.04	0.05	0.03	0.04	**0.03**
MP - 16	0.04	0.03	0.05	0.04	0.05	0.05	0.05	0.06	**0.05**
MP - 17	0.24	0.00	0.00	0.02	0.00	0.00	0.11	0.12	**0.04**
MP - 18	0.00	0.03	0.03	0.00	0.00	0.03	0.02	0.04	**0.02**
MP - 19	0.02	0.04	0.08	0.02	0.02	0.03	0.03	0.04	**0.03**
MP - 20	0.00	0.00	0.00	0.00	0.00	0.00	0.03	0.00	**0.00**
Average	**0.31**	**0.05**	**0.06**	**0.07**	**0.09**	**0.10**	**0.09**	**0.10**	**0.10**

Measurements taken at 5 feet bgs
Values measured in inches of water

Monitoring Point	Hour 4 9/15/98	Day 1 9/16/98	Day2 9/17/98	Day5 9/21/98	Week 2 9/28/98	Week 3 10/5/98	Month1 10/14/98	Month 2 11/3/98	Normal Average
MP - 1	1.40	0.00	0.01	0.00	0.00	0.06	0.00	0.03	**0.02**
MP - 2	0.20	0.20	0.20	0.23	0.21	0.21	0.21	0.23	**0.25**
MP - 3	0.15	0.13	0.18	0.15	0.14	0.19	0.13	0.13	**0.18**
MP - 4	0.21	0.18	0.17	0.00	0.20	0.14	0.20	0.21	**0.22**
MP - 5	0.11	0.11	0.12	0.12	0.12	0.00	0.12	0.13	**0.14**
MP - 6	0.21	0.21	0.22	0.24	0.23	0.23	0.23	0.24	**0.27**
MP - 7	0.11	0.10	0.11	0.10	0.10	0.10	0.10	0.11	**0.12**
MP - 8	0.03	0.00	0.00	0.00	0.00	0.00	0.19	0.20	**0.04**
MP - 9	0.00	0.04	0.03	0.00	0.00	0.00	0.00	0.00	**0.01**
MP - 10	0.11	0.11	0.10	0.06	0.05	0.06	0.00	0.00	**0.08**
MP - 11	0.04	0.04	0.08	0.05	0.05	0.09	0.05	0.06	**0.07**
MP - 12	0.11	0.10	0.12	0.10	0.10	0.10	0.10	0.11	**0.12**
MP - 13	0.10	0.00	0.09	0.09	0.10	0.11	0.04	0.11	**0.11**
MP - 14	0.05	0.00	0.04	0.04	0.03	0.04	0.03	0.05	**0.05**
MP - 15	0.00	0.04	0.00	0.03	0.00	0.00	0.00	0.04	**0.01**
MP - 16	0.18	0.00	0.00	0.00	0.00	0.06	0.04	0.00	**0.02**
MP - 17	0.11	0.04	0.11	0.10	0.00	0.11	0.11	0.12	**0.12**
MP - 18	0.02	0.04	0.01	0.02	0.02	0.02	0.02	0.04	**0.03**
MP - 19	0.03	0.05	0.11	0.02	0.02	0.06	0.03	0.04	**0.05**
MP - 20	0.09	0.03	0.00	0.00	0.00	0.04	0.03	0.07	**0.03**
Average	**0.16**	**0.07**	**0.09**	**0.07**	**0.07**	**0.08**	**0.08**	**0.10**	**0.10**

Table 7: 1999 Vacuum Monitoring Field Data

Measurements taken at 2.5 feet bgs
Values measured in inches of water

Monitoring Point	Hour 4 5/3/99	Day5 5/8/99	Week 2 5/18/99	Week 3 5/26/99	Month1 6/7/99	Month 2 7/12/99	Month 3 8/11/99	Month 4 8/31/99	Month 5 10/26/99	Average
MP - 1	0.10	0.09	0.11	0.09	0.09	0.09	0.08	0.11	0.09	**0.09**
MP - 2	0.10	0.26	0.30	0.22	0.21	0.24	0.22	0.25	0.23	**0.23**
MP - 3	0.14	0.14	0.17	0.16	0.15	0.14	0.14	0.13	0.11	**0.14**
MP - 4	F	0.22	0.24	0.23	0.22	0.20	0.20	0.21	0.19	**0.21**
MP - 5	F	0.00	0.00	0.00	0.12	0.15	0.16	0.00	0.10	**0.06**
MP - 6	F	0.28	0.28	0.31	0.30	0.28	0.26	0.53	0.28	**0.29**
MP - 7	0.00	0.00	0.14	0.00	0.00	0.00	0.11	0.10	F	**0.04**
MP - 8	0.22	0.21	0.22	0.23	0.21	0.21	0.20	0.22	0.21	**0.21**
MP - 9	0.00	0.01	0.00	0.00	0.02	0.07	0.06	0.00	0.04	**0.02**
MP - 10	0.15	0.00	0.20	0.18	0.16	0.15	0.13	0.16	F	**0.16**
MP - 11	0.02	0.01	0.06	0.00	0.00	0.08	0.00	0.00	0.00	**0.01**
MP - 12	0.00	0.12	0.14	0.11	0.11	0.12	0.11	0.11	0.11	**0.11**
MP - 13	0.10	0.11	0.14	0.12	0.11	0.12	0.10	0.03	0.11	**0.11**
MP - 14	0.05	0.07	0.05	0.06	0.07	0.06	0.05	0.03	0.06	**0.06**
MP - 15	0.07	0.06	0.16	0.07	0.07	0.00	0.07	0.00	0.08	**0.06**
MP - 16	0.08	0.09	0.10	0.09	0.08	0.08	0.07	0.07	0.08	**0.08**
MP - 17	F	0.02	0.18	0.15	0.15	0.14	0.13	0.14	0.14	**0.14**
MP - 18	0.06	0.05	0.10	0.08	0.07	0.05	0.06	0.00	0.06	**0.06**
MP - 19	0.06	0.00	0.05	0.07	0.07	0.07	0.05	0.05	0.06	**0.06**
MP - 20	0.08	0.08	0.00	0.00	0.05	0.08	0.07	0.07	0.06	**0.06**
Average	**0.08**	**0.09**	**0.13**	**0.11**	**0.11**	**0.12**	**0.11**	**0.11**	**0.11**	**0.11**

Measurements taken at 2.5 feet bgs
Values measured in inches of water

Monitoring Point	Hour 4 5/3/99	Day5 5/8/99	Week 2 5/18/99	Week 3 5/26/99	Month1 6/7/99	Month 2 7/12/99	Month 3 8/11/99	Month 4 8/31/99	Month 5 10/26/99	Average
MP - 1	0.02	0.09	0.11	0.10	0.10	0.09	0.07	0.10	0.09	**0.09**
MP - 2	0.00	0.24	0.25	0.21	0.23	0.22	0.21	0.06	0.11	**0.18**
MP - 3	0.14	0.16	0.17	0.15	0.16	0.15	0.16	0.15	0.10	**0.15**
MP - 4	0.00	0.21	0.32	0.29	0.22	0.20	0.00	0.21	0.00	**0.16**
MP - 5	0.00	0.00	0.00	0.00	0.00	0.00	0.14	0.00	0.10	**0.01**
MP - 6	0.00	0.26	0.28	0.29	0.24	0.25	0.24	0.25	0.17	**0.24**
MP - 7	0.00	0.00	0.00	0.14	0.12	0.13	0.12	0.10	F	**0.08**
MP - 8	0.24	0.21	0.22	0.21	0.21	0.21	0.20	0.22	0.20	**0.21**
MP - 9	0.00	0.00	0.00	0.00	0.04	0.06	0.06	0.00	0.01	**0.02**
MP - 10	0.30	0.14	0.06	0.08	0.12	0.15	0.13	0.17	F	**0.13**
MP - 11	0.00	0.01	0.02	0.09	0.09	0.08	0.00	0.00	0.00	**0.03**
MP - 12	0.12	0.11	0.03	0.11	0.11	0.12	0.11	0.10	0.10	**0.11**
MP - 13	0.10	0.11	0.13	0.11	0.12	0.11	0.11	0.11	0.11	**0.11**
MP - 14	0.06	0.06	0.09	0.08	0.08	0.07	0.06	0.05	0.07	**0.07**
MP - 15	0.00	0.06	0.14	0.07	0.07	0.07	0.06	0.05	F	**0.06**
MP - 16	0.07	0.08	0.10	0.10	0.09	0.07	0.07	0.00	0.08	**0.08**
MP - 17	0.00	0.91	0.34	0.13	0.13	0.13	0.12	0.14	0.17	**0.17**
MP - 18	0.00	0.09	0.09	0.09	0.05	0.06	0.06	0.00	0.06	**0.06**
MP - 19	0.06	0.00	0.07	0.10	0.09	0.07	0.05	0.07	0.07	**0.07**
MP - 20	0.00	0.00	0.12	0.11	0.11	0.08	0.07	0.07	0.07	**0.07**
Average	**0.06**	**0.14**	**0.13**	**0.12**	**0.12**	**0.12**	**0.10**	**0.09**	**0.09**	**0.11**

F = Frozen or Faulty Monitoring Point

Table 8: 1998 Soil Moisture Monitoring Field Data

Moisture Sensor	Pre Start 9/11/98	Hour 4 9/15/98	Day 1 9/16/98	Day2 9/17/98	Day5 9/21/98	Week 2 9/28/98	Week 3 10-5-98	Month1 10/14/98	Month 2 11/3/98
H1 (%)	96.2	95.5	95.5	95.5	95.4	95.2	95.1	94.6	94.6
H2 (%)	96.6	95.7	95.7	95.8	95.6	95.3	95.2	94.7	94.4
H3 (%)	96.2	95.8	95.8	95.8	95.4	95.4	95.3	94.8	94.6
H4 (%)	96.4	96.0	96.0	96.0	95.4	95.5	95.4	94.8	94.6
H5 (%)	96.2	95.6	95.6	95.4	95.1	95.1	95.0	94.5	94.3
H6 (%)	96.4	96.1	96.1	96.0	95.6	95.4	95.4	94.8	94.6
H7 (%)	96.2	95.8	95.8	95.6	95.2	95.1	95.1	94.5	94.6
Average	**96.3**	**95.8**	**95.8**	**95.7**	**95.4**	**95.3**	**95.2**	**94.7**	**94.5**

Soil Gradation	Moisture content at which irrigation is needed (% Saturation)
Fine Soil	60-80
Medium Soil	70-88
Coarse Soil	80-90

Average Soil Moisture % Saturation in the Treatment Area

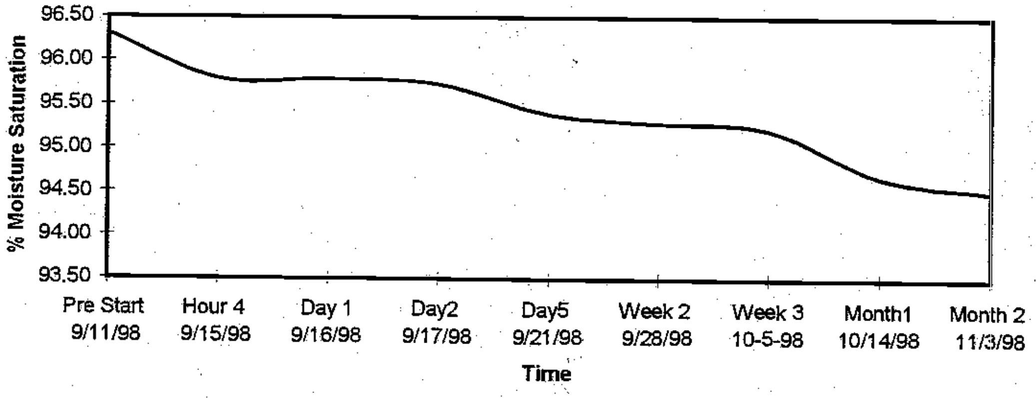


Table 9: 1999 Soil Moisture Monitoring Field Data

Moisture Sensor	Hour 4 5/3/99	Day1 5/4/99	Day5 5/8/99	Week 2 5/18/99	Week 3 5/26/99	Month1 6/7/99	Month 2 7/12/99	Month 3 8/11/99	Month 4 8/31/99	Month 5 10/26/99
H1 (%)	93.0	93.2	93.7	94.1	94.3	95.6	F	F	F	F
H2 (%)	F	F	F	F	F	F	F	F	F	F
H3 (%)	94.2	94.2	93.9	94.5	94.7	95.5	96.1	95.8	95.5	93.4
H4 (%)	94.0	94.1	93.9	93.9	F	F	F	F	F	F
H5 (%)	93.9	93.9	94.2	94.6	94.8	95.6	96.1	95.8	95.6	93.6
H6 (%)	95.2	95.2	94.8	95.2	95.2	96.0	96.5	96.3	95.9	93.8
H7 (%)	F	F	F	F	F	F	F	F	F	F
Average	**94.1**	**94.1**	**94.1**	**94.5**	**94.8**	**95.7**	**96.2**	**96.0**	**95.7**	**93.6**

F = Frozen or Faulty Moisture Indicator

Soil Gradation	Moisture content at which irrigation is needed (% Saturation)
Fine Soil	60-80
Medium Soil	70-88
Coarse Soil	80-90

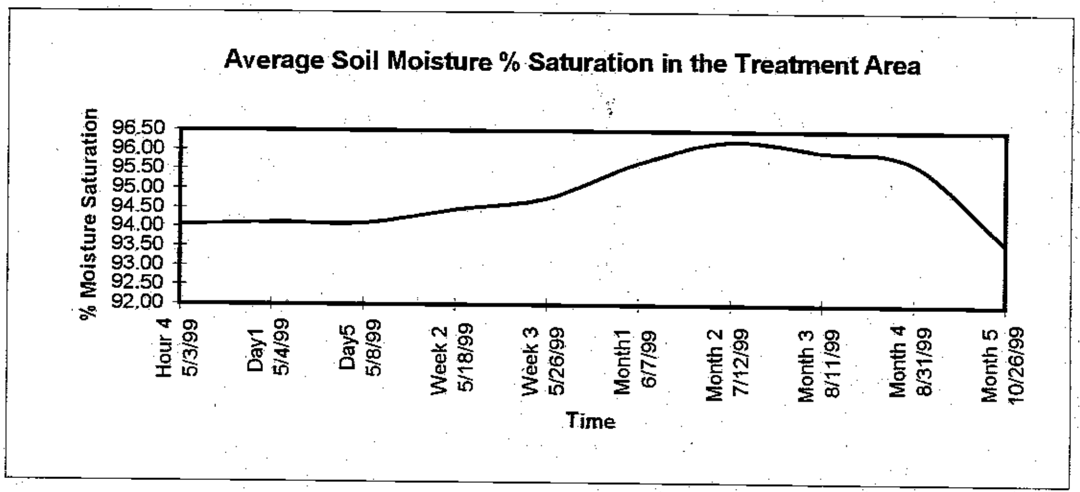

Average Soil Moisture % Saturation in the Treatment Area

Table 10: 1998 System Equipment Monitoring Data

	Hour 4 9/15/98	Day 1 9/16/98	Day2 9/17/98	Day5 9/21/98	Week 2 9/28/98	Week 3 10/5/98	Month1 10/14/98	Month 2 11/3/98	Average
Line 1 Flow (cfm)	80	75	80	80	85	85	85	85	82
Line 2 Flow (cfm)	78	75	75	80	85	85	85	88	81
Line 3 Flow (cfm)	-	-	-	-	110	105	95	85	99
Line 1 Vacuum (inches H_2O)	0	0	0	0	3	3	2.2	1.2	1
Line 2 Vacuum (inches H_2O)	0	0	0	0	2	2	2	1	1
Line 3 Vacuum (inches H_2O)	0	0	0	0	6	7	6.1	3.2	3
Vacuum moist.sep.(inches H_2O)	0	0.8	0.8	1	10	10	10.3	5.8	5
LEL at Exhaust (%)	1	1	0	0	0	1	1	1	1
LEL at Conex (%)	-3	-2	-3	-3	-3	4	4	-5	-1
Temp. In Flow (^oF)	53	50	54	53	51	73	50	47	54
Temp. Out Flow (^oF)	78	74	80	79	76	77	70	68	75
SA-1 PID (ppm)	43	29.4	34	25.5	23	28.1	18	-	29

- Indicates no readings due to faulty instrumentation

Sum of flow for lines 1, 2 and 3 is 262 cfm, with 15% dilution air, the flow at the sampling point is 301 cfm.

Table 11: 1999 System Equipment Monitoring Data

	Hour 4 5/3/99	Hour 8 5/3/99	Day1 5/4/99	Day5 5/8/99	Week 2 5/18/99	Week 3 5/26/99	Month1 6/7/99	Month 2 7/12/99	Month 3 8/11/99	Month 4 8/31/99	Month 5 10/26/99	Average
Line 1 Flow (cfm)	75	75	75	80	80	75	75	75	75	75	70	75
Line 2 Flow (cfm)	90	90	90	90	90	82	80	80	82	80	83	85
Line 3 Flow (cfm)	85	85	85	85	95	92	90	95	100	100	95	92
Line 1 Vacuum (inches H_2O)	1.5	1.2	1.2	1.2	1.2	1.1	1	1	1	3	1.1	1
Line 2 Vacuum (inches H_2O)	1	1.1	1.1	1.1	1.1	1.1	1	1	1	2	1	1
Line 3 Vacuum (inches H_2O)	3.1	3.2	3.2	3.1	3.2	3.1	3	3	3	7	3.2	3
Vacuum moist.sep.(inches H_2O)	26	22.9	26	26	26	23	23	23	27	23	27	25
LEL at Exhaust (%)	2	2	-5	-5	-	-	-	4	5	7	-	1
LEL at Conex (%)	-4	-4	1	1	-	-	-	-4	-3	-3	-	-2
Temp. In Flow (°F)	40	40	40	42	46	49	50	58	56	58	42	47
Temp. Out Flow (°F)	68	68	66	68	70	71	76	81	81	80	66	72
SA-1 PID (ppm)	4.6	7.2	8.2	-	13	-	-	-	6.4	5.1	2.8	7

- Indicates no readings due to faulty instrumentation

Sum of flow for lines 1, 2 and 3 is 252 cfm, with 20% dilution air, the flow at the sampling point is 290 cfm.

APPENDIX A

U.S. ARMY CORPS OF ENGINEERS REPORT ON THE RUFF ROAD FIRE TRAINING AREA
FORT RICHARDSON, ALASKA

RUFF ROAD FIRE TRAINING AREA

FORT RICHARDSON, ALASKA

NOVEMBER 1999

PREPARED BY THE

ALASKA DISTRICT U.S. ARMY CORPS OF ENGINEERS

MATERIALS SECTION

ENGINEERING SERVICES BRANCH

MARCH 2000

TABLE OF CONTENTS

1 Executive Summary

This report presents the chemical results obtained during the subsurface chemical investigation for the Ruff Road fire training area. The investigation was requested by Programs and Project Management Division, Military Branch of the Alaska District, U.S. Army Corps of Engineers (USACE), and performed in November 1999, by the Engineering Services Branch of the Alaska District, USACE.

Twenty borings were drilled, in a grid pattern covering the Ruff Road fire training area bioremediation site, to a depth of approximately 10 feet. Soil samples were collected and screened for fuel contaminants near the soil surface, at approximately 5 feet, and approximately 10 feet. All samples collected at the site were submitted for laboratory analysis and tested for gasoline range organics (GRO), diesel range organics (DRO), residual range organics (RRO), benzene, toluene, ethylbenzene, xylenes (BTEX). All samples were field screened with a photoionization detector (PID) and visual/olfactory inspection of the sample. Samples that exhibited signs of contamination were also tested for polyaromatic hydrocarbons (PAHs).

At the time this report was drafted, a decision had not been made as to what cleanup levels will be used for the site. Since the cleanup levels are not known, this report compared the chemical results of the sampling event to the most conservative 18 AAC 75 regulations considered to apply, which were ADEC Method One (Category B), and Method Two (Migration to Groundwater in the Under 40 Inch Zone). GRO, DRO, and benzene were detected at the project site at concentrations exceeding these cleanup levels. If these cleanup levels are used for this project, a large volume of soil will require additional treatment. Alternatively, if it is determined that migration to groundwater is not a complete pathway to any potential receptors, Method Two, Migration to Groundwater cleanup levels may not be applied to the site. If it is determined that Method Two, Migration to Groundwater does not apply, and Method Two, Inhalation or Ingestion cleanup levels are used, the site would be eligible for closure, as no contaminant concentrations reported during this investigation exceeded Inhalation or Ingestion cleanup levels.

2 Objective

The purpose of the chemical investigation was to determine the current extent of petroleum, oil, and lubricant (POL) contamination at the Ruff Road fire training area bioremediation project. The information is to be used to determine whether the bioremediation project has reduced POL contamination at the site to the point that the site can be closed. If there is still contamination above regulatory limits, then these chemical results will be used to determine whether the bioremediation system should be operated for another season, or if some other action should be taken, such as excavation and thermal treatment of the remaining contaminated soil. At the time this report was drafted, a decision had not been made as to what the cleanup levels should be used. Since the cleanup levels are not known, this report will compare the chemical results of the sampling event to the most conservative 18 AAC 75 regulations that could apply.

3 Site Background

3.1 Location

The project area is on Fort Richardson, Alaska. Fort Richardson encompasses approximately 60,000 acres (94 square miles). It is in south-central Alaska, Northeast of Anchorage. The post is bounded on the east by the Chugach Mountains (Chugach State Park), on the north by the Knik Arm of Cook Inlet, on the west by Elmendorf Air Force Base and the city of Anchorage, and on the south by privately owned lands. The Ruff Road fire training area (RRFTA) is located east of Bryant Airfield near the Glenn Highway (see Figures 1 and 2).

3.2 Site History

The site consists of an area used for fire fighting exercises from the 1940's to 1980. The exercises involved applying fuels and other waste combustible liquids to an unlined earthen pit, igniting the fuels, and extinguishing the resulting fires with water. The fire training area began operations during initial establishment of the Post approximately 1940, and it was used until 1980 to conduct exercises for training fire department and rescue crews. The fire training exercises were conducted by saturating unlined excavations with water, pumping fuel into the excavation, and igniting the fuel. Petroleum fuel products burned during the fire training exercises included jet fuel, waste oil, diesel, brake fluid, and solvents. Based on the assumption that 1,500 to 2,300 gallons of combustible material were burned annually at this site, approximately 85,500 gallons of wastes were burned and disposed of at the fire training area. The former fire training area has been estimated to be an area of petroleum-stained soil approximately 50 feet in diameter. In 1991, the original road in the area was demolished and the present Ruff Road was constructed. The charred debris associated with the fire training area was removed at that time. In 1994, the fire training area was filled with approximately 18 inches of soil and regraded. During the winter of 1994, the National Guard parked vehicles at the present site. No visual evidence of the fire training area remained at that time.

The treatment system demonstration project was implemented in the early summer of 1998. Its purpose was to remove volatile fuel and organic compounds through enhanced biological

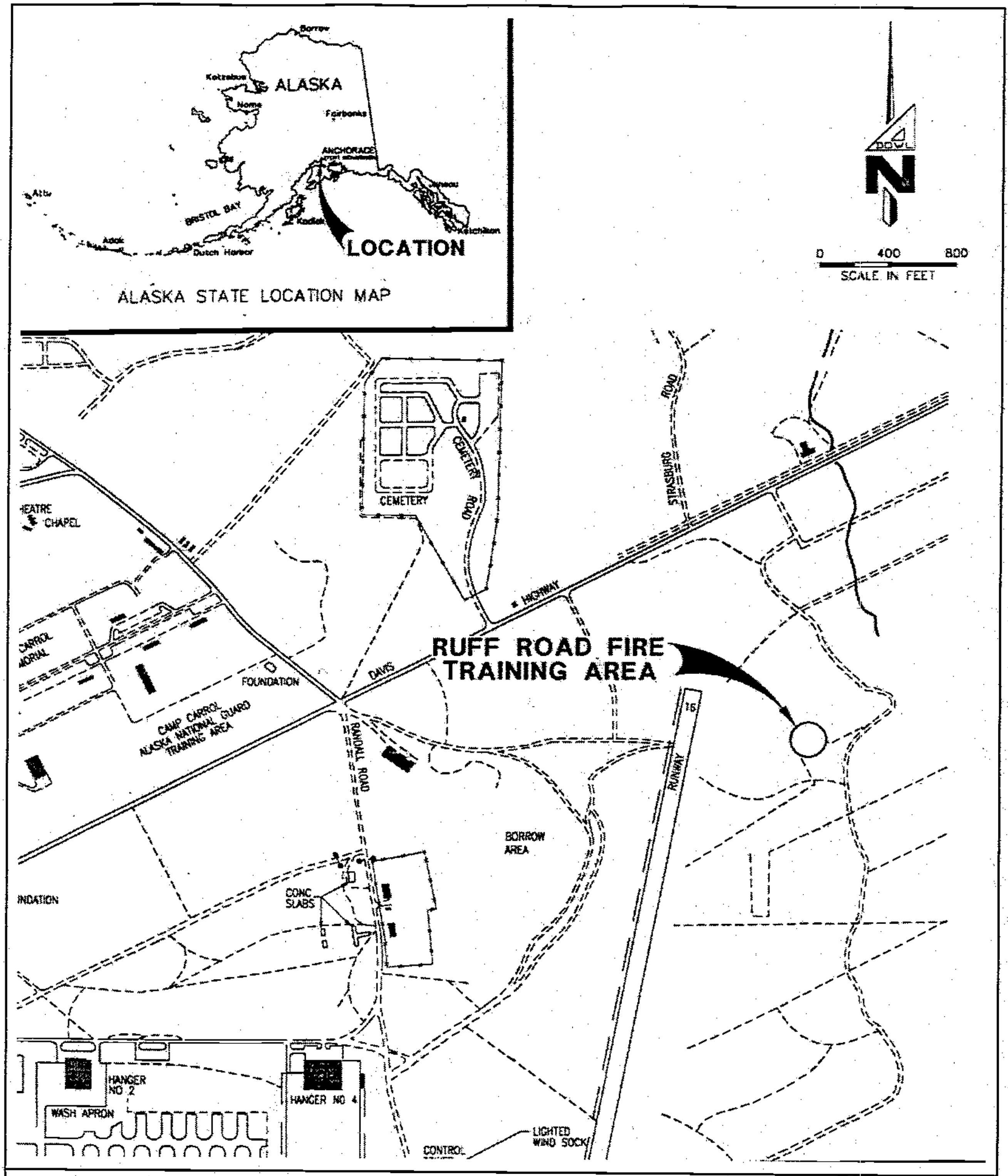


Figure 1
Location and Vicinity Map

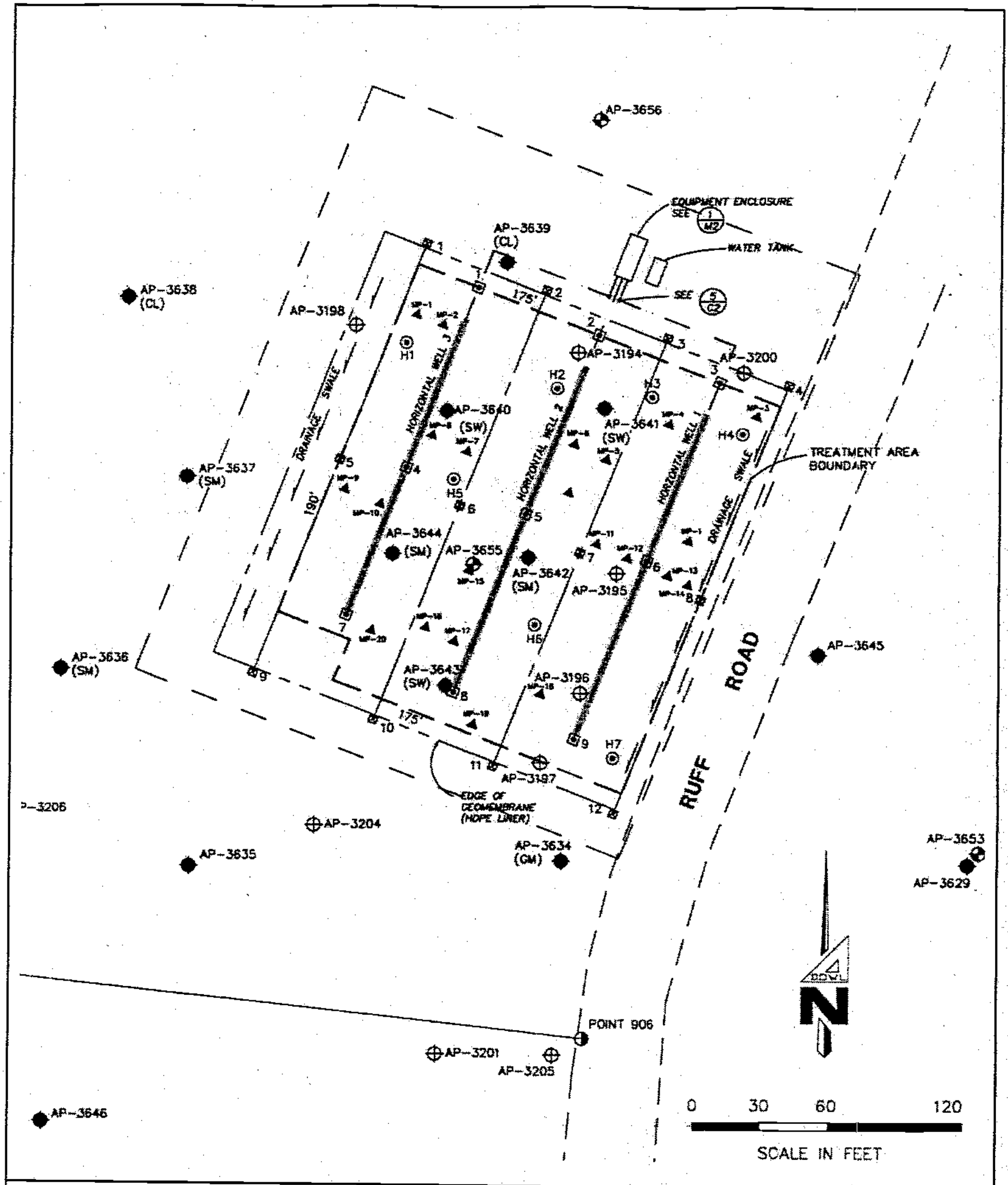


Figure 2
Site Map

degradation while extracting air from the near surface soils of the treatment area. The treatment area covers a rectangular area of 175 by 190 feet (approximately 3/4 acre). Three horizontal wells were installed to a depth of about 5 feet below ground surface (bgs). The 3 wells are spaced at about 50 feet on center. Four passive air infiltration galleries run parallel to and on both sides of the 3 horizontal wells. In addition, 7 moisture sensors and 40 monitoring points were installed in the treatment area. After the installation of the horizontal wells, air infiltration galleries, moisture sensors, and monitoring points, the area was covered by a 30-mil geomembrane, which was overlain by 1 foot of silty sand to protect the liner. This was done to prevent disruption of the system by uncontrolled air infiltration from the surface. Figure 2 shows some of these various components at the project site. System startup was performed on 3 May 1999. The system operated continuously until 26 October 1999, at which time the system was shut down for the season and winterized.

3.3 General Geology

Fort Richardson lies within the upper Cook Inlet region, an area influenced by intense, ongoing tectonic activity, and by the interplay of glacial events and sea level changes during the Pleistocene. In general, the geology at Fort Richadson consists primarily of glacial deposits complicated by marine and alluvial sediments. Together, these deposits form a 300 to 400-foot layer over bedrock consisting of densely consolidated siltstone, sandstone, coal, and shale.

The project site is near the southern margin of the Elmendorf Moraine, a terminal moraine running northeast to southwest across the base. This feature consists of unconsolidated glacial till with poorly sorted boulders, gravel, sand and silt. South of the moraine are alluvial and glacial deposits of the outwash plain.

3.4 Surface and Ground Water

The primary surface drainage features of Fort Richardson are Eagle River and Ship Creek, which originate in the Chugach Mountains and flow westerly across the installation into Knik Arm of Cook Inlet. The project site is in an area used for gravel excavation, and is surrounded by relatively undisturbed forested areas. There is a small pond approximately 600 feet from the southwest corner of the former fire training area. Ground water occurs from 140 to 153 feet bgs and within the unconfined sandy gravel aquifer and flows in a westerly direction.

4 Summary of Field Work

Sampling activities began on 09 November 1999, and ended on 17 November 1999. All fieldwork was conducted by CEPOA-EN-ES personnel including Bill Tester (driller), Larry McCain (driller assistant), James Robsen (geotechnical engineer), and Doug Deters (chemist).

Twenty borings were drilled to a depth of approximately 10 feet. These borings are arranged in a grid pattern that covers the project area (Figure 3). The drilling was done with a mobile drill rig, mounted on an all-terrain vehicle. Hollow stem augers (8 inch), A-rod, 300 pound slide hammer and a 3 inch by 2 foot steel split spoon were used for collecting soil. Samples near the surface were sampled directly from the sidewalls of the borings at a point below the existing geomembrane (approximately 2 feet). Subsurface sampling was performed using hollow stem augers and a split spoon. Subsurface soil samples were collected with a split spoon at approximately 5 and 10 feet bgs. Upon retrieval from the boring, a preliminary PID reading was taken from the end of the split spoon. All samples collected at the site were submitted for laboratory analysis and tested for gasoline range organics (GRO), diesel range organics (DRO), residual range organics (RRO), benzene, toluene, ethylbenzene, and xylenes (BTEX). Samples that exhibited signs of contamination were also tested for polyaromatic hydrocarbons (PAHs). Samples were analyzed by the following methods:

GRO by State of Alaska Method AK101
DRO by State of Alaska Method AK102
RRO by State of Alaska Method AK103
BTEX by EPA Method 8021B (Modified)
PAHs by EPA Method 8270C

Soil samples were collected immediately after opening the split spoon. A stainless steel spoon was used to transfer soil from the split spoon into the appropriate containers provided by the laboratory. A new, clean, spoon was used for each sample. The samples were collected in the following order: GRO/BTEX, PAHs, DRO, RRO.

Field notes and observations are summarized in the field-log summary contained in Appendix A to this report. Additional information and observations associated with the borings is provided in the boring logs contained in Appendix B.

5 Analytical Results

Primary samples were packaged and shipped to Sound Analytical Services (SAS) in Tacoma Washington for chemical analyses. Quality assurance duplicate samples were sent to Columbia Analytical Services (CAS) and analyzed by their Anchorage (Alaska) and Kelso (Washington) laboratories. Complete data packages are on file at the Alaska District U.S. Army Corps of Engineers.

5.1 Chemical Results

The ADEC regulatory cleanup levels that will be used for site closure have not yet been determined. This report will compare the chemical results of this project against the most conservative ADEC 18 AAC 75 regulatory limits that are thought might realistically apply to the site. For GRO, DRO, and RRO, the results are compared against 18 AAC 75 Method One, Category B regulatory limits. For BTEX and PAHs, the results are compared against 18 AAC 75 Method Two, Soil Cleanup Levels Table (Migration to Groundwater in the Under 40 Inch Zone). Table 1 summarizes the Maximum Contaminant Level (MCL) that was used for each analyte and the regulation that was used to derive that value.

TABLE 1: APPLICABLE MCLs

Contaminant of Concern	Maximum Contaminant Level	Reference
GRO	100 mg/kg	18 AAC 75 Method One - Petroleum Hydrocarbon Soil Levels in Non-Arctic Zones (Category B)
DRO	200 mg/kg	
RRO	2000 mg/kg	
PAHs	See Table in Regulations for Individual Values	18 AAC 75 Method Two - Soil Cleanup Levels Table (Migration to Groundwater in the Under 40 Inch Zone)
Benzene	0.02 mg/kg	
Toluene	5.4 mg/kg	
Ethylbenzene	5.5 mg/kg	
Total Xylenes	78 mg/kg	

Contaminants exceeding MCLs are identified in the following sections and included in Appendix D. In addition, Figure 4 shows the GRO, DRO, RRO, and BTEX sampling results in relation to where the samples were collected at the project site. Values that exceed MCLs are identified in bold type in the figure.

5.1.1 GRO

GRO was detected in 51 of 59 samples analyzed (60 samples were collected, but one sample container broke before shipment). However, GRO results for thirteen samples (99RRFS02SL through 99RRFS15SL) are attributed to method blank contamination, and should not be considered present in the sample. GRO exceeding the regulatory level of 100 mg/kg was detected in 2 samples from AP-4076, at approximately 370 mg/kg and 1500 mg/kg. GRO was detected below the regulatory level in 49 samples, at estimated concentrations ranging from 0.7 mg/kg to 60 mg/kg. Method reporting limits (MRLs) for GRO are all well below the ADEC regulatory level used in this report. The majority of the GRO data for this project has been qualified as estimated by the chemical data quality review, but is considered usable for this report. Section 5.2 explains in further detail why the data was qualified.

5.1.2 DRO

DRO was detected in 25 of 60 samples. DRO exceeding the regulatory level of 200 mg/kg was detected in 7 samples from 4 boreholes (AP-4066, AP-4076, AP-4077, AP-4078), at estimated concentrations of 260 mg/kg to 6100 mg/kg. DRO was detected below the regulatory level in 18 samples, at estimated concentrations ranging from 2 mg/kg to 140 mg/kg. MRLs for DRO are all well below the ADEC regulatory level used in this report. The majority of the data has been qualified as estimated by the chemical data quality review, but is considered usable for the purpose of this report. Section 5.2 explains in further detail why the data was qualified.

5.1.3 RRO

RRO was detected in 29 of 60 samples. Concentrations ranged from an estimated 20 mg/kg to an estimated 720 mg/kg. All samples are well below the regulatory level of 2000 mg/kg. MRLs for RRO are all well below the ADEC regulatory level used in this report. The majority of the data has been qualified as estimated by the chemical data quality review, but is considered usable for the purpose of this report. Section 5.2 explains in further detail why the data was qualified.

5.1.4 BTEX

Benzene was detected in 6 of 59 samples (60 samples were collected, but one sample container broke before shipment). Of these 6 detected, 5 exceeded the regulatory level of 0.02 mg/kg, with concentrations ranging from an estimated 0.037 mg/kg to an estimated 1.4 mg/kg. MRLs for 55 of 59 benzene samples were higher than the regulatory level used in this report, however, method detection limits (MDL) were typically tenfold lower than the regulatory level. If benzene was detected below the MRL and above the MDL, it would have been reported by the lab as an estimated value. Toluene, ethylbenzene, and/or xylenes were detected in 24 of 59 samples, but all were at concentrations lower than regulatory levels. MRLs for toluene, ethylbenzene, and xylenes were all well below the regulatory level used in this report. All BTEX data has been qualified as estimated by the chemical data quality review, but is considered usable for the purpose of this report. Section 5.2 explains in further detail why the data was qualified.

5.1.5 PAHs

Soil samples that exhibited the greatest signs of contamination (during collection of the samples) were tested for PAHs. Low levels of various PAHs were detected in 3 samples from 2 boreholes (AP-4076 and AP-4077). All PAHs were well below regulatory levels used for this project. The highest detected values were 6.9 mg/kg for 2-methylnaphthalene and 3.2 mg/kg for naphthalene (both from AP-4076, 9.5 feet bgs). MRLs for all PAHs are all well below the ADEC regulatory levels used in this report. All PAH data has been qualified as estimated by the chemical data quality review, but is considered usable for the purpose of this report. Section 5.2 explains in further detail why the data was qualified. Complete qualified PAH results are provided in Appendix D.

5.2 Quality Assurance and Quality Control

5.2.1 Data Quality Review

Laboratory results were sent to Ethix, in Modesto California, for independent chemical data quality review. The review included evaluation of sample collection, holding times, field, laboratory, and method blanks (to assess cross-contamination), sample duplicates (to assess precision), laboratory control samples (to assess accuracy) and matrix spike/matrix spike duplicate and surrogate recoveries (to assess matrix effect). The Chemical Data Quality Review Report is summarized in Section 5.2, and included as Appendix C to this report. The complete set of reviewed analytical results is included as Appendix D to this report.

5.2.1.1 Overall Assessment of GRO Data

Due to no surrogate recovery, the gasoline range organics result for sample 99RRFS57SL was rejected. Due to poor laboratory control sample accuracy, the gasoline range organics result for sample 99RRFS01SL was rejected. Rejected data are unusable for any purpose. Due to method blank contamination, gasoline range organics results for thirteen samples were qualified as nondetected. Due to temperature exceedance, GRO results for sixty-eight samples were qualified as estimated. State of Alaska GRO soil method states that the sample temperature should be kept below 25°C (not 4°C +/-2°C) and therefore should not have been flagged by the data reviewer. Due to poor surrogate recovery, gasoline range organics results for ten samples were qualified as estimated. Due to poor laboratory control sample accuracy, results for thirteen samples were qualified as estimated. Due to calibration range exceedance, the gasoline range organics result for one sample was qualified as estimated. Estimated data are useable for limited purposes. Sample 99RRFS61SL was reanalyzed at a dilution, due to calibration range exceedance. Results from the diluted analysis should be used as the final validated result.

5.2.1.2 Overall Assessment of DRO Data

Due to temperature exceedance, diesel range organics results for sixty-six samples were qualified as estimated. Estimated data are useable for project purposes.

5.2.1.3 Overall Assessment of RRO Data

Due to temperature exceedance, residual range organics results for sixty-six samples were qualified as estimated. Due to no surrogate recovery, detected results for two samples were qualified as estimated. Estimated data are useable for project purposes.

5.2.1.4 Overall Assessment of BTEX Data

Due to no surrogate recovery, BTEX results for sample 99RRFS60SL were rejected. Rejected data are unusable for any purpose. Due to temperature exceedance, BTEX results for sixty-eight samples were qualified as estimated. Due to holding time exceedance, BTEX results for forty-six samples were qualified as estimated. Of these 46 samples, 43 exceeded the holding time by one day, and 3 exceeded the holding time by 3 days. These samples should be considered biased low, but usable for the purposes of this report. Due to poor MS/MSD precision, toluene for one sample was qualified as estimated. Samples 99RRFS61SL and 99RRFS62SL were reanalyzed at a dilution due to o-xylene exceeding the calibration range. Results for all other compounds should be used from the original and the diluted analysis should be used as the final validated results for o-xylene.

5.2.1.5 Overall Assessment of PAHs Data

Due to method blank contamination, the dibenzo(a,h)anthracene result for one sample was qualified as nondetected. Due to temperature exceedance, semivolatiles organics results for nine samples were qualified as estimated. Estimated data are useable for limited purposes.

5.2.1.6 Overall Assessment of Cooler Temperatures

Samples 99RRFS01 through 99RRFS25 to SAS (primary laboratory) were flagged as estimated due to temperature blanks arriving at their lab at 0°C. The cooler temperature was measured to be 4°C. Data flagged by data quality review as estimated due to temperature range exceedance should be considered usable for this report, as the cooler temperature was within the acceptable temperature range of 4°C±2°C.

Samples 99RRFS26 through 99RRFS37 to SAS were flagged as estimated due to temperature blanks arriving at their lab at 0°C. The cooler temperature was measured to be 2°C. Data flagged by data quality review as estimated due to temperature range exceedance should be considered usable for this report, as the cooler temperature was within the acceptable temperature range of 4°C±2°C.

Samples 99RRFS38 through 99RRFS56 to SAS were flagged as estimated due to temperature blanks arriving at their lab at 1°C. The cooler temperature was measured to be 2°C. Data flagged by data quality review as estimated due to temperature range exceedance should be considered usable for this report, as the cooler temperature was within the acceptable temperature range of 4°C±2°C.

Samples 99RRFS57 through 99RRFS73 to SAS were flagged as estimated due to temperature blanks arriving at their lab at 1°C. The cooler temperature was measured to be 1°C. Although the cooler temperature is slightly below the acceptable temperature range of 4°C±2°C, none of the samples was noted to be frozen, therefore data flagged by data quality review as estimated due to temperature range exceedance will be considered usable for this report.

5.2.2 Duplicate Samples

Duplicate samples submitted for analysis by the Quality Assurance (QA) laboratory and blind duplicate samples submitted to the primary laboratory were collected for 6 of the 60 primary samples analyzed. The intra and inter laboratory data for a sample must be within a factor of five for results to be considered in agreement. The primary and QA laboratories MDL/MRL must be within a factor of 10 to be considered comparable. Results reported by the primary and referee laboratories were in agreement except the following: The primary/QC/QA duplicate samples for RRO at AP-4072 (4.5 feet bgs) differed by over a factor of 5, and are considered in major disagreement. The primary/QC/QA duplicate samples for DRO at AP-4074 (9.5 feet bgs) differed by over a factor of 10, and are considered in major disagreement. The primary/QC/QA duplicate samples for the polyaromatic hydrocarbon anthracene at AP-4076 (4.5 feet bgs) differed by over a factor of 5, and are considered in major disagreement. The primary/QC/QA duplicate samples for benzene at AP-4076 (9.5 feet bgs) differed by over a factor of 10, and are considered in major disagreement.

6 Conclusion

In order to approximate the extents of the current contamination at the project site, an estimate needs to be made as to how far away from a contaminated borehole should the soils still be assumed contaminated. We can reasonably assume that the soil surrounding a POL contaminated borehole will have similar POL concentrations to the samples collected from the boreholes, and likewise, the soil surrounding a 'clean' borehole should also be 'clean'. Figures containing isopack lines have been generated to illustrate the probable areas of contamination. These rough estimates of the contamination exceeding ADEC Method One, Category B (for GRO and DRO), and ADEC Method Two, Migration to Groundwater in the Under 40 Inch Zone (for benzene), , have been plotted on Figures 5 - 14. If these cleanup levels are used for this project, then there is a large volume of soil that would still need to be treated. Another option would be to demonstrate that migration to groundwater is not a pathway to any potential receptor, and therefore not be required to use Method Two, Migration to Groundwater cleanup levels. In Dowl/Ogden's Final Work Plan, they state:

> "Contaminants were detected in surface and subsurface soil. Off-site contaminant transport through surface runoff and windblown particulates is possible, but not expected to contribute significantly to contaminant transport from the site. The absence of site-related contaminants in the surface water and sediment samples collected at the nearby ponds substantiates the conclusion that surface water runoff and particulate transport are not migration pathways of concern at the Fire Training Area. The RI conducted transport modeling of petroleum constituents in the subsurface soil. The model predicted that petroleum contaminants will migrate approximately 10 feet vertically from their present location over a 90-year period and that groundwater would not likely be impacted. Based on this result and the absence of contaminants in groundwater samples collected at the site, groundwater is not a contaminant migration pathway."

If it is agreed that Method Two, Migration to Groundwater does not apply, and Method Two, Inhalation or Ingestion cleanup levels were to be used instead, then the site would be eligible for closure, as no contaminants detected at the project site exceeded these cleanup levels.

7 References

18 AAC 75 Oil and Hazardous Substances Pollution Control Regulations, effective October 1, 1999.

DOWL/Ogden Joint Venture. "Draft 1999 System Monitoring Report, Treatment System Demonstrations and Design Verification Study, Ruff and Roosevelt Road, Fort Richardson, Alaska". Prepared for Alaska District Corps of Engineers. January 2000.

DOWL/Ogden Joint Venture. "Final Work Plan, Treatment System Demonstrations and Design Verification Study, Ruff and Roosevelt Road, Fort Richardson, Alaska". Prepared for Alaska District Corps of Engineers. March 1998.

U.S. Air Force, "Elmendorf AFB OU6 Remedial Investigation/Feasibility Study (Final)." January 1996.

APPENDIX B

FINAL WORK PLAN FOR THE TREATMENT SYSTEM DEMONSTRATION AND DESIGN VERIFICATION STUDY RUFF AND ROOSEVELT ROAD FORT RICHARDSON, ALASKA

FINAL WORK PLAN

TREATMENT SYSTEMS DEMONSTRATIONS AND DESIGN VERIFICATION STUDY
RUFF AND ROOSEVELT ROAD, FT. RICHARDSON, ALASKA

DACA85-95-D-0008
DELIVERY ORDER No. 0026

Prepared for:

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TABLE OF CONTENTS

LIST OF TABLES

APPENDICES

LIST OF ACRONYMS AND ABBREVIATIONS

ADCOE	U.S. Army Corps of Engineers (Alaska District)
ADEC	Alaska Department of Environmental Conservation
ADSCPT	Advanced Drainage System Corrugated Plastic Tubing
bgs	Below Ground Surface
BTEX	Benzene, Toluene, Ethylbenzene, Xylene
CERCLA	Comprehensive Environmental Response Compensation & Liability Act
CO2	carbon dioxide
COR	Contracting Officer Representative
DoD	Department of Defense
DOT	Department of Transportation
DPW	Department of Public Works
DRO	Diesel Range Organics
cfm	cubic feet per minute
EPA	Environmental Protection Agency
FFA	Federal Facility Agreement
GRO	Gasoline Range Organics
IDW	Investigation Derived Waste
LCS	Laboratory Control Samples
mg/kg	milligrams per kilogram
02	oxygen
PID	Photoionization Detector
QA	Quality Assurance
QAPP	Quality Assurance Project Plan
QC	Quality Control
RRFTA	Ruff Road Fire Training Area
RRTSL	Roosevelt Road Transmitter Site (Leach Field)
SOP	Standard Operating Procedures
TPH	Total Petroleum Hydrocarbon
ug/l	micrograms per liter
USCS	Unified Soil Classification System
USDOA	United States Department of the Army

1.0 INTRODUCTION

1.1 Authorization and Objective

This Work Plan describes the activities to be performed during two separate treatment system demonstrations and design verification studies to be performed at the Ruff Road Fire Training Area (RRFTA) and Roosevelt Road Transmitter Site Leachfield (RRTSL) at Fort Richardson, Alaska. The studies consist of design, installation, operation, and monitoring of a three-fourth acre bio-venting system at the Ruff Road site and the plugging of buried lines and solidification of cesspool contents at the Roosevelt Road site.

This Work Plan was prepared as authorized under Contract No. DACA85-95-D-0008, Delivery Order No. 0026 and addresses work required to design, install, operate, and monitor the bio-venting system at RRFTA and plug the buried lines and solidify cesspool contents at RRTSL. This work is further described in the Scope of Work which is included as Appendix D and the design drawings which are included as Appendix A.

All work under this contract shall comply with the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) and the Federal Facility Agreement (FFA) entered into in December of 1994 by the Army, the United States Environmental Protection Agency (EPA), and the Alaska Department of Environmental Conservation(ADEC).

1.2 Location

Fort Richardson, established in 1940 as a military staging and supply center during World War II, occupies approximately 56,000 acres north of the City of Anchorage. The Fort is bounded to the west by Elmendorf Air Force Base, to the east by Chugach State Park, and to the north and south by the Municipality of Anchorage.

Ruff Road Fire Training Area (RRFTA)

RRFTA is located east of Bryant Airfield near the Glenn Highway. (See Appendix A, Sheet C-1) The site consists of an area used for fire fighting exercises from the 1940's to 1980. The exercises involved applying fuels and other waste combustible liquids to an unlined earthen pit, igniting the fuels, and extinguishing the resulting fires with water.

The Fire Training Area began operations during the initial establishment of the Post in approximately 1940, and it was used until 1980 to conduct exercises for training fire department and rescue crews. The fire training exercises were conducted by saturating unlined excavations with water, pumping fuel into the excavation, and igniting the fuel. Petroleum fuel products burned during the fire training exercises included jet fuel, waste oil, diesel, brake fluid, and solvents. Based on the assumption that 1,500 to 2,300 gallons of combustible material were burned annually at this site, approximately 85,500 gallons of wastes were burned and disposed of at the Fire Training Area.

The former Fire Training Area has been estimated to be an area of petroleum-stained soil approximately 50 feet in diameter. In 1991, the original road in the area was demolished and the present Ruff Road was constructed. The charred debris associated with the fire training area was removed at that time. In 1994, the Fire Training Area was filled with approximately 18 inches of soil and regraded. During the winter of 1994, the National Guard parked vehicles at the present site. At present, no visual evidence of the fire training area remains.

Roosevelt Road Transmitter Site Leach Field (RRTSL)

RRTSL is located north of the main Fort area near Otter Lake. (See Appendix A, Sheet C-1) The site includes an underground communications bunker used during the 1950's and 1960's. The sanitary facilities within the bunker are connected to a septic leachfield.

The Transmitter Site was utilized from World War II through the end of the Korean War as part of the Alaska communications system, established to provide command and control communications in the event of enemy attacks on Anchorage or Fort Richardson. The leachfield was associated with the sanitary system facilities at the underground bunker. Two sewer lines originate from the west side of the bunker and extend westward, eventually connecting to a septic tank and a concrete cesspool that is the nucleus of the leachfield. The quantity of sewage disposed of through the septic system is unknown. Additionally, at least two other sewage disposal facilities were present at the Transmitter Site.

In approximately 1978, dielectric oils containing polychlorinated biphenlys (PCBs) leaked from several transformers stored in the former transmitter annex building, which was located on the concrete foundation of the building. The spill was later remediated by washing the concrete foundation of the transmitter annex building with diesel fuel. In 1988, an Army contractor excavated 150 tons of PCB-contaminated soil surrounding the concrete pad. Another clean-up effort was conducted in 1992 when at least 600 tons of PCB-contaminated soil was removed.

Three separate investigations that included geophysical surveys, surface and subsurface soil, ground water, and sludge sampling, were conducted to characterize the nature and extent of PCB contamination in surface and subsurface soil adjacent to the transmitter annex foundation, and to determine whether PCB-containing wastes were released inside the underground bunker. Analytical results of the samples indicated the presence of volatile organic compounds (VOCs), BNAs, PCBs, and heavy metals in both the sludge and soil within the cesspool. Fuels were not analyzed for during these investigations

1.3 Summary of Site Characteristics

The northern and central section of Fort Richardson, where these two sites are located, feature flat to gently rolling, wooded terrain, including ponds and numerous streams leading from the mountains and uplands westward to Cook Inlet. Drainages flow primarily west-northwest into Knik Arm. However, streams in the southernmost portion of the Fort, including Ship Creek, flow through Anchorage before entering Knik Arm.

RRFTA

The Fire Training Area is located near the southern margin of the Elmendorf Moraine on the Naptowne outwash deposits. Generalized geologic descriptions of the site indicate that the soil consists of dry, massive, well graded gravel, with minor silt and clay. However, often the geologist's description of the soil targeted for treatment include estimated silt contents of 10 percent to 30 percent.

The Fire Training Areas is located within an area used for gravel excavation, and it is surrounded by relatively undisturbed forested areas. A small pond is located approximately 600 feet from the southwest corner of the former fire training area. A former gravel pit is located approximately 0.6 mile south and hydraulically upgradient of the site. The pit has filled with water.

Ground water occurs from 140 to 153 feet BGS (approximately 236-250 feet AMSL) and within the unconfined sandy gravel to gravelly sand aquifier. Ground water flows westward and has an average horizontal hydraulic gradient from 0.018 to 0.023.

Contaminants were detected in surface and subsurface soil. Off-site contaminant transport through surface runoff and windblown particulates is possible, but not expected to contribute significantly to contaminant transport from the site. The absence of site-related contaminants in the surface water and sediment samples collected at the nearby pond substantiates the conclusion that surface water runoff and particulate transport are not migration pathways of concern at the Fire Training Area. The RI conducted transport modeling of petroleum constituents in the subsurface soil. The model predicted that petroleum contaminants will migrate approximately 10 feet vertically from their present location over a 90-year period and that ground water would not likely be impacted. Based on this result and the absence of contaminants in ground water samples collected at the site, ground water is not a contaminant migration pathway.

RRTSL

]The Transmitter Site is located near the northern margin of the Elmendorf Moraine on the Naptowne outwash deposits. Site soil boring logs indicate that the soil consists of dry, very dense, gravel and sand, with silt and clay.

The Transmitter Site is located in an undeveloped portion of Fort Richardson. The site is surrounded by forests. Wetlands are located within one-half mile of the site to the southwest, southeast, and northeast.

Ground water at the Transmitter Site occurs at depths from 88 to 99 feet BGS (approximately 176-178 feet AMSL) within a sandy gravel deposit of the Naptowne outwash formation. Ground water generally flows southwest with an estimated gradient of 0.01. This ground water flow direction is not consistent with the regional west-northwest ground water flow.

Because the contaminant source is in the subsurface, the most likely contaminant migration pathway at the Transmitter Site is lateral and vertical transport through subsurface soil. Ground water is not a contaminant migration pathway as indicated by the absence of contaminants in the samples collected at the site.

2.0 BACKGROUND

2.1 Summary of Previous Site Investigations

RRFTA

Previous investigations were conducted at the Ruff Road Fire Training Area in 1986, 1989, and from 1991 to 1992:

In 1986, AEHA drilled three soil borings and collected 20 subsurface soil samples at the site. Eight samples were analyzed for VOCs, but VOCs were not detected at concentrations exceeding detection limits.

In 1989, as part of the Installation Restoration Program, 15 soil-gas probes were installed in the area to a depth of nine feet. Benzene, toluene, and xylene were identified in the soil-gas samples with maximum concentrations of 250 parts per million (ppm), 2,500 ppm, and 1,200 ppm, respectively.

In 1991, E & E collected surface and subsurface soil samples at the site. A composite surface soil sample was collected in triplicate from stained soil near the center of the fire training area. The sample contained lead (80.8 ppm to 543 ppm), diesel and other fuels (10,000-20,000 ppm), pyrene (750 ug/kg), PCE (48-485 ug/kg), toluene (732 ug/kg), xylene (1116 ug/kg), bis(2-ethylhexyl) phthalate (4100 ug/kg), and dioxins (0.0022 ug/kg toxicity equivalent factor [TEF]). Subsurface soil samples were also collected during the 1991 effort. The highest VOC concentrations detected in these samples were acetone (283 ug/kg), trichloroethene (TCE; 46 ug/kg), toluene (56 ug/kg), and xylene (42 ug/kg). In 1992, analytical results confirmed the presence of petroleum contamination in soil.

The RI field investigation was conducted in 1995 to investigate surface and subsurface soil, ground water, and surface water/sediment. The results confirmed the presence of petroleum hydrocarbons and dioxins in the surface and subsurface soil. This contamination is a result of the historical application of the fuels and other combustible materials used during training activities at the site. The lateral extent of surface soil contamination was estimated based on the findings of the RI and previous site investigations, and by applying ADEC's Interim Guidance for Non-UST Contaminated Soil Cleanup Levels for petroleum hydrocarbons. Contamination above the acceptable cleanup level was estimated to be confined to an area 175 feet by 190 feet to a depth of five feet. Using these boundaries, the estimated volume of contaminated soil is 6,200 cubic yards.

RRTSL

In 1990, a limited characterization of the RRTSL septic system was performed. A cesspool sample was obtained from a layer of sludge and detritus on the bottom of the concrete-lined cesspool while soil samples were obtained from sloughed material in the cesspool. Analytical results indicated the presence of VOCs, base/neutral and acid-extractable organic compounds (BNAs), PCBs (up to 5,600 ug/kg), and heavy metals including copper (up to 1,100 ug/kg) and lead (up to 1,200 mg/kg). Analysis for fuel was not performed.

The OU-A RI for RRTSL conducted in 1995. The principal objectives of the RI were to conduct a geophysical survey and investigate the cesspool, subsurface soil, and ground water. The results of the RI indicated that soil in isolated locations within the leachfield have been impacted by petroleum contamination. Low levels of heavy metals and PCBs were encountered. The levels do not pose an unacceptable risk to human health of the environment. The presence of DRO in subsurface soil indicates that these contaminants have dispersed from the leachfield and associated plumbing and have migrated to a depth of 15 feet BGS. The lateral extent of DRO contamination appears to be limited to an area extending northwest from the buried sewer line, which connects the transmitter building and the cesspool, to a portion of the leachfield. The presence of PCBs near the bunker at a depth of five feet BGS suggests that either contaminated soil was reworked during remedial activities or limited migration through subsurface soil has occurred. These concentrations probably represent residual, contamination remaining from remedial activities conducted between 1988 and 1992 at the transmitter annex foundation. It is unlikely that this contamination is related to discharges from the leachfield or its associated plumbing, because the leach field is located at a depth of six to seven feet below ground surface and PCB sampling at the leach field did not find contamination.

Sloughing soil within the cesspool contained petroleum hydrocarbons, PCB Aroclor 1260, cyanide, and heavy metals including barium, cadmium, lead, and mercury. Petroleum hydrocarbons were detected up to a maximum concentration of 23,000 mg/kg. Cyanide was detected at a concentration of 1.2 mg/kg.

No site-related contaminants were detected at concentrations exceeding screening criteria in the Transmitter Site ground water samples.

2.2 Treatment Systems Demonstration Study

2.2.1 Key Design Criteria

The RRFTA treatment systems designed by DOWL/Ogden JV (design documents are included in Appendix A) are intended to achieve the cleanup objectives inside the treatment areas utilizing volatilization, biodegradation, and containment. The RRFTA system is designed for operation in non-winter conditions. Remedial Investigation (RI), and Feasibility Study (FS) the soil targeted for treatment are within a defined area 190 feet by 175 feet to a depth of five feet. In accordance to the SOW and FS, soil vapor extraction was to be considered using three horizontal wells 160 feet long beneath a geomembrane. Each horizontal well was to draw 101 SCFM from the vadose zone. In accordance with the design meeting of November 18, 1997, the scope was modified to utilize bio-venting technology, and to pulse air flow through the soil targeted for treatment. Accordingly, the system was designed to draw 100 SCFM from each of the horizontal wells on a timed sequential basis with rest periods.

RRTSL

The RRTSL system is designed for a one-time consolidation and containment of the contaminants in a permanent concrete matrix.

2.2.2 Compliance with Alaska Department of Environmental Conservation Regulations

The information below is provided to document compliance with State of Alaska Regulations 18AAC78.312 Soil Remediation Requirements.

- This Work Plan including the design drawings contained in Appendix A, details the specifications for the bio-venting system (18AAC78.312(a)(1)).
- The anticipated schedule for 1998 and 1999 is presented in Section 3.2 of this Plan (18AAC78.312(a)(3)).
- Only ambient air is to be added to the subsurface for the RRFTA treatment system. The expected effects resulting from addition of oxygen include production of carbon dioxide and water vapor and reduction of the petroleum hydrocarbon to a fatty acid that will be further reduced to carbon dioxide and water vapor (18AAC78.312(a)(4)).
- The plan does not include installation of additional site controls beyond those already in place by Fort Richardson. All metering equipment and air handling equipment is to be located in locked enclosures (18AAC78.312(a)(5)).
- No discharge of regulated wastewater is anticipated to require a permit (18AAC78.312(a)(6)).
- Air flows to the system are to be regulated so that most volatile petroleum hydrocarbons are biodegraded prior to escape at the ground surface. Ambient air monitoring is to be conducted to verify vapors do not exceed relevant air quality standards (18AAC78.312(a)(7)).
- Non-domestic wastewater discharge is not anticipated (18AAC78.312(a)(9)).
- Existing monitoring well locations are shown on the design drawings presented in Appendix A (18AAC78.312(e)(1)).

- A summary hydrogeologic description of the site is presented in this plan. Detailed hydrologic information is provided in the document entitled Remedial Investigation Report, Operable Unit A, Fort Richardson, Alaska, November 1996, Ecology and Environmental, Inc. (18AAC78.312(e)(2)).

3.0 SCOPE OF WORK

This section summarizes the scope of work to be conducted in order to install, operate, and monitor the designed bio-venting system at the former Ruff Road Fire Training Area (RRFTA) at Fort Richardson, Alaska. It also summarizes the scope of work to solidify sediments and grout pipes at the Roosevelt Road Transmitter Site Leachfield (RRTSL) at Fort Richardson, Alaska.

3.1 Summary of Project Methodology (RRFTA)

The treatment system will be installed at the RRFTA in accordance with the design documents (plans) presented in Appendix A, to be modified by approved subcontractor submittals and comments by the ADCOE.

The Subcontractor will mobilize personnel, equipment and materials to the RRFTA site to perform all trenching, grading and other earthwork, piping installation and liner installation under the direct supervision of DOWL/Ogden JV.

The RRFTA treatment area will be cleared of all vegetation. All sharp objects and organic debris will be removed from the surface. The surface of the treatment area will be graded to drain. Trenches for the air infiltration galleries and the horizontal wells will be excavated to a depth of five feet with any excess trench spoil spread evenly over the treatment area. Six inches of "Pea Gravel" will be placed in the bottom of the trenches. The length of Advanced Drainage System (ADS) factory slotted Corrugated Plastic Tubing (CPT) covered with a fabric "sock" will be installed as shown on the plans. The CPT will then be covered with "Pea Gravel" so that the CPT is covered with eight inches and completely bedded in the "Pea Gravel". The trenches will be backfilled as shown on the plans with either native soil or Gravel with Sand (GW) containing no more than three percent material finer than the No. 200 screen (silt).

The trenches for the horizontal wells will be continued to the equipment enclosure as shown on the plans. The piping will be transitioned from CPT to High Density Polyethylene (HDPE). The trenches will be backfilled with compacted native soil over and around the HDPE pipe.

The surface of the treatment area will be covered with a layer of fine sandy silt bedding and a 20 mil HDPE liner. The thickness of the bedding will be determined in the field, as sufficient to protect the HDPE liner from punctures. The liner will be installed in accordance with the manufacturer's recommendations and covered with a minimum of 12 inches of Gravel with Sand (GW) or Sand with Gravel (SW). The equipment working over the liner will be limited to protect the liner from punctures.

The subcontractor will install pressure/soil gas monitoring points in the locations shown on the plans. The monitoring points will be six-inch screens installed in sand packs placed at various depths in borings augered in the treatment area. The screens will be connected to the subsurface with one-fourth inch PE tubing terminating in a one-fourth turn ball valve and one-fourth inch hose nipple. The ball valve and hose nipple shall be protected within a monitoring well manhole installed above the HDPE liner.

The subcontractor will install soil moisture sensors as shown on the plans using an auger and backfilling the auger hole with the native soil after the installation of the soil moisture sensor. Samples of the soil at the depth of sensor placement will be tested for water content to calibrate the moisture meter.

DOWL/Ogden JV will fabricate the equipment enclosure containing the blower, valves and electrical controls off-site, and mobilize the equipment enclosure to the site after the completion of the earthwork. DOWL/Ogden JV will connect the equipment enclosure to the horizontal wells with "TigerFlex" suction hose, and insulate the connection in place.

Prior to mobilizing the equipment enclosure, the Fort Richardson Directorate of Public Works (DPW) will have caused three phase power to be brought to the site terminating at three, pole mounted, 25 KVA transformers installed in the location shown on the plans.

An electrical subcontractor will provide electrical hookup to the treatment system equipment enclosures. The electrical subcontractor will coordinate the hookup with Fort Richardson (DPW).

After the installation of the system components, but prior to starting the system, all monitoring points will be monitored for pressure using the magnehelic pressure gage set; concentration of carbon dioxide, CO_2, and concentration of oxygen, O_2, using the GasTech model 3252OX analyzer; and concentration of volatile hydrocarbons using the GasTech TractTechtor™. These will be referred to as the baseline parameters. Below atmospheric O_2 measurements and elevated CO_2 measurements may indicate aerobic reduction of the petroleum hydrocarbon may be occurring intrinsically. A low flow extraction pump will be used to extract soil vapor from the monitoring point until the baseline parameters stabilize or peak. Cure will be taken to avoid breakthrough of atmospheric air during these measurements.

After this baseline data is obtained, the system will be started with soils vapor drawn from the center horizontal well unless the baseline measurements indicate a higher intrinsic aerobic reduction elsewhere in the treatment area. The response to the induced partial vacuum will be measured in all monitoring points with all baseline parameters measured. The system will be operated in this manner until the measurements of all baseline parameters stabilize. The pressure response in the monitoring points will be measured to provide data regarding the radius of influence. The measurements will be plotted as a function of the log of the distance from the horizontal well to obtain assurance that the radius of influence of the well intercepts the air infiltration galleries. Changes in the O_2 concentration will indicate adequate ventilation of the vadose zone.

If funding for in-situ respirometry is provided, the system will be shut down after stabilization and the baseline parameters will be measured at 2, 4, 6, and 8 hours and then every 4 to 12 hours, depending on the rate at which the oxygen is utilized. The in-situ respirometry test will be terminated when the O_2 level is five percent or after five days of sampling.

From these data, the timing of the pulsed vapor extraction will be computed to optimize the supply of O_2 to the indigenous microorganisms and programmed into the logic controller provided by the manufacturer of the equipment. The minimum air required to supply the microorganisms with sufficient O_2 would be targeted as optimal to avoid unnecessary drying of the soils. All O_2 reduction will be attributed to respirometry, and no account for diffusion will be made unless the calculated air flow is unreasonably high. If in-situ respirometry is not budgeted, then the system will be programmed to draw vapor from each well for 24 hours, once a week. This default operation will be intended to provide one pore volume exchange in the soils targeted for treatment every 24 hours as suggested in the EPA publication "How to Evaluate Alternative Cleanup Technologies for Underground Storage Tank Sites" (1994).

DOWL/Ogden JV will start the system with subcontractor representatives present. An operating and maintenance manual consisting of a compilation of equipment documentation provided by the manufacturer will be prepared by DOWL/Ogden JV and available on-site during system start-up.

All treatment system installation activities will be observed and documented in accordance with Section 4.0, Treatment System Installation Plan, of this Work Plan by a DOWL/Ogden JV field representative. After completing the installation activities, DOWL/Ogden JV will provide ADCOE with a copy of the field notes documenting the field installation efforts at both RRFTA and RRTSL.

The system at RRFTA will be operated and monitored for a period of two summer seasons. A total of four quarterly reports will be prepared for RRFTA to present the methodology and results of the treatment system monitoring, including field notes and tabulated data and measurements. Monitoring will include two events of in-situ respirometry.

DOWL/Ogden JV will prepare a Treatment System Report after two seasons of system operation that includes a copy of the final Work Plan, summary of the treatment system implementation activities and results, and a summary of the findings of the treatment system monitoring program. In the report, DOWL/Ogden JV will provide conclusions and recommendations regarding continued operation of the treatment system and system modifications.

3.2 Summary of Project Methodology (RRTSL)

The clean up work at RRTSL will be performed in accordance with the design documents presented in Appendix A to be modified by approved subcontractor submittals and comments by the ADCOE.

The subcontractor will mobilize personnel, equipment, and material to the RRTSL site to perform excavation, grouting, soil - concrete mixing, backfilling, forming and placing concrete for slab over cesspool, and grading under the supervision of DOWL/Ogden JV.

The area around the cesspool will be excavated to two feet below the bottom of the cesspool. All pipes (11) connected to the cesspool will be cut and pressure-grouted with bentonite until refusal. The area around the cesspool will then be backfilled and compacted in one-foot lifts. All debris and soil within the cesspool will then be removed, mixed with cement, and backfilled into the cesspool. A 10 bag cement mix will be used for the soil cement mix. The remainder of the cesspool will be filled and compacted with clean soil to the top. The cesspool will then be capped with a four to six-inch thick reinforced concrete slab.

At the location of the subsurface bunker the contractor will excavate along the west side wall to a depth of about 10 feet. All piping found (two assumed) will be cut and grouted till refusal. The excavation will then be backfilled and compacted.

All activities performed at the RRTSL will be monitored and observed by a qualified DOWL/Ogden JV field representative. After completing the work DOWL/Ogden JV will provide ADCOE with a copy of the field notes documenting the field activities.

3.3 Project Scheduling

A summary of the 1998 and 1999 schedule is shown below:

COE Approval of Final Work Plan	February 20, 1998
Notice to Proceed to the Subcontractor (Estimated)	February 20, 1998
Fabrication of System Enclosures	March 1, 1998 to May 15, 1998
DPW Provide 3-Phase Power to RRFTA	May 1, 1998
Field Mobilization	May 1, 1998
Installation of Treatment Systems (RRFTA and RRTSL)	May 1, 1998 to June 15, 1998
System Startup (RRFTA)	June 15, 1998
1998 System Operation and Monitoring (RRFTA)	June 30, 1998 to October 31, 1998
1999 System Operation and Monitoring (RRFTA)	May 15, 1999 to October 31, 1999
Final Design Verification Study Report (RRFTA and RRTSL)	December 29, 1999

The schedule is subject to modifications if needed to facilitate plan review and unforeseen circumstances.

3.4 Permits

The subcontractor will arrange utility locates and obtain Excavation Permits from the Fort Richardson DPW prior to field implementation.

4.0 TREATMENT SYSTEM INSTALLATION PLAN

DOWL/Ogden JV will inspect and document the solidification of sediments and pipe grouting at RRTSL and the installation of the designed bio-venting system at RRFTA to be installed by the subcontractor to verify the system is installed in accordance with the design drawings presented in Appendix A as modified by Alaska District comments. DOWL/Ogden JV personnel will fabricate, or cause to be fabricated, the equipment enclosure, provide inspection of field activities and provide field screening, field sampling, and field testing as described in this section.

4.1 Mobilization/Demobilization

Upon receipt of approval of this work plan and the design drawings in Appendix A, DOWL/Ogden JV will begin fabrication of the equipment enclosures. An engineer from DOWL/Ogden JV will direct the fabrication of the enclosures prior to shipment to the site.

Prior to installation of any portion of the system at either site, the Subcontractor will arrange utility locates and obtain an excavation permit from Fort Richardson DPW. Field equipment checklists for DOWL/Ogden JV personnel are included in Appendix C.

4.2 Excavation and Placement of Piping, Enclosures, Grouting, and Consolidation of Sediments

DOWL/Ogden JV will observe and document the trenching; placement of Advanced Drainage System Corrugated Plastic Tubing (ADSCPT), sealed cleanouts, and vents; placement and butt welding of the HDPE pipe; placement of backfill; and placement of the liner and cover. Excavated soil will be field screened with a photoionization detector (PID) in accordance with the relevant SOP and the Quality Assurance Project Plan to detect contamination, if encountered. Any contaminated soil encountered during trenching will be documented. Contaminated soil encountered in the treatment areas will be spread over the treatment area beneath the liner, or returned to the trench as backfill. DOWL/Ogden JV will verify pipe installation is in accordance with the manufacturer's recommendations and the design drawings presented in Appendix A.

Upon completion of the installation, DOWL/Ogden JV will participate in the initial start-up of the systems with the subcontractor. DOWL/Ogden JV will provide a manual that includes the manufacturer's operating literature for all the installed equipment, including all relevant operating and maintenance procedures provided by the manufacturer to be available on-site during operation.

4.3 Field Documentation

4.3.1 Field Logbooks

Field records will be sufficiently maintained to recreate field installation and testing activities in a permanently bound or "rite-in-the-rain" type notebook with consecutively numbered pages and on project field forms. Field records will be written in permanent ink and erasures will not be allowed.

A copy of the field notes will be submitted to the Alaska District at the conclusion of installation. The original documents will be provided to the ADCOE at the conclusion of the project.

Field memos to the subcontractor will be made on Advisory/Non-Compliance Forms (Appendix C).

4.3.2 Project Field Forms

The information contained and entered into the Field Logbooks will be summarized on inspection reports prepared for each day the inspection occurred. The inspection reports will document the work performed during the day, the results of field testing and field screening, any contaminated soil encountered and the disposition of these soil, and any sampling performed and the results of field testing of the samples. The inspection reports will also document weather conditions, the Subcontractor's work force, the equipment in use or idle, and other items that may be important to document the quality of subcontractor work or affect claims issues. Color photographs of the site and specific installation activities will be taken to document the progress of the work. Records of the photographs will be kept in the field book and transcribed to a photo log. Copies of the standard inspection report and photo log forms are presented in Appendix C.

5.0 SAMPLING AND ANALYSIS PLAN

The objective of the Sampling and Analysis Plan is to describe field measurements and sampling that will be conducted to document that the treatment system installation, operation, and monitoring are conducted in accordance with standard and accepted procedures and the requirements of the Alaska District. Sampling will be conducted as required to perform field screening and testing during installation, treatment system monitoring in accordance with this Work Plan, the relevant Standard Operating Procedures (SOPs) presented in Appendix B, and the relevant portions of the Quality Assurance Project Plan.

In accordance with the statement of work (SOW), this Sampling and Analysis Plan (SAP) will serve to delineate the methods which will be used to assure accurate, precise, representative, and comparable data.

The SAP is organized in the following manner: Section 5.1 is the Field Sampling Plan (FSP) which outlines the treatment system monitoring programs. The FSP describes monitoring and sampling methodologies, parameters, locations, and frequency. Section 5.2 is the Quality Assurance Project Plan (QAPP) which discusses quality control(QC)/quality assurance(QA) procedures followed by the Dowl/Ogden JV personnel and laboratory personnel to ensure reproducible and comparable analytical data.

5.1 Field Sampling Plan

This FSP presents the treatment system monitoring and ground water sampling program technical approach and is divided into four subsections: 1) Summary of Project Monitoring, 2) Bio-venting Monitoring and Sampling Program, 3) Reporting, and 4) Monitoring, Sampling, and Analytical Methodologies.

5.1.1 Summary of Project Monitoring

5.1.1.1 Objective

The project scope of work includes monitoring the performance of the treatment system to verify that it is operating within the design parameters. This monitoring summary outlines activities to be conducted to monitor the performance of the treatment system in accordance with the SOW.

The objective of the proposed monitoring program is to verify compliance with established system performance standards. The program in not designed, or intended, to monitor the progress of site remediation.

5.1.1.2 Monitoring Schedule

Treatment system operation and monitoring will be conducted for two summer seasons following system startup. System operation and monitoring will be conducted from system startup until seasonal system shut down in late October. The system will not be operated or monitored during the winter.

Treatment system monitoring will be conducted as close as is feasible to the following times after system start-up.

- 4 hours;
- 8 hours;
- 1 day;
- 5 days;
- 2 weeks;
- 3 weeks;
- 4 weeks;
- 2 months;
- 3 months; and
- 4 months.

5.1.1.3 Personnel

All monitoring will be performed by technical or professional personnel employed by the DOWL/Ogden JV. They will be selected by the Principal Site Investigator, based on their familiarity with the site and with the performance of the specified monitoring procedures. At a minimum, the selected personnel will meet requirements for Field Technicians established in the Quality Assurance Project Plan (QAPP).

5.1.1.4 PID Monitoring

Ambient air will be monitored for volatile organics at selected locations in and around the treatment area during the scheduled events. Actual locations will be selected by the field technician, based upon perceived system performance at the time of monitoring. PID readings will be taken at waist-level, at a minimum of six locations around the treatment area, with a Microtip HL-2000 photoionization detector or equivalent equipment. The resulting information will be recorded on the project field form (Appendix C). Measuring equipment will be calibrated to read in benzene equivalent according to procedures and schedules designated for the specific instruments using isobutylene at 100 parts per million. Calibration activities will be documented on the field form.

5.1.1.5 Bio-venting System Monitoring

The following measurements and tasks will be performed to monitor the bio-venting system during each event.

- Air flow and induced partial vacuum will be recorded for each horizontal well at the equipment enclosure.
- Partial vacuums at each sealed clean out on the horizontal wells.
- Induced partial vacuum will be measured and recorded at all monitoring points.
- The moisture content of the soil will be measured at each of the locations of the soil moisture sensor.
- Concentration of O_2, CO_2 and petroleum hydrocarbons will be measured at each monitoring point and the exhaust gas.

- An air sample will be collected from the exhaust gas and analyzed for VOCs by EPA Method TO-14 during the first day of operation and the monitoring events thereafter if significant petroleum hydrocarbon is detected in the exhaust gas.
- PID readings will be recorded at the sampling points located inside the equipment enclosures.

5.1.1.6 System Equipment Monitoring

Equipment controls will be monitored at the scheduled times. Equipment meters will be read for temperature, vacuum, and pressure and recorded on the project field form (Appendix C). The field technician will visually observe conditions at the equipment control sites and note those conditions on the same form. System adjustments and items in need of repair or maintenance will be recorded and corrections made as required.

5.1.2 Bio-venting Monitoring and Sampling Program

The goal of the monitoring and sampling program is to collect sufficient data to evaluate treatment system performance. In general, this program is designed according to the performance of the treatment system and has to maintain a certain level of flexibility so that it may be modified and adjusted over time based on various system operational results. The anticipated performance of this bio-venting system is described below. In this discussion the terms "monitoring" and "sampling" are used to describe two different data collection activities. "Monitoring" refers to the use of gauges or hand-held measuring instruments that provide a real time indication of site and treatment system conditions. "Sampling" refers to the collection of soil gas samples which are submitted to an off-site laboratory for chemical analysis.

The goals of the monitoring program in the design application employed on this project from a systems operation perspective are three fold. First, to monitor the exhaust gases to verify that any volatilization of the contaminants attendant with the bio-venting process are insufficient to adversely affect the air quality; second, to verify that adequate air flow is being achieved through the soil to be treated; and third, to verify the soil are not being overly dried by the introduction of atmospheric air. From a treatment perspective, the uptake of the oxygen in the vadose zone and the generation of carbon dioxide are indicators of respirometry required in aerobic biological digestion of the hydrocarbons.

To evaluate the systems operation, the concentration of hydrocarbons will be sampled and the flow rates monitored in order to calculate the contaminants exhausted into the atmosphere. Also the pressure response and concentrations of oxygen in the vadose zone adjacent to the horizontal wells will be monitored to verify that adequate oxygen is being forced through the soil targeted for treatment. If significant concentrations of hydrocarbons exist in the exhaust gas, the flow rates will be decreased to only that level required to provide oxygen to the microbes. Alternatively, the air quality impact will be modeled using EPA “Screen 87”to evaluate the impact on potential receptors. If insufficient oxygen is available to the microbes, the pressure gradient across the soil to be treated will be increased to promote greater airflow.

The soil moisture sensors will be monitored. If the targeted soil appear to be drying due to the forced air flow, water will be added at the infiltration galleries to humidify the forced air.

Because the system is designed to pulse the air flow through the targeted soil by intermittent operation of the blower and sequenced extraction from the three horizontal wells, the pressure and composition of the soil gas in the soil targeted for treatment can be monitored. To evaluate the treatment, the uptake of oxygen and generation of carbon dioxide in the areas not being ventilated can be monitored. A decrease in oxygen and increase in carbon dioxide would be indicative of aerobic biological activity.

Initially, the vadose zone will be flushed by the air forced through it. Initial concentration of volatile constituents of the contamination will be expected to be higher in the exhaust gas than later during the treatment process. As the process continues the volatile components will go through a phase controlled by the evaporation of the constituents from either the separate phase hydrocarbons or hydrocarbons absorbed by the soil particles. The evaporative rate is generally less than required to reach saturation in the vadose zone when air is being forced through the vadose zone, so concentrations due to evaporation are typically less than during flushing. After evaporation has occurred in the predominant flow paths, then the volatiles diffuse from the less permeable soil deposits to the more permeable soil deposits. Diffusion occurs at a rate slower than evaporation. Separately, as the microorganisms in the vadose zone respond to the increased oxygen supply, more of the hydrocarbons will be reduced biologically until equilibrium with the oxygen, food supply and nutrients is achieved. When the more volatile components of the contaminant are exhausted from either biological reduction or volatilization, the less volatile components will continue to be reduced biologically.

Because the concentration of petroleum hydrocarbons in the exhaust are likely to be greatest in the initial phases of the operation and diminish rapidly during operation by the physical/chemical process associated with volatilization and biological reduction, the monitoring will be performed more frequently during the first days of operation and less frequently thereafter. This monitoring is consistent with good practice during the startup of new equipment and processes where frequent monitoring of the equipment performance and response of the vadose zone during the initial phases of operation allows for timely modification during startup. Lastly, because little design data was provided by the investigations to date regarding response of the vadose zone to impressed pressure gradients, the response of the vadose system to the treatment systems will allow modification if the design assumptions are not confirmed by the design verification study.

5.1.2.1 Monitoring and Sampling Locations

The following locations have been identified for the monitoring and sampling program. These locations include: 1) the metering for each horizontal extraction wellhead and metering inside the equipment enclosure; 2) monitoring points; 3) soil moisture sensor

5.1.2.2 Bio-venting Horizontal Wellhead and Metering

The airflow and vacuum will be recorded for each horizontal well. These measurements will be taken at the metering in the equipment enclosure.

5.1.2.3 Monitoring Points

Numerous monitoring points will be installed at the site depending in part on the locations of observed contamination during trenching The design drawings detail the monitoring points, including the depths of the screened intervals. Induced vacuum will be measured at these monitoring points.

This will provide an indication of the pressure gradient induced across the soil to be treated and will indicate whether air is being moved through the targeted soil.

The concentration of oxygen and carbon dioxide will be measured in the field at each monitoring point. In areas being pulsed with air this will indicate the adequacy of the air flow to provide oxygen to the microorganisms. In areas resting between pulsing, this will provide an indication of the uptake of oxygen by the indigenous microorganisms reducing the contaminants. This will provide verification that biological reduction of the contaminants is taking place.

The moisture of the soil will be measured by the soil moisture sensor. Trends will be noted. If a drying trend is detected then water will be added at the air infiltration galleries to humidify the air being forced through the soil targeted for treatment.

5.1.2.4 Bio-venting Exhaust Gas Concentrations

Offgas will not be treated. PID readings will be taken at these sampling ports during each monitoring event. An analytical air sample will be collected to determine analyte concentrations being removed from the ground.

5.1.2.5 Bio-venting Monitoring Program Parameters

Table 5-1 presents the monitoring program for physical and chemical parameters. The monitoring program will help to optimize system operation.

TABLE 5-1

BIO-VENTING SYSTEM MONITORING AND SAMPLING PROGRAM PARAMETERS

Monitoring/Sampling Location	Air Flow Rate (SCFM)	Vacuum (inches of H_2O)	VOC Concentration by PID (ppmv)	Petroleum Hydrocarbon, O_2, CO_2 concentrations	Laboratory Analysis (1) (ug/L)
Equipment Enclosure, (vapor stream before the blower)	❉	❉	❉	❉	❉
Monitoring Points		❉		❉	
Sealed Cleanouts in each Horizontal Well (at metering enclosure)	❉	❉		❉	

(1) Notes:
VOCs by EPA Method TO-14

5.1.2.6 Sampling Program Parameters

Samples for chemical analysis will only be collected from the influent sampling port inside the equipment enclosure. Summa® canisters are initially received from the laboratory with sufficient vacuum to overcome the vacuum generated by the treatment system. This will facilitate collecting the samples directly into the Summa® canisters without having to shut off the system. The gas samples collected during each sampling event will be analyzed for VOCs using EPA Method TO-14.

5.1.2.7 Field Quality Control Samples

No field quality control samples will be collected as part of the bio-venting system monitoring.

5.1.2.8 Monitoring and Sampling Stages

For the purposes of the monitoring and sampling program, four stages have been developed for system operation. These stages are defined in Table 5-2.

5.1.2.8.1 Baseline Monitoring Stage

Immediately prior to initiating remediation, it is necessary to determine the soil gas concentrations in the treatment area. Establishing a baseline field condition at system startup allows for better evaluation of system performance and progress of remediation by comparing changes in soil gas concentrations resulting from the system operation relative to undisturbed conditions.

TABLE 5-2

MONITORING AND SAMPLING STAGES

Baseline Stage	Represents the period immediately prior to system startup.
Start-Up Stage	Represents the first five days of system operation during which monitoring and sampling occur on an hourly to daily basis.
Weekly Stage	Represents the first month of system operation during which weekly monitoring and sampling occur.
Monthly Stage	Represents system operations after the first three monitoring stages are complete, during which monthly monitoring and sampling occur.

5.1.2.8.2 Start-Up Monitoring and Sampling Stage

The start-up stage begins once the system is turned on and operating. During the flushing phase, it is expected that the highest volatile contaminant concentrations will be observed in the extracted vapor. Therefore, it is important to closely monitor the performance of the system during start-up. During the start-up stage, monitoring will occur on a frequent basis to collect sufficient data for rapid evaluation of system performance, and sampling will occur when the monitoring indicates the concentrations of petroleum hydrocarbons has peaked in the exhaust gas.

The duration of the system start-up depends on both proper installation and operation of the system as well as on soil and contaminant characteristics. It may take only a few hours or several days for the system to reach a steady-state flow condition depending on soil/air permeability and heterogeneity. For the purposes of this monitoring and sampling program, it is assumed that after one week of continuous operation, a near-steady-state regime will be achieved in the subsurface formation. The scope of start-up monitoring and sampling will be limited to the first five days of bio-venting system operation.

Monitoring will occur four times during the start-up stage. Physical and chemical parameters will be monitored at four hours, one day, and five days after bio-venting system start-up.

5.1.2.8.3 Weekly Monitoring and Sampling Stage

Following the first five days of system operation, the frequency of monitoring and sampling will be decreased to once a week for a period of three weeks. It is assumed that steady state will be achieved after the first week and contaminant concentrations in the extracted vapor will begin to decrease.

5.1.2.8.4 Monthly Monitoring and Sampling Stage

Following the first month of system operation, the frequency of monitoring and sampling will be reduced to a monthly schedule. Monthly monitoring and sampling will continue at the specified locations for the remainder of the first season of system operation.

5.1.3 Reporting

Quarterly progress reports will be prepared during system operation which summarize operational status of the system and present monitoring and laboratory analytical results. Additionally, the amount of time the system has been in operation, the amount of liquid collected in the moisture separator, and any problems encountered during operation shall also be reported. The monitoring report will include a section on conclusions and recommendations for further monitoring. After two seasons of system operation, a final report will be prepared evaluating system effectiveness and summarizing all the work done and data collected from the site. Recommendations for any necessary modifications to the monitoring and sampling program or bio-venting system operation will also be provided in the report.

5.1.4 Monitoring, Sampling, and Analytical Methodologies

This section describes the monitoring, sampling, and analytical methodologies associated with performance evaluation of the treatment system. Whenever applicable, detailed operating procedures are provided in appendices. The procedures followed in this project will incorporate procedures detailed in the U.S. Army Corps of Engineers guidance document *Engineering and Design, Chemical Data Quality Management for Hazardous Waste Remedial Activities*, dated October 1, 1990.

5.1.4.1 Monitoring Methodology

System performance will be evaluated using real-time monitoring data obtained with direct-reading hand-held instruments and permanently-installed system gauges. System monitoring data will be recorded in a project dedicated field book.

Several different types of direct-reading instruments are generally available for each type of measurement. However, to promote standardization between each of the monitoring events, the same instrument or same brand of instrument will be used to take readings whenever possible. Field instruments will be calibrated and maintained according to instructions supplied by the manufacturer. Instruments are anticipated to be calibrated at a minimum of once each day that they are used at the site.

The system will have permanently installed gauges to measure air flow rate, vacuum/pressure, and temperature. The gauges will be designed for use in a potentially explosive environment and will be selected so that system measurements are made near the midpoint of their ranges.

5.1.4.2 Sampling Methodology

Soil vapor samples will be collected from the extraction wellhead with Summa® canisters. Procedures for collecting Summa® canister samples will be in accordance with specific guidelines provided by the laboratory that supplies the canisters. General sample collection methodology is described below.

5.1.4.2.1 Sample Collection

The six-liter Summa® canisters will be supplied by the laboratory under a partial vacuum. The air inlet for the Summa® canister will be connected to the extraction wellhead sampling port with polyethylene or tygon tubing. Summa® canisters are initially received from the laboratory with sufficient vacuum to overcome the vacuum generated by the treatment system. This will facilitate the collecting of samples directly into the Summa® canisters without having to shut off the system. Samples will be collected by opening the sampling port valve and the inlet valve to the Summa® canister. Vapor from the wellhead will then flow into the partially evacuated Summa® canister and the operator will close the valve when the pressure inside the canister reaches the level specified by the laboratory.

5.1.4.2.2 Sample Labeling and Record Keeping

Sample labeling, which encompasses sample identification numbering, record keeping, and chain-of-custody procedures, will follow the guidelines presented in the QAPP.

5.1.4.2.3 Sample Handling

Sample handling encompasses sample storage and shipping methodologies. Guidelines provided by the laboratory supplying the Summa® canisters will be followed during the project. Soil vapor samples collected in Summa® canisters will not be placed on ice during transport to avoid condensation inside the sample container. The samples will be handled and maintained under strict chain-of-custody during collection, transport, and laboratory analysis. An example of the chain-of-custody form that will be used during the project is provided in Appendix C.

5.1.4.3 Analytical Methodologies

BTEX, GRO, DRO, and other petroleum hydrocarbons have been identified as contaminants at the site. The analytical program for the system sampling plan has been developed to detect these contaminants in extracted vapor samples.

Air samples collected from the SVE system will be analyzed for VOCs using EPA Method TO-14.

5.2 Quality Assurance Project Plan

5.2.1 Project Overview

The purpose of this Quality Assurance Project Plan (QAPP) is to outline procedures the DOWL/Ogden JV will use throughout work on the subject delivery order.

This QAPP has been designed to meet the guidelines of the ADEC in accordance with 18 AAC 60.310 and 18 AAC 60.410. The QAPP was prepared using the ADEC guidance entitled *Guidelines for Preparing Quality Assurance Project Plans* with reference to *the DRAFT Guidance Manual for Underground Storage Tank Regulations 18 AAC 78, January 1993 and Chapter 2 of the Underground Storage Tank Procedures Manual, September 22, 1995.*

The purpose of this QAPP is to outline laboratory methodologies and procedures, specific compounds to be analyzed for, detection limits, quality assurance and quality control (QA/QC) criteria, and assessment of data quality objectives (DQOs). The quality assurance (QA) and quality control (QC) measures utilized are to ensure that the chemical and field data on the samples collected are accurate, precise, and complete as defined by established criteria. The procedures are the basis for achieving the goal of quality collection, analysis, and review of the Fort Richardson samples. The DQOs assessment is designed as a guide for system operational changes and modifications based on the monitoring and sample analytical results. The data will be evaluated to determine if further actions are warranted.

The QAPP is intended to address the sampling and testing to be performed during treatment system installation and monitoring.

5.2.2 Program Approach

The primary objective of this QAPP is to provide a methodology for air sampling of the system to be installed at the RRFTA. The treatment system to be installed and operated as part of this scope of work is designed to volatilize and biodegrade contamination in treatment areas.

Reference is made to Section 2 of this Work Plan to specific information regarding site history including existing documents for historical information and available data. Specific reference is made to the design documents in Appendix A for the selected treatment areas identified as contaminated.

In order to meet the project objective stated above, this QAPP outlines a systematic approach to sample (data) collection, handling, preparation, and analysis. The QAPP will address the procedures concerning: personnel, data quality objectives, sampling procedures, sample transfer log, equipment maintenance, equipment calibration, laboratory QAPP, precision, accuracy, and completeness of assessment.

5.2.3 Project Organization and Responsibilities

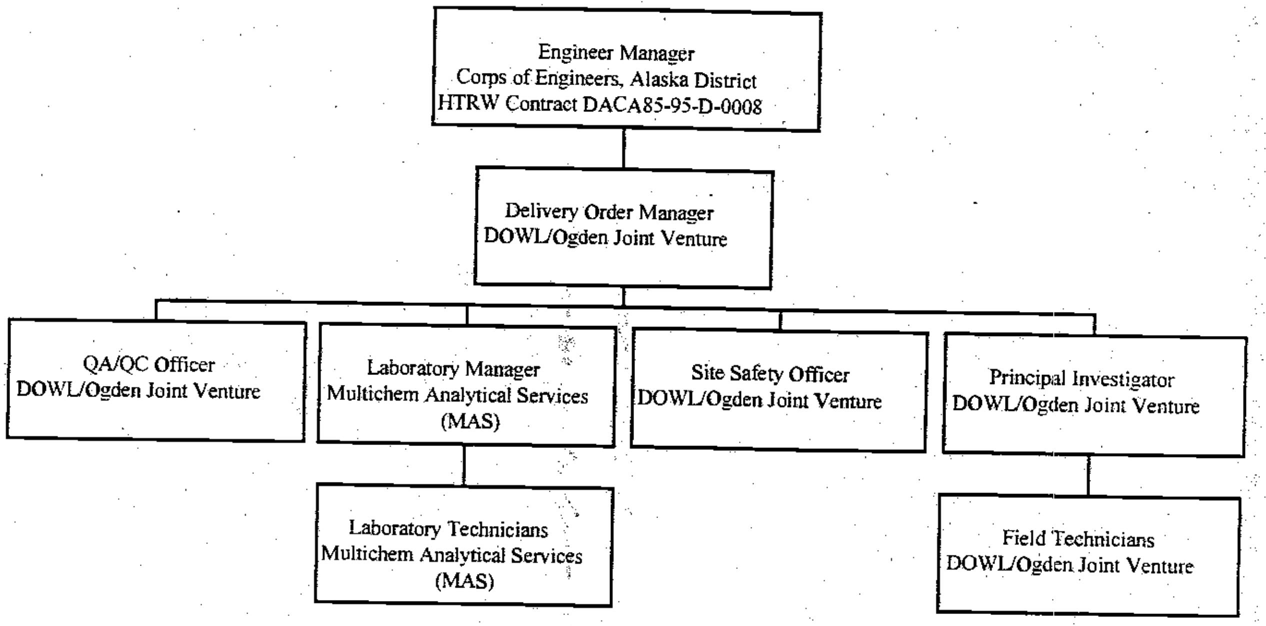
5.2.3.1 Organization Chart

The organization of the project team is outlined below.

Ruff Road Fire Training Area and Roosevelt Road Transmitter Site Leachfield

Operable Unit A, Fort Richardson, Alaska

Project Organization Chart



5.2.3.2 Key Personnel Responsibilities

The key personnel positions responsible for ensuring that the RRFTA project activities are conducted in accordance with standard and accepted operating procedures, including QA/QC criteria, are shown in the project organization chart shown above. The duties of each position are described in the following text. All DOWL/Ogden JV personnel filling these positions shall be listed on the Qualified Personnel Form for DOWL and Ogden on file with ADEC.

Engineer Manager: The Alaska District project director responsible for guiding the overall direction of the program. This individual shall be responsible for the final review and approval of all sampling procedures, reports, and field data.

Delivery Order Manager: The individual acting as the lead person for DOWL/Ogden JV during the Fort Richardson project. This individual shall be responsible for ensuring that the outlined tasks and objectives of the QAPP are completed. The accurate completion of the Fort Richardson field implementation includes ensuring that all sampling protocol and quality control measures outlined in this QAPP are met, proper field documentation is being performed, instrument calibrations are being performed correctly, and that the final reports logically convey data necessary to fulfill the sampling program objectives.

QA/QC Officer: The individual responsible for review of any data for samples collected and verification of the accuracy and reliability of that data. The QA/QC officer is responsible for ongoing review, monitoring, and evaluation of the field activities. The QA/QC officer will determine if data are acceptable for use in interpretations and will validate or supervise validation of all data reports. This individual will have a strong analytical chemistry background, as well as experience in completing analytical data reviews.

Principal Site Investigator(s): The individual responsible for conducting the sampling, including all field QC, instrument calibrations, and field documentation. These individuals will be experienced in the collection of soil and water samples and shall be knowledgeable of the sampling protocols outlined in this QAPP. They will have knowledge of standards and regulations applying to the sampling of soil and water, and meet the criteria definition of a "qualified person" as stated in 18 AAC 78.995.

Field Technicians: The field technicians are responsible for providing support in the field to the Principal Site Investigator. These individuals will be assigned field work activities by the Principal Site Investigator, which may include implementation inspections, and monitoring activities, and will comply with procedures outlined in the sampling and analysis plan, work plan, and this QAPP.

Laboratory Manager: This individual works for Multichem Analytical Services (MAS) This individual shall be responsible for ensuring that all the required laboratory QA/QC measures are completed from the time that samples are received at their laboratory until the analytical results arrive at the DOWL/Ogden JV office. This person will work closely with the DOWL/Ogden JV project manager to assure that the sample delivery is completed efficiently and will help troubleshoot any potential problems encountered during sampling. Directing the lab assistants in completing the sample analysis shall be a primary duty of the MAS Lab

Manager. This person is responsible for the review and validation of the analytical data before it is submitted in final form to the DOWL/Ogden JV.

Laboratory Technicians: The laboratory technicians are responsible for completing the laboratory's outlined internal quality assurance procedures. These individuals will follow these procedures and will work closely with the Lab Manager to meet the strict laboratory QA/QC criteria necessary to meet ADEC approval of analytical laboratories.

5.2.3.3 Changes to Organization or Key Personnel Responsibilities

Any changes to either the described organization, personnel, or responsibilities from the information provided in this document, will be reported directly to the Alaska District. The changes will be transmitted as amendments to the QAPP. Any amendments must be received by the Alaska District prior to or concurrently with any site-specific project activities or site assessment reports that are submitted subsequent to the changes.

5.2.3.4 Health and Safety Training

All DOWL/Ogden JV personnel working in the field during an environmental investigation in which contaminated materials may be encountered shall meet the requirements of 29 CFR 1910.120 and shall have successfully completed 40 hours of health and safety training. In addition, DOWL/Ogden JV environmental personnel shall have successfully completed an eight-hour refresher course addressing health and safety issues within the 12 months prior to participating in the field portion of any investigation. Field personnel will have first aid and CPR training.

5.2.4 Quality Assurance Objectives for Measurement of Data

5.2.4.1 Definitions

In general, QA objectives are quantitative and qualitative goals needed to meet specific regulatory requirements. The QA objectives show the total acceptable error due to sample collection, handling, preparation, and analysis.

The quantitative QA objectives deal with the *precision*, *accuracy*, and *completeness* of the sampling process.

Precision is defined as the measure of the variability or random error in sampling, sample handling, preservation, and laboratory analysis. For purposes of this plan, precision is indicated by the relative percent difference in concentrations between duplicate samples.

Accuracy is defined as a measure of the closeness of the individual measurement or average of a number of measurements to the true value. For purposes of this plan, accuracy is indicated by matrix analyte or surrogate spiked samples.

Completeness is a measure of the amount of valid data obtained compared to the amount expected. For purposes of this plan, completeness is calculated as the number of valid samples divided by the minimum number of required samples (expressed as a percentage).

The qualitative QA objectives are *representativeness* and *comparability* of the sampling results. Representativeness describes the degree to which the data characterizes the actual conditions on site. Comparability expresses the level of confidence with which one data set may be compared with another. Standard operating procedures will be used for the collection, preservation, and analysis of the samples. Data will be reported in the same units of quantification and in accordance with ADEC reporting requirements.

5.2.4.2 Data Quality Objectives

The objective for the monitoring and sampling to be conducted during this project is to document the installation and operation of the treatment system to be installed at the site.

The primary data quality objective for monitoring of treatment system installation is to document the proper installation of the system, and identify locations of contamination if encountered. The primary data quality objective for monitoring the operation of the system is to verify and document contaminant concentration in the bio-venting exhaust; verify and document degradation of the targeted contamination; and verify, document and evaluate oxygen uptake.

Contaminant mass removal rates can be used to evaluate the impact of the remediation system and are calculated using measured extracted vapor flow rates and concentration results gathered during the sampling program. Contaminant concentrations in the extracted vapor will typically rapidly decrease over time. The rate at which contaminant concentrations in the extracted vapor decrease depends on the nature and extent of contamination, the response of the indigenous microbes, and site soil characteristics. For example, a rapid decrease in the contaminant concentrations in the extracted vapor could be due to low air permeability of soil or relatively low contaminant vapor pressure and Henry's Law Constant (two parameters used to determine whether a compound will volatilize from an aqueous phase and exist in the soil gas.)

Pressure measurements at the monitoring points will verify a pressure gradient has been induced on the contaminated soil targeted for remediation. The establishment of a gradient will infer the forced introduction of oxygen to the targeted soil.

Monitoring the concentrations of oxygen and carbon dioxide at the monitoring points will allow the evaluate of the presence of biological activity assumed to be reducing the hydrocarbon contamination. If biological activity is occurring in the targeted soil, then the baseline line oxygen readings should be depressed and the carbon dioxide readings elevated. As air is forced through the targeted soil, the oxygen level should increase and concentration of carbon dioxide should decrease. As the area rests between pulsed introduction of air, the oxygen level should decrease and the carbon dioxide level increase as the microbes aerobically degrade the petroleum hydrocarbons.

Monitoring the moisture content of the soil targeted for treatment will assure that moisture conditions in the soil remain suitable to support biological activity.

Based on these evaluation criteria, three cases have been developed to evaluate system performance following the start-up monitoring and sampling stage.

5.2.4.2.1 Case I

Case I refers to a situation where the baseline oxygen and carbon dioxide levels are nearly atmospheric and little response in concentration of these analytes is noted with time, even with the presence of a measurable induced gradient, and no significant difference in concentration of oxygen, carbon dioxide or hydrocarbons from atmospheric exists in the bio-venting exhaust nor is any uptake of oxygen measured between forced air pulses. Case I conditions would indicate that the system is operating as designed, but not effective in treatment. The lack of measurable gradient would indicate that the system is not successfully forcing oxygen through the soil targeted for clean up, a condition needing correction prior to evaluating the adequacy of bio-venting to this remediation. If soil conditions are dry, then moisture should be added to condition of soil to a state more hospitable to microorganisms before evaluating the adequacy of bio-venting.

5.2.4.2.2 Case II

Case II refers to a situation where the baseline level of oxygen is below atmospheric and the baseline concentration of carbon dioxide is equal to or greater than atmospheric; a measurable pressure response, increase in oxygen and reduction in carbon dioxide is noted while the horizontal well in the area is extracting vapor, and the oxygen level decreases and carbon dioxide level increases in the same area between pulses. Case II conditions indicate that the system is operating as designed and the conditions are supporting biological reduction of the contaminants. If the concentration of hydrocarbons in the exhaust is high, then soil vapor extraction is also taking place and the airflow rate could probably be reduced. If the concentrations of hydrocarbons in the exhaust are small, then most of the remediation is being accomplished by biodegradation. If the concentrations in the exhaust are nondetectable, then oxygen supply may be limiting the biological reduction of the hydrocarbons and the amount of air could be increased.

5.2.4.2.3 Case III

Case III refers to a situation where initially the conditions were as in Case II, but the oxygen uptake is decreasing, the carbon dioxide production is decreasing, the moisture conditions are adequate and the induced pressure gradient remains acceptable. Case III would indicate that the hydrocarbons used as a food source are being consumed and are limiting the biological activity. Variation of water content in the soil or air supply could also limit the biological activity, consequently if the soil moisture sensor or pressure measurements indicate a variation, it must be corrected to evaluate Case III.

TABLE 5-3

DATA QUALITY OBJECTIVES

Parameter	Matrix	Method[a]	Limit (ppbv)	Precision (≤%)	Accuracy (%)	Completeness (%)
Volatile Organics	Air	EPA TO-14	0.5-2	30	70-130	N/A

(a) These methods refer to those described in Test Method for the Evaluation of Solid Waste Physical/Chemical Method, SW-846, 1986, Environmental Monitoring and Support Laboratory, Cincinnati, OH 45268. The modified ADEC methods are available from ADEC Laboratory, 10107 Brentwood Place, Juneau 99801, (907) 790-2169.

5.2.5 Quality Control Samples

For samples that will be field tested and screened, no quality control samples will be collected. No quality control samples will be collected as part of the gas sampling to be conducted during monitoring of the system.

5.2.6 Laboratory Quality Control for Air Sampling, SVE System

Air samples collected during monitoring of the system will be analyzed for VOCs using EPA Method TO-14.

Target detection limits for Method TO-14 are provided in Table 5-3.

Laboratory holding times are 14 days for EPA Methods TO-14.

5.2.6.1 Laboratory Calibration Procedures

The project laboratory calibration procedures are specified in the appropriate analytical methods.

Calibration check standards will be analyzed before and after each batch of samples. If the recovery for the standard is not within established method-specific acceptance criteria, then corrective measures will be taken to remedy the situation. This may involve the re-analysis of the samples.

5.2.6.2 Data Qualifying and Corrective Actions

Analytical data generated with laboratory control samples (LCS) which fall within the established control limits will be judged to be in control. Data generated with LCS that do not fall within control limits will be considered suspect, and the analysis will be repeated or the results will be reported with appropriate qualifiers if re-analysis is not possible or necessary.

Corrective actions will be necessary if any of the following occurs:

- QC data are outside the warning or acceptable windows for precision and accuracy established for laboratory control samples;
- Blanks containing contaminants at concentrations above the levels specified in the Laboratory Quality Management Plan for any target compound;
- Undesirable trends are detected in matrix spike recoveries or relative percent difference (RPD) between matrix spike duplicates;
- Unusual changes in detection limits are observed; and

- Deficiencies are detected by the laboratory QA director during internal and external audits, or from the results of performance evaluation samples.

Corrective actions will be handled initially at the bench level by the analyst, who will review the preparation or extraction procedure for possible errors, check the instrument calibration, spike and calibration mixtures, and the instrument sensitivity. The analyst will immediately notify his/her supervisor of the identified problem and what actions have been undertaken. If the problem persists or cannot be identified, the matter will be referred to the laboratory supervisor and the laboratory QA director for further investigation. Once resolved, full documentation of the corrective action procedure will be filed by the QA director, and if the data are affected, a corrective action memorandum will be prepared for the project file.

Examples of corrective actions may include, but are not limited to:

- Reanalyzing suspect samples;
- Re-sampling and analyzing new samples;
- Evaluation and amending sampling and/or analytical procedures;
- Accepting data with an acknowledged level of uncertainty;
- Re-calibrating analytical instruments, and/or
- Rejecting the data.

5.2.6.3 Instrument Maintenance

Preventive maintenance in the laboratory will be the responsibility of the laboratory personnel. This maintenance includes routine care and cleaning of instruments, as well as inspection and monitoring of carrier gases, solvents, and glassware. Details of the maintenance procedures are addresses in the respective laboratory's Standard Operating Procedures and Methods manuals.

Precision and accuracy data will be examined to determine if there is evidence of instrument malfunction. Maintenance will be performed when an instrument begins to change as indicated by the degradation of peak resolution, shifts in retention times, a decrease in sensitivity, or a failure to meet method-specific quality control criteria.

5.2.6.4 Quality Control

Surrogate spikes, method blanks, duplicates, and laboratory control samples, and laboratory duplicates will be analyzed by the laboratory. Matrix spikes and matrix spike duplicates are not applicable to the analytical methods being used for this project.

5.2.6.4.1 Surrogates/Surrogate Spike

A surrogate is a compound added to every blank, sample and standard, as specified in the analytical methodology. Following analysis, the surrogate recovery results will be analyzed to evaluate the accuracy of the analytical measurement on a sample-specific basis. Results are expressed in terms of percent recovery of the surrogate spike amount.

Surrogates have only been established for EPA Method TO-14; these are listed in Table 5-4.

TABLE 5-4

SURROGATES

Surrogate	Accuracy (% Recovery)	Precision (%RPD)
Octafluorotoluene	70-130	± 30
Toluene-d8	70-130	± 30
4-Bromofluorobenzene	70-130	± 30

5.2.6.4.2 Method Blanks

For this project, a method blank will consist of air that has been certified analyte-free. The method blank will be carried through each step of the analytical method. The method blank data will be used to assess the presence of laboratory contamination during the analysis. Method blanks will be used for all three analytical methods. Method blanks will be used at a frequency of one per batch of samples (up to a maximum of 20 samples per batch). Accuracy and precision criteria used by the laboratory for blanks are 70-130 percent and ± 30 percent respectively.

5.2.6.4.3 Laboratory Control Samples

Laboratory control samples (LCS) are well-characterized, laboratory-generated samples used to monitor the laboratory's day-to-day performance of routine analytical methods. Accuracy and precision criteria used by the laboratory for LCSs are 70-130 percent and ±30 percent respectively. The purpose of the LCS is to monitor the precision and accuracy of the analytical process, independent of matrix effects.

The results of the LCS are compared to well-defined laboratory acceptance criteria to determine whether the laboratory system is "in control." The LCS offers the advantage of being able to differentiate low recoveries due to procedural errors from those due to matrix effects.

LCS will be used only for EPA Method TO-14. All target analytes will be spiked in the LCS sample(s). LCS will be used at a frequency of one per batch of samples (up to a maximum of 20 samples per batch).

5.2.6.4.4 Laboratory Duplicates

Laboratory duplicates are used to assess the reproducibility of the analytical results. Laboratory duplicates will be used for the analytical method, at a frequency of one per batch of samples (up to a maximum of 20 samples per batch).

5.2.6.5 Data Validation

Since the primary purpose of the sample collection effort is to assess the functioning of the SVE system and monitor the mass removal rate of contaminants, formal validation of the analytical data is not warranted. In addition, there are no procedures for validating air and soil gas sample analyses.

5.2.6.6 Laboratory Quality Control Document

The project laboratory QC Document Provides information on typical laboratory calibration procedures and standards to be used during the sample analysis, additional information on laboratory QC samples, and information on the reduction of analytical data.

5.2.7 Field Procedures

5.2.7.1 Field Measurements

A variety of sampling and field analytical equipment will be used during implementation of the treatment system. Proper calibration, maintenance, and use of instruments is required to ensure the quality of all data collected. An Equipment Calibration Log Sheet will be kept in the project dedicated field book for each instrument that has been affected by use. Equipment calibration log include:

- Date of calibration,
- All data pertaining to the calibration procedures,
- Initials of analyst performing calibration,
- Adjustments made and the accuracy of the equipment prior to and following calibration,, and
- Record of equipment failure or inability to meet specifications.

The field equipment and calibration procedures for each instrument that will be used are described below:

Photoionizor Detector: A photoionizer detector will be used for on-site detection of organic vapors and gases from excavated soil and potentially contaminated equipment. The PID should be calibrated twice a day using a two-point standardization procedure. Compressed isobutylene gas will be used to calibrate the instrument over the 0-200 ppm operating range.

Temperature Probe: The digital-readout temperature probe will be used to determine water temperature of samples during field testing. The temperature probe is calibrated by comparing five points on the scale to a factory-calibrated mercury thermometer once every six months.

Vacuum Gages: A set of three Dyer Magnehelic® will be connected in series and zeroed in the position that measurements will be obtained. The ranges of the gages shall be 0 to 1 inch of water, 0 to 10 inches of water, and 0 to 100 inches of water to measure pressure response at the monitoring points. An additional Magnehelic® gage will be used on site to measure the vacuum in the horizontal well. The range of this gage shall be 0 to 15 psi.

GasTech Model 3252OX: The GasTech Model 32520OX will be used to measure oxygen and carbon dioxide levels at the monitoring points and in the vapor extracted from the horizontal wells. The battery level will be checked prior to use to ensure proper operation. The air filters will be checked and cleaned or replaced, as necessary, prior to use. The instrument will be turned on and equilibrated for at least 30 minutes prior to calibration of obtaining measurements. The sampling pump will be checked. The meter will be calibrated each day prior to use against purchased Oxygen and carbon Dioxide calibration standards. The Carbon Dioxide calibration will be performed against atmospheric (0.05 percent) and a five percent standard. The Oxygen will be calibrated against atmospheric (20.9 percent) and a five percent standard and a zero percent standard in accordance with the manufacturer's recommendations.

GasTech Trace Techtor™: The Trace Techtor™ meter will be used to measure the concentration of hydrocarbons at the monitoring points and in the exhaust gas. Prior to use the instrument will be checked and equilibrated and calibrated against two hexane calibration standards (500 ppm and 4400 ppm) in accordance with the manufacturers recommendations.

Other equipment that might be required during the field work will be calibrated according to the manufacturer's recommendations and/or generally accepted practice.

Moisture Meter:- The Delmhorst KS-D1 Digital Soil Moisture Tester will be used to observe variations in water content. Model GB-1 Gypsum Block sensors will be installed in augered holes and bedded in silica flour. During installation, a sample of the soil at the level of installation will be obtained and tested for water content. Meter readings will be correlated to the soil sample results and to calibration curves found in the meters operating instructions.

5.2.7.2 Exhaust Gas Sampling Methodology

Soil vapor samples will be collected form the exhaust gas with Summa® canisters. Procedures for collecting Summa® canisters samples will be in accordance with specific guidelines provided by the laboratory that supplies the canisters. General sample collection methodology is described below. Detailed procedures for sample labeling and handling are provided in appendices.

5.2.7.2.1 Sample Collection

The six-liter Summa® canister will be supplied by the laboratory under a partial vacuum. The air inlet for the Summa® canister will be connected to the exhaust gas sampling port with polyethylene or tygon tubing. The sampling port will be one-fourth inch steel pipe tapped into the exhaust pipe and fitting with a quarter turn ball valve. A one-fourth inch hose middle will be attached to the ball valve. Samples will then be collected by opening the sample port valve and the inlet valve to the Summa® canister. Vapor from the exhaust will then flow into the partially evacuated Summa® canister and the operator will close the valve when the pressure inside the canister reaches the level specified by the laboratory. The QC duplicate (replicate) samples will be collected every three months by immediately attaching and filling a second canister after the primary sample is collected.

5.2.7.3 Field Record Keeping

The record keeping tasks described below will be performed to provide documentation of the field activities that are traceable and defensible.

A bound project dedication field book will be maintained for all activities conducted at the site. Notes on activities will be recorded, with ball point pen, in the field book on a daily basis. Pencil will be used only if wet conditions prevent use of a pen. Entries will include at a minimum the following information:

- Date, beginning, and ending times of field work;
- Names of field team members;
- Names of persons contacted at the site or any visitors to the site;
- Conditions of the site and observations;
- Samples collected, time collected, and their location;
- Observations of the soil, surface water and ground water, if encountered;
- Equipment used on-site, calibration methods, and information gathered;
- Other operations performed; and
- Any other pertinent site activity information.

Each day's entry will begin on a new page and blank lines on the final page for each day will be crossed out to the bottom. Daily entries will be signed by the person making the entry into the field book. Any corrections to the log will be made by crossing out the errors with one line, initialing the deletion, dating the deletion, entering the correction, initialing the correction and dating the correction.

If sampling is conducted during a day's field activity, the information about the samples and observations described above will be entered into the field book.

5.2.8 Sample Collection and Management

5.2.8.1 Sample Designation

Each sample will be identified by a coded 10 to 13 digit sample number. The sample identification number is composed of the year, week, site number, location number, sample depth, sample number, and sample matrix as shown below:

97 30 FR 01 05 1 AI

Year______ (97)
Week____ (30)
Ft. Richardson ______ (FR)
______Location Number (01)
______Sample Depth (as applicable) (05)
______Sample Number (1)
______Sample Matrix (AI)

Three designations will be used for the sample number; one represents a primary sample, two represents a duplicate sample (QC) for the project laboratory, and three represents a triplicate sample (QA) for the QA laboratory. The sample matrix is identified by the following abbreviations:

- SL for soil;
- SD for sediment;
- DR for drummed liquid/waste;
- MI for miscellaneous;
- ST for stockpiled/containerized soil;
- WA for water;
- TK for tank; and
- AI for air.

5.2.8.2 Sample Containers

Sample containers used during environmental investigations conducted by the DOWL/Ogden JV will be new, pre-cleaned, analytical grade containers. Table 5-5 presents the sample containers for use on this project.

TABLE 5-5

SAMPLE CONTAINERS, PRESERVATION, AND HOLDING TIME

PARAMETER	METHOD	Sample Holding Time (Days)	AIR Number and size of Sample Containers and Preservative
Volatile Organics	TO-14		1- 6 Liter Summa Canister

5.2.8.3 Sample Handling and Storage

Protocols for handling and storing samples once they are collected are intended to maintain sample integrity. Sample handling and storage procedures for ground water samples shall be conducted following the guidelines set forth in the ("Management Plan for Operable Alaska" as applicable.

Sample handlers will use clean, analyte-free, supplies and equipment while collecting, transferring, and packaging all sample materials. Samplers will wear new nitrile gloves while handling any sample material. These gloves are to be discarded after each sample is completed. Contact between the sample material and the sampler's gloved hands will be minimal.

For samples that are to be retained, sample containers will be labeled immediately following collection of the sample material. Each sample will be identified by a self-adhesive sample label. The sample identification number, the date and time the sample was collected, the material identification or sample type, the analysis to be performed, and the initials or signature of the person collecting the sample will be written in indelible ink on each sample label.

Air samples will be stored in a cooler. Ice will not be used.

Delivery of the samples to the laboratory will be prompt to ensure that holding times are met.

5.2.8.4 Sample Custody

A chain-of-custody form will be completed for each sample cooler delivered to the laboratory. Every sample that is submitted for analysis will be listed on a chain-of-custody form. The chain-of-custody form will function as the chain-of-custody record for the sample and as the receipt-for-sample record for the laboratory. The forms will be in triplicate using carbonless paper and the original will always remain with the samples. An example of the chain-of-custody form is found in Appendix C.

The Principal Site Investigator will be responsible for ensuring that the samples are properly labeled, packaged, and delivered to the contract laboratory with a chain-of-custody form which has been completed, dated, and signed. When transferring custody of the samples, the custodian will sign and record the date and time on the chain-of-custody form. Each person who acquires custody of the samples will be required to sign and date the appropriate section on the chain-of-custody form.

If possible, samples will be delivered to the contract laboratory at the end of each day's sampling operations. If samples require shipping, they will be shipped via air express in a cooler with the completed chain-of-custody form taped to the underside of the cooler lid, the cooler securely sealed with tape, and custody seals in place. During the time between collection and shipping, the samples will remain in the possession of the DOWL/Ogden JV Principal Site Investigator. The air shipper's bill of lading or airwaybill will be retained as part of the chain-of-custody record for that period of time that the sample is in route to the laboratory from the Principal Site Investigator.

Upon delivery of the samples to the contract laboratory, an inspection will be made of the containers to confirm that the containers' integrity have not been compromised during shipment. If any of the sample container seals appear to have been broken or are loose, the samples will be considered suspect and the collection of new environmental samples may be required.

5.2.9 Data Reporting

DOWL/Ogden JV has contracted a project laboratory for the analytical testing for this project. The Quality Control Document for this laboratory shall remain on file at the DOWL/Ogden JV office and will be provided to both the Alaska District and the ADEC at their request.

It is the responsibility of the project laboratory to perform all laboratory calibration procedures and maintain all approved standards according to accepted laboratory and EPA approved practices. In addition, the project laboratory will perform and certify all QA/QC procedures, performance audits, and data validation and reduction computations, and will provide the DOWL/Ogden JV with the required Data Deliverable package necessary for the DOWL/Ogden JV personnel to review and validate the analytical results.

Laboratory data will be submitted to the DOWL/Ogden JV by the project laboratory no later than 30 days after the laboratory receives the samples. The Alaska District will be responsible for transfer of any pertinent information or report copies to the ADEC.

6.0 WASTE MANAGEMENT

The IDW plan outlined herein establishes an approach to the handling, transport, and storage of the IDW. Handling of IDW will be in accordance with EPA document 540/G-91/009 "Management of Investigation-Derived Wastes."

6.1 Miscellaneous Decontamination Trash

All miscellaneous trash will be segregated from other IDW and collected in plastic bags upon generation and marked with a Non-Regulated Waste Label with:

- Firm Name
- Date
- Location
- Contents

Miscellaneous decontamination trash will be collected in plastic garbage bags and disposed of at an acceptable solid waste disposal facility.

6.2 Other Wastes

An element in the design of this remediation system was the minimization of waste.

Field screening of the soil excavated at RRFTA during the shallow trenching may identify near surface contamination. As the shallow trenching will be inside the treatment areas, any identified contaminated soil will be returned to the trenches as backfill to be addressed as part of the remediation program.

The location of any identified contaminated soil will be documented in the field logs, inspection reports, and the letter report.

7.0 REFERENCES

Alaska Department of Environmental Conservation (ADEC) (1995) Underground Storage Tanks, Title 18, Alaska Administrative Code, Chapter 78, as amended through November 3, 1995.

Alaska Department of Environmental Conservation (ADEC) (1994) Drinking Water. Title 18, Alaska Administrative Code, Chapter 80, as amended through November 10, 1994.

Alaska Department of Environmental Conservation (ADEC) (1990) Interim Guidance For Surface and Groundwater Cleanup Levels, September 26, 1990.

Decision Summary, Record of Decision for Operable Units A and B, Fort Richardson, Anchorage, Alaska, January 1997, Working Draft No. 1.

Ecology and Environment Site Investigation Report and Fire Training Pits at Fort Richardson and Fort Greely, Alaska, September 1993.

Ecology and Environment Final Feasibility Study, Operable Unit A, Ruff Road Fire Training Area, Fort Richardson, Alaska, Contract No. DACA85-93-D-0009, DO No. 38, November 1996.

Kenneth W. Simpson, Mauer General, USA Commanding Decision Document for Environmental Cleanup Action, Ruff Road Fire Training Area, Fort Richardson, Alaska.

Meeting November 18, 1997. DOWL - Fort Richardson.

APPENDIX A

DESIGN DRAWINGS

Note: The design drawings presented in this Appendix have been reduced to 11" x 17" from a 24" by 36" format. This results in scales not as indicated on the drawings.

APPENDIX B

STANDARD OPERATING PROCEDURES

STANDARD OPERATING PROCEDURE — 201

FIELD SCREENING OF HAND-AUGERED AND GRAB SAMPLES

1.0 OBJECTIVE

The objective of this procedure is to define the requirements and methods for field screening hand-augered and grab samples.

2.0 BACKGROUND

The use of field screening samples for either hand-augered or grab samples allows field teams to develop a general understanding of contaminant profiles with the objective of optimizing confirmation sampling activities. Consistent sampling procedures help to ensure uniformity of results and to reduce either false positives or negatives. Field-screening analysis of surficial grab samples or surficial/shallow subsurface hand-augered samples permits (1) a more informed selection of samples to be analyzed for contamination at an off-site laboratory, or (2) a preliminary/cursory investigation of shallow soils' contamination by on-site analytical equipment.

3.0 RESPONSIBILITIES

Site Manager: The Site Manager, or Field Team Leader, is responsible for ensuring that field activities are completed to meet the project objectives, are conducted in accordance with the project plans and requirements, and that all activities are performed according to the respective procedures. The Site Manager is responsible for ensuring that all site personnel are trained in the procedures, that the procedures are adhered to, and that all activities are documented.

Field Team: All members of the field team (samplers, technicians, field geologists, engineers, etc.) are responsible for understanding and implementing this field procedure as well as ensuring that all of the team members also perform in accordance with this procedure.

It is the responsibility of all field personnel to identify, document, and submit recommendations to improve the quality, usability, and implementability of this procedure.

4.0 REQUIRED EQUIPMENT

The equipment for sampling and transporting soils to the on-site analytical laboratory for screening analyses is as follows:

- certified clean sample containers of the appropriate size and material for specific analysis,
- latex gloves,
- clean stainless steel spoon or spatula,
- labels,

- coolers and ice,
- chain-of-custody (COC) forms,
- portable organic vapor detector [i.e., flame ionization detector (FID) or photoionization detector (PID)] if volatile organic compounds (VOCs) are expected to be present, and
- field logbook.

If surficial or relatively shallow subsurface soil contamination (especially VOCs) is to be investigated at the site by screening analyses, the following equipment will be needed:

- certified clean glass sample containers or zip-top type bags,
- aluminum foil,
- latex gloves,
- clean stainless steel spoon or spatula,
- labels,
- portable organic vapor detector (i.e., FID or PID), and
- field logbook.

5.0 PROCEDURES

The procedures for collecting field-screening samples for on-site screening analyses/analysis are:

1. Screen the sample with an organic vapor detector. Using gloved hands and the spatula/spoon, remove the soils from the bucket auger or collect the grab sample directly from the sampling device and place the required sample volume into the container(s) designated for on-site analysis/analyses. If the sample is to be sent for off-site analyses, the remainder of the sample will be placed in the appropriate laboratory-provided containers. Excess sampled soils will be disposed of as stated in the project Work Plan. Sleeved VOC samples that will be held for potential off-site laboratory analysis will not be disturbed by screening sample collection but will be capped and properly stored.

2. Complete and affix a label onto the sample container.

3. The sample will be transported directly to the on-site laboratory, or several samples may be retained and placed in a cooler with ice until the batch is transported to the laboratory.

4. A completed COC form will accompany each sample or batch of samples to the on-site laboratory and will be signed and dated by the appropriate parties when receiving or relinquishing the samples.

Soil contamination can be cursorily investigated by field screening analysis at the site by the following procedures:

1. Determine and stake the sample-collection locations and collect the hand-augered or grab samples.

2. Using gloved hands and spatula/spoon, fill either a clean container or zip-top type bag approximately one-half to two-thirds full with soil and tightly seal the zip-top type bag or tightly cap the clean container with a piece of aluminum foil.
3. Properly identify the sample.
4. Allow the sample to set for approximately 30 min in a warm environment (e.g., the sun or a heated car).
5. Pierce the aluminum foil or the zip-top type bag with the sample probe of the organic vapor detector and record the highest initial reading from the container's headspace in a field book.
6. Dispose of the soils and containers as stated in the project Work Plan.

STANDARD OPERATING PROCEDURE - 329

FIELD MEASUREMENT OF SUBSURFACE GASEOUS ANALYTE CONCENTRATIONS

1.0 OBJECTIVE

The objective of this procedure is to define the requirements for field measurements of subsurface gaseous analyte concentrations.

2.0 BACKGROUND

Field measurement of gaseous concentrations of oxygen, carbon dioxide, and hydrocarbon is often conducted for evaluation of bioventing, biosparging, and testing to verify the radius of influence for these technologies.

3.0 RESPONSIBILITIES

Site Manager: The Site Manager, or Field Team Leader, is responsible for ensuring that field activities are completed to meet the project objectives, are conducted in accordance with the project plans and requirements, and that all activities are performed according to the respective procedures. The Site Manager is responsible for ensuring that all site personnel are trained in the procedures, that the procedures are adhered to, and that all activities are documented.

Field Team: All members of the field team (samplers, technicians, field geologists, engineers, etc.) are responsible for understanding and implementing this field procedure as well as ensuring that all of the team members also perform in accordance with this procedure.

It is the responsibility of all field personnel to identify, document, and submit recommendations to improve the quality, usability, and implementability of this procedure.

4.0 REQUIRED EQUIPMENT

- Vacuum pump.
- Gas tech Model 3252OX CO2/O2 analyzer or equal.
- Photoionization detector.
- Calibration equipment.

- Magnehelic gage set.

5.0 PROCEDURE

5.1 Field Measurement

Prior to sampling, the sampling point will be purged as required for gaseous concentration to stabilize without drawing atmospheric air.

5.2 Carbon Dioxide/Oxygen Concentrations

Gaseous concentrations of carbon dioxide (CO2) and oxygen (O2) will be analyzed using a Gas Tech Model 3524OX CO2/O2 analyzer or equivalent. The battery charge level will be checked to ensure proper operation. The air filters will be checked and, if necessary, cleaned or replaced before each days field measurements. The instrument will be turned on and equilibrated for at least 30 minutes before conducting calibration or obtaining measurements. The sampling pump of the instrument will be checked to ensure that it is functioning. Low flow of the sampling pump can indicate that the battery level is low or that sediment is trapped in the pump of tubing.

Meters will be calibrated each day prior to use against purchased CO2 and O2 calibration standards. These standards will be selected to be in the concentration range of the soil gas to be sampled. The CO2 calibration will be performed against atmospheric CO2 (0.05 percent) and a five percent standard. The O2 will be calibrated using atmospheric O2 (20.9 percent) and against a five percent and zero percent standard. For each calibration point, a one liter Tedlar bag will be filled with the calibration gas. The instrument is then calibrated against the standard gas in accordance with the manufacturer's instructions.

5.3 Hydrocarbon Concentrations

Gaseous concentrations of organic vapors will be analyzed using a Photoionizer Detector (PID). The PID should be calibrated twice per day using a two-point standardization procedure. Compressed isobutylene gas will be used to calibrate the instrument over the 0-200 ppm operating range.

5.4 Pressure Monitoring

Wells and monitoring points will be fitted with caps that are tapped for quarter inch pipe thread. Quarter turn ball valves will be installed in the tap. The ball valve will terminate in a 3/16-inch hose nipple. The ball valve will remain closed between monitoring events. Prior to opening the well or monitoring point for field monitoring sampling, a magnehelic gage set will be connected to the hose nipple, the valve opened and the static pressure in the well or monitoring point will be recorded. The magnehelic gage set will consist of three gages with one gage in each of the following ranges (in inches of water): zero to one-inch, zero to 10inches, and zero to 100 inches.

STANDARD OPERATING PROCEDURE — 601

FIELD EQUIPMENT DECONTAMINATION

1.0 OBJECTIVE

The objective of this procedure is to describe the proper procedures for decontaminating sampling equipment used to perform field investigations.

2.0 BACKGROUND

Decontamination of field equipment is necessary to ensure that chemical analyses reflect actual concentrations at sampling locations by maintaining the quality of samples and preventing cross-contamination. Further, decontamination reduces the health hazards to field personnel and prevents the spread of contaminants off-site.

3.0 RESPONSIBILITIES

Site Manager: The Site Manager, or Field Team Leader, is responsible for ensuring that field activities are completed to meet the project objectives, are conducted in accordance with the project plans and requirements, and that all activities are performed according to the respective procedures. The Site Manager is responsible for ensuring that all site personnel are trained in the procedures, that the procedures are adhered to, and that all activities are documented.

Field Team: All members of the field team (samplers, technicians, field geologists, engineers, etc.) are responsible for understanding and implementing this field procedure as well as ensuring that all of the team members also perform in accordance with this procedure.

It is the responsibility of all field personnel to identify, document, and submit recommendations to improve the quality, usability, and implementability of this procedure.

4.0 REQUIRED EQUIPMENT

4.1 Definition And Equipment

Sampling equipment includes split spoons, liners, hand augers, bailers, bowls, knives, scoops, water samplers, nondisposable filtration equipment, or any equipment that directly contacts samples. Equipment necessary to complete decontamination procedures includes:

- 5-gal or larger plastic buckets and/or troughs;
- laboratory-grade detergent (phosphate free);
- stiff-bristle brushes capable of cleaning the inside and outside of equipment;
- Teflon sprayers or wash bottles, or 2- to 5-gal manual pump sprayer (pump sprayer material must be compatible with the solution used);

- plastic sheeting;
- disposable wipes;
- aluminum foil;
- potable water;
- deionized, organic-free water [American Society for Testing and Materials (ASTM) Type II or equivalent] [high-pressure liquid chromatography (HPLC)-produced water is not acceptable] (**Note: the equivalent of ASTM Type II water can be processed on-site by using a mobile deionization/organic filtration system**);
- gloves, goggles, and other protective clothing as specified in the site-specific Health and Safety Plan; and
- steam cleaner.

5.0 PROCEDURES

5.1 General Procedure

Before samples are collected, the equipment used to collect water, soil, sediment, and other samples will be decontaminated by the following method:

1. Set up a decontamination line on plastic sheeting or on a table covered by aluminum foil (shiny side away from equipment). The decontamination area should progress from "dirty" to "clean" and end with an area for drying equipment. At a minimum, clean plastic sheeting must be used to cover the ground, and plastic sheeting or aluminum foil must cover tables or other surfaces where decontaminated equipment is to be placed.
2. Dislodge as much loose dirt as possible from equipment before beginning the decontamination process. Wash the item thoroughly in a bucket or trough of soapy water. Use a stiff-bristle brush to dislodge any clinging dirt. Disassemble any items that might trap contaminants internally before washing.
3. Rinse in second bucket or trough containing tap water. Rinse water should be replaced as necessary (generally when water is cloudy).
4. Repeat step 3 in a separate bucket or trough (optional).
5. Using a hand sprayer, rinse the item with ASTM Type II or equivalent water over a separate bucket.
6. If the equipment will have time to fully air dry before its next use, allow to air dry. If the equipment will not be allowed to fully air dry, repeat step 5 before reassembling or using any equipment.
7. If equipment will not be used immediately after drying, wrap in aluminum foil (shiny side out) for storage and transport.
8. Record decontamination protocol, equipment types, and date in the appropriate logbook at each occurrence.

9. After decontamination activities are complete, collect all contaminated waters, solvents, plastic sheeting, aluminum foil, disposable gloves, boots, and clothing. Place contaminated items in properly labeled containers for disposal. Liquids and solids must be drummed separately.

5.2 Downhole And Heavy Equipment

Downhole equipment consists of nonsampling tools such as hollow-stem augers, drill pipe, bits, casing, and screen. Drill rigs, backhoes, and other heavy machinery are also included. Equipment necessary to complete decontamination procedures includes:

- plastic sheeting;
- metal, wooden, or plastic sawhorses or other stands;
- laboratory-grade detergent (phosphate free);
- steam cleaner;
- stiff-bristle brushes;
- 2- to 5-gal manual pump sprayer (pump sprayer must be compatible with the solution used);
- deionized, organic-free water (ASTM Type II or equivalent) (HPLC-produced water is not acceptable); and
- gloves, goggles, boots, and other protective clothing as specified in the site-specific Work Plan.

Before drilling, sampling, excavating, leaving the site, and in between each locaiton, all drilling equipment used in field sampling activities must be decontaminated. All downhole augering, drilling, and sampling equipment shall be sandblasted (off-site) if it is new, painted equipment (such as split spoons or auger flights) or exhibits build-up of rust or caked material. Heavy equipment not directly used for sampling will be decontaminated at a designated area designed to contain decontamination wastes and waters. The following steps must be taken when decontaminating this equipment:

1. Set up a decontamination pad that is large enough to fully contain the equipment to be cleaned. If practical, a centralized decontamination area should be established. This area should be set up to contain contaminated rinse waters and may be constructed using one or more layers of heavy plastic sheeting with bermed sides, a lined excavated pit, or a bermed concrete or asphalt pad. The decontamination area must be constructed so that fluids can be easily pumped from the area to holding containers.

2. Set up a "clean" area upwind of the decontamination area to receive cleaned equipment for air drying. At a minimum, clean plastic sheeting must be used to cover surfaces on which decontaminated equipment is to be placed.

3. Don personal protective equipment as specified in the site-specific Health and Safety Plan before beginning cleaning activities.

4. For heavy equipment, spray areas exposed to contaminated soil using steam-spray unit. Be sure to spray down all surfaces, including the undercarriage. It is also good practice to clean the motor, hydraulic lift, oil fill, and fuel tank area to avoid introducing contamination at the work site.

5. For smaller equipment such as augers, place the objects to be cleaned on metal or plastic-covered wooden sawhorses or supports. Using the steam-spray unit, spray the contaminated equipment. Be sure to spray inside corners and gaps especially well using a brush, if necessary, to dislodge dirt.

6. For steps 4 and 5, aim the sprayer downward as much as possible to avoid spraying outside the decontamination area.

7. If the condition of downhole or heavy equipment warrants using hot soapy water in the steam-spray unit, rinse the equipment with clean, clear tap water following the steam spray. If using steam, the rinse is not necessary if the steam does not contain a detergent.

8. Remove the equipment from the decontamination area to the "clean" area to dry.

9. Record decontamination protocol, equipment types, and date in the appropriate logbook.

10. After decontamination procedures are complete, or any time the decontamination fluids fill the bermed or contained area, collect all decontamination fluids and transfer them to appropriate containers. Place all plastic and personal protective equipment into appropriate containers. All containers must be labeled properly for disposal. Liquids and solids must be stored separately.

5.3 Pumps And Pump Assemblies

Any pump in which potentially contaminated fluids come into contact with any part of the pump equipment requires decontamination. This requirement does not include peristaltic pumps. Dedicated tubing should be used for peristaltic pumps so decontamination will not be needed. If the tubing is to be reused, it must be properly decontaminated. Equipment necessary to complete decontamination procedures includes:

- ASTM Type II water;
- plastic sheeting;
- sufficient containers, two for decontamination procedure and one for waste water;
- laboratory-grade detergent (phosphate free); and
- gloves, goggles, boots, and other protective clothing as specified in the site-specific Work Plan.

Following the use of a pump for development, purging, and/or sampling, the pump should be decontaminated by the following method.

1. Set up containers in a line on the plastic.

2. Add potable water with detergent to the first container; add potable water alone to the second container. There should be sufficient water to accomplish the decontamination procedure in each container. **(Note: before using pumps, check state and regional guidance on the use of a detergent rinse. Detergent rinse of pumps is not allowed in all areas.)**

3. Place one container close enough to the decontamination area to collect the spent decontamination fluids.

4. Place the pump in the first container, and pump enough water through it to equal at least three pump-and-pump-hose volumes. Pump the water into the waste drum. Move the pump to the second container and repeat. Rinse out and fill the second container with ASTM Type II water and repeat again.

5. Record decontamination protocol, equipment types, and date in the appropriate logbook.

6. After decontamination activities are complete, collect all contaminated water; solvents; plastic sheeting; aluminum foil; and disposable gloves, boots, and clothing. Place contaminated items in properly labeled drums for disposal. Liquids and solids must be drummed separately.

6.0 RESTRICTIONS AND LIMITATIONS

Filtering of samples, when required, should be done in the field as quickly as possible. The sample shall be preserved immediately after filtration. Three basic filter systems are typically used: an in-line disposable filter, an inert gas over-pressure filtration system, and the vacuum filtration system. For systems where disposable filters are used, decontamination is not required. The filters should be discarded after the desired sample is obtained. For reusable systems, decontamination procedures for sampling equipment are found in Section 4.0.

ASTM Type II water can be produced on-site with a mobile filtration system. If field-produced ASTM-type water is used, blank samples should be taken and analyzed to ensure the purity of the water.

5.6.3 Post-Permeability Test Soil Gas Monitoring

Immediately after completion of the permeability test, soil gas samples will be collected from the vent well, the background well, and all monitoring points, and analyzed for O_2, CO_2, and hydrocarbons. If the O_2 concentration in the vent well has increased by 5% or more, O_2 and CO_2 will be monitored in the vent well in a manner similar to that described for the monitoring points in the in situ respiration test. (Initial monitoring may be less frequent.) The monitoring will provide additional in situ respiration data for the site.

5.7 In Situ Respiration Test

The in situ respiration test will be conducted using four screened intervals of the monitoring points and a background well. The results from this test will determine if in situ microbial activity is occurring and if it is O_2-limited.

5.7.1 Test Implementation

Air with 1 to 2% helium will be injected into the monitoring points and background well. Following injection, the change of O_2, CO_2, total hydrocarbon, and helium in the soil gas will be measured over time. Helium will be used as an inert tracer gas to assess the extent of diffusion of soil gases within the aerated zone. If the background well is screened over an interval of greater than 10 ft, the required air injection rate may be too high to allow helium injection. The background monitoring point will be used to monitor natural degradation of organic matter in the soil. A schematic of the apparatus to be used in the in situ respiration test is presented in Figure 2-9.

The O_2, CO_2, and total hydrocarbon levels will be measured at the monitoring points before air injection. Normally, air will be injected into the ground for at least 20 hours at rates ranging from 1.0 to 1.7 cfm (60 to 100 cfh). Blowers to be used will be diaphragm compressors Model 4Z024 from Grainger (or equivalent) with a nominal capacity of 1.7 cfm (100 cfh) at 10 psi. The helium used as a tracer will be 99% or greater purity, which is available from most welding supply stores. The flow rate of helium will be adjusted to 0.6 to 1.0 cfh to obtain about 1% in the final air mixture which will be injected into the contaminated area. Helium in the soil gas will be measured with a Marks Helium Detector Model 9821 (or equivalent) with a minimum sensitivity of 0.01%.

After air and helium injection is completed, the soil gas will be measured for O_2, CO_2, helium, and total hydrocarbon. Soil gas will be extracted from the contaminated area with a soil gas sampling pump system similar to that shown in Figure 5-1. 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 will be acceptable.

At shallow monitoring points, there is a risk of pulling in atmospheric air in the process of purging and sampling. Excessive purging and sampling may result in erroneous readings. There is no benefit in over sampling, and when sampling shallow points, care will be taken to minimize the volume of air extraction. In these cases, a low-flow extraction pump of about 0.03 to 0.07 cfm (2.0 to 4.0 cfh) will be used. Field judgment will be required at each site in determining the sampling frequency. Table 5-1 provides a summary of the various parameters which will be measured and their frequency.

The in situ respiration test will be terminated when the oxygen level is about 5% or after 5 days of sampling. The temperature of the soil before air injection and after the in situ respiration test will be recorded.

5.7.2 Data Interpretation

Data from the in situ respiration and air permeability tests will be summarized, and their O_2 utilization rates, air permeability, and R_I will be computed. Further details on data interpretation are presented in Sections 5.7.2.1 and 5.7.2.2.

5.7.2.1 Oxygen Utilization

Oxygen utilization rates will be determined from the data obtained during the bioventing tests. The rates will be calculated as the percent change in O_2 over time. Table 5-2 contains the two sets of sample data which are illustrated in Figure 5-2. The O_2 utilization rate is determined as the slope of the $O_2\%$ vs. time line. A zero-order respiration rate as seen in the Fallon NAS data is typical of most sites; however, a fairly rapid change in oxygen levels may be seen as in the data from Kenai, Alaska. In the later, the oxygen utilization rate was obtained from the initial linear portion of the respiration curve.

To estimate biodegradation rates of hydrocarbon from the oxygen utilization rates, a stoichiometric relationship for the oxidation of the hydrocarbon will be used. Hexane will be used as the representative hydrocarbon, and the stoichiometric relationship used to determine degradation rates will be:

$$C_6H_{14} + 9.5\ O_2 \rightarrow 6CO_2 + 7H_2O$$

Based on the utilization rates (change of oxygen [%] per day), the biodegradation rate in terms of mg of hexane-equivalent per kg of soil per day will be estimated using the following equation.

$$K_B = -K_o\ A\ D_o\ C/100 \qquad (1)$$

where:

K_B = biodegradation rate (mg/kg day)
K_o = oxygen utilization rate (percent per day)

TABLE 5-1. Parameters to be Measured for the In Situ Respiration Tests

Parameter/Media	Suggested Method	Suggested Frequency	Instrument Sensitivity (Accuracy)
Carbon dioxide/soil gas	Infrared adsorption method, GasTech Model 32520X (0 to 5% and 0 to 25% carbon dioxide)	Initial soil gas sample before pumping air, immediately after pump shut off, every 2 hours for the first 8 hours, and then every 8 to 10 hours	±0.2%
Oxygen/soil gas	Electrochemical cell method, GasTech Model 32520X (0 to 21% oxygen)	Same as above	±0.5%
Total hydrocarbons (THC)/soil gas	GasTech hydrocarbon detector or similar field instrumentation	Initial soil gas sample before pumping air, then same as above if practical	±1 ppm
Helium	Marks Helium Detector Model 9821 or equivalent	Same as for carbon dioxide	±0.01%
Pressure	Pressure gauge (0 to 30 psia)	During air injection	0.5 psia
Flow rate/air	Flowmeter	Reading taken during air injection	±5 cfh

A = volume of air/kg of soil (l/kg)
D_o = density of oxygen gas (mg/l)
C = mass ratio of hydrocarbon to oxygen required for mineralization.

Using several assumptions, values for A, D_o, and C can be calculated and substituted into equation 1. Assumptions used for these calculations are:

- Porosity of 0.3 (the air-filled porosity, which can range from 0.0 to 0.6 depending on the site soils and varies with moisture content in any given soil)
- Soil bulk density of 1,440 kg/m^3

TABLE 5-2. Sample Data Set for Two In Situ Respiration Tests

Fallon NAS, Nevada (Test Well A2)			Kenai, Alaska (Test Well K1)			
Time (Hours)	O_2(%)	CO_2(%)	Time (Hours)	O_2(%)	CO_2(%)	Helium
-23.5	0.05	20.4	-22.0	3.0	17.5	—
0	20.9	0.05	0	20.9	0.05	1.8
2.5	20.3	0.08	7.0	11.0	2.7	1.4
5.25	19.8	0.10	12.25	4.8	4.6	1.4
8.75	18.7	0.13	19.50	3.5	6.0	1.3
13.25	18.1	0.16	26.25	1.8	6.5	1.0
22.75	15.3	0.14	46.00	2.0	7.0	0.9
27.0	15.2	0.22				
32.5	13.8	0.14				
37.0	12.9	0.23				
46.0	11.2	0.22				
49.5	10.6	0.16				

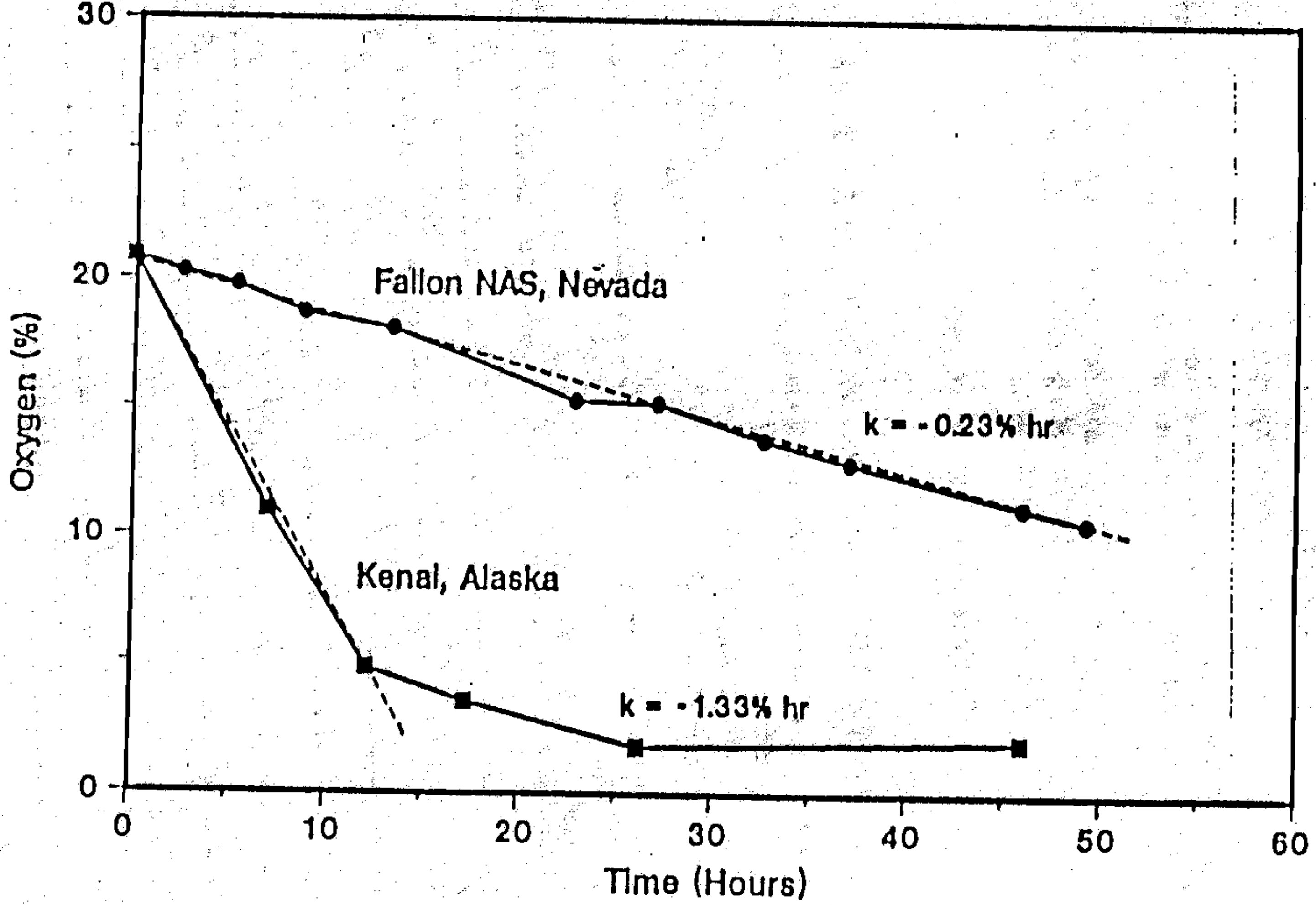


Figure 5-2. In Situ Respiration Test Results for Two Bioventing Test Sites: Fallon NAS, Nevada (Monitoring Point A2) and Kenai, Alaska (Monitoring Point K1).

KA/OW/5-01

- D_o oxygen density of 1,330 mg/l (varies with temperature, altitude, and atmospheric pressure)
- C, hydrocarbon-to-oxygen ratio of 1/3.5 from the above equation for hexane.

Based on the above assumed porosity and bulk density, the term A, volume of air/mg of soil, becomes 300/1,440 = 0.21. The resulting equation is:

$$K_B = -(K_o)(0.21)(1330)(1/3.5)/100 = 0.8\ K_o \qquad (2)$$

This conversion factor, 0.8, was used by Hinchee et al. (1991b) in their calculations of biodegradation rates of hydrocarbons. Another way to estimate biodegradation rates is based on CO_2 generation rates, but as discussed in Section 2.3, this is less reliable than using O_2 utilization rates.

5.7.2.2 Helium Monitoring

Figures 5-3 and 5-4 show typical helium data for two test wells. The helium concentration at monitoring point S1 (Figure 5-3) at Tinker AFB started at 1.5% and after 108 hours had dropped to 1.1%, i.e., a fractional loss of –0.25. In contrast, for Kenai K3 (Figure 5-4), the change in helium was rapid (a fractional drop of about 0.8 in 7 hours), indicating that there was possible short-circuiting at this monitoring point. This suggested that the data from this monitoring point were unreliable, and so the data were not used in calculating degradation rates.

As a rough estimate, diffusion of gas molecules is inversely proportional to the square root of the molecular weight of the gas. Based on the molecular weights of 4 and 32 g mol for helium and oxygen, respectively, helium diffuses about 2.8 times faster than oxygen. This translates into a fractional oxygen loss of –0.095 for S1 of Tinker AFB, a minimal loss. The data from this monitoring point were used in the calculation rates. As a guide, data from tests where fractional helium loss is 0.4 or less over 100 hours, or an equivalent fractional oxygen loss of 0.15, are acceptable.

5.8 Bioventing Test

The bioventing test is the third and final part of the field treatability study and will consist of a longer term (6 months or more) air injection or withdrawal procedure. A blower will be installed immediately following completion of the air permeability and in situ respiration tests, and will be started before the field crew leaves the site. At some sites where regulatory approval is pending, the bioventing blower will be installed and started at a later date.

CHAPTER 2. STANDARD SAMPLING PROCEDURES

SECTION 1. PROGRAM DESCRIPTION

1.1 Program objectives

This manual outlines the standard operating procedures, quality control procedures and data quality objectives for regulated underground storage tank (UST) site characterization, site assessments, release investigations, and corrective actions. It directs the collection, interpretation, and reporting of data. This data will enable tank owners and operators and the Alaska Department of Environmental Conservation (ADEC) to evaluate the presence, degree, and extent of any groundwater, surface water, and soil contamination and to determine if further action is necessary.

The term "assessment firm," wherever used in this manual, refers to the organization conducting the activity.

1.2 Program approach

To meet program objectives, this manual outlines a systematic approach to conducting UST site assessments and investigations. This approach is based on scientific studies, United States Environmental Protection Agency (EPA) guidance and methods, Alaska's UST regulations in 18 AAC 78, guidelines, input from the Alaska UST regulations workgroup, and assessment strategies currently used in Alaska and other states. This manual details sampling, laboratory analysis, and data reporting procedures, along with all required quality control functions. It also lists persons responsible for the major tasks required by 18 AAC 78. The manual covers activities in the following areas:

- personnel
- data quality objectives
- sampling procedures
- sample transfer log
- laboratory analytical procedures
- equipment maintenance and calibration
- data reduction, validation, and reporting
- quality control checks
- precision, accuracy, and completeness assessment
- corrective action scenarios
- internal audits
- reporting to management

Information about site sampling locations and site history, with reference to any existing documents for historical information and data available, must be included in the each site-specific project plan or report submitted for each project undertaken for which a plan is required.

SECTION 2. PROGRAM ORGANIZATION AND RESPONSIBILITIES

2.1 Personnel and responsibilities

The Qualified Personnel Form, Appendix A, must be submitted to ADEC with a resume for each qualified person to document that all activities under this chapter, including the collection, interpretation, and reporting of data, are conducted or supervised by a qualified person as required by 18 AAC 78. The submitted document must also identify the assessment firm's key UST personnel including the principal investigator and the quality assurance (QA) officer. Their responsibilities under this chapter are as follows:

(1) the assessment firm's principal investigator is responsible for overall management of the UST site assessment and site investigation program, including adherence to the procedures outlined in this chapter;

(2) the assessment firm's QA officer is responsible for overall quality assurance of the assessment firm's UST program; the QA officer is responsible for conducting scheduled field audits and providing ongoing review, monitoring, and evaluation of the field and laboratory activities; the QA officer shall validate or supervise validation of all reports to ADEC.

2.2 Accountability

While a laboratory must assure satisfactory levels of quality control within the laboratory to maintain approval status with ADEC, the owner or operator shall ensure that the assessment firm

(1) verifies the approval status of the laboratory being used; a list of approved laboratories is available from ADEC;

(2) ensures that analytical testing meets the objectives of this chapter that refer to laboratories and the applicable requirements of 18 AAC 78;

(3) reports in any project report connected with this chapter any deviation from standard laboratory procedures of which it becomes aware;

(4) takes appropriate corrective actions as outlined in Section 10 if questions or problems arise with the laboratory analysis.

2.3 Changes in personnel or responsibilities

If there is a change in personnel or their responsibilities after submitting the Qualified Personnel Form, the form must be amended to reflect the new personnel or responsibilities and resumes must be forwarded to ADEC with the revised form. Resubmittals or amendments to the form must be received by ADEC before or concurrently with any site specific project plans or reports that are submitted subsequent to the personnel change.

SECTION 3. FIELD QUALITY ASSURANCE

3.1 Responsibility and definitions

Quality assurance (QA) objectives are quantitative and qualitative criteria needed to support specific regulatory action and describe the acceptability of data. The assessment firm has primary responsibility for field QA and is accountable for the overall QA of the samples. Quantitative QA criteria are precision, accuracy, and completeness. Qualitative QA criteria are representativeness and comparability. QA is determined on a site-specific basis for each project based on the following:

(1) **Precision**: Precision is a measure of the variability or random error in sampling, sample handling, preservation, and laboratory analysis.

(2) **Accuracy**: Accuracy is a measure of the closeness of an individual measurement or an average of a number of measurements to the true value.

(3) **Completeness**: Completeness is a measure of the amount of valid data obtained compared to the amount expected. For purposes of this chapter, completeness is calculated as the amount of usable samples divided by the minimum number of required samples, expressed as a percentage. A minimum confidence level of 85 percent is required.

(4) **Representativeness**: Representativeness describes the degree to which data characterize the actual conditions at a site.

(5) **Comparability**: Comparability expresses the confidence with which one data set can be compared with another. Data must be reported in the same units of quantitation and in accordance with the reporting requirements of 18 AAC 78. Sampling and laboratory reports and procedures might be audited to assure that they follow standard procedures and reporting formats.

SECTION 4. SAMPLING PROCEDURES

4.1 Overview of sampling approach

The systematic sampling approach outlined below must be used to assure that data collection activities provide usable data.

(1) Sampling must begin with an evaluation of background information, historical data, and site conditions. This evaluation is used to prepare a site-specific sampling strategy.

(2) In combination with the requirements of 18 AAC 78 and the results of the pre-sampling investigation, field screening results must be used to determine where samples will be collected. Field screening results may also be used to segregate soils, based on apparent levels of contamination, to help monitor potential exposures, and for health and safety monitoring. However, field screening may not take the place of laboratory samples required as discussed in Section 4.5 (Determining sample locations).

(3) Samples must be collected with appropriate, clean tools. All decontamination of sampling equipment must follow the practices described in this section or, where applicable, EPA recommended procedures.

(4) Stockpiles must be sampled in accordance with Sections 4.5.1 (Sample locations for contaminated untreated stockpiles).

(5) If necessary, sufficient monitoring and observation wells must be properly installed to determine the presence, degree, or extent of groundwater contamination. Sampling of groundwater must follow the standard procedures outlined in Section 4.7.2 (Sampling groundwater monitoring wells).

(6) Samples must be collected and preserved in appropriate sample containers, as listed in Table 1.

Table 1: Reference Guide to Sample Collection and Laboratory Analysis

Part A: Soils, Sediments, Sludges, and Fill Materials

Parameter	Preparation Method[1]	Analytical Method[1]	Method Detection Limit[2]	Practical Quantitation Limit[3]	Container Description	Preservation/ Holding Time
Diesel Range Organics	AK102*	AK102*	0.5 mg/kg	4 mg/kg min.	4 oz. amber glass, TLC	4° ± 2°C / 14 days to extract, analyze < 40 days
Gasoline Range Organics	AK101*	AK101*	0.7 mg/kg	5 mg/kg min.	4 oz. amber glass, TLS	methanol, < 25°C / 28 days
Residual Range Organics	AK103*	AK103*	10 mg/kg	100 mg/kg	min. 4 oz. amber glass, TLC	4° ± 2°C / 14 days to extract, analyze < 40 days
Total BTEX	5030	8020, 8240, 8260, or AK101	0.007 mg/kg	0.05 mg/kg	min. 4 oz. amber glass, TLS	4° ± 2°C / 14 days or per method requirements
Total Polynuclear Aromatic Hydro-carbons (PAH	3540, 3541 3550	8100, 8270, or 8310	0.1 mg/kg	10 mg/kg	min. 4 oz. amber glass, TLS	4° ± 2°C / 14 days or per method requirements
Total Volatile Chlorinated Solvents	5030	8010, 8240, or 8260	0.008 mg/kg	0.05 mg/kg	min. 4 oz. amber glass, TLS	4° ± 2°C / 14 days
Polychloronated biphenyls (PCBs)	3550 or 3540	8080 or 8081	0.01 mg/kg	0.05 mg/kg	min. 4 oz. amber glass, TLC	4° ± 2°C / 14 days to extract, analyze < 40 day
Arsenic	3050	6010, 6020, 7060, or 7061	1 mg/kg	10 mg/kg	min. 4 oz. amber glass, TLC	4° ± 2°C / 6 months max. on digestate
Total Cadmium	3050	6010, 6020 7130, or 7131	1 mg/kg	10 mg/kg	min. 4 oz. amber glass, TLC	4° ± 2°C / 6 months max. on digestate
Total Chromium	3050	6010, 6020 7190, or 7191	1 mg/kg	10 mg/kg	min. 4 oz. amber glass, TLC	4° ± 2°C / 6 months max. on digestate
Total Lead	3050	6020 or 7421	1 mg/kg	10 mg/kg	min. 4 oz. amber glass, TLC	4° ± 2°C / 6 months max. on digestate

Legend:

Total BTEX = Benzene, Toluene, Ethylbenzene, Xylene;
Total PAH = naphthalene, 1- and 2-methylnaphthalene, 2,6-dimethylnapthalene, 2,3,5-trimethylnapthalene, other C-2 and C-3 napthalenes,dibenzothiophene, biphenyl, fluorene, phenanthrene, 1-methylphenanthrene, anthracene, fluoranthene, pyrene, benzo-a-anthracene, acenaphthylene, chrysene, benzo-e-pyrene, benzo-a-pyrene, dibenzo-a,h-anthracene, benzo-b-fluoranthene, benzo-k-fluoranthene, ideno-123-cd-pyrene, dibenzo a,h-anthracene and benzo-g,h,i-perylene;
VOA = Volatile Organic Analysis;
TLC = Teflon lined screw caps;
TLS = Teflon lined septa sonically bonded to screw caps;

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[1] Unless otherwise noted, all preparation and analytical methods refer to those contained in the United States Environmental Protection Agency's Methods for Chemical Analysis of Water & Wastes, EPA 600/4-79-020, revised March, 1983 or its Test Method for the Evaluation of Solid Waste Physical/Chemical Methods, SW-846, (PB84128677), 1986, revised ovember 1992, revised 1994 updates (proposed). Environmental Monitoring and Support Laboratory, Cincinnati, OH 45268. These methods, along with the ADEC analytical methods cited below, are the standard operating procedures referred to in 18 AAC 78.800(b).

[2] Method detection limits are determined, as specified in 40 C.F.R., Part 136, Appendix B, at the Department of Environmental Conservation's Juneau Laboratory. Each laboratory ust verify its own method detection limits and must be better than or equal to those listed here.

[3] Practical quantitation limits (PQLs), like method detection limits, are instrument specific. PQLs must be established by each laboratory and must be equal to or exceed those listed

* ADEC Analytical Methods AK101, AK102, and AK103 are included in the Department of Environmental Conservation's Underground Storage Tank Procedures Manual as Appendix D-F.

Table 1: Reference Guide to Sample Collection and Laboratory Analysis (cont.)
Part B: Ground, Surface, Waste, and Marine Waters[4]

Parameter	Preparation Method[1]	Analytical Method[1]	Method Detection Limit[2]	Practical Quantitation Limit[3]	Container Description	Preservation/ Holding Time
Diesel Range Organics	AK102*	AK102*	20 µg/L	100 µg/L	1 L amber glass, TCL	pH < 2 (HCL) 4° ± 2°C / 7 days to extract, analyze < 40 days
Gasoline Range Organics	AK101*	AK101*	30 µg/L	100 µg/L	40 mL VOA, TLS	pH < 2 (HCl), 4° ± 2°C / 14 days
Residual Range Organics	Soils only method.					
Total BTEX	5030	602, 624, or AK101	0.7 µg/L	5 µg/L	40 mL VOA, TLS	pH < 2 (HCl), 4° ± 2°C / 14 days
Total Polynuclear Aromatic Hydrocarbons (PAH)	5030	610 or 625	1 µg/L	15 µg/L	40 mL VOA, TLS	pH < 2 (HCl), 4° ± 2°C / 14 days
Total Volatile Chlorinated Solvents	5030	601 or 624	0.8 µg/L	5 µg/L	40 mL VOA, TLS	pH < 2 (HCl), 4° ± 2°C / 14 days
Polychloronated biphenyls (PCBs)	3510	608	1 µg/L	5 µg/L	1 L amber glass, TLC	pH < 2 (HCl), 4° ± 2°C / 14 days to extract, analyze < 40 days
Total Arsenic	3010 or 3015	6010, 6020, 7060, or 7061	100 µg/L	1000 µg/L	min. 100 mL HDPE[5]	pH < 2 (HNO3), 4° ± 2°C /6 months max. on digestate
Total Cadmium	3010 or 3015	6010,6020, 7130, or 7131	100 µg/L	1000 µg/L	min. 100 mL HDPE[5]	pH < 2 (HNO3), 4° ± 2°C /6 months max. on digestate
Total Chromium	3010 or 3015	6010, 6020 7190, or 7191	100 µg/L	1000 µg/L	min. 100 mL HDPE[5]	pH < 2 (HNO3), 4° ± 2°C /6 months max. on digestate
Total Lead	3010 or 3015	6010, 6020 or 7421	100 µg/L	1000 µg/L	min. 100 mL HDPE[5]	pH < 2 (HNO3), 4° ± 2°C /6 months max. on digestate

Legend: See Part A of this table

[1] See Part A of this table

[2] See Part A of this table

[3] See Part A of this table

[4] Sample collection and laboratory analyses for water collected from drinking water sources should be done in accordance with 18 AAC 80.

[5] HDPE, High Density Polyethylene sample collection bottles, critically cleaned for trace metals analysis.

* ADEC Analytical Methods AK101, AK102, and AK103 are included in the Department of Environmental Conservation's Underground Storage Tank Procedures Manual, as Appendix D-F.

4.2 Documentation of sampling procedures

A field log book or another type of field record must be used to document the collection of samples and site data. This record should include:

(1) the name of each qualified person on site supervising or conducting a characerization, assessment, or investigation;

(2) the date and time of sampling;

(3) weather conditions, including temperature, wind speed, humidity, and precipitation;

(4) the name of each person who physically collected the samples;

(5) clear photographs of site, bottom of excavation, and removed tanks;

(6) the results of an inspection of the tank and piping for corrosion;

(7) a site sketch that, at a minimum, shows

(A) locations of all known present and past USTs, piping and pump islands, including UST identification numbers assigned by ADEC;

(B) distances from tanks to nearby structures;

(C) property line locations;

(D) sampling locations and depths and corresponding sample ID numbers;

(E) any release sites;

(F) any free product sites;

(G) scale; and

(H) a north arrow.

When appropriate, the site sketch should include the following relevant features:

(1) a description of the size of the excavation;

(2) field instrument readings;

(3) location of stockpiled soils;

(4) depth, width, and type of backfill material used to surround tanks and piping;

(5) soil types;

(6) utility trenches;

(7) wells within 100 feet;

(8) depth to groundwater or seasonal high groundwater level; and

(9) surface drainages, including potential hydraulic connections with groundwater.

4.3 Pre-sampling activities

Before conducting field sampling activities, the site background information, inspect site conditions shall be compiled as provided in Sections 4.3.1 and 4.3.2, and the necessary notifications shall be made to agencies as provided in Section 4.3.3.

4.3.1 Site background

Before beginning field work, the following information must be collected and recorded:

(1) the names, addresses, and telephone numbers of the owner, operator, and businesses on the site;

(2) for rural areas, the quarter section, township, and range of the site;

(3) locations of all present and past USTs, piping and pump islands;

(4) a description of known UST systems, including capacity, dimension, age, and material of construction and location and types of fill and vent pipes, valves, and connectors;

(5) history of types of products stored in the tanks;

(6) history of known releases and available data from previous soil or groundwater sampling at the site;

(7) type and classification of native soil;

(8) location of wells within 100 feet of the site;

(9) surface waters and wetlands in the immediate vicinity of site;

(10) depth to groundwater or seasonally high groundwater level;

(11) property line locations;

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(12) distances from tanks to nearby structures; and

(13) type and location of belowground utility lines that could create pathways for contaminant migration.

In addition, where relevant and practical, the following additional information on the site shall be collected and recorded:

(1) location of each hold-down pad or anchoring system, if any;

(2) the name of the contractor who installed the tank, if known;

(3) dates of each installation and upgrade;

(4) performance history, including repair records, inventory records, tightness testing records, leak detection system records, or records of water pullouts;

(5) depth and width of backfill area and type of backfill material used to surround tanks and piping;

(6) surface drainage characteristics, including potential hydraulic connections with groundwater;

(7) location of other nearby USTs, either active or inactive, or other potential sources of contamination; and

(8) previous site uses, including historical waste handling procedures.

4.3.2 Surface observation of site conditions

An observation of the site's surface must be conducted before sample collection to assist in determining field sampling approaches and locations. Activities that must be completed during this observation include:

(1) locating the aboveground components of each UST;

(2) confirmation of the amount of fuel currently in each tank;

(3) determination of tank size;

(4) observation for aboveground utilities;

(5) underground utility locates (contact utility location centers where available);

(6) visual inspection for surface indications of releases;

(7) if practical and no safety hazard exists, check for odor of petroleum in nearby structures (basements); and

(8) check sumps and access manholes for evidence of pump leakage.

Key areas that must be observed for surface indications of a release include:

(1) vent pipes and fill holes;

(2) pavement depressions, buckling, cracks, or patches that could indicate that subsurface problems have historically occurred;

(3) cracks or stains at base of pumps; and

(4) evidence of stressed vegetation that may have resulted from a release or spill.

The results of the site observations must be recorded in a field log book or other appropriate document.

4.3.3 Notification to agencies

Notification to ADEC, local governments and fire departments before any site assessment work is performed for closure or change-in-service is subject to the requirements of 18 AAC 78.085.

4.4 Field screening

Field screening is the use of portable devices capable of detecting petroleum contaminants on a real-time basis or by rapid field analytical technique. Field screening must be used to help assess the following locations where contamination is most likely to be present:

Tank area

- areas of suspected or obvious contamination;
- adjacent to and below all fill and vent pipes;
- excavation sidewalls below the tank midline;
- one representative sample for at least every 100 square feet of excavation bottom

Piping run

- areas of suspected or obvious contamination;
- below piping joints, elbows, connections, and damaged piping components; if these locations are unknown then screening must occur below original level of piping at 10 foot-intervals; the 10-foot interval is chosen because pipe sections commonly used are 10-foot lengths and because of limits of detection of soil gas vapors from the release source;
- adjacent to and below all dispensers.

When possible, field screening samples should be collected directly from the excavation or from the excavation equipment's bucket. If field screening is conducted only from the equipment's bucket, then a minimum of one field screening sample must be collected from each 10 cubic yards of excavated soil. If instruments or other observations indicate contamination, soil must be separated into stockpiles based on apparent degrees of contamination. At a minimum, soil suspected of contamination must be segregated from soil observed to be free of contamination. Two levels of field screening procedures are:

(1) use of field screening devices to perform synoptic surveys of potentially contaminated areas to determine the approximate locations containing contaminants (qualitative screening); and

(2) use of field screening devices to provide a semi-quantitative estimate of the amount of contaminant present at a specific location (semi-quantitative screening).

4.4.1 Field screening devices

Many field screening instruments are available for detecting petroleum contaminants in the field on a rapid or real-time basis. Acceptable field screening instruments must be suitable for the contaminant being screened. The procedure for field screening using photoionization detectors (PID)s and flame ionization detectors (FIDs) is described in Section 4.4.2. If other instruments are used, a description of the instrument or method and its intended use must be provided to ADEC. Alternative methods must provide equivalent or better accuracy for field screening when compared to the FID or PID devices. Whichever field screening method is chosen, the accuracy of the method must be verified throughout the sampling process through use of appropriate standards to match the use intended for the data. Wherever the requirement for field screening is stated in this chapter, instrumental or analytical methods of detection must be used, not olfactory or visual screening methods.

4.4.2 Headspace analytical screening procedure for field screening (semi-quantitative field screening)

The most commonly used field instruments for UST site assessments in Alaska are FIDs and PIDs. The following headspace screening procedure to obtain and analyze field screening samples must be adhered to when using FIDs and PIDs:

(1) partially fill (one-third to one-half) a clean jar or clean ziplock bag with the sample to be analyzed; total capacity of the jar or bag may not be less than eight ounces (app. 250 ml), but the container should not be so large as to allow vapor diffusion and stratification effects to significantly affect the sample;

(2) if the sample is collected from a split spoon it must be transferred to the jar or bag for headspace analysis immediately after opening the split-spoon; if the sample is collected from an excavation or soil pile, it must be collected from freshly uncovered soil;

(3) if a jar is used, its top must be quickly covered with clean aluminum foil or a jar lid; screw tops or thick rubber bands must be used to tightly seal the jar; if a ziplock bag is used, it must be quickly sealed shut;

(4) headspace vapors must be allowed to develop in the container for at least 10 minutes but no longer than one hour; containers must be shaken or agitated for 15 seconds at the beginning and end of the headspace development period to assist volatilization; temperatures of the headspace must be warmed to at least 40° F (approximately 5° C); with instruments calibrated for the temperature used;

(5) after headspace development, the instrument sampling probe must be inserted to a point about one-half the headspace depth; the container opening must be minimized and care must be taken to avoid uptake of water droplets and soil particulates;

(6) after probe insertion, the highest meter reading must be taken and recorded, which normally will occur between two and five seconds after probe insertion; if erratic meter response occurs at high organic vapor concentrations or conditions of elevated headspace moisture, a note to that effect must accompany headspace data;

(7) calibration of PID and FID field instruments must follow the procedures outlined in Section 7.1 (Calibration and maintenance of field equipment); and

(8) all field screening results must be documented in the field record or log book.

4.5 Determining sample locations

The locations and numbers of laboratory samples to be taken depend on the requirements of 18 AAC 78 for the specific type of sampling activity. The results of field screening must be used to determine the location from which to obtain samples. Samples must be obtained from locations that field screening and observations indicate are most heavily contaminated. A positive field screening result is one in which any deflection in the meter reading occurs and samples are required for that location. Samples analyzed with field screening devices may not be substituted for required laboratory samples. Specific types of sampling activity are as follows:

(1) site assessment for a UST closed in place (18 AAC 78.090);

(2) site assessment for a UST that has been removed (18 AAC 78.090);

(3) site assessment for temporary closure, or change in service, of a UST (18 AAC 78.090);

(4) investigating a suspected release (18 AAC 78.200 - 18 AAC 78.235);

(5) release investigation (18 AAC 78.235); and

(6) documentation that corrective actions have met applicable cleanup levels for soil (18 AAC 78.320) and water (18 AAC 78.327) through final verification sampling.

Within the constraints for sampling locations listed above, laboratory samples must be taken where contamination is most likely to be present.

4.5.1 Sample locations for contaminated untreated stockpiles

As noted in Section 4.4 (Field screening), soils must be segregated during excavation based on apparent degrees of contamination. Soils must be stockpiled in accordance with 18 AAC 78.311. For stockpiles greater than 500 cubic yards, sampling frequency must be determined before sampling by consultation with the ADEC project manager.

Characterizing stockpiled soil is necessary to determine whether treatment or disposal of the soil is needed, to assist with selection of treatment or disposal methods, and to establish baseline data for use in evaluating the effectiveness of treatment.

To determine if untreated stockpiled soils can be disposed or considered not contaminated, stockpiled soils must be characterized by using:

(1) field screening; at least one soil sample must be obtained from each 10 cubic yards of stockpiled soil for field screening purposes; samples must be obtained from various depths in the pile, but none less than 18 inches beneath the exposed surface of the pile; field screening must follow the procedures outlined in this section and results must be documented in a site log book; and

(2) laboratory analysis of grab samples collected from each stockpile according to the requirements of 18 AAC 78.320(c).

4.5.2 Alternative sample collection procedures

Alternative sampling collection procedures, such as Cone Penetrometer Testing, HydroPunch and Borehole Geophysical Logging may be used to determine soil hydrogeologic characteristics, contaminant distribution, and contaminant concentration.

These procedures may be useful, with proper evaluation, in providing essential data to assess and delineate the extent of contamination during site characterizations, release investigations, and corrective actions. These alternative procedures may not be used in collecting samples for final verification during site assessment or corrective action.

4.6 Collecting soil samples

As required by 18 AAC 78, the following procedures must be used to collect soil samples for laboratory analysis:

(1) unless otherwise approved by ADEC, all laboratory soil samples must be grab samples and may not be composited before analysis, except that soil samples for total arsenic, cadmium, chromium, and lead that are for screening purposes may be composited in the field or in the laboratory before analysis;

(2) soil samples taken directly from the surface of excavations must be obtained from freshly uncovered soil; a minimum of six inches of soil must be removed immediately before collection, and the sample must be obtained from the newly uncovered soil; if the excavation has been open for longer than one hour, at least 18 inches of soil must be removed immediately before collection;

(3) soil samples collected from excavation equipment buckets must be obtained from the center of the bucket and away from the bucket sides; at least six inches of soil must be removed immediately before collection;

(4) if soil samples are collected from a soil boring, samples should be collected using a hollow stem auger and split spoon sampler or Shelby tube; using an auger, the drill hole must be advanced to the desired depth; then the center rods of the auger must be withdrawn from the drill hole and the plug and pilot bit removed from the center rods; the sampler must be attached to the correct length of drill rod and must be driven ahead of the auger flights in order to collect a relatively undisturbed sample; after the split spoon or Shelby tube has been retrieved back out of the boring, the desired sample section must be immediately removed from the sampling device; only soil from the middle portion of the spoon may be used for samples; soil from the very ends of the spoon must be discarded as they often contain disturbed soils; a clean sampling tool must be used to quickly collect the sample from the undisturbed portion with a minimum of disturbance and the sample container must be quickly capped, sealed, and labeled; and

(5) soil samples for all parameters listed in Table 1 must be collected in accordance with method specifications.

Alternative methods to obtain soil samples may be used only if the methods have been approved by ADEC before sampling.

The following steps must be taken to minimize collection errors:

(1) all samples must be collected with disposable or clean tools that have been decontaminated as outlined in Section 4.8 (Decontamination of equipment);

(2) disposable gloves must be worn and changed between sample collections;

(3) sample containers must be filled quickly;

(4) soil samples must be placed in containers in the order of volatility; i.e. volatile organic aromatic samples must be taken first, gasoline range organics next, heavier range organics next, and soil classification samples last;

(5) containers must be quickly and adequately sealed, rims cleaned before tightening lids and tape used only if known not to affect sample analysis;

(6) sample containers must be labeled as outlined in Section 4.9.2 (Labeling sample containers); and

(7) containers must immediately be preserved according to procedures in Section 4.9.1 (Sample containers). Unless specified otherwise, at a minimum, the samples must be immediately cooled to 4±2°C and this temperature must be maintained throughout delivery to laboratory and analysis until samples are analyzed.

If groundwater is encountered while soil sampling, the provisions of 18 AAC 78.090 must be followed concerning sampling of the groundwater interface.

4.7 Obtaining groundwater samples from borings/wells

Groundwater samples might be required if contamination of the groundwater is suspected. Water sampled directly from an excavation is not necessarily representative of normal groundwater conditions and will not be evaluated as a representative groundwater sample. In such cases, installation and sampling of a groundwater monitoring well might be required, as determined by ADEC under 18 AAC 78.327.

4.7.1 Installing groundwater monitoring wells

Unless otherwise directed by ADEC, if groundwater monitoring wells are required, the installation must be as required by 18 AAC 78.327(b), and the following procedures must be used:

(1) if the direction of groundwater flow is known, at least three monitoring wells must be installed and sampled, one upgradient and two downgradient of the potential contamination source;

(2) if the direction of groundwater flow is unknown, it is recommended that the number of wells installed be sufficient to characterize the groundwater flow; at least three monitoring wells must be installed and sampled;

(3) well drilling equipment must be decontaminated as outlined in Section 4.8 (Decontamination of equipment) before drilling at each new location; and

(4) wells should be driven with a hollow stem auger or cable drill; if other methods are used, ADEC approval must be obtained before the well is installed.

The following details of well construction must be recorded in the field record:

(1) well location, determined by reference to site bench mark;
(2) total depth of boring;
(3) depth to groundwater at time of drilling;
(4) diameter of boring;
(5) depth to top and bottom of screened interval;
(6) diameter of screened interval;

(7) diameter of casing;
(8) well construction material;
(9) depth of packed filter interval;
(10) depth and thickness of seals;
(11) type of surface cap;
(12) names of drilling firm and drilling personnel; and
(13) soil log completed using the Unified Soil Classification System, U. S. Soil Conservation Service classification system, or another similar soil classification system.

Under 11 AAC 93.140, a log of the well must be submitted to the Alaska Department of Natural Resources (ADNR) within 45 days after installing a well. The log must include the location and depth of the well, an accurate log of the type and depths of soil and rock formations encountered, the depth and diameter of the casing, screened intervals, well completion materials, and the static water level in the well. Well logs should be submitted to ADNR/Mining and Water Management, P.O. Box 107005, Anchorage, AK 99510; (907) 762-2165. Well logs for sites within the northern region should be sent to ADNR/Division of Water, 3700 Airport Way, Fairbanks, AK 99706; (907) 451-2772. Well log reporting forms are available from the ADNR/Alaska Hydrologic Survey at the above addresses.

4.7.2 Sampling groundwater monitoring wells

If multiple wells are sampled, the wells upgradient of the site should be sampled first to minimize cross-contamination. Before sampling wells, the depth to groundwater must be determined by manual or electronic means. Measurement devices must be calibrated before use to an accuracy of at least 0.02 foot.

4.7.2.1 Determining well depth and presence of non-aqueous phase liquids

Before sampling a monitoring well, the column of water in the well casing must be checked for the presence of nonaqueous phase liquids, including free petroleum products that might be floating on top of the water or in a separate layer at the bottom of the casing. Nonaqueous phase liquids are identified by:

(1) carefully lowering a clear bailer, in a manner that will create minimum disturbance, into the well before purging and observing the liquids removed from the top and the bottom of the water column;

(2) using a paste type of detector with ingredients that will not lead to cross-contamination; or

(3) using an electronic device designed to detect nonaqueous liquids and to measure the thickness of the nonaqueous layer.

If free product is present, the well must be bailed or pumped to remove the product and must be monitored to evaluate the recharge rate.

4.7.2.2 Well purging

Monitoring wells must be purged before sampling, using the following procedure (or an equivalent):

(1) at least three casing volumes of water must be removed from the well before sample collection or, for low yield wells, until the well bore is evacuated; instead of purging three casing volumes, measure the purge water temperature, pH, and conductivity until these parameters are stable to within 10 percent variability between measurements;

(2) all purged water must be carefully collected, containerized, and stored for proper disposal pending evaluation of groundwater sample analyses; the results of the analyses and the applicable federal, state, and local water quality criteria must determine the acceptable method for disposal of the purge water; and

(3) upgradient wells should be purged before downgradient wells to help minimize possible cross contamination.

4.7.2.3 Collecting groundwater samples with bailers

If a bailer is used to collect samples, the following procedure must be used:

(1) after purging the well, sufficient time must be allowed for the well to equilibrate and fines to settle; if full recovery exceeds two hours, samples must be extracted as soon as sufficient volume is available;

(2) the water level must be remeasured after purging has occurred and water level has returned to the static level;

(3) if decontaminated equipment is used to collect the water sample, the sampler must be rinsed with analyte-free distilled or deionized water; a portion of this rinsate must be collected into a container appropriate for the most volatile analyte suspected (typically BTEX); this equipment blank (also termed decontamination blank) must be contained, preserved, and analyzed according to the procedures outlined in this chapter for that analyte;

(4) bailers must be made of glass, Teflon, stainless steel, other suitable materials, or of disposable materials; plastic bailers are not acceptable for sampling volatile organic compounds; all bailers must be decontaminated as outlined in Section 4.8 (Decontamination of equipment);

(5) the bailer must be fitted with a new bailer line for each well sampled; the bailer and line may be handled only by personnel wearing decontaminated or disposable gloves;

(6) the bailer should be slowly lowered to minimize disturbance of the well and water column; the bailing line should be prevented from contact with the outside of the well, equipment, and clothing; special care must be taken to minimize disturbance of the water table interface when inserting the bailer;

(7) samples must be obtained as close as possible to the water level/air interface, unless analysis indicates that contamination is at a different depth;

(8) grab samples must be obtained;

(9) the bailer must be slowly lifted and the contents transferred to a clean sample container with a minimum of disturbance and agitation to prevent loss of volatile compounds; if different analytes are sampled, samples must be transferred to containers in the order of their volatility; headspace in the sample container must be minimized by filling the sample jar until a positive meniscus is present;

(10) containers must be quickly and adequately sealed; container rims and threads must be cleaned before tightening lids; unless otherwise specified, teflon-lined screw caps must be used to seal the jar;

(11) sample containers must be labeled as outlined in Section 4.9.2 (Labeling sample containers); and

(12) containers must be preserved immediately according to procedures in Section 4.9.1 (Sample containers). Unless specified otherwise, at minimum the samples must be immediately cooled to 4±2°C and this temperature must be maintained through delivery to the laboratory until the samples are analyzed.

4.7.2.4 Alternative methods of collecting groundwater samples

If a positive displacement pumping system or another system is used instead of a bailer, it must be clean or decontaminated as described in Section 4.8 (Decontamination of equipment). Disturbance of the well, water column, and samples must be minimized. Only grab samples may be obtained, not composite samples. Samples must be obtained as close as possible to the water level/air interface unless analysis indicates that contamination is at a different depth. If different analytes will be sampled, samples must be transferred to containers in the order of volatility. Volatiles must be collected first, followed, in order, by gasoline range organics, heavier range organics, and metals. Container headspace must be minimized by filling the sample jar until a positive meniscus is present. Containers must be quickly and adequately sealed. Rims must be cleaned before tightening lids. Sample containers must be labeled as outlined in Section 4.9.2 (Labeling sample containers). Containers must be preserved immediately according to procedures in Section 4.9.1 (Sample containers). Unless specified otherwise, at a minimum the samples must be immediately cooled to 4±2°C and this temperature must be maintained through delivery to laboratory until the samples are analyzed.

4.8 Decontamination of field equipment

Decontamination of personnel, sampling equipment, and containers before and after sampling must be used to ensure collection of representative samples and to prevent the potential spread of contamination. Decontamination of personnel prevents ingestion and absorption of contaminants and must be done with a soap and water wash and deionized or distilled water rinse.

All previously used sampling equipment must be properly decontaminated before sampling and between sampling locations to prevent introduction of contamination into uncontaminated samples and to avoid cross-contamination of samples. Cross-contamination can be a significant problem when attempting to characterize extremely low concentrations of organic compounds or when working with soils that are highly contaminated.

Clean, solvent-resistant gloves and appropriate protective equipment must be worn by persons decontaminating tools and equipment.

4.8.1 Decontamination of soil sampling tools

At a minimum, soil sampling tools must be cleaned and decontaminated by the following three-step procedure:

(1) tools must be scrubbed with a stiff brush in a solution of hot water and laboratory-grade, critical cleaning detergent such as Alconox or a similar product;

(2) tools must be rinsed twice in clean water; and

(3) tools must be thoroughly rinsed with distilled or deionized water.

If concentrated petroleum products or highly contaminated soils are encountered during sampling, an appropriate solvent should be used to remove heavy petroleum residues from the sampling tools. This must be followed by the minimum cleaning procedure outlined above. If a solvent is used, it must be properly collected, stored, and disposed of according to acceptable hazardous waste disposal guidelines.

4.8.2 Decontamination of water sampling tools

Drill auger sections, split spoons, and drive hammers that come in contact with bore holes must be cleaned before use and between borings using the following three-step procedure:

(1) tools must either be

(A) scrubbed with a stiff brush in a solution of water and laboratory grade, critical cleaning detergent such as Alconox or a similar product; or

(B) cleaned with high pressure hot water or steam and a laboratory grade, critical cleaning detergent;

(2) tools must be rinsed twice in clean water; and

(3) tools must be thoroughly rinsed with distilled or deionized water.

Steel tapes, well sounders, transducers, and water quality probes must be rinsed with clean water and then with deionized water.

Reusable bailers must be washed in Alconox or another laboratory grade, critical cleaning detergent solution, rinsed twice in clean water, and then rinsed with distilled or deionized water.

4.8.3 Excavation equipment

Excavation equipment must be clean before each site excavation begins.

4.8.4 Cleaning sample containers

Sample containers must be cleaned and prepared by an analytical laboratory. The exterior of sample containers must be cleaned after the samples are collected and the container lids are tightly sealed. Solvents may not be used for this procedure because of the potential to contaminate the sample.

4.8.5 Disposal of washwater, rinsate, and disposable sampling tools

Washwater and rinsate solutions must be collected in appropriate containers and disposed of properly in accordance with federal, state, and local regulations. Bailing strings and wires and other disposable sampling tools must be properly discarded after use at each well.

4.9 Sample containers and holding conditions

Containers used to collect samples must be chosen based on their suitability for the analyte of interest and may vary according to the laboratory contracted to perform the analysis. Preservation methods and maximum holding conditions are method-specific and must be adhered to.

4.9.1 Sample containers

Most containers should be glass jars with Teflon-lined lids. Sample jars of the acceptable type of material, size, and type of lid are shown in Table 1. Use of sample containers must conform to these specifications. Also shown in that table are the preservation methods and maximum holding times for each analyte of interest.

All sample containers must be inspected before transit to the site to ensure that they have undamaged lids and are tightly sealed. Jars must be placed into containers that are secured to prevent damage or tampering in transit to the site. Containers and lids must be re-inspected at the job site; containers that have lost lids or that have been damaged may not be used for sample containment.

4.9.2 Labeling sample containers

Indelible, waterproof ink must be used to label sample containers. Labels, if used, must be securely fastened to the container. All information entered onto the label or container must be duplicated in the field record or log book. Information on the containers or labels must include:

(1) unique identifying number assigned to the sample for laboratory analysis;
(2) date and time of collection, if possible;
(3) name of person collecting the sample;
(4) each intended laboratory analysis for the sample;
(5) preservation method.

If possible, the following information should also be included on the container or label:

(1) project name and location of sample;
(2) maximum holding time (or date by which sample must be extracted and analyzed).

4.9.3 Holding times, conditions, and methods of preservation

Sample handling, transport, and analysis must be arranged so that the holding times and conditions shown in Table 1 are met. Also, volatile compounds must be extracted and analyzed as quickly as practical after collection.

Appropriate acidic preservation of samples must be provided if required in Table 1.

4.9.4 Site safety plan

The assessment firm is responsible for a site safety plan as required by the Alaska Department of Labor's General Safety Code, Section 01.0102 (adopted by reference at 8 AAC 61.010), for construction activities and activities within a confined space.

SECTION 5. SAMPLE TRANSFER LOG

5.1 Sample transfer log

The requirements in this section apply to all sampling associated with a site assessment, from initial investigation through all final verification samples.

A transfer log is required for each sample taken, including all associated field quality control (QC) samples. A transfer log consists of a document or label that physically accompanies each sample bottle and sample, or each batch of bottles and samples, and that provides for the name of each person assigned control of the sample and the period covered by each person's assignment. Sufficient space must be provided on the form to accommodate several different control persons, the name of their respective organization or agency, and specific spaces for commercial carriers.

The laboratory receiving samples must process the samples using control procedures documented in its approved Quality Assurance (QA) Manual and Standard Operating Procedures. This section does not apply to internal laboratory procedures.

SECTION 6. ANALYTICAL PROCEDURES

6.1 Field screening procedures

Use of field screening analyses with Photo Ionization Detectors (PIDs) and Flame Ionization Detectors (FIDs) must follow the relevant procedures outlined in Section 4 (Sampling Procedures) and Section 7 (Calibration and Maintenance of Field Equipment). If other instruments are used, a written description of that use must be provided to ADEC by the assessment firm.

6.2 Identification of laboratory conducting analyses

Only results from a laboratory approved by ADEC will be accepted by ADEC for use in reports prepared under this chapter.

6.3 Determination of analyses for petroleum hydrocarbons

Unless approval to deviate from these specifications is obtained in advance from ADEC, selection and use of all laboratory analyses must conform to the provisions of Table 2 and appropriate sections of this chapter. The identity of a released refined petroleum product is assumed to be unknown unless a laboratory analysis shows that a contaminant is only a gasoline or only a nongasoline refined product, unless this requirement is waived by ADEC.

If it can be documented that only one type of product was stored or distributed during the operational life of a facility, a waiver may be requested from ADEC for the requirement to determine the identity of the product, in accordance with 18 AAC 78.315(d). The information collected in the examination of the site background (Section 4.3.1) will be used to determine if a waiver should be sought.

If leaded gasoline is a potential contaminant at the site, a preliminary laboratory analysis for lead might be required. The ADEC project manager must be contacted for this determination. Samples collected for lead may be composited before analysis. Unless the concentration of total lead exceeds 100 mg/kg, the analysis may be used only to document the level of lead for use in meeting treatment and disposal data needs and criteria.

Table 2: Determination of Laboratory Analyses for Soils

Product(s) stored at facility

Parameter	Leaded Gasoline	Unleaded Gasoline	Jet Fuel	Kerosene	Diesel	Bunker C	Waste or Used Oil	Unknown
Diesel Range Organics	--	--	X	X	X	X	X	X
Gasoline Range Organics	X	X	X	--	--	--	X	X
Residual Range Organics	--	--	--	--	--	X	X	X
Total BTEX	X	X	X	X	X	X --	X	X
Volatile Chlorinated Solvents	--	--	--	--	--	--	X	X
Polychloro-biphenyls Bs)	--	--	--	--	--	--	X	X
senic	--	--	--	--	--	--	X	X
Cadmium	--	--	--	--	--	--	X	X
Chromium	--	--	--	--	--	--	X	X
Lead	X[1]	--	--	--	--	--	X	X

Legend:

X = Analysis required
-- = Analysis not required
BTEX = Benzene, Toluene, Ethylbenzene, Xylene

[1] Analysis for lead must be performed if required by the project manager.

SECTION 7. CALIBRATION AND MAINTENANCE OF FIELD EQUIPMENT

Calibration and proper maintenance of field instruments are critical to obtaining acceptable data. Improper calibration or failure of an instrument in the field might result in improper choice of sample locations, failure to detect contamination, and inefficient and inadequate segregation of clean soils from contaminated soils and, thus, potentially much higher disposal or remediation costs.

7.1 Calibration and maintenance of field instruments

To ensure that field instruments will be properly calibrated and remain operable in the field, the procedures set out in this section must be used.

7.1.1 Calibration

(1) If PID and FID field instruments are used, instruments must be calibrated before each testing session to yield "total organic vapors" in parts per million to a benzene equivalent. The PID instrument must be operated with a lamp source that is able to detect the contaminants of concern, operates at a minimum of 10.2 eV, and is capable of ionizing those contaminants of concern.

(2) Field instruments must be calibrated onsite.

(3) All standards used to calibrate field instruments must meet the minimum requirements for source and purity recommended in the equipment's operation manual.

(4) If the instrument's operation manual recommends specific calibration requirements for other criteria in calibrating the instrument (such as pH, conductivity, temperature, etc.), those criteria must be adhered to.

(5) Acceptance criteria for calibration must be determined depending on the potential contaminant(s) and must be within the limits set in the manufacturer's operations manual.

(6) The dates, times, and results of all calibrations and repairs to field instruments must be recorded in the field record and in the instrument's log.

(7) All users of the instrument must be trained in the proper calibration and operation of the instrument and must be required to read the operation manual before initial use.

7.1.2 Maintenance

(1) At a minimum, operation, maintenance, and calibration must be performed in accordance with the instrument manufacturer's specifications.

(2) All users of the instrument must be trained in routine maintenance, including battery and lamp replacement, lamp and sensor cleaning, and battery charging.

(3) Each instrument's operation and maintenance manual must be present at the site.

(4) Field instruments must be inspected before departure for the site and on site.

(5) Instrument battery charge must be inspected far enough ahead of time to bring the instrument up to full charge before departure for the site.

(6) At a minimum, a source of extra batteries and lamps (if applicable) must be readily available.

SECTION 8. DATA REDUCTION, VALIDATION, AND REPORTING

Data reduction describes the handling of standard, sample, and blank results; how blank analysis results must be used in calculating final results; examples of data sheets; and positions of persons responsible for data reduction.

Data validation is the systematic process of reviewing the data against criteria to assure the adequacy of the data.

Data reporting details how reports will be generated and what must be included in them.

8.1 Responsibility for laboratory data

The laboratory must conduct these activities on, and be responsible for, data that is processed within the laboratory. The owner or operator shall ensure that the assessment firm reviews final laboratory data reduction, validation, and reporting and

(1) selects a laboratory based on demonstrated ability to properly reduce, validate, and report data;

(2) verifies laboratory approval status; a list of approved laboratories is available from ADEC; and

(3) reviews all laboratory results and performance to ensure that the objectives of this chapter are met; if questions or problems arise with the laboratory analysis, the owner or operator shall ensure that the assessment firm takes appropriate corrective actions as outlined in Section 10 (Corrective Actions); significant problems must be reported to ADEC.

8.2 Final data reduction

Data reduction is the compilation, condensation, and simplifying of information into a more easily understood product. The owner or operator shall ensure that the product furnished by the laboratory is examined, using standard statistical methods, by assessment firm personnel with the education, professional experience, and training necessary to meet a project's technical and regulatory requirements, and that these personnel conduct or supervise any further reduction of field and laboratory data into the final report.

8.3 Final data validation

The owner or operator shall ensure that validation of field data by the assessment firm occurs before the data are inserted into a report. The results of the evaluations discussed in this subsection must be documented in the report, must be used in data interpretation, and may be used to initiate corrective actions outlined in Section 10 (Corrective Actions).

8.3.1 Validation of field reports

The owner or operator shall ensure that the assessment firm QA officer examines all information collected through the field documentation process (Section 4.2). This information must be checked for

(1) completeness;
(2) accuracy (for example, transcription errors, internal consistency);
(3) unexpected results, with accompanying possible explanations;
(4) adherence to sampling procedures outlined in Section 4;
(5) comparison of field instrument results with laboratory results.

8.3.2 Review of laboratory data

The owner or operator shall ensure that the assessment firm reviewers pay special attention to the establishment of detection and control limits and deviations from them; if deviations are identified, they must be flagged for discussion in final reports and possible corrective action. Examples of limits and deviations include

(1) any limits outside of the acceptable range;
(2) lack of documentation showing the establishment of necessary controls; and
(3) unexplainable trends.

8.3.3 Determining the final validity of samples

Samples collected in accordance with this chapter are considered valid unless otherwise indicated. Samples that are not collected in accordance with this chapter will be considered invalid; in particular, a sample will be considered invalid if

(1) the sample collection was not conducted by or supervised by a qualified person as required by 18 AAC 78;

(2) the sample was collected with previously-used tools that were not decontaminated as outlined in this chapter;

(3) the sample was not taken at the location or depth specified by this chapter;

(4) the sample was not taken at a location determined by a correctly calibrated and operated field instrument or by other documented observation to be representative of the most likely areas of contamination;

(5) the sample was collected using a method not listed in this chapter or a method that is inappropriate for the analyte;

(6) the sample was composited before analysis, unless compositing of the sample is explicitly specified by this chapter or approved by ADEC in the workplan required under 18 AAC 78;

(7) the sample jar was not clean before soils or water were deposited into it;

(8) the sample was incorrectly labeled (or not labeled) and field records do not show the location where the sample was collected;

(9) a water sample from a boring or well was not collected in accordance with Section 4.7 of this chapter;

(10) an improper analysis method was performed on the sample;

(11) the analysis of the sample was conducted by a laboratory that was not approved by ADEC at the time of analysis.

8.4 Data reporting

8.4.1 Information to be included in reports

Reports prepared under this chapter must, at a minimum, contain the following:

(1) the laboratory's data summary as required by Section 8.4.2 (Laboratory data reports for samples) for each sample analyzed;

(2) an interpretation of data and sampling results, as required by the tasks discussed in Section 8.3 (Final data validation);

(3) a table that contrasts the required field quality control data (discussed in Section 9.1.1) with the limits specified by this chapter (see Report Format subsection below);

(4) a case narrative for the project;

(5) a separate section or attachment that discusses all deviations from procedures outlined in this chapter and any relevant information compiled from field records or other information required by 18 AAC 78 including a discussion of any deviations from this chapter for any sampling or analytical methods and procedures, whether used by the assessment firm or by the laboratory;

(6) for corrective action sampling activities, a separate section or attachment that discusses all corrective actions taken as required by Section 10, and any other corrective action for other deviations from this chapter including corrective action (such as resubmission of the sample) for sample results that fall within a factor of 2 of the action level after having had corrections for matrix interferences applied (see discussion in Section 10.5 (Corrective actions with laboratory);

(7) a summary of the site assessment or release investigation information, provided to the owner or operator on a form available from ADEC (Site Assessment and Release Investigation Summary Form, see Appendix B), or similar format containing the same information; and

(8) other items required for reports by 18 AAC 78.

8.4.2 Laboratory data reports for samples

For each project conducted under this chapter, a data transmittal summary must be provided for each sample analyzed by the laboratory, including all field and laboratory QC samples, whether the samples are rejected or not. The following items must be submitted in the report:

(1) laboratory name, address, telephone number, fax number (if available), LAN number, and the name of the person authorizing release of laboratory data;

(2) report date;

(3) type of analysis (gasoline, diesel, etc.);

(4) the analytical and extraction method used and method number (see Tables 1 and 2);

(5) the type of matrix;

(6) the field sample number;

(7) the laboratory sample number;

(8) laboratory file identification number;

(9) the date sampled;

(10) the date received;

(11) the date extracted and digested;

(12) the date analyzed;

(13) the location of the sample collection point;

(14) the site or project name;

(15) the concentrations of analyte (reported in micrograms per liter for liquids, milligrams per kilogram, dry weight basis for solids);

(16) definitions of any characters used to qualify data;

(17) precision and accuracy values for each sample set, with at least one precision and accuracy evaluation for each set of 20 samples;

(18) the ambient temperature of the interior of the shipping container adjacent to the sample container WHEN RECEIVED by the laboratory;

(19) a copy of the sample transfer logs for each sample or group of samples;

(20) the analyst's name, signature or initials, and date signed;

(21) the dilution factor;

(22) a narrative summary report for each set of samples (not to exceed 20 samples per set), including a discussion of any significant matrix interferences, low surrogate recoveries, or analyte identifications as appropriate; and

(23) Laboratory Data Report Check Sheet (Appendix C).

The following items must be retained on file by the laboratory for at least three years after the analysis. They are not required in the report, but must be made available to ADEC upon request:

(1) the laboratory file identification number;

(2) copies of all sample gas chromatogram traces with the attached integration report; copies of the reconstructed ion chromatograms (RIC's) must be provided if performing the analysis by mass spectroscopy; chromatograms must be provided for all samples, method blanks, and daily calibration standard; chromatograms must be identified with a sample identification and the time and date of analysis;

(3) a document containing the date and time for the initial calibration and the standards used to verify instrument settings for the data reported; include the composition and concentration range of standards used to establish and verify maintenance of instrument calibration; and

(4) a document explaining laboratory quality control samples used for the data reported and results obtained; include information concerning surrogates, alkane standard, column performance, matrix spike and matrix spike duplicate samples, blank data, reference samples, and pattern match narrative summary.

8.4.3 Submission of reports to tank owner or operator

All reports must be submitted to the tank owner or operator by the qualified person identified in Section 2 (Qualified personnel). If submission of reports to ADEC is required by 18 AAC 78 or by ADEC, the assessment firm must inform the tank owner or operator of the requirement.

SECTION 9. INTERNAL QUALITY CONTROL CHECKS

Required quality control (QC) checks include field QC check samples and laboratory QC samples. Comparison of acceptable tolerances and actually derived values for each required QC element must appear in each project report submitted, as discussed in Section 8.4.1.

9.1 Field quality control checks

This section defines the types of field QC checks that must be used and the circumstances in which each type is to be used. All field QC check samples must be analyzed, the results of the analysis used to calculate data quality indicators, and must be summarized as shown in Table 3 or a similar format. When used, QC measures must be performed, at a minimum, for the most volatile analyte under investigation.

TABLE 3
Field Quality Control Summary

Quality Control Designation	Tolerance	Results for This Project
Holding times:		
Holding time to extract; DRO; for soil	14 days at 4° ± 2° C	
Holding time to extract; DRO; for liquid	7 days at 4° ± 2° C	
Holding time to analyze; DRO; for soil	Less than 40 days	
Holding time to analyze; DRO; for liquid	Less than 40 days	
Holding time w/methanol;GRO; for soil	28 days	
Holding time; GRO; liquid	14 days at 4° ± 2° C	
Holding time to extract; RRO; soil	14 days at 4° ± 2° C	
Holding time to analyze; RRO; soil	Less than 40 days	
Holding time to anaylze; BTEX; soil	14 days at 4° ± 2° C or per method requirements	
Holding time; BTEX; liquid	14 days at 4° ± 2° C	
Holding time; PAH; soil	14 days at 4° ± 2° C or per method requirements	
Holding time; PAH; liquid	14 days at 4° ± 2° C	
Holding time; Total VCS; soil	14 days at 4° ± 2° C	
Holding time; Total VCS; liquid	14 days at 4° ± 2° C	
Holding time; to extract; PCB; soil	14 days at 4° ± 2° C	
Holding time; to extract; PCB; liquid	14 days at 4° ± 2° C	
Holding time; to analyze; PCB soil	Less than 40 days	
Holding time; to analyze; PCB liquid	Less than 40 days	
Holding time; on digestate; Total arsenic; soil	6 months max. at 4° ± 2° C	
Holding time; on digestate; Total arsenic; liquid	6 months max. at 4° ± 2° C	
Holding time; on digestate; Total cadmium; soil	6 months max. at 4° ± 2° C	
Holding time; on digestate; Total cadmium; liquid	6 months max. at 4° ± 2° C	
Holding time; on digestate; Total chromium; soil	6 months max. at 4° ± 2° C	
Holding time; on digestate; Total chromium; liquid	6 months max. at 4° ± 2° C	
Completeness	85%	
Field Duplicate	From ADEC project manager	
Decontamination Blank (s)	Analytical method detection limit	
Trip Blank (s)	Analytical method detection limit	
Methanol Trip Blank	Analytical method detection limit	
Field Blank	Analytical method detection limit	
Background Sample (s)	Assess background influence on final verification samples	

Legend:
BTEX = Benzene, Toluene, Ethyl-benzene, Xylene;
DRO = Diesel Range Organics;
GRO = Gasoline Range Organics;
PAH = Polychlorinated Biphenols;
PCB = polychlorinated biphenyls
RRO= Residual Range Organics;
VCS = Volatile chlorinated solvents.

9.1.1 Minimum field QC sample requirements

The following is the minimum level of sample QC scrutiny that must be applied to field sampling. A description of each type of field QC sample appears in Sections 9.1.2. - 9.1.5. Reference to sets of samples in this and subsequent subsections refers to samples taken from the same site (or, for multiple sampling points within a single project, from the same area within a site that has uniform characteristics such as grain size and organic content) during the same sampling event during a discrete time period. It does not apply to sampling points from different sites, samples taken at significant time differences from each other, nor multiple samples from the same site, but with nonuniform site characteristics.

Table 4. Minimum Quality Control Scrutiny

Minimum Field QC Samples Required	When Required	Allowable Tolerance
Field Duplicate (One per set of 10 samples, minimum of one)	All samples	Set by Project Manager
Decontamination Blank (One per set of 20 similar samples, minimum of one)	All samples	Less than the analytical method detection limit
Trip Blank (One per set of 20 volatile samples, minimum of one)	All GRO, BTEX and volatile chlorinated solvent samples	Less than the analytical method detection limit
Methanol Trip Blank (One per set of 20, minimum of one)	Soil samples using AK101	Less than the analytical method detection limit
Field Blank (One per set of 20, minimum of one)	Per project specifications	Less than the analytical method detection limit

9.1.2 Field duplicate sample

Field duplicate samples are independent samples collected as close as possible to the same point in space and time. They are two separate samples taken from the same source, stored in separate containers, and analyzed independently. These duplicates are useful in documenting the precision (variability) of the sampling process.

At least one field duplicate must be collected for every 10 samples for each matrix sampled, for each target compound.
Duplicate water samples must be collected as close as possible to the same point in space and time and must be collected before any decontamination blanks are collected.

Duplicate soil samples must be collected as close as possible to the same point in space and time.

All field duplicates must be blind samples and must be given unique sample numbers just like any other field sample. Their collection should be adequately documented.

The results from field duplicate samples must be used to calculate a precision value for field sampling quality control.

9.1.3 Decontamination blank (equipment blank)

A decontamination blank is a sample of analyte-free media used to rinse sampling equipment. It must be collected after completion of decontamination procedures and before sampling. Decontamination blanks for water samples must be collected as described in Section 4.7.2 (Sampling groundwater monitoring wells). Decontamination blanks for soil samples must be collected in a similar manner.

If decontamination blanks are required, at least one decontamination blank must be collected and analyzed for each set of water samples that might contain volatiles. In addition, at least one decontamination blank must be collected and analyzed for every 20 soil samples collected each day.

9.1.4 Trip blank

A trip blank is a sample of analyte-free media taken from the laboratory to the sampling site along with each batch of samples and returned to the laboratory unopened. A trip blank must be used to document contamination attributable to shipping and field handling procedures. This type of blank can be especially useful in documenting when trace volatile organic compounds are being investigated. If a trip blank is required, at least one trip blank must accompany each set of 20 samples that might contain volatiles.

9.1.5 Field blank

A field blank is a sample of analyte-free media taken from the laboratory to the sampling site and opened onsite during the sampling procedure. The field blank is then sealed and appropriately labeled and returned to the laboratory for analysis with the sample batch. A field blank is used to document ambient contamination at a highly contaminated site and is especially useful for volatile organic compounds. The field blank does not replace the trip blank.

If required, a field blank must accompany each set of 20 samples destined for volatile organics analysis.

9.1.6 Background sample

A background sample is collected in an area judged to be free of a site contaminant. The background sample is taken to document and assess analyte baseline or historical information.

A background sample must be collected whenever, in the QA officer's judgment, it is required:

(1) to document the occurrence of naturally occurring organics, especially when their presence might interfere with analytical tests;

(2) to document the presence of contamination by migration of contaminants from offsite or non-UST-related sources; and

(3) in a corrective action or treatment plan.

SECTION 10. CORRECTIVE ACTIONS

Corrective actions are procedures and actions taken to correct unacceptable or unexpected deviations in sampling or analysis. An example is the re-analysis of one or more affected samples or the reporting of questionable data with a note of explanation on the situation.

Ultimate responsibility for corrective actions rests with the assessment firm. While appropriate corrective actions for out-of-control situations in the laboratory must be addressed by laboratory QA/QC documents, the owner or operator is responsible for ensuring that the assessment firm shows that all corrective actions enable the data quality objectives to be met.

10.1 Staff training

Normally, the need for training of sampling personnel will be determined through the auditing procedures outlined in Section 11.1.1 (Auditing of sampling personnel). If the corrective actions outlined in Section 11.1.1 do not result in acceptable performance, the sampling personnel must be removed from sampling activities until they can demonstrate adherence to the procedures in this chapter. The need for additional training of non-sampling personnel is indicated through scheduled audits and data validation and reporting. The owner or operator shall ensure that the assessment firm contracts for or provides necessary training of the appropriate persons if a potential problem with data quality is identified before the person performs the activity again.

10.2 Handling invalid samples

If an invalid sample is taken, the following procedures must be followed:

(1) if the completeness objective for the project is met and observations and field screening do not indicate the invalid sample was collected at a location with higher than the average contamination levels at the site, an explanatory note of the deviation from this chapter must accompany the report and no further corrective action for deviation is required; and

(2) if the completeness objective for samples at the site is not met or observations and field screening indicate the invalid sample was collected at a location with higher than the average contamination levels at the site, sample(s) must be recollected at the proper location on the site, properly analyzed and reported, and an explanatory note of the deviation from this chapter must accompany the data report.

10.3 Field instrument failure and improper use

If an audit of field sampling performance indicates that field instruments are being improperly used (or not used), the instrument operators must be retrained and their activities audited as specified in Section 11.1.1, and field data must be re-collected.

10.4 Failures in data processing, management, or analysis

Problems with data processing, management, or analysis is typically discovered during data reduction, validation, and reporting (see Section 8) or during scheduled audits (see Section 11). If these problems occur, the owner or operator shall ensure that the QA officer or another appropriate person is notified. Upon review of the problem, the owner or operator shall ensure that the QA officer or other appropriate person

(1) initiates steps to retrain the person performing the task;

(2) initiates actions to correct the improper procedure;

(3) adheres to procedures outlined for notifying the QA officer and project manager of potential problems with data quality;

(4) adheres to procedures for documenting potential problems and noncompliance; and

(5) adheres to procedures for determining when nonscheduled audits are needed.

10.5 Corrective actions with laboratory

Normally, any corrective actions necessary in a laboratory are handled internally by the approved laboratory through its approved QA/QC procedures on file with ADEC. The need for corrective action in the laboratory is identified by

(1) the laboratory's internal QC checks;
(2) the data review conducted by the assessment firm (see Section 8.3); or
(3) the laboratory's performance audits (see Section 11.2).

If appropriate satisfactory corrective actions are not performed by the laboratory, the assessment firm may not contract with that laboratory to perform future analyses until the problem is resolved.

10.6 Corrective actions for other problems

Other problems not discussed in this chapter might interfere with the assessment firm meeting the data quality objectives of this chapter. Appropriate corrective actions must be taken for these problems and must be initiated by the QA officer, principal investigator, or assessment firm management.

SECTION 11. PERFORMANCE AUDITS

The owner or operator shall ensure that the assessment firm prepares an annual report that compiles information obtained from audits of the firm's activities under this chapter. Activities described in this section are to be used as a guideline in designing the audits.

11.1 Auditing of field sampling

11.1.1 Auditing of sampling personnel

The owner or operator shall ensure that all employees of the assessment firm are properly trained and their performance audited before participating without supervision in sampling activities. At a minimum, before engaging in any sampling procedure for the first time, an employee must:

(1) be trained by a qualified person who has conducted the procedure before; and

(2) have read the expected procedures outlined in this chapter, the relevant provisions of 18 AAC 78, and the assessment firm's relevant operations manual.

After initial instruction in the procedure, the trainer must audit the employee's sampling activities. The employee's performance must continue to be audited until the employee can consistently perform the activity in accordance with the expected procedures.

After demonstrating satisfactory performance in a procedure, each employee's field procedures must be audited at least annually. All field sampling performance must be evaluated during this audit.

If any corrective actions result from an employee's deviation from the expected field procedures, the employee's performance on the activity that prompted the corrective action must be audited during the next sampling event. The performance must continue to be audited until the employee consistently performs the activity in accordance with expected procedures.

11.1.2 Auditing of field procedures

The owner or operator shall ensure that, at least annually, the sufficiency of the sampling procedures in this chapter are audited by the assessment firm's QA officer. This audit may be combined with an annual audit of an employee.

11.1.3 Monitoring of field subcontractors

The owner or operator shall ensure that, at a minimum, assessment firm field staff routinely monitors the performance of:

(1) well drillers;
(2) excavation equipment operators;
(3) drilling or excavation equipment;
(4) removers of product;
(5) treatment facility operators; and
(6) treatment equipment.

If this monitoring indicates that changes in subcontractors or equipment quality will improve or lessen the quality of field sampling activities, the owner or operator shall ensure that the QA officer or principal investigator is notified and that, if necessary, the officer or investigator implements appropriate corrective measures.

11.1.4 Monitoring of field equipment

Field instruments must be maintained and calibrated as outlined in Section 7.1. In addition, the results of field instrument analyses must be compared with analytical results. Unexpected or unexplained discrepancies must be reviewed and, if necessary, corrective action must be taken as outlined in Section 10 (Corrective Actions).

Performance of decontamination equipment and solutions must be audited by periodic collection and analysis of decontamination (equipment) blanks. Unexpected or unexplained results must be reviewed and, if necessary, corrective action must be taken as outlined in Section 10 (Corrective Actions).

11.1.5 Auditing of field records

All field records and any other relevant field data must be audited by a qualified person before reports are submitted.

11.1.6 Personnel conducting field audits

Auditing of all activities must be conducted by a person who has conducted or supervised the audited activities before. This activity must be performed by the assessment firm's UST QA officer.

11.1.7 Documentation and submission of field audits

Each person performing an audit shall document relevant observations and submit them to the QA officer or principal investigator, who shall evaluate the observations and implement appropriate corrective measures.

11.2 System audits

The owner or operator shall ensure that at least once each year the QA officer examines:

(1) documentation that ADEC approved laboratories are used for all UST projects;

(2) all field and laboratory audit reports;

(3) major corrective actions taken;

(4) overall program for compliance of the assessment firm's UST program with industry standards, regulatory requirements, and emerging technology; and

(5) the adequacy of all elements of this chapter.

This audit may be conducted as part of the assessment firm's review of non-UST activities.

At a minimum, the documentation of this audit must be submitted as part of a quality assurance report to management, as outlined in Section 12.

SECTION 12. QUALITY ASSURANCE REPORTS TO MANAGEMENT

The owner or operator shall ensure that the assessment firm prepares a quality assurance (QA) report for the assessment firm's management that covers the firm's use of the procedures in this chapter and adheres to the protocols in this section.

12.1 Contents of reports to management

The QA report to management must be based on a review of data quality indicators, results of field and laboratory performance audits, reports on corrective action or sample alteration, or limitations on the use of measurement data and the effects on legal defensibility.

12.2 Preparation of reports to management

A QA report must be prepared by those individuals who possess the education, professional experience, and training necessary to assess the quality of data being generated, to evaluate the results of field and laboratory audits and the sufficiency of corrective actions, and to recommend effective solutions to problems encountered.

12.3 Schedule of reports to management

At a minimum, QA reports must be provided annually after completion of system audits. In addition, a report to appropriate management must be provided when significant QA problems arise.

12.4 Who receives reports to management

At a minimum, the assessment firm's supervisor of all UST program activities must review QA reports. QA reports are for internal use and might be confidential; there is no requirement to submit these reports to ADEC. However, if a question arises concerning an assessment firm's compliance with this chapter, copies of the reports must be available for review by ADEC. The assessment firm may include information in a QA report that helps document compliance with this chapter or with 18 AAC 78.

ENSR.
Consulting • Engineering • Remediation

4600 Business Park Blvd.
Suite 22
Anchorage, AK 99503-7143

(907) 561-5700
FAX (907) 273-4555

Fort Richardson Environmental Staging Facility IDW Delivery Protocol

General Information:

- Prior to delivery of any IDW, the generating contractor must make an appointment with ENSR personnel to coordinate receiving of IDW.

  To make an appointment, call Mike Field at (907) 561-5700.

- All IDW (liquid or soil) must be accompanied with laboratory analytical results and/or equivalent generator/source information sufficient to properly characterize the IDW for disposal. All characterization activities are the responsibility of the generating contractor, including any necessary sampling.

- Unless other arrangements are made with ENSR, generating contractors must supply all necessary equipment (i.e. forklift, pumps, trucks, etc) for IDW transfer and unloading at the Environmental Staging Facility.

- All drums staged at the facility must be appropriately labeled prior to acceptance. Labeling requirement information is available through ENSR at the contact number above. Labeling requirements are based on information supplied by the generating contractor.

Special Consideration for Liquid IDW Delivery:

- No liquid IDW containing measurable free product will be accepted (light sheen is OK).

Special Consideration for Soil IDW Delivery:

- All soil drums must not be filled beyond 3/4 full, and must weigh less than 800 lb (Note: 85-gallon drums may weigh more than 800 lb when 3/4/full).

- A written affidavit stating the final characterization of the IDW must be supplied by the generating contractor.

- Soil IDW drums staged at the facility originally characterized as pending analysis for final characterization must have confirmation of final characterization within 45 days of delivery.

APPENDIX C

PROJECT FIELD FORMS

Field Equipment Checklist

Treatment System Installation

FIELD EQUIPMENT CHECKLIST - TREATMENT SYSTEM INSTALLATION

Treatment System Demonstration
Ruff and Roosevelt Road
U.S. Department of the Army, Corps of Engineers, Alaska District
Contract No. DACA85-95-0008, Delivery Order No. 0026

Item	Check	Comments
Documentation		
Project Plans		
Field Forms - Write in Rain Paper		
Design Drawings (2-sets)		
Applicable Phone Numbers		
General Field Gear		
Battery		
Battery Converter and Cables		
Calculator		
Camera		
Card Table		
Cash/Credit Card/Applicable Acct #s		
Cell Phone		
Cloth Tape		
Cooler		
Custody Seals		
Duct Tape		
Field Book		
Field Clothing and Quality Rain Gear		
Film		
Hard Hat		
Knife/Scissors		
Laptop Computer		
Metal Clip Board		
Pencils		
Pens - Ball Point		
Pens - indelible Markers		
Pens - Sharpies		
Pipe Wrenches		
PPE per SHHP		
Shovel		
Soil Bags (Sieve Samples)		
Straight Edge		
Tape Measure		
Tent		
Tools		
Tuff Tote(s)		
Water Level Indicator		
Meters		
Calibration Kits		
PID		
Thermometer		

DOWL / OGDEN
Joint Venture

INSPECTION REPORT

PROJECT: DO No. 26 Ruff Road Treatment System
OWNER: U.S. Army, Fort Richardson/ADCOE
CONTRACTOR:
INSPECTOR:

REPORT NO.
DATE:
WO: D56177

EQUIPMENT:
(in use)
(idle)

PERSONNEL:

MAJOR ACTIVITY:

MEMO ISSUED: YES NO

WEATHER:
TEMPERATURE:

TIME	COMMENTS

Page ____ of ____

DOWL / OGDEN
Joint Venture

INSPECTION REPORT (cont'd)

PROJECT:	DO No. 26, Ruff Road Treatment System	**REPORT NO.**	
OWNER:	U.S. Army, Fort Richardson/ADCOE	**DATE:**	
CONTRACTOR:	Chugach Development Corporation	**WO:**	D56177
INSPECTOR:	C. Shuman		

TIME	COMMENTS

Page ______ of ______

DOWL / OGDEN
Joint Venture

PHOTO LOG

PROJECT: DO No. 26, Ruff Road Treatment System
OWNER: U.S. Army, Fort Richardson/ADCOE
CONTRACTOR:
INSPECTOR:

REPORT NO.
DATE:
WO: D56177

Photo Number	Description
1	
2	
3	
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6	
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24	

DOWL ENGINEERS
ALASKA TESTLAB

☐ ADVISORY
☐ NON-COMPLIANCE

To:	W.O.#: Date:
	Owner:
Attention:	Project:

Issued by:

Comments:

Received by: Date:

4040 B Street•Anchorage, Alaska 99503•(907) 562-2000•(907) 563-3953 (fax)—DOWL/ATL, June 1995

Field Equipment Checklist

Field Testing for Soil Vapor Extraction/Bioventing Pressure, Water Content, Respirometry

INSTRUMENT CALIBRATION LOG

Delivery Order #:______________________ Location:______________________

Date	Time	Serial Number	Span Gas Substance	Span Concentration	Instrument Reading at Calibration	Instrument Reading After Calibration	Comments

02 November 1995

FIELD EQUIPMENT CHECKLIST - RESPIROMETRY

Treatment System Demonstration
Ruff and Roosevelt Road
U.S. Department of the Army, Corps of Engineers, Alaska District
Contract No. DACA85-95-0008, Delivery Order No. 0026

Item	Check	Comments
Documentation		
Project Plans		
Field Forms - Write in Rain Paper		
Design Drawings		
Applicable Phone Numbers		
General Field Gear		
Applicable Field Clothing and Rain Gear		
Bailers and Line		
Calculator		
Camera		
Cash/Credit Card/Applicable Acct #s		
Cell Phone		
Cloth Tape		
Field Book		
Film		
Hand Air Pump		
Hard Hat		
Key to Enclosure		
Knife/Scissors		
Laptop Computer and Auto Converter		
Metal Clip Board		
Pencils		
Pens - Variety		
PPE per SHPP		
Pre-made Caps for Monitoring Points		
Resealable Plastic Bags		
Shipping Account Numbers		
Shipping Containers		
Sterile Sample Containers		
Straight Edge		
Tape Measure		
Tedlar Bags		
Tools and Pipe Wrenches		
Tuff Tote(s)		
Two 5-Gallon Buckets		
Meters		
PID		
Air Pump		
Calibration Kits		
Carbon Dioxide Meter		
Dissolved Oxygen Meter		
LEL/02 Meter		
Spare DO Meter Membranes		
Magnehelic Gages		
Moisture Meter		

TREATMENT SYSTEM DEMONSTRATION
RUFF AND ROOSEVELT ROADS
U.S. Department of the Army, Corps of Engineers, Alaska District
Contract No. DACA85-95-0008, Delivery Order No. 0026

SYSTEM EQUIPMENT
DATE ______
TIME ______

DOWL/Ogden JV Field Representative: ______

Page ___ of ___

Monitoring Subject	Measurement or Reading	Comments
Control Panel		
CGS1	% LEL	
CGS2	% LEL	
High Water Sensor		
High Pressure Sensor		
Process Gas	Pressure Flow	
Horz Well 1		
Horz Well 2		
Horz Well 3		
Temp Before PDB1		
Pressure Before PDB1		
Temp After PDB1		
Pressure After PDB1		
Adjustments		
Repair/Maintenance		
Performed		
Required		

TREATMENT SYSTEM DEMONSTRATION
RUFF AND ROOSEVELT ROADS
U.S. Department of the Army, Corps of Engineers, Alaska District
Contract No. DACA85-95-0008, Delivery Order No. 0026

RESPIROMETRY

Monitoring Point
02 Meter:
CO2 Meter:
Hydrocarbon Meter:
Shutdown Date ____________
Shutdown Time: ________

DOWL/Ogden JV Field Representative: ____________________________

Page ____ of ____

Date/Time	Elapsed Time	CO2%	02%	Total HC	Pressure	Comments

TREATMENT SYSTEM DEMONSTRATION
RUFF AND ROOSEVELT ROADS
U.S. Department of the Army, Corps of Engineers, Alaska District
Contract No. DACA85-95-0008, Delivery Order No. 0026

DOWL/Ogden JV Field Representative: ______________________________

MOISTURE READINGS
DATE __________

Page _____ of _____

Moisture Sensor	Reading	Corrected Moisture Content	Comments/Adjustments		

Field Equipment Checklist
Ground Water Monitoring

FIELD EQUIPMENT CHECKLIST - GROUND WATER MONITORING

Treatment System Demonstration
Ruff and Roosevelt Road
U.S. Department of the Army, Corps of Engineers, Alaska District
Contract No. DACA85-95-0008, Delivery Order No. 0026

Item	Check	Comments
Documentation		
Project Plans		
Applicable Phone Numbers		
Chain of Custody Forms		
Design Drawings		
Field Forms - Write in Rain Paper		
OU4 Management Plan		
General Field Gear		
Applicable Field Clothing and Rain Gear		
Arrange Drums and Transport		
Bailers and Line		
Buble Wrap		
Calculator		
Camera		
Cash/Credit Card/Applicable Acct #s		
Cell Phone		
Cloth Tape		
Combination to Locks		
Coolers		
Field Book		
Film		
Hard Hat		
Insul Ice		
Key to Enclosure		
Knife/Scissors		
Metal Clip Board		
Nitrile Gloves		
Pencils		
Pens - Variety		
PPE per SHPP		
Redi-Flow Pump and Controller		
Resealable Plastic Bags		
Sample Jars, Labels, Seals		
Shipping Account Numbers		
Shipping Containers		
Straight Edge		
Tape Measure		
Tools and Pipe Wrenches		
Tuff Tote(s)		
Two 5-Gallon Buckets		
Meters		
Calibration Kits		
Dissolved Oxygen Meter		
Oxidation/Reduction Meter - mv		
pH, Temp, Conductivity Meter		
Spare DO Meter Membranes		

DOWL
ENGINEERS
4040 B STREET ANCHORAGE ALASKA 99503-5999
PH: (907) 562-2000 FAX: (907) 563-3953

CHAIN OF CUSTODY
SAMPLE RECEIPT FORM

Proj. No.

Project Name

Samplers *(Signature)*

Sample No.	Date	Time	Comp.	Grab	Station Location	No. Of Containers	Analyses Requested									Remarks

Relinquished by: *(Signature)*	Date/Time	Received by: *(Signature)*	Relinquished by: *(Signature)*	Date/Time	Received by: *(Signature)*
Relinquished by: *(Signature)*	Date/Time	Received for Laboratory by: *(Signature)*	Date/Time	Remarks:	

LIQUID/SOLID DERA IDW TEMPORARY STORAGE FORM

a. CONTRACTOR NAME, CONTRACT NO./DELIVERY ORDER NO.: ______

b. CONTRACTOR POC AND COE POC: ______

c. LIQUID IDW DRUM COUNT: ______

d. SOLID IDW DRUM COUNT: ______

e. IDW ORIGIN (PHYSICAL LOCATION)/DATE: ______

f. IDW DRUM IDENTIFICATION NUMBERS: LIQUID from ______ to ______ SOLID from ______ to ______

g. SAMPLE DATE/TEST METHOD(S): ______

h. SAMPLE ANALYSIS TURN-AROUND DATE: ______

i. PROPOSED DISPOSAL MECHANISM (i.e., Landfill, carbon treatment, etc.): ______

j. PARTY RESPONSIBLE FOR IDW (NAME): ______

k. TEMPORARY STORAGE LOCATION: ______

l. SIGNATURES FOR TEMPORARY STORAGE LOCATION:

DPW, FWA Representative	*Contractor Name*
Signature	*Signature*

Date: ______

APPENDIX D

SCOPE OF WORK

STATEMENT OF WORK

22 August 1997

CONTRACT NO. DACA85-95-D-0008
DELIVERY ORDER NO.

TREATMENT SYSTEM DEMONSTRATIONS AND DESIGN VERIFICATION STUDY

RUFF ROAD AND ROOSEVELT ROAD
FORT RICHARDSON, ALASKA

1. INTRODUCTION AND BACKGROUND

1.1 General. Fort Richardson is located in southcentral Alaska, and is surrounded by the Municipality of Anchorage to the south and Elmendorf Air Force Base to the west. The Fort was established in 1940 to defend Alaska against foreign invaders, and covered approximately 67,000 hectares. Presently, the fort uses approximately 25,000 hectares of land situated between the foothills of the nearby Chugach Mountains and Knik Arm of Cook Inlet.

Fort Richardson was placed on the Comprehensive Environmental Response, Compensation and Liability Act (CERCLA) National Priorities List (NPL) in June 1993 in response to the documented evidence of uncontrolled and/or abandoned hazardous substance release from several contaminant source areas. As a result, a Federal Facilities Agreement (FFA) between the United States Environmental Conservation (ADEC), and the Department of Defense (DoD). The FFA details the responsibilities and authorities of each of the above parties with respect to environmental assessment and remediation needs at Fort Richardson. The FFA also establishes the operable units at Fort Richardson to be addressed under the CERCLA program. One of these units is Operable Unit A (OU-A), the subject of this scope of work.

OUA is comprised of three sites, the Roosevelt Road Transmitter Site Leachfield, the Ruff Road Fire Training Area, and the Petroleum, Oil, and Lubricant Laboratory Dry Well. The remedial investigation, human health risk assessment, and ecological risk assessment were completed in November 1996. A feasibility report for the Ruff Road site was submitted in December 1996. The Army, ADEC, and EPA have determined that the sites included within OUA will be addressed under the conditions of the State-Fort Richardson Environmental Restoration Agreement between the Army and ADEC. This design verification study addresses the Ruff Road and Roosevelt Road sites.

This statement of work presents the contract objectives, a description of the tasks required from the contractor, the completion schedule, discussion of the submittals and presentations required, the relationship of the contractor with the public, the method of payment, health and safety requirements, chemical quality management procedures, and general requirements and standards for the implementation of the treatment system demonstrations.

1.2 Project Request. U.S. Army 6th Infantry Division (Light), Directorate of Public Works, has tasked the United States Army Corps of Engineers (USACE), Alaska District, with performing treatment system demonstrations at the sites.

2. OBJECTIVE

2.1 The objective of this contract is to design, implement, monitor, and evaluate treatment systems for the Roosevelt Road and Ruff Road sites. At Roosevelt Road the treatment system will be plugging buried lines, solidification of cesspool contents, and groundwater monitoring to determine the effectiveness of treatment. At Ruff Road, in-situ vapor extraction with a vapor barrier is the treatment system that will be evaluated.

2.2 The Architectural and Engineering Firm (AE) shall accomplish the objectives by performing the following tasks:

Task 1	Schedule
Task 2	Site Visit and Document Review
Task 3	Treatment Systems Development/Work Plan
Task 4	Treatment Systems Installation
Task 5	Monitoring/Evaluation
Task 6	Design Verification Study Report
Task 7	Review Conferences and Meetings

3. DETAILED DESCRIPTION OF TASKS

3.1 General: The work under this contract shall follow the definition of tasks described in this section. All work shall be identified within one of the described tasks for the purposes of scheduling and costing. No work shall be identified outside of these tasks.

3.2 Task 1 – Schedule:

3.2.1 The A/E shall provide, within 10 days of notice to proceed, a schedule of all activities under the tasks for this contract. The schedule shall indicate all submittal dates, data requirements, review periods, transmittal and publishing time periods, coordination dates, anticipated meetings, etc. A Critical Path Method shall be used to determine critical tasks, tasks with float, and estimates of tasks and project completion. Schedules shall be a fenced bar (Gantt) chart, showing predecessor and successor tasks, actual start and finish dates, and actual progress. The schedule shall be prepared using Microsoft Project 4.0, and shall be transmitted to the Corps in paper and electronic formats.

3.2.2 The schedule shall be updated and submitted to the Corps when schedule variances, planned or not, exceed 5 working days.

3.3 Task 2 - Site Visit and Document Review:

3.3.1 The AE is required to visit the project area. This will be a reconnaissance level investigation designed to give the AE a thorough understanding of the site conditions. While on site, the AE shall observe relevant conditions, and obtain site photographs. Access to the site will be coordinated through the Alaska District Corps of Engineers (ADCOE). The AE shall prepare photos and appropriate documentation to support general conclusions and impressions of the site conditions. The AE shall be responsible for the safety of their own personnel while they investigate the project area. The review of existing documents shall take place before the site visit. At the completion of the site visit the AE shall meet with the ADCOE to discuss the findings and their approach to the project (see below, Task 8 – Review Conferences and Meetings). The site visit and document review shall be completed within ten days of NTP.

3.4 Task 3 - Treatment System Development and Work Plan:

3.4.1 The AE shall design treatment systems to meet the objectives developed in the Feasibility Study (FS) and the subsequent documents (Proposed Plan and the Record of Decision (ROD)) and subsequent draft decision documents. For purposes of estimating this Delivery Order it is to be assumed that the treatment technologies which will be evaluated are solidification at Roosevelt Road Transmitter Site Leachfield, and in-situ vapor extraction with vapor barrier at Ruff Road Fire Training Area. The design shall include all components necessary for operation. The work plan shall be submitted 4 weeks after NTP.

3.4.2 **Draft Work Plan** The AE shall develop a work plan which describes the field activities to be conducted for the treatment system demonstrations. The work plan shall clearly describe the project background, objectives and rationale for implementation of the treatment systems. The work plan shall provide specific matrices for evaluation of the system and methods of correction, explanation of the system implementation, explanation of the field installation, optimization, and field verification of radius of influence. The work plan shall include detailed system sketches and design calculations to determine spacing of the wells. It shall also address system monitoring and evaluation criteria, required permits, and any other project specific information. The work plan may cite the OUA Management Plan for information not specific to this treatment system demonstration.

3.4.3 **Site Safety and Health Plan** The most important aspect of this project is the health and safety of all on-site personnel. The AE shall develop a Site Safety and Health Plan (SSHP) to cover the work to be performed under this SOW. The AE shall develop health and safety criteria and practices sufficient to protect on-site personnel, the public, and the environment from physical, chemical, and/or biological hazards particular to the sites. The AE shall utilize a Certified Industrial Hygienist (CIH) or Certified Safety Professional (CSP) in formulating the SSHP for this project. The site specific SSHP is subject to review and approval by the CO prior to the start of field work. Field work shall be performed according to the approved SSHP. The SSHP shall be attached to the work plan.

3.4.4 **Review** The work plan will be subject to review and approval by the Corps, DPW, and DEC. Some of the comments may be transmitted to the A/E via the ARMS system. The A/E shall attend a review conference (see below, Task 8 – Review Conferences and Meetings) approximately 30 days after submittal of the draft work plan technical memorandum.

3.4.5 **Final Work Plan** The A/E shall address and annotate all comments received. Those received via ARMS shall be transmitted back to the Corps via ARMS in annotated format. The A/E shall incorporate review comments into the work plan as appropriate. The final work plan shall be submitted 7 days after the review conference, and all annotated comments shall be attached.

3.5 Task 4 - Treatment Systems Installation:

3.5.1 The AE shall install the treatment systems at Ruff Road and Roosevelt Road in strict accordance with the final work plan. The A/E shall be responsible for obtaining any permits required by the state or federal government. Installation shall include all components necessary for operation.

3.5.2 **Ruff Road** For purposes of costing this delivery order the AE shall assume that Ruff Road will require 3 horizontal wells installed in trenches, 160 feet long and 5 feet deep. In addition, a minimum 40-mil geomembrane vapor barrier shall be installed over a 1-ft. layer of gravel and covered by a 6-inch layer of sand. The vapor barrier shall cover an area of 0.75 acre. After installation the AE shall perform a startup test to balance the system and optimize system operation.

3.5.3 **Roosevelt Road** For purposes of costing this delivery order the AE shall assume that Ruff road will require the grouting of 11 pipes and the solidification of approximately 1 cubic yard of cesspool sediments. After solidification the sediments shall be returned to the cesspool and the cesspool area backfilled with clean soil.

3.5.4 **Investigation Derived Waste** IDW shall not be stored on site. Soil IDW shall be spread at the site or transported by the A/E to the hazardous waste transfer, storage, and disposal facility at Building 45-125, whichever is appropriate. Liquid IDW shall be transported by the A/E to the Environmental Staging Facility located at the southeast corner of the intersection of Warehouse Rd. and the Davis Highway. The Environmental Staging Facility operates year-round, however, the A/E is responsible for insuring that liquid IDW is not frozen upon delivery. All IDW containers shall be clearly labeled with the date, project name, drum number, boring number, contents (i.e. soil cuttings) and A/E point of contact. Deliveries of IDW shall be coordinated with Kevin Gardner of DPW and the operators of the disposal facilities. The A/E shall be fully responsible for characterizing and profiling the IDW for the purpose of disposal.

3.5.5 **Field Notes** The AE shall maintain field notes in a bound book with consecutively numbered pages. Field notes shall be written in permanent ink. Erasures shall not be allowed.

The AE shall document all field activities, visibly contaminated soil, and collection of samples. The AE shall submit a copy of the field notes to the ADCOE. The original field notes shall be submitted at the completion of the project.

3.6 Task 5 - Monitoring/Evaluation:

3.6.1 The AE shall monitor and evaluate the treatment system demonstrations at the two sites for two years after installation. This shall include all maintenance and repairs necessary to keep the systems functioning properly. All repair/maintenance costs shall be the responsibility of the AE. Monitoring requirements at Ruff Road include: measurement of organic vapor concentrations, air flow rates, measurement of vacuum pressure at each VE well point and in common flow lines, collection of air samples from the VE exhaust line for quantitative analyses (air samples shall be submitted for analyses by EPA method TO-14), and dissolved oxygen content. Monitoring requirements at both the Ruff Road and Roosevelt Road sites includes groundwater sampling to determine the effectiveness of the treatment systems. Assume that groundwater sampling will be conducted semi-annually.

3.6.2 The AE shall submit a brief report outlining the monitoring efforts and results on a quarterly basis. The monitoring report shall contain all data collected to date, and the data shall be presented in tabular and graphic formats. The reports shall be subject to review and approval by the ADCOE. The monitoring report shall include a section on conclusions and recommendations for further monitoring.

3.7 Task 6 – Design Verification Study Report:

3.7.1 **Draft Design Verification Study Report** The AE shall submit a draft report summarizing the activities and results of the field efforts. The report shall include a summary of the installation of the treatment systems with detailed site drawings, a copy of the final approved work plan, a description of any changes from the work plan that were instituted in the field, a description of monitoring efforts, results from the chemical analysis of the samples collected, and overall results of the monitoring program. The AE shall discuss the results and the significance of the findings, evaluate the suitability of the treatment systems for the Ruff Road and Roosevelt Road sites, and describe recommended changes to the treatment systems configurations or monitoring protocol. Conclusions and recommendations shall also be discussed. The report shall be submitted to the ADCOE for review and comment within 30 days of completion of monitoring.

3.7.2 **Review** The draft design verification study report will be subject to review by the Corps, DPW, and DEC. The AE shall attend a review conference approximately 30 days after submittal of the report. At the review conference the AE shall make a brief presentation of the design verification study before comments are discussed.

3.7.3 **Final Design Verification Study Report** After the review conference the AE shall modify the report as appropriate. Final versions of the report shall be submitted within 14 days of the review conference and shall include annotated comments.

3.8 Task 7 - Review Conferences and Meetings:

3.8.1 The AE's principal investigators are required to attend four meetings for this project, each 3 hours in length. The meetings are: 1) post-site visit meeting, 2) work plan review conference, 3) progress meeting, and 4) design verification study report review conference. Minutes of the meetings shall be prepared and signed by the AE. The conferences will be held at the US Army Corps of Engineer's Alaska District Office in Anchorage, Alaska.

3.8.2 **Minutes** The AE shall take minutes of the discussions at each of the meetings. The AE shall record all significant discussions and decisions, and all comment resolutions. The AE shall FAX the draft minutes to the Corps within three working days of each meeting. The final minutes shall be submitted one day after receipt of the marked-up draft comments from the Corps.

3.8.3 **Comments** The AE shall review all comments forwarded to them before the review conference and be prepared to discuss controversial comments. The AE may receive some comments at the review conference. Comments may also be transmitted to the AE over the ARMS system, and the AE will be required to annotate and transmit those comments back to the Corps over the ARMS system. The AE shall annotate all comments as to the resolution of the comment. The annotation shall include a brief description of the changes made, and where in the report they were made, or if changes were not made, an explanation of why not. Annotated comments shall be attached to final documents.

4. SUBMITTALS

4.1 Required Number of Copies:

REPORT	COPIES DRAFT	COPIES FINAL
Task 1 - Schedule	5	5
Task 3 - Work Plan and SSHP	12	12
Task 5 - Quarterly Monitoring Report	10	10
Task 6 - Design Verification Study Report	12	12
Task 7 - Meeting Minutes	1	5

4.2 Distribution: All distribution of submittals shall be made by the AE. A cover letter and distribution list for each submittal will be provided by ADCOE. The AE is required to notify the Engineer Manager three working days before the submittal is to go out.

4.3 Correspondence: The contractor shall make a record of each phone conversation and written correspondence regarding information related to the performance of this contract. A summary of the phone conversations and written correspondence shall be submitted to the CO upon request.

4.4 Due Dates. Submittals and Action Items:

Notice to Proceed (NTP) anticipated by 30 September 1996.

SUBMITTALS	DATE
Task 1 - Schedule	NTP + 10 days
Task 2 - Site Visit	NTP + 10 days
Task 3 - Draft Work Plan and SSHP	NTP + 30 days
Task 3 - Final Work Plan and SSHP	review conference + 7 days
Task 5 - Quarterly Monitoring Report	quarterly after start of monitoring
Task 6 - Draft Design Verification Study Report	completion of monitoring + 30 days
Task 6 - Final Design Verification Study Report	review conference + 14 days
Task 7 - Draft Meeting Minutes	review conference + three days
Task 7 - Final Meeting Minutes	receipt of marked-up minutes + 1 day

4.5 Reports: All project reports presenting data, analyses, and recommendations shall be prepared in a standard format for the AE project reports. All site drawings shall be of engineering quality with sufficient detail to show interrelations of major features on the site map (i.e., north arrows, keys, scales, etc.). The project report shall consist of 8-1/2" by 11" pages with drawings folded, if necessary, to this size. A decimal paragraphing system shall be used. Project reports shall be bound in durable binders which hold pages. A project report title page shall identify the project title, the contractor, the Alaska District, Corps of Engineers, and the date. Submittals shall include incorporation of all previous review comments as well as the disposition of each comment. All final submittals shall be sealed by a Professional Civil Engineer registered in the State of Alaska.

5. PERSONNEL QUALIFICATIONS

5.1 All team members must be designated at the onset of the project and must remain actively involved in their position throughout the duration of this contract as long as they are employed by the AE. Substitute team members must be approved by the Contracting Officer. Team member resumes must be provided to the CO with the AE's proposal. The team members for this project must have extensive experience in environmental restoration work. All AE team members are subject to approval by the CO.

5.1.1 One team member must have 3-years experience developing remediation, cleanup alternatives and site work plans.

5.1.2 The environmental engineer must have a minimum of 4-years experience in designing remediation for fuels, oils, metals, and solvent spills in soils. Past projects must include vapor extraction and air spagring, and other appropriate in-situ treatments. The engineer must also be a registered civil engineer.

5.1.3 The geologist/geotechnical engineer must have a minimum of 3 years experience in geotechnical investigations in the State of Alaska with demonstrated experience interpreting behavior of surface and subsurface water.

5.1.4 The chemist must have a minimum of two years experience in the HTW field, work to include both field sampling and chemical data review.

6. PUBLIC AFFAIRS

The AE shall not make available to the news media or publicly disclose any data generated or reviewed under this contract. When approached by the news media, the AE shall refer them to the CO for response. Project reports and data generated under this contract shall become the property of the government and distribution to any other source by the AE, unless authorized by the CO is prohibited.

7. METHOD OF PAYMENT

This shall be a firm fixed-price contract. The agreed price shall constitute full compensation by the government to the AE for work performed under this contract. The AE shall prepare the cost estimate for the negotiation with the CO based on work tasks as presented in Paragraph 3.0 " Detailed Description of Tasks" only. No estimate shall be prepared for paragraphs not identified by a specific task.

8. SCHEDULE

All work associated with this delivery order shall be completed by 30 December 1999.

APPENDIX A

Criteria and Documents Listing

1. "Procedures Manual for Groundwater Monitoring at Solid Waste Disposal Facilities," USEPA Publ. No. EPA 530/SW-611.

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1 August 85

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21. "Federal Facilities Compliance Strategy," USEPA, November 1988.

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APPENDIX E

CALCULATIONS

PRESSURE DRAW DOWN AND RADIUS OF INFLUENCE CALCULATIONS
ALTERNATIVE 4: VAPOR EXTRACTION SYSTEM
RUFF ROAD FIRE TRAINING AREA
FORT RICHARDSON, ALASKA

Using aqueous hydraulic conductivity and soil sieve analysis to estimate vapor-phase hydraulic conductivity, the Theis equation is used to estimate pressure crawdown (Massmann 1989):

$P= Q*W(U)/4Kb$, with $W(U)$ as well function.

Where: $U= rad^2 * Ss / 4 K t$

$K= k*r/\mu$

$k = C*(d15)^2$

Note: k is a function of the matrix only.

$Ss= g*na*MW/(R*T)$

$na= nt*(1- \% \text{ saturation})$

Notation

P = Pressure (Vacuum)
Q = Air Flow Rate
W(U) = Theis Well Function
K = Hydraulic Conductivity
b = Extraction Well Screened Le
U = Dimenisionless Term in Thei
rad = Radius (distance from well)
Ss = Specific Storage
t = System Run Time
k = Intrinsic Permeability
r = Specific Weight
μ = Dynamic Viscosity
C = Shape Factor
d15 = Particle Size at 15% Passing
g = Gravitational Acceleration
na = Air Porosity
MW = Molecular Weight
R = Gas Constant
T = Temperature in Degrees K
d = Medium Pore Size
nt = Total Porosity

Constants			Site Variables		
μ(aq) =	1.00E-02	g/cm/sec	d15=	0.32	mm
μ(gas)=	1.80E-04	g/cm/sec	K(aq)=	57.6	ft/day
den(aq) =	1.00E+00	g/cm^3	=	2.03E-02	cm/sec
den(gas)=	1.30E-03	g/cm^3	nt=	0.3	unitless
MW(gas)=	2.80E+01	g/mole	Satur=	7.8	%
R=	8.20E+07	cm^2 g/sec^2 mol K	T=	277	degrees K

Calculated Parameters						
na=	0.2766					
Ss=	3.34E-07	1/cm	=	1.02E-05	1/ft	
K(gas)=	1.47E-03	cm/sec	=	4.16E+00	ft/day	–From K(aq)
K(gas)=	9.06E-03	cm/sec	=	2.57E+01	ft/day	– From d15
K(gas) AVG=	3.65E-03	cm/sec	=	1.03E+01	ft/day	

FROM: FINAL FEASIBILITY STUDY OPERABLE UNIT-A
RUFF ROAD FIRE TRAINING AREA, FORT RICHARDSON, ALASKA
NOVEMBER 1994, ECOLOGY/ENVIRONMENT

C VES Well Calculations

OPERATIONAL TIME CALCULATION FOR BIOVENTING
RUFF ROAD FIRE TRAINING AREA
FORT RICHARDSON, ALASKA

Assume: 1st order reaction is applicable for degradation rate.

1st order reaction rate is defined as:

$C_t = C_o e^{-ut}$ Where:

		Unit
C_t =	Contaminant Concentration at time (t)	mg/kg
C_o =	Initial Contaminant Concentration	mg/kg
e =	Exponential factor	unitless
u =	Contaminant utilization rate	1/months
t =	time	month

Using data from the Eielson Air Force Base, Alaska, bioventing pilot test, the contaminant utilization rate is determined.

Initial Petroleum Hydrocarbon Concentration (C_o):	1,500 mg/kg
Time of Operation (t):	16 months
Concentration of Petroleum Hydrocarbon at t (C_t):	750 mg/kg

Rearrange 1st order reatction rate:

$u = (-1/t) * \ln(Ct/Co) \quad = \quad (-1/16) * \ln(1500/750)$

Utilization rate (u):	0.043 months

Applying the utilization rate from Eielson AFB, to the RRFTA site, the time required to operate the bioventing system is estimated.

Initial Petroleum Hydrocarbon Concentration (C_o)*:	3,400 mg/kg
u:	0.043 months
Cleanup Objective (C_t) **:	1,000 mg/kg

$C_t = C_o e^{-ut} \qquad 3,400 \quad = \quad 1,000 \quad * e^{-0.043*t}$

Time to achieve remediation goal (t):	28 months

Notes: * Maximum DRO concentration determined by RI.
** Cleanup objective for DRO.

VE SYSTEM VACUUM REQUIREMENTS

Screened Interval:	160 feet
Mass Flow Rate:	101 scfm
Required radius of influence:	40 feet

Required Vacuum

	Time				P	P
(ft)	(days)	(hour)	U	W(U)	(" H2O)	(" Hg)
0.1	0.17	4	3.67E-08	16.54	1.81	0.13
0.1	1	24	6.12E-09	18.33	2.00	0.15
0.1	15	360	4.08E-10	21.04	2.30	0.17
0.1	30	720	2.04E-10	21.74	2.37	0.17
0.1	90	2160	6.80E-11	22.83	2.49	0.18
0.1	180	4320	3.40E-11	23.53	2.57	0.19
0.1	365	8760	1.68E-11	24.23	2.65	0.19
0.1	730	17520	8.38E-12	24.93	2.72	0.20

Radius of Influence Versus Pressure Drop for the Given Parameters

	Time				P	P
(ft)	(days)	(hour)	U	W(U)	(" H2O)	(" Hg)
10	0.17	4	3.67E-04	7.33	0.80	0.06
20	0.17	4	1.47E-03	5.95	0.65	0.05
40	0.17	4	5.88E-03	4.57	0.50	0.04
60	0.17	4	1.32E-02	3.76	0.41	0.03
80	0.17	4	2.35E-02	3.20	0.35	0.03
100	0.17	4	3.67E-02	2.76	0.30	0.02

1/29

PRESSURE DRAW DOWN AND RADIUS OF INFLUENCE CALCULATIONS
ALTERNATIVE 4: VAPOR EXTRACTION SYSTEM
RUFF ROAD FIRE TRAINING AREA
FORT RICHARDSON, ALASKA

Using aqueous hydraulic conductivity and soil sieve analysis to estimate vapor-phase hydraulic conductivity, the Theis equation is used to estimate pressure drawdown (Massmann 1989):

P= Q*W(U)/4Kb, with W(U) as well function.

Where: U= rad^2 * Ss / 4 K t

Massman

$$P = \frac{Q\,W(U)}{4\pi K b}$$

K= k*r/μ

k = C*(d15)^2

Note: k is a function of the matrix only.

$k = 1{,}250\,(D_{15})^2$

Ss= g*na*MW/(R*T)

na= nt*(1- % saturation)

Notation

P = Pressure (Vacuum)
Q = Air Flow Rate
W(U) = Theis Well Function
K = Hydraulic Conductivity
b = Extraction Well Screened Le
U = Dimenisionless Term in Thei
rad = Radius (distance from well)
Ss = Specific Storage
t = System Run Time
k = Intrinsic Permeability
r = Specific Weight
μ = Dynamic Viscosity
C = Shape Factor
d15 = Particle Size at 15% Passing
g = Gravitational Acceleration
na = Air Porosity
MW = Molecular Weight
R = Gas Constant
T = Temperature in Degrees K
d = Medium Pore Size
nt = Total Porosity

Constants			Site Variables		
μ(aq) =	1.00E-02	g/cm/sec	d15=	0.32	mm
μ(gas)=	1.80E-04	g/cm/sec	K(aq)=	57.6	ft/day
den(aq) =	1.00E+00	g/cm^3	=	2.03E-02	cm/sec
den(gas)=	1.30E-03	g/cm^3	nt=	0.3	unitless
MW(gas)=	2.80E+01	g/mole	Satur=	7.8	%
R=	8.20E+07	cm^2 g/sec^2 mol K	T=	277	degrees K

$D_{30} = 0.075$ (SILT)

FOR SILTY SOIL W/ GRAVELS EST W/C = 15%

SATURATION WOULD BE 78%

Calculated Parameters						
na=	0.2766					
Ss=	3.34E-07	1/cm	=	1.02E-05	1/ft	
K(gas)=	1.47E-03	cm/sec	=	4.16E+00	ft/day	–From K(aq)
K(gas)=	9.06E-03	cm/sec	=	2.57E+01	ft/day	– From d15
K(gas) AVG=	3.65E-03	cm/sec	=	1.03E+01	ft/day	

NOTE SEVERAL ORDER OF MAGNITUDE DIFFERENCE -

RECALCULATE TO CHECK

VE SYSTEM VACUUM REQUIREMENTS

Screened Interval:	160 feet
Mass Flow Rate:	101 scfm
Required radius of influence:	40 feet

Required Vacuum

	Time				P	P
(ft)	(days)	(hour)	U	W(U)	(" H2O)	(" Hg)
0.1	0.17	4	3.67E-08	16.54	1.81	0.13
0.1	1	24	6.12E-09	18.33	2.00	0.15
0.1	15	360	4.08E-10	21.04	2.30	0.17
0.1	30	720	2.04E-10	21.74	2.37	0.17
0.1	90	2160	6.80E-11	22.83	2.49	0.18
0.1	180	4320	3.40E-11	23.53	2.57	0.19
0.1	365	8760	1.68E-11	24.23	2.65	0.19
0.1	730	17520	8.38E-12	24.93	2.72	0.20

Radius of Influence Versus Pressure Drop for the Given Parameters

	Time				P	P
(ft)	(days)	(hour)	U	W(U)	(" H2O)	(" Hg)
10	0.17	4	3.67E-04	7.33	0.80	0.06
20	0.17	4	1.47E-03	5.95	0.65	0.05
40	0.17	4	5.88E-03	4.57	0.50	0.04
60	0.17	4	1.32E-02	3.76	0.41	0.03
80	0.17	4	2.35E-02	3.20	0.35	0.03
100	0.17	4	3.67E-02	2.76	0.30	0.02

DOWL ENGINEERS ALASKA TESTLAB	COMPUTATIONS		W.O.# D50177.421
Project Name	Client Name COE		Sheet 3 of 29
DOZL	Prepared by: HAL Date 11/3/97	Checked by:	Date

MASSMAN 1989

$$h - h_0 = \frac{Q}{4\pi K b} W(u)$$

$$u = \frac{r^2 S_s}{4Kt}$$

$$n = n_T (1 - S)$$

$$K = \frac{\rho g k}{\mu}$$

Assume $\gamma_d = 110$ pcf

$n_T = 0.34$

$$k = 1{,}250 (D_{15})^2$$

darcies

1 darcie $= 10^{-8}$ cm^2

@ $w_c = 15\%$

$S = 78\%$

$$\boxed{n_a = 0.075}$$

$$S_s = \frac{g \rho W_m}{RT}$$

SUBSTANTIVELY DIFFERENT THAN E/E

DATA

$\boxed{D_{(15)} = 0.03 \text{ mm}}$ SUBSTANTIVELY DIFFERENT THAN E/F

W_m = molecular weight, 28 (M/mole)

$\mu = 1.8 \times 10^{-4}$ g/cm/sec

$\rho = 1.3 \times 10^{-3}$ g/cm^3 ~0.081 lb/ft^3

$RT = 2.5 \times 10^{10}$ cm^2 g/s^2 mole

$g = 980$ cm/s^2

n (POROSITY) $= 0.075$

DOWL ENGINEERS
ALASKA TESTLAB

COMPUTATIONS

W.O.# D56177

Project Name: D024

Client Name: COE

Sheet 4 of 29

Prepared by: HML Date 11/4/97

Checked by: Date

CALCULATIONS

1: COMPUTE CHANGE IN PRESSURE @ INFILTRATION
2: TRENCH AND VACUUM TRENCH AT 2 TIMES TO
COMPARE

$k = 1250\,(0.03)^2 = 1.125$ darcys

$1.125 \times 10^{-8}\ cm^2$

$$K = \frac{1.3 \times 10^{-3}\ g/cm^3 \quad 980\ cm/sec^2 \quad 1.125 \times 10^{-8}\ cm^2}{1.8 \times 10^{-4}\ g/cm/sec}$$

$796 \times 10^{-7}\ cm/sec$

$\boxed{7.96 \times 10^{-5}\ cm/sec}$ ~ 2 ORDERS OF MAGNITUDE LESS THAN EJE

$$S_s = \frac{980\ cm/sec^2 \quad (0.075) \quad 28\ g/mole}{2.5 \times 10^{10}\ cm^2\ g/sec^2\ mole}$$

$S_s = 8.23 \times 10^{-10}$

$8.23 \times 10^{-8}\ cm^{-1}$

DOWL ENGINEERS ALASKA TESTLAB	COMPUTATIONS		W.O. # D56177
Project Name D024	Client Name COE		Sheet 5 of
	Prepared by: WHL Date 11/4/97	Checked by: Date	

Let $r = 35$ feet $= 1.01 \times 10^{3}$ cm

$$u = \frac{r^2 S_s}{4Kt}$$

$t = 4$ hrs

$t = 14400$ sec

FIRST POINT'S TIME

$$u = \frac{(1.01\times10^{3})^{2}\ \mathrm{cm}^{2} \times 8.23\times10^{-8}/\mathrm{cm}}{4\ (7.96\times10^{-5}\ \mathrm{cm/sec})\ (1.44)\times10^{4}\ \mathrm{sec}} \qquad 10^{6}$$

0.183×10^{-1}

1.83×10^{-2}

From Attach Appendix E

$W(u) = 3.46$

If Screen Interval = 200 FT $= 6.1 \times 10^{3}$ cm

$Q = 100$ scfm $= 4.72 \times 10^{4}$ cm^3/sec
PER E&E

Then

$$h - h_0 = \frac{4.72\times10^{4}\ \mathrm{cm^3/sec}\ (3.46)}{4\ (3.1415)\ 7.96\times10^{-5}\ \mathrm{cm/sec}\ (6.1\times10^{3}\ \mathrm{cm})}$$

0.0268×10^{6} cm

2.68×10^{4} cm Gas

8.79×10^{2} FT Gas

349 - 7059

DOWL ENGINEERS ALASKA TESTLAB	COMPUTATIONS		W.O. # D8177
Project Name D026	Client Name COE		Sheet 6 of ___
	Prepared by: JML	Date 11/4/97	Checked by: Date

@ 0.081 lb/ft^3

71.2 lbs/ft^2

@ 62.4 lbs/ft^2-ft

1.17 FEET H_2O

14 INCHES H_2O @ 33' FROM WELL AFTER 4 HRS

CHECK 100 scfm

NEED 1 PORE VOLUME/DAY PER EPA

If TOTAL VOLUME PER SUCTION LINE

5' × 200' × 66' = 66,000 ft^3

IF ALLOW FOR SOILS TO DRY n_T = 0.34

V_A = 22,440

REQD FLOW 22,440/DAY = 16 scfm

100 scfm O.K. ~ APPROX 6 AIR TRANSFERS/DAY (LOSS INFLUENCE FROM BELOW)

R [illegible]

DOWL ENGINEERS ALASKA TESTLAB	COMPUTATIONS		W.O.# D52177
Project Name DO2C	Client Name COE		Sheet 7 of 29
	Prepared by: JML Date 11/4/77	Checked by:	Date

Assuming that in 4 hours @ 100 scfm

$h-h_0 = 13'$ H_2O @ Infiltration

What is Pressure @ Suction Trench if Trench 2' wide

$r = 1$ feet $= 30.5$ cm

$$u = \frac{(30.5\,cm)^2 (8.23 \times 10^{-8})\,cm^{-1}}{4 (7.96 \times 10^{-5})\,cm/sec \quad 1.4400 \times 10^{4}\,sec}$$

$u = 16.71 \times 10^{-7}$

$u = 1.67 \times 10^{-5}$

$W(u) = 10.4$

$$h-h_0 = \frac{4.72 \times 10^{4}\,cm^3/sec \qquad (10.4)}{4\pi \quad 7.96 \times 10^{-5} \quad 6.1 \times 10^{3}}$$

0.080×10^{4}

$.87 \times 10^{4}$ cm Gas

2640 ft gas

214 lbs/ft²

3.4 ft H_2O

41 inches H_2O in Trench

DOWL ENGINEERS ALASKA TESTLAB	COMPUTATIONS		W.O.# D58177
Project Name DOZL	Client Name COE		Sheet 8 of 29
	Prepared by: JML Date 11/4	Checked by: Date	

Check @ $Z = 4$ mos

$4 \times 30 \times 24 \times 60 \times 60 = 1.04 \times 10^7$ sec

Pressures at Infiltration Trench

$$u = \frac{(1.01 \times \overset{10^6}{10^3})^2 \times 8.23 \times 10^{-8}}{4(7.96 \times 10^{-5})(1.04 \times 10^7 \text{ sec})}$$

6.25×10^{-4}

$u = 2.5 \times 10^{-3}$

$W_u = 5.42$

$$h - h_0 = \frac{4.72 \times 10^4 \ (5.42)}{4(3.1415)(7.96 \times 10^{-5}) \ 6.1 \times 10^5}$$

0.0419×10^6

4.19×10^4 cm Gas

1375 FT Gas

21 in H_2O

@ Vacuum Trench

$$u = \frac{(30.5)^2 \times 8.23 \times 10^{-8}}{4 \ (7.96 \times 10^{-5})(1.04 \times 10^7)}$$

$u = 231 \times 10^{-10}$

2.31×10^{-8}

$W(u) = 17.0$

DOWL ENGINEERS ALASKA TESTLAB

COMPUTATIONS

W.O.# D56177

Project Name D024

Client Name COE

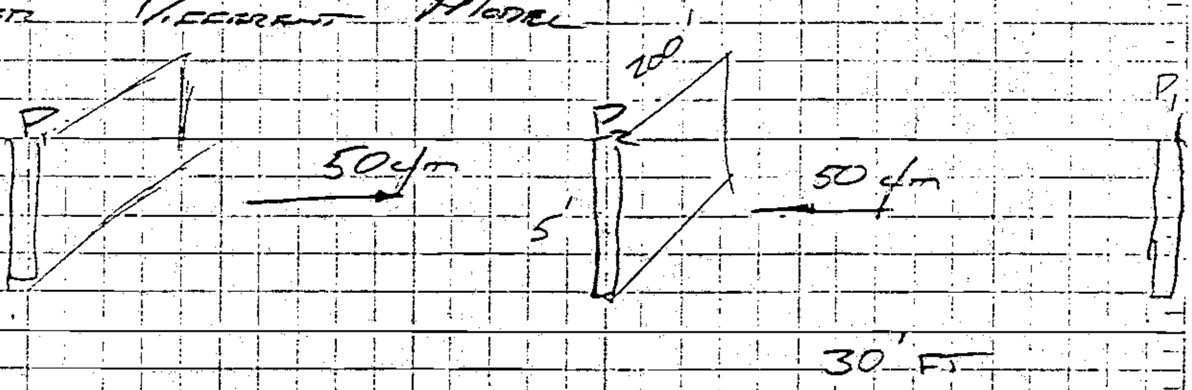
Sheet 9 of 29

Prepared by: HML Date 11/4

Checked by: Date

$h_1 - h_0 = \frac{17}{5.42} \times 21 = 66 \text{ in } H_2O$

CONSIDER DIFFERENT MODEL



$Q = K\,i\,A = K\,\frac{(P_2 - P_1)}{30'} \times (200' \times 5')$

$= K\,(P_2 - P_1) \times 33.3 \text{ FEET}$

LET $P_1 = 0$

$Q = K\,P_2 \times 33.3 \text{ FEET}$

$P_2 = \frac{Q}{K\,33.3 \text{ FT}}$

$P_2 = \frac{2.36 \times 10^{4} \text{ cm}^3/\text{sec}}{7.94 \times 10^{5} \text{ cm/sec} \left(33.3 \text{ ft} \times 12 \frac{\text{in}}{\text{ft}} \times 2.54 \frac{\text{cm}}{\text{in}}\right)}$ (7.[illegible]

$P_2 = 0.00292 \times 10^{9} \text{ cm}$

$P_2 = 2.92 \times 10^{5} \text{ cm}$

$9.43 \times 10^{3} \text{ FT}$ GAS

$\times\ 0.081 = 776\ \text{lbs/FT}^2$

5.4 psi

DOWL ENGINEERS
ALASKA TESTLAB

COMPUTATIONS

W.O.# D56177

Project Name D026

Client Name COE

Sheet 10 of 29

Prepared by: HML Date 11/4/97

Checked by: Date

12.4 ft of H_2O

149 in of H_2O

× 0.0736 11 inches Hg

CONCLUSION

LINEAR MODEL CONSERVATIVE, THEIS MODEL OPTIMISTIC DUE TO BOUNDARY CONDITIONS.

CONSIDER

USING ROTARY LOBE OR OTHER PDB FOR THIS APPLICATION. CALLED H_2O-L - CUT SHEETS ON WAY 11/4/97

ansformation function;
arquardt parameter;
ıp   ıt adsorbent density (M/L^3);
ard deviation;
derivative;
partial derivative;
ranspose of a matrix;
verse of a matrix;
tegration;
mmation; and
zero vector.

derivative with respect to r;
second order derivative with respect to r;
rivative with respect to t.

11/29

APPLYING GROUNDWATER FLOW MODELS IN VAPOR EXTRACTION SYSTEM DESIGN

By J. W. Massmann,[1] Associate Member, ASCE

ABSTRACT: Vapor extraction systems have recently been used in a variety of environmental engineering applications, including controlling methane migration and remediating problems associated with spills of volatile and semi-volatile organic compounds. The differential equations that govern pressure flow of gas and vapor in soil are nonlinear in that gas density depends upon gas pressure. However, if the maximum pressure difference between any two points in the flow field is less than approximately 0.5 atmospheres, the differential equations developed to model groundwater flow provide good approximations to gas transport. Vapor extraction systems generally operate under pressure differences on the order of 0.2 atmospheres. Analytical and numerical groundwater flow models can therefore be used to model vapor and gas transport if the proper set of input variables is defined. Analytical groundwater flow models are used to evaluate the results of a field gas extraction test. The results of these evaluations indicate groundwater models can provide an efficient and readily-accessible tool to aid in designing vapor extraction systems.

INTRODUCTION

Several recent environmental concerns have caused an increase in the use of shallow vapor extraction systems. Included in these concerns are the generation and migration of methane gas from landfills and the migration of vapors from spills of petroleum products and other volatile and semi-volatile organic compounds. Methane gas, which is generated within landfills by the bacterial decomposition of organic materials, can migrate through unsaturated soils for distances of hundreds of meters. Although methane is nontoxic, it presents an explosion hazard when mixed with air at concentrations between 5 and 15% by volume. One of the most effective methods to control methane migration is by pumping the methane out of the ground with vapor extraction systems (e.g., Emcon, 1980).

The second principal application of vapor extraction systems is to clean soils contaminated with volatile and semi-volatile organic compounds as a result of leaking underground tanks, pipelines, and other accidental spills. These compounds may be present in the unsaturated zone in both liquid and vapor phases. The liquid portion generally cannot be directly extracted from the unsaturated soils. However, applying a vacuum to the soil will cause the volatile vapors to be removed. As the vapors are extracted, more liquid will vaporize and will be removed from the soil. This application of vapor extraction systems has proven very effective in a number of situations, e.g., Wootan and Voynick (1984), Crow et al. (1985).

A typical vapor extraction system consists of a gas pump or blower connected to a series of wells that have been completed in unsaturated soil. The vacuum from the pump causes gas to flow through the soil to the extraction

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[1] Asst. Prof., Dept. of Geol. and Geol. Engrg., Michigan Tech., Houghton, MI 49931.

Note. Discussion open until July 1, 1989. To extend the closing date one month, a written request must be filed with the ASCE Manager of Journals. The manuscript for this paper was submitted for review and possible publication on March 14, 1988. This paper is part of the *Journal of Environmental Engineering*, Vol. 115, No. 1, February, 1989. ©ASCE, ISSN 0733-9372/89/0001-0129/$1.00 + $.15 per page. Paper No. 23208.

wells. The extraction rates are usually quite low, generally on the order of 15–150 L/s (30–300 cu ft/min) for each extraction well. Pressure drops within the extraction wells are typically less than 7,000 Pascals (30 in. of water or 1 lb/sq in.). Air-injection wells are sometimes used in conjunction with the extraction wells to further control gas flow. Depending upon the application, gas treatment equipment such as carbon adsorption beds may be required before the vapors can be discharged into the atmosphere.

Vapor extraction systems are generally designed using an empirical and site-specific approach. Prototypes or pilot-scale systems are often constructed at each site to determine system parameters such as well depths, well spacings, and extraction rates. One of the reasons that the design process has been primarily empirical is that readily accessible analytical tools have not been available to practicing professionals.

During the same-time period that applications of vapor extraction systems have increased, the popularity of prepackaged groundwater flow models has also increased. These models may range from relatively simple analytical models to more complex finite-element or finite-difference numerical models. With a few exceptions, the physical processes on which vapor extraction systems are based are very similar to the physical processes on which groundwater pumping systems are based. It seems natural, then, that groundwater flow models could play a role in the design of vapor extraction systems.

The objective of this paper is to present a methodology for using groundwater flow models as an aid in the design of gas extraction systems. The goal is to obtain approximate results that can be used to infer design parameters. The emphasis of the presentation is on describing methods to predict the number of injection and extraction wells, and the injection and extraction rates, required to obtain a specified pressure drawdown throughout a prescribed zone of influence. This information is required to select blowers and pumps, manifold diameters, and well geometries. Rigorous methods for predicting vapor composition are not included in the development. This information would be required to select vapor treatment equipment if treatment were necessary. Predicting the zones of influence and the sensitivities of these zones to system configurations is of fundamental importance in vapor system design. Predicting time-varying vapor compositions is a more tenuous task and is arguably of secondary importance in many applications.

Although the analytical methods discussed are approximate, they are relatively easy to complete and may result in significant savings in extraction system design. Care has been taken in preparing the paper so that simplifying assumptions are explicitly identified and the limitations that they present are discussed.

DARCY'S LAW AND GAS TRANSPORT IN POROUS MEDIA

The flow of gases and vapors through porous media is treated in a relatively extensive literature, including texts by Satterfield (1970), Geankoplis (1972), and Dullien (1979). The presentation in this section, based in part on the developments by Collins (1961) and Dullien (1979), is intended to illustrate the similarities and differences between the equation of motion for gas flow and the equation of motion for groundwater flow.

The transport of gas or vapor through porous media results from both pressure and concentration gradients. As stated above, the primary objective is to predict drawdowns in gas pressures caused by extraction systems, rather than to predict gas compositions. Neglecting diffusional flow due to concentration gradients will not have an appreciable impact on gas pressure predictions.

The flow of gases due to pressure gradients differs from the flow of liquids in that the velocity at the pore walls cannot generally be assumed to be zero for gas transport (Dullien 1979). Darcy's law, which governs the flow of liquids in porous media, is based on viscous flow in which the molecular velocity is zero along pore walls. Nonzero velocities at the pore wall will result in greater flow than predicted by Darcy's law. The additional flow is termed "slip flow" or "drift flow." Dullien (1979) presents an expression for the pressure flow of gases that includes the effects of both viscous flow and slip flow:

$$F = -\left(\frac{r^2 p}{8\mu} + \frac{4rRT}{3W_m V_m}\right)\frac{1}{RT}\nabla P \quad \ldots\ldots (1)$$

where F = molar flux (mole/L^2/T); r = average pore radius (L); P = gas pressure (M/L/T^2); μ = gas viscosity (M/L/T); R = gas constant (L^2/degree K/T^2/mole); T = gas temperature (degree K); W_m = molecular weight (M/mole); and V_m = mean molecular velocity (L/T).

The first term on the right side of Eq. 1 accounts for viscous flow and the second term accounts for slip flow. Slip flow is proportional to the average pore radius, whereas viscous or Darcy flow is proportional to the average pore radius squared. The importance of slip flow increases as the average pore radius decreases and as the pressure decreases. The relative importance of slip flow and viscous flow for gas composition, pressure, and temperature conditions typical of vapor extraction systems is illustrated on Fig. 1. For pore radii greater than approximately 10^{-3} mm (4×10^{-5} in.), the effects of slip flow are small relative to viscous flow. Silt and clay materials will have pore radii of this magnitude. Sand and gravel materials will have pore radii on the order of 10^{-1} mm (4×10^{-3} in.) and greater.

The magnitude of viscous flow relative to the slip flow for transport in silt, sand, and gravel materials indicates that the equation of motion for gas flow in these types of materials should be of the same form as the equation of motion for groundwater flow, which is given by Darcy's law:

$$q = \frac{-k\rho}{\mu}\nabla\phi \quad \ldots\ldots (2)$$

where q = specific discharge (L/T); k = permeability of the soil (L^2); μ = viscosity of the fluid (M/L/T); ρ = density of the fluid (M/L^3); and ϕ = fluid potential (L^2/T^2). The fluid potential for a compressible fluid is given by

$$\phi = gZ + \int_{P_0}^{P}\frac{dP}{\rho} \quad \ldots\ldots (3)$$

where P = pressure of the fluid (M/L/T^2); Z = elevation (L); and g = gravitational acceleration (L^2/T).

A number of assumptions are required to get Eq. 1 in a form similar to

12/29

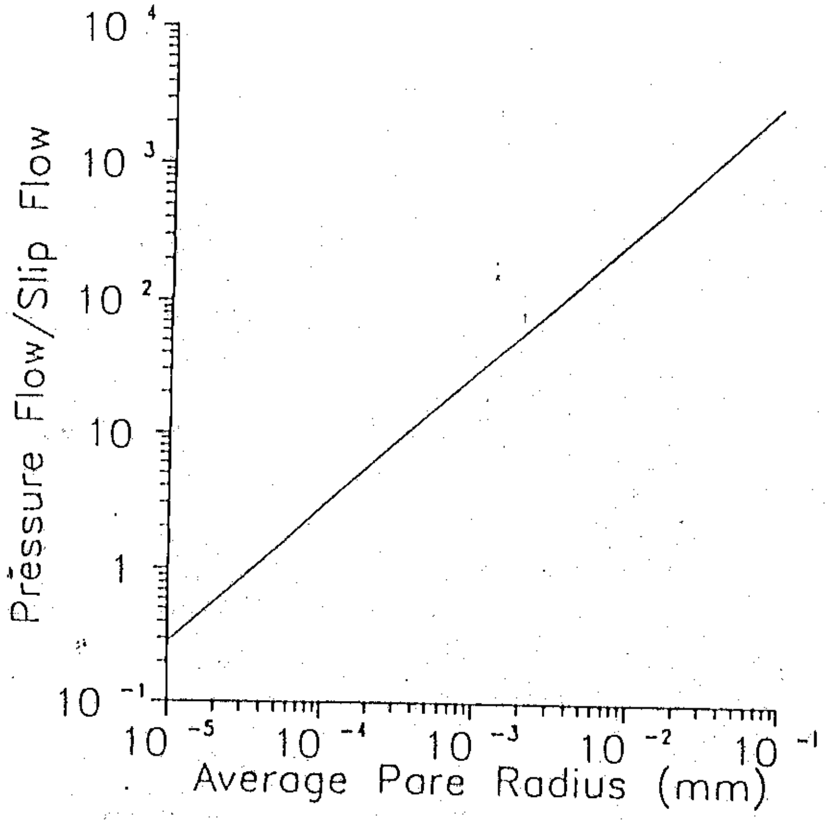

FIG. 1. The Relative Importance of Pressure and Slip Flow for Conditions Typical of Vapor Extraction Systems

Darcy's law. The first assumption is that slip flow can be neglected for flow in sand and gravel materials. Experiments performed by Alzaydi and Moore (1978) show that if pressure gradients typical to those used for vapor extraction systems are imposed across columns containing Ottawa sand, the discharge of air through the samples becomes a linear function of the pressure gradient within a short period of time, as predicted by Darcy's law. These same experiments performed on columns containing kaolinite clay show similar behavior, although more time is required to achieve linear pressure gradients. Their results support the evidence presented on Fig. 1 that Darcy's law provides a good approximation for gas flow in sands and gravels and a fair approximation for flow in silts, clays, and other low-permeability materials.

The second step in relating Darcy's law to gas transport involves expressing volume flux q in terms of molar flux F. The relationship between the two is given by

$$q = \frac{W_m F}{\rho} \qquad (4)$$

The driving force for flow in Darcy's law is potential gradient, whereas the driving force in the gas transport equation is pressure gradient. An equation of state relating gas density as a function of gas pressure and temperature is required to convert from potentials to pressures. For the pressures and temperatures used in vapor extraction systems, the gas can be modeled as an ideal gas dependent only upon pressure. The relationship between pressure and density for an ideal gas is given by the Boyle-Mariotte law (Collins 1961):

$$\rho = \frac{W_m P}{RT} \qquad (5)$$

Eqs. 3 and 5 can be combined to obtain an expression for fluid potential as a function of pressure:

$$\phi = gZ + \frac{RT}{W_m}\int_{P_0}^{P}\frac{dP}{P} \qquad (6a)$$

$$\phi = gZ + \frac{RT}{W_m}\ln\left(\frac{P}{P_0}\right) \qquad (6b)$$

The gradient in potential is given by

$$\nabla\phi = g\nabla Z + \frac{RT}{PW_m}\nabla P \qquad (7)$$

The second term on the right side of Eq. 7 is generally much greater than the first term for vapor extraction system applications. The potential gradient can therefore be approximated by

$$\nabla\phi = \frac{RT\nabla P}{PW_m} = \frac{\nabla P}{\rho} \qquad (8)$$

For many groundwater applications, fluid potential is converted to hydraulic head using the relationship

$$\nabla h = \frac{\nabla\phi}{g} = \frac{\nabla P}{\rho g} \qquad (9)$$

Combining Eqs. 2 and 8 gives Darcy's law in terms of pressure gradient:

$$q = \frac{-k\rho\nabla P}{\mu\rho} = \frac{-k}{\mu}\nabla P \qquad (10)$$

Finally, combining Eqs. 1, 4, and 10 and neglecting slip flow gives Darcy's law in terms of the gas transport coefficient:

$$q = \frac{-k}{\mu}\nabla P = \frac{W_m F}{\rho} = \frac{-r^2 W_m P}{\rho 8RT\mu}\nabla P = \frac{-r^2}{8\mu}\nabla P \qquad (11)$$

Eq. 11 shows that the relationship between the Darcy coefficient of permeability and the Dullien coefficient for viscous gas transport is given by

$$k = \frac{r^2}{8} \qquad (12)$$

15/-1

GAS TRANSPORT EQUATIONS AND SIMPLIFYING ASSUMPTIONS

Three general equations are required to model pressure drawdowns caused by vapor extraction systems. These are: (1) A continuity equation; (2) an equation of motion; and (3) an equation of state. The continuity equation is given by

$$\frac{\partial(n\rho)}{\partial t} = -\nabla(\rho q) \quad \text{.......... (13)}$$

where n = porosity of the soil (dimensionless).

As discussed in the previous section, the equation of motion for gas transport can be approximated using the form of Darcy's law given by Eq. 11. The equation of state relating gas density to pressure and temperature is given by Eq. 5, which is based on ideal gas behavior. Eqs. 5, 11, and 13 can be combined to obtain a general transport equation for the transient flow of gas in soils. This equation is of the form

$$\frac{\partial(n\rho)}{\partial t} = \nabla\left(\frac{\rho k}{\mu}\nabla P\right) \quad \text{.......... (14)}$$

A number of simplifying assumptions can be made to get Eq. 14 to look like the groundwater flow equation that is solved by most models. The first assumption that can be made is an outgrowth of the assumption of ideal gas behavior. In most groundwater flow models, the left-hand side of Eq. 14 is given by Freeze and Cherry (1979):

$$\frac{\partial(n\rho)}{\partial t} = \frac{S_s}{g}\frac{\partial P}{\partial t} \quad \text{.......... (15)}$$

where S_s = specific storage (L^{-1}).

The term on the left side of Eq. 15 can be expanded using the chain rule to give

$$\frac{\partial(n\rho)}{\partial t} = \frac{n\partial\rho}{\partial t} + \frac{\rho\partial n}{\partial t} \quad \text{.......... (16)}$$

The second term on the right is negligible compared to the first and can be dropped. Combining Eq. (16) with Eq. 5 gives

$$\frac{\partial(n\rho)}{\partial t} = \frac{n\partial\rho}{\partial t} = \frac{nW_m}{RT}\frac{\partial P}{\partial t} \quad \text{.......... (17)}$$

A comparison of Eqs. 15 and 17 shows that the specific storage term for transport of an ideal gas is given by

$$S_s = \frac{gnW_m}{RT} \quad \text{.......... (18)}$$

Eqs. 14, 15, and 18 can be combined to give that equation for transient flow of an ideal gas in a porous media:

$$S_s\frac{\partial P}{\partial t} = \nabla\left(\frac{\rho g k}{\mu}\nabla P\right) \quad \text{.......... (19)}$$

TABLE 1. Summary of Assumptions and Limitations

Assumption (1)	Limitations (2)
The equation of motion for gas transport can be approximated using equation similar to Darcy's law	In fine-grained materials, Darcy's law underestimates discharge by neglecting slip flow; however, assumption is likely valid approximation for flow in sands and gravels
Effects of diffusional flow are negligible	Valid assumption for predicting pressure distributions
Vapor behaves as ideal gas	Valid approximation for temperature and pressure conditions typical of vapor extraction systems
Constant and uniform porosity	Porosity will generally vary with time and with location due to natural variations in geologic materials and due to temporal and spatial variations in moisture content
Molecular weight is uniform	Molecular weight will vary with gas composition; variations will generally be small for typical applications of methane control and organic vapor recovery
Gravitational effects are negligible	Valid assumption for vapor extraction applications
Compressibility of the porous media is negligible	Valid assumption for essentially is small as compared to all systems; compressibility the vapor
Gas transport can be modeled using the equation for incompressible flow	Valid assumption for pressure variations on order of one-half an atmosphere and less

This equation compares to the equation for transient flow of groundwater (Freeze and Cherry 1979):

$$S_s\frac{\partial h}{\partial t} = \nabla(K\nabla h) \quad \text{.......... (20)}$$

where K = hydraulic conductivity (L/T).

A summary of the assumptions used to develop a gas transport equation that is in the same form as the groundwater flow equation is presented in Table 1. A brief description of the limitations imposed by these assumptions is also included in Table 1.

The fundamental difference between Eqs. 19 and 20 is that Eq. 19 is nonlinear because of the dependence of gas density on gas pressure. In a strict sense, this nonlinearity does not allow computer models developed to solve the groundwater flow equation to be used to model gas transport. Some type of linearization is required before this can occur. An analytical solution to Eq. 19 for one-dimensional flow in a semi-infinite and homogeneous medium (Kidder 1957) can be used to select this linearization. The equation that Kidder solves is

$$D_v\frac{\partial P}{\partial t} = \frac{\partial}{\partial x}\left(\frac{P\partial P}{\partial x}\right) \quad \text{.......... (21)}$$

14/29

TABLE 2. Comparison of Exact and Approximate Solutions to Eq. 21

Y (1)	Exact solution (2)	Eq. 24		Eq. 25	
		Value (3)	Error (4)	Value (5)	Error (6)
		(a) $P_1/P_\bullet$ = 0.90			
0.00000	0.90000	0.90000	0.00%	0.90000	0.00%
0.10000	0.91201	0.91179	0.02%	0.91125	0.08%
0.20000	0.92360	0.92321	0.04%	0.92227	0.14%
0.40000	0.94475	0.94414	0.06%	0.94284	0.20%
0.80000	0.97571	0.97519	0.05%	0.97421	0.15%
2.00000	0.99957	0.99956	0.00%	0.99953	0.00%
		(b) $P_1/P_\bullet$ = 0.80			
0.00000	0.80000	0.80000	0.00%	0.80000	0.00%
0.10000	0.82580	0.82492	0.11%	0.82249	0.40%
0.20000	0.85024	0.84863	0.19%	0.84454	0.67%
0.40000	0.89361	0.89119	0.27%	0.88568	0.89%
0.80000	0.95442	0.95245	0.21%	0.94842	0.63%
2.00000	0.99921	0.99916	0.00%	0.99906	0.01%
		(c) $P_1/P_\bullet$ = 0.50			
0.00000	0.50000	0.50000	0.00%	0.50000	0.00%
0.10000	0.58433	0.57823	1.04%	0.55623	4.81%
0.20000	0.65594	0.64577	1.55%	0.61135	6.80%
0.40000	0.76928	0.75584	1.75%	0.71420	7.16%
0.80000	0.90761	0.89810	1.05%	0.87105	4.03%
2.00000	0.99846	0.99824	0.02%	0.99766	0.08%
		(d) $P_1/P_\bullet$ = 0.20			
0.00000	0.20000	0.20000	0.00%	0.20000	0.00%
0.10000	0.40031	0.38466	3.91%	0.28997	27.56%
0.20000	0.52597	0.50378	4.22%	0.37816	28.10%
0.40000	0.69742	0.67175	3.68%	0.54271	22.18%
0.80000	0.88395	0.86742	1.87%	0.79368	10.21%
2.00000	0.99811	0.99775	0.04%	0.99626	0.19%

where $D_1 = n\mu/k$.

Eq. 21 is of the same form and has the same terms as Eq. 19. The boundary and initial conditions that Kidder assumes are as follows: $P(x,0) = P_\bullet$ for all x greater than zero; and $P(0,t) = P_1$ for all t greater than zero. The solution to Eq. 21 for several values of $P_1/P_\bullet$ is presented in Table 2. The dimensionless variable Y used to present the solution is given by

$$Y = \sqrt{\frac{D_1}{P_\bullet}}\frac{x}{2\sqrt{t}} \quad \ldots\ldots (22)$$

Kidder also developed an approximate solution to Eq. 21. This approximation is of the form

$$\frac{P^2 - P_1^2}{P_0^2 - P_1^2} = erf(Y) \quad \ldots\ldots (23)$$

where $erf(Y)$ is the error function of Y.

A comparison of the approximate and exact solutions to Eq. 21 i[illegible]e-sented in Table 2 for several values of $P_1/P_\bullet$. The difference between the two is less than one percent for all values of Y if $P_1/P_\bullet$ is greater than 0.8 and is less than five percent if $P_1/P_\bullet$ is greater than 0.2. Kidder notes that Eq. 23 is the exact solution to the following linear differential equation:

$$\frac{\partial P^2}{\partial t} = \frac{P_\bullet}{D_1}\frac{\partial^2(P^2)}{\partial x^2} \quad \ldots\ldots (24)$$

Kidder showed that the values of $P/P_\bullet$ obtained using Eq. 24 differ by less than five percent from the more accurate values obtained using Eq. 21 for all values of $P_1/P_\bullet$. The largest discrepancy occurs in the extreme case in which $P_1/P_\bullet$ approaches zero. Pressure differences in vapor extraction systems are typically on the order of 10–20% ($P_1/P_\bullet$ = 0.8–0.9). Given these relatively small pressure differentials, a second approximation to Eq. 21 can be given by

$$\frac{\partial P}{\partial t} = \frac{P_\bullet}{D_1}\frac{\partial^2 P}{\partial x^2} \quad \ldots\ldots (25)$$

Eq. 25 is a linear differential equation with P as the dependent variable, whereas P^2 is the dependent variable in Eq. 24. The solution to Eq. 25 has the same form as Eq. 23, only written in terms of P instead of P^2. Solutions to Eq. 25 for several values of $P_1/P_\bullet$ are included in Table 2. The difference between the exact solution for compressible flow (Eq. 21) and the solution to Eq. 25 is less than one percent for all values of Y if $P_1/P_\bullet$ is greater than 0.8. However, the approximation becomes quite poor as $P_1/P_\bullet$ drops below 0.5.

Because the solution to Eq. 25 is very close to the solution of Eq. 21 for $P_1/P_\bullet$ greater than 0.8, it follows that the linear differential equation given by 25 is a close approximation of the nonlinear equation given by 21 for vapor extraction applications. This allows us to rewrite Eq. 19, the equation for gas transport in porous media, as a linear differential equation of the form

$$S_1\frac{\partial P}{\partial t} = \nabla\left(\frac{\rho_\bullet g k}{\mu}\nabla P\right) \quad \ldots\ldots (26)$$

where $\rho_\bullet$ is the initial gas density.

Eq. 26 is now in the same form as the groundwater flow equation, Eq. 20, with pressure, P, replacing hydraulic head, h, and initial gas conductivity replacing hydraulic conductivity. All the models developed to evaluate groundwater flow can be applied to vapor extraction systems if these replacements are made.

METHODS FOR ESTIMATING INPUT PARAMETERS AND BOUNDARY CONDITIONS

The six input parameters required to model vapor transport using Eq. 26 are the viscosity, initial density, temperature, and molecular weight of the gas, and the porosity and permeability of the porous media. Methods to

15/129

TABLE 3. Approximate Viscosities for Typical Gas Components in Vapor Extraction Systems (Weast 1968)

Gas or vapor (1)	Viscosity (Micropoise) 30° C (2)	40° C (3)
Air	180	190
Carbon dioxide	148	157
Ethane	90	96
Ethylene	100	106
Methane	108	114
Nitrogen	174	182

Note: 1 micropoise is equal to 1 × 10^{-4} g/cm/s.

estimate each of these parameters and typical values for vapor extraction systems are discussed below.

Gas Viscosity

The viscosity of a gas mixture is a function of composition and can be estimated using formulas presented by Geankoplis (1972) and Dullien (1979). For most gas mixtures associated with vapor extraction systems, a simple composition-weighted average of viscosities gives a good approximation:

$$\mu_{mix} = \sum_{i=1}^{m} X_i \mu_i \quad \ldots\ldots (27)$$

where X_i = mole fraction of component i; μ_{mix} = viscosity of gas mixture; μ_i = viscosity of component i; m = number of gas components in the mixture. Viscosities for typical components of concern in methane and organic vapor recovery systems are listed in Table 3.

Gas Density

The initial density of an ideal gas varies inversely with pressure, and varies with molecular composition. Density variations due to changes in composition will depend upon site-specific gas compositions and can be estimated with Eq. 5. Densities for gas compositions typically encountered in vapor extraction system applications will generally vary from approximately 0.7 g/L (0.04 lb/cu ft) for 100% methane to approximately 1.3 g/L (0.08 lb/cu ft) for air with high concentrations of volatile organic vapors.

Molecular Weight

The molecular weight of a gas mixture is equal to the composition-weighted average of the molecular weights of the individual gas components:

$$W_m = \sum_{i=1}^{m} X_i (W_m)_i \quad \ldots\ldots (28)$$

where $(W_m)_i$ is the molecular weight of component i.

TABLE 4. Typical Permeability Values for Unconsolidated Geologic Mater. (Freeze and Cherry 1979)

Geologic material (1)	Range of permeability (Darcies) (2)
Silt	10^{-3}–1
Silty sand	10^{-1}–10^{1}
Clean sand	10^{-1}–10^{1}
Gravel	10^{2}–10^{3}

Porosity

The porosity that should be used in the storage coefficient in Eqs. 18 and 26 is the fraction of the soil volume filled with vapor or gas. Because of the presence of moisture in the soil pores, the air porosity will generally be less than the total porosity. The relationship between air porosity and total porosity is given by

$$n_a = n_T(1 - S) \quad \ldots\ldots (29)$$

where n_a = air porosity; n_T = total porosity; and S = degree of saturation.

Permeability

Permeability is overwhelmingly the most uncertain and variable of the input parameters included in Eq. 26. Its value can range over more than 13 orders of magnitude, depending upon the type of geologic material and the presence of moisture. Most vapor extraction systems are installed in unconsolidated materials consisting of silts, sands, and gravels. Ranges of permeabilities for dry samples of these materials are summarized in Table 4.

Three general methods for estimating gas permeability are presented in this section. These are: (1) Estimating permeability as a function of saturated hydraulic conductivity; (2) estimating permeability as a function of grain size parameters; and (3) estimating permeability from gas extraction tests.

The relationship between saturated hydraulic conductivity and permeability is given by

$$K = \frac{\rho g k}{\mu} \quad \ldots\ldots (30)$$

Permeability is a function only of properties of the porous media, while hydraulic conductivity is a function of both porous media properties and fluid properties. For vapor extraction systems that will be operated in dry soils whose saturated hydraulic conductivities are known, Eq. 30 can be solved to obtain permeability by incorporating the viscosity and density of water. For hydraulic conductivities in centimeters per second and gas permeabilities in darcies (1 darcy = approximately 1 × 10^{-8} cm²), the conversion is given by:

$$k = 1{,}040\ K \quad \ldots\ldots (31)$$

Gas permeability can also be estimated from grain size analyses performed on soil samples. Eq. 12 presents permeability as a function of pore radius:

$$k = 0.125 r^2 \quad \ldots\ldots (32)$$

where pem.   lity k and pore radius r are in units of L^2. For k in darcies and r in millimeters, Eq. 32 can be rewritten as

$$k = 125{,}000r^2 \quad (33)$$

Relationships have been developed to estimate the average pore radius of sands and gravels from the results of grain size analyses. These estimates, which should be viewed as order-of-magnitude approximations, are generally of the form

$$r = cD_{15} \quad (34)$$

where c = empirical constant; and D_{15} = grain size for which 15% by weight of particles are smaller. Sherard et al. (1984) have found that a c value of 0.1 gives reasonable approximations for sand and gravel soils.

Combining Eqs. 33 and 34 gives an expression for gas permeability as a function of the grain size parameter:

$$k = 1{,}250D_{15}^2 \quad (35)$$

where the permeability, k, is in darcies and the grain size parameter, D_{15}, is in millimeters. It should be emphasized that the permeability value predicted by Eq. 35 is a gross approximation that should be viewed as an order-of-magnitude estimate, at best.

The third general method for estimating gas permeability is from data collected during gas extraction tests. Curve-fitting techniques similar to the Theis, Jacob, and Hantush methods that are used to evaluate groundwater pumping tests can also be used to evaluate these extraction tests. The general procedure for performing extraction tests is to attach a vacuum pump to an extraction well completed in unsaturated soils and to measure pressure drawdowns in adjacent gas probes as a function of time. A plot of pressure drawdown versus time can be used to estimate "gas conductivity" in an approach directly analogous to groundwater pumping tests. Gas permeability can then be estimated from the gas conductivity by incorporating the viscosity and density of gas into Eq. 30. This procedure is presented in more detail in the section describing the case history.

The estimated values for the viscosity, initial density, temperature, and molecular weight of the gas, and the porosity and permeability of the porous media, can be directly incorporated into groundwater flow models to evaluate conceptual designs for vapor extraction systems. A summary of the method is as follows:

1. Estimate gas viscosity using Eq. 27. If no information is available regarding gas composition, assume a viscosity of air equal to 1.8×10^{-4} g/cm/s (0.018 centipoise).
2. Estimate initial gas density based on vapor composition. If no information is available regarding composition, assume a density of air equal to 1.3×10^{-3} g/cm^3 (1.3 g/L).
3. Estimate permeability using either Eqs. 30, 31, or 35. Convert into units of cm^2 by using the conversion of 1 darcy equals 1×10^{-8} cm^2.
4. Calculate a "gas conductivity" using Eq. 30 and the viscosity, initial density, and permeability from items 1–3. Use a gravitational constant equal to 980 cm/s^2. The resulting gas conductivity will be in units of cm/s.

5.   'mate the molecular weight of the gas mixture using Eq. 28. If no information is available regarding gas composition, assume a molecular weight of air equal to 28 g/mole.
6. Estimate a storage coefficient using Eq. 18. Use the molecular weight from item 5, the gravitational constant from item 4, and the porosity from Eq. 29. Use a value of RT equal to 2.5×10^{10} cm^{2}g/s^{2}mole. The resulting storage coefficient will be in units of cm^{-1}.

The storage coefficient and gas conductivity can be directly incorporated into groundwater flow models. The only other items that need to be addressed are boundary conditions. Prescribed flow boundaries and impermeable boundaries are directly analogous to groundwater flow conditions: one simply specifies flow rates in units of length cubed per time (e.g., cm^3/s). Prescribed head boundaries need to be replaced with prescribed pressure boundaries.

CASE HISTORY: MIDWAY LANDFILL, KENT, WASHINGTON

A case history is presented in this section to further illustrate the methodology for using groundwater flow models to evaluate the design of vapor extraction systems. The motivation for including the case history is to illustrate the details of the approach. The presentation is divided into two parts. In the first part, the Theis solution for groundwater flow is used to develop a preliminary design for a gas extraction well. In the second part, the results of field extraction tests are analyzed and the effectiveness of the gas extraction well is evaluated.

The case history is based on the Midway Landfill in Kent, Washington. The landfill is located in an abandoned gravel quarry just south of Seattle. A generalized cross section through the landfill is illustrated on Fig. 2 [Hart-Crowser (1986)]. The site stratigraphy can be summarized as a three-layer system. The top layer consists of low-permeability glacial till. This till overlies a thick deposit of sand and gravel. Beneath the sand and gravel is a layer of clay and clayey-silt. The approximate location of the groundwater table is at the top of the clay unit.

Methane gas produced by the decomposition of organic materials within the landfill had been detected in the immediate vicinity of the landfill at concentrations above the lower explosive limit. An extensive gas monitoring program was undertaken in the fall and winter of 1985 by the Washington Department of Ecology (WDOE) and the City of Seattle to evaluate the extent of methane migration. The program involved installing and monitoring more than 80 subsurface gas probes and monitoring gas concentrations in homes and businesses in the vicinity of the landfill. These activities indicated that potentially explosive conditions were present over distances greater than 500 m from the landfill site. The most extensive migration occurred to the east of the landfill. Homes and business were evacuated in response to these potentially explosive conditions, some for periods in excess of several months.

Two general activities to alleviate the problems associated with the methane migration were undertaken in late 1985 and early 1986. The first activity was to install a methane collection system on the landfill to prevent additional gas from leaving the site. This on-site system was intended to stop the gas source but not to clean areas in which gas had previously migrated.

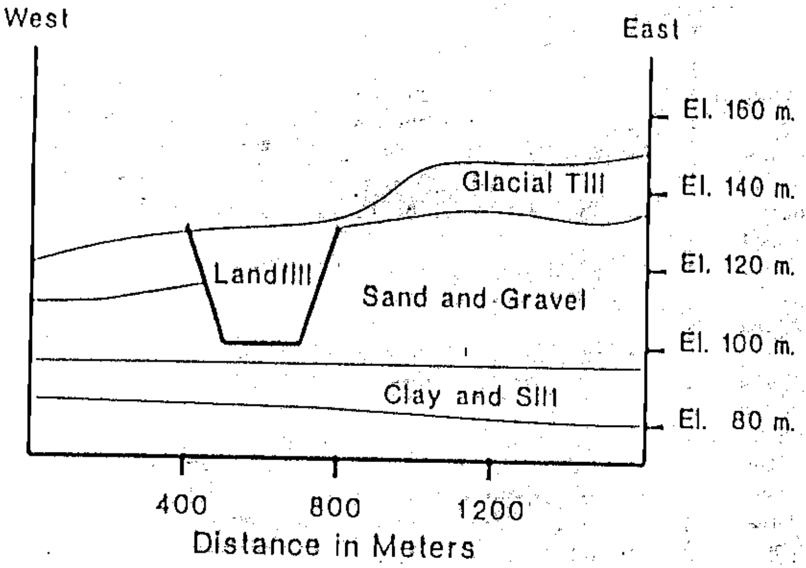

FIG. 2. Generalized Geologic Cross Section Through Midway Landfill

The second activity was to install several off-site extraction wells east of the landfill to reduce the methane concentrations in these areas. Groundwater flow models were used to help evaluate the design of both the on-site and off-site methane control systems. The evaluations pertaining to the off-site system are described below.

PRELIMINARY DESIGN OF OFF-SITE EXTRACTION WELLS

The WDOE decided to install several off-site extraction wells in the neighborhoods east of the landfill in an effort to reduce methane concentrations in the vicinities of homes that had been evacuated. The approach adopted by the WDOE was to extract the methane by using a relatively small number of large extraction wells. The off-site wells were to be completed in the sand and gravel formation immediately beneath the surface till and were to be approximately 100 ft deep.

Extraction systems were available that were capable of delivering 115 L/s of gas (250 cu ft/min) when operating against a vacuum equal to approximately 1 m of water (0.1 atmosphere). The Theis solution for groundwater flow was used to predict pressure drawdowns within the extraction well as a function of extraction rate to determine if these systems would be suitable for the Midway site. The steps included in this evaluation are summarized below:

1. Gas viscosity. Monitoring activities had indicated that the subsurface gas composition near the proposed site for the extraction well was approximately 50% methane and 50% air, by volume. The viscosity of methane is 1.1×10^{-4} g/cm/s and the viscosity of air is 1.8×10^{-4} g/cm/s. The viscosity for the gas mixture is given by Eq. 27: $\mu_{mix} = 0.5(1.1 \times 10^{-4}) + 0.5(1.8 \times 10^{-4}) = 1.45 \times 10^{-4}$ g/cm/s.

TABLE 5. Predicted Pressure Drawdowns Within Extraction Well as ction of Time for Extraction Rate Equal to 115 L/s

Time after start-up (1)	Pressure drawdown (cm of water) (2)
10 min	43
100 min	52
1,000 min	62
7 days	71
70 days	80

2. Gas density. The density of methane is approximately 0.7×10^{-3} g/cm^3 and the density of air is approximately 1.3×10^{-3} g/cm^3. The resulting density of the gas mixture is therefore 1.0×10^{-3} g/cm^3.

3. Permeability. Soil samples collected at the time the gas monitoring probes were installed were available for grain size analyses. The average D_{15} grain size from 47 samples collected from the sand and gravel formation was approximately 0.1 mm. Incorporating this value into Eq. 35 gives an order-of-magnitude estimate for permeability equal to 10 darcies (1×10^{-7} cm^2).

4. Gas conductivity. The gas conductivity can be estimated using Eq. 30: $K = \rho gk/\mu = 1 \times 10^{-3}(980)1 \times 10^{-7}/(1.45 \times 10^{-4}) = 7 \times 10^{-4}$ cm/s.

5. Molecular weight. The molecular weights for methane and air are 16 g/mole and 28 g/mole, respectively. The molecular weight for the mixture is given by Eq. 28: $W_m = 0.5(16) + 0.5(28) = 22$ g/mole.

6. Storage coefficient. The storage coefficient, assuming a value for porosity equal to 0.15, is given by Eq. 18: $S_s = gnW_m/RT = 0.15(980)22/(2.5 \times 10^{10}) = 1.3 \times 10^{-7}$ cm^{-1}.

The gas conductivity and storage coefficient values can be directly incorporated in the Theis equation to estimate pressure drawdowns:

$$h - h_0 = \frac{Q}{4\Pi Kb} W(u) = \frac{QW(u)}{4(3.14)(0.0007)(2{,}500)} \quad \text{.....................} \quad (36)$$

where b = the thickness of the unsaturated zone (L); Q = volumetric flow rate (L^3/T); $W(u)$ = well function (dimensionless); $h - h_o$ = drawdown (L); and $u = r^2S_s/4Kt$.

The drawdowns calculated with Eq. 36 will be in centimeters of gas. To convert to equivalent centimeters of water, it is necessary to multiply the calculated drawdown by the specific gravity of the gas, which is approximately 0.001 for a gas density of 1×10^{-3} g/cm^3. Estimated pressure drawdowns within a 15-cm diameter extraction well operating at an extraction rate of 115 L/s (250 cu ft/min) are presented in Table 5. After 70 days of pumping, the estimated drawdown within the extraction well is approximately 80 equivalent cm of water. This estimate suggested that the extraction system capable of delivering 120 L/s against 1 m of vacuum would be suitable for the Midway site.

18/29

EVALUATION OF FIELD EXTRACTION TESTS

An extraction well was installed east of the Midway Landfill in January 1986. The construction of the well, based in a part on the preliminary design evaluations described above, is illustrated on Fig. 3. A pumping test was performed on the extraction well in February 1986 to evaluate the overall performance of the system. The test involved measuring the pressure drawdowns in the extraction well and in nearby observation probes as a function of time while the extraction well was pumped at a constant rate.

The pressures within the well were measured with a mercury manometer. The construction of the extraction well allows the pressures to be measured at the bottom of the well and at the ground surface. The pressure at the bottom of the well during the test was approximately −100 cm of water and the pressure at the top was approximately −95 cm of water (negative values denote vacuum). The extraction rate during the test, which was estimated by measuring the velocity within the header pipe at the ground surface, fluctuated between 100 and 110 L/s (215–235 cu ft/min). The gas temperature was 11° C (52° F).

The cluster of observation probes, which is illustrated on Fig. 3, contains shallow, intermediate, and deep probes. The pressures within the probes were measured with an electronic pressure transducer. The transducer provides continuous digital readings accurate to about 0.05 cm of water. The majority of the pressure measurements were made in the intermediate probe, which is screened between the depths of 40 and 60 ft. The measurements were made for approximately five hours. The observed pressures within the intermediate probe are listed in Table 6 and are illustrated on Fig. 4. The shallow probe, which is screened in the silty-sand confining materials, responded more slowly than the intermediate probe. The slower response is expected because of the lower permeability of the materials in which it is completed. The deep probe responded as quickly as the intermediate, but the total drawdown during the test was about 10% less than the drawdown in the intermediate probe. The smaller response of the deep probe may be due to its vertical position relative to the extraction well. The deep probe is completed below the bottom of the extraction well.

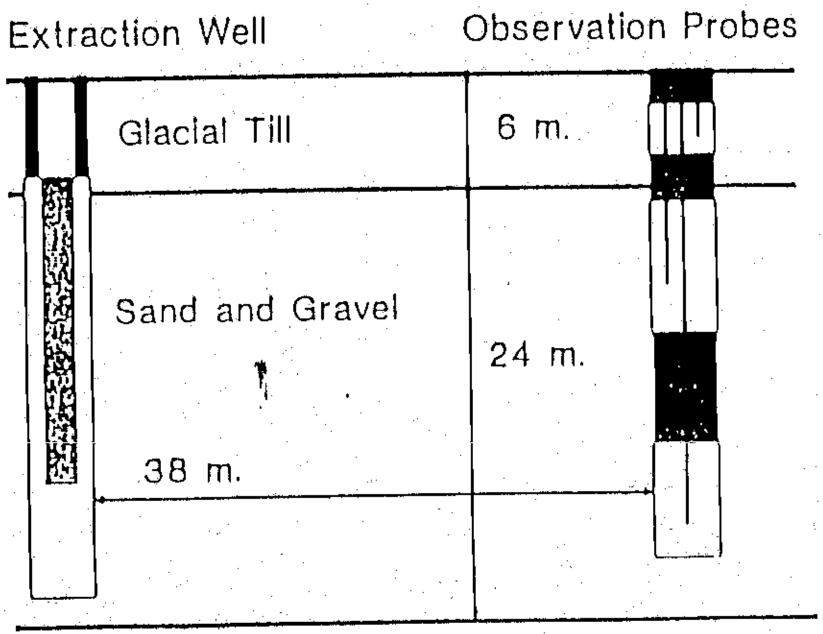

FIG. 3. Geometry of Extraction Well and Gas Probes used in Field Extraction Test

TABLE 6. Summary of Field Test Data and Evaluations; All Pressures and Drawdowns are in Equivalent Centimeters of Water

Time (min.) (1)	Observed pressure (2)	Corrected pressure (3)	Corrected drawdown (4)	Calculated drawdown (5)
0	−7.37	−7.37	0.00	0.00
1	−7.29	−7.42	0.05	0.00
2	−7.26	−7.45	0.08	0.00
3	−7.26	−7.42	0.05	0.02
5	−7.32	−7.40	0.03	0.15
6	−7.44	−7.55	0.18	0.25
7	−7.62	−7.75	0.38	0.43
9	−7.87	−8.03	0.66	0.74
11	−8.20	−8.39	1.02	1.04
14	−8.74	−8.97	1.60	1.52
18	−9.35	−9.66	2.29	2.16
21	−9.86	−10.19	2.82	2.60
26	−10.36	−10.80	3.43	3.22
31	−10.92	−11.43	4.06	3.81
41	−11.76	−12.42	5.05	4.82
46	−12.07	−12.81	5.44	5.23
61	−12.90	−13.90	6.53	6.35
101	−13.69	−15.32	7.95	8.00
166	−14.07	−16.74	9.37	9.14
306	−13.82	−17.48	10.11	10.16

An important aspect of the extraction test is that pressures are measured relative to atmospheric pressure. Atmospheric pressure is seldom constant and therefore the observed drawdowns need to be corrected for variations in barometric pressures. During the 24 hours preceding the extraction test, the barometric pressures steadily increased by approximately 15 cm of water. The pressures steadily dropped by approximately 3 cm of water during the test.

Pressures were measured during the test in several gas probes outside the zone of influence of the extraction well to gain information on the effects of barometric pressures. As an example, Table 7 lists pressures in a gas probe approximately 150 m from the extraction well during the extraction test. This probe is screened over approximately the same depth as the intermediate observation probe shown on Fig. 3. The pressures within the probe clearly show the effects of variations in barometric pressure.

19/129

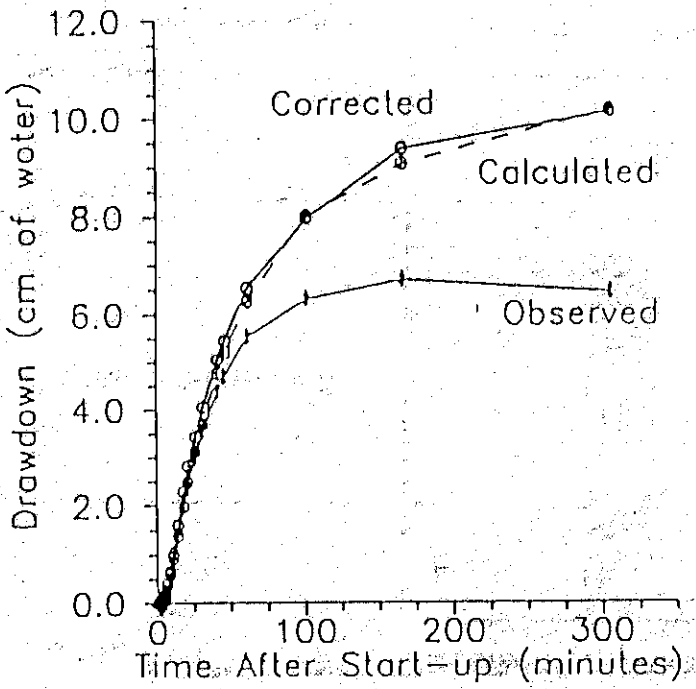

FIG. 4. Observed, Corrected, and Calculated Pressure Drawdowns for Field Extraction Test

The atmospheric high-pressure system that moved into the Midway area the day before the extraction test caused negative gauge pressures in the gas probes prior to pumping. Compensation can be made for these barometric effects by subtracting the gauge pressures that would be observed without pumping from the gauge pressures that were observed with pumping. The gauge pressures that would be observed without pumping can be predicted from measurements made in probes outside the extraction well's zone of influence. The corrections for barometric effects can be estimated by linearly interpolating the values in Table 7. This process results in the following corrections:

$$P_{cw} = P_{obs} - .016t \quad \text{for} \quad t < 150 \text{ minutes} \qquad (37a)$$

TABLE 7. Gas Pressures Used to Correct for Barometric Effects—Probe GP-50 Is Located 150 m from Extraction Well

Time after start of extraction test (min) (1)	Pressure in gas probe GP-50 (cm of water) (2)
0	−9.50
150	−7.11
300	−6.04

$$P_{cw} = P_{obs} - 2.4 - .007t \quad \text{for} \quad t > 150 \text{ minutes} \qquad (37)$$

where P_{cw} is the corrected pressure in equivalent centimeters of water and P_{obs} is the observed pressure in centimeters of water. Time $t = 0$ denotes the beginning of the test. The corrected pressures for the observation probe are included in Table 6 and Fig. 4.

A plot on logarithmic scales of the corrected drawdowns from Table 5 versus time indicates that the system responds as predicted by the Theis solution for the first 200 min of the test. The estimated gas conductivity from this portion of the test is 6.2×10^{-4} cm/s. This value was calculated using a match point of $W(u) = 1.2$; $u = 0.25$; $h - h_s = 5$ cm; and $t = 50$ min. The distance to the observation probe is 38 m (125 ft) and the extraction rate is 105 L/s (225 cu ft/min). In terms of permeability, this corresponds to a value of 9.2 darcies, which is remarkably close to the value of 12.5 darcies estimated from grain size analyses. The close correspondence is more likely an exception than a rule.

After 200 min, the observed drawdowns were less than the drawdowns predicted using the Theis solution. This discrepancy is likely due to leakage of air through the till confining unit shown on Fig. 3. The leaky-aquifer solution developed by Hantush (1956) can be used to incorporate the effects of air intrusion. The permeability of the confining unit can be estimated by matching the observed drawdowns with curves developed by Hantush (1956). A permeability of 0.2 darcies for the confining unit results a good fit to the data collected at the Midway site. The calculated drawdowns included in Table 6 and Fig. 4 are based on permeability for the confining unit equal to 0.2 darcies and permeability for the sand and gravel formation equal to 10 darcies. Except for the first three or four data points, the overall fit is quite good. It should be noted that the early data are close to the precision of the pressure transducer used to make the measurements.

The results of the extraction test were used to predict the performance of the extraction well over times and distances greater than those evaluated during the test. An analysis using the Hantush solution indicates that if the extraction well operates at 100 L/s, the steady-state drawdown at 150 m (500 ft) will be approximately 1 cm of water and steady-state conditions will be achieved after approximately 100 hours of pumping. These results, which were used to estimate a radius of influence for the well equal to 150 m, are based on the assumption that the geometric and material properties of the flow system determined during the pumping test can be extrapolated over an area much larger than actually tested. Boring logs from gas probes in the vicinity indicates that such an extrapolation is reasonable.

CONCLUSIONS

The conclusions that can be developed are summarized below:

1. The effects of slip flow are negligible for gas transport in silts, sands, and gravels under the pressure and temperature conditions typical of vapor extraction systems. An equation of motion with the same form as Darcy's law can therefore be used to model gas flow.

2. The differential equation governing gas transport in porous media is nonlinear because gas density is a function of gas pressure. However, if the differ-

20/29

ence in gas pressure between any two points in the flow field is less _ ai proximately 0.2 atmospheres, the linear differential equation developed to mod groundwater flow gives a good approximation when applied to gas flow. Th approximation is within 1% of the exact solution under these pressure conditio Most vapor extraction systems will operate in this range of pressures.

3. For pressure differences greater than approximately 0.5 atmospheres, th groundwater flow equation gives a poor approximation to the gas flow equatio A linear differential equation written in terms of gas pressure squared (Eq. 1 will still provide a good approximation to the nonlinear gas transport equatio under these conditions.

4. The storage coefficient term for gas transport is a function of molecul weight, porosity, and temperature. It can be determined without relying up field tests.

5. The results of the field extraction tests illustrate the importance of co recting field data for the effects of fluctuations in barometric pressures.

6. Data collected from field extraction tests can be analyzed in a manner anal ogous to groundwater pumping tests. Analytical solutions for modeling ground water flow in confined and leaky aquifers give good approximations to gas flo phenomena.

ACKNOWLEDGMENTS

The gas extraction tests described in the paper were completed while th author was a Project Engineer at Hart-Crowser, Inc., Seattle, Washington. The work was performed as part of a contract between Black and Veatch and the Washington Department of Ecology. Pete Kmet, an engineer with the Washington Department of Ecology, was instrumental in completing th extraction tests.

APPENDIX I. REFERENCES

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APPENDIX II. NOTATION

The following symbols are used in this paper:

b = thickness of unsaturated zone (L);
c = empirical constant relating soil grain and pore sizes;
D_1 = $\mu n/k$;
D_{10} = grain size parameter;
$erf(\ )$ = error function;
F = molar flux (mol/L^2/T);
g = gravitational acceleration (L^2/T);
h = fluid head (L);
h_o = initial fluid head (L);
K = hydraulic conductivity (L/T);
k = permeability of soil (L^2);
m = number of gas components in mixture;
n = porosity of soil;
n_a = air porosity;
n_T = total porosity;
P = gas pressure (M/L/T^2);
P_i = gas pressure at extraction well or boundary (M/L/T^2);
P_{cor} = pressures corrected for barometric effects (M/L/T^2);
P_o = initial gas pressure (M/L/T^2);
P_{obs} = observed gas pressure (M/L/T^2);
Q = volumetric flow rate (L^3/T);
q = specific discharge (L/T);
R = gas constant (L^3/degree K/T^2/mole);
r = average pore radius (L);
S = degree of saturation;
S_s = specific storage (L^{-1});
T = gas temperature (degree K);
t = time;
u = dimensionless time used in Theis well function;
V_m = mean molecular velocity (L/T);
W_m = molecular weight (M/mol);
$(W_m)_i$ = molecular weight of component i;
$W(u)$ = Theis well function;
X_i = mol fraction of component i;
x = distance;
Y = $(D_1/P_o)(x/2t)$;
Z = elevation (L);
μ = gas viscosity (M/L/T);
μ_{mix} = viscosity of gas mixture (M/L/T);
μ_i = viscosity of component i (M/L/T);
ϕ = fluid potential (L^2/T^2);
ρ = density of the fluid (M/L^3); and
ρ_0 = the initial gas density (M/L^3).

21/29

22/29

EN/CP 14
Explosion-Proof Regenerative Blower

EN FEATURES

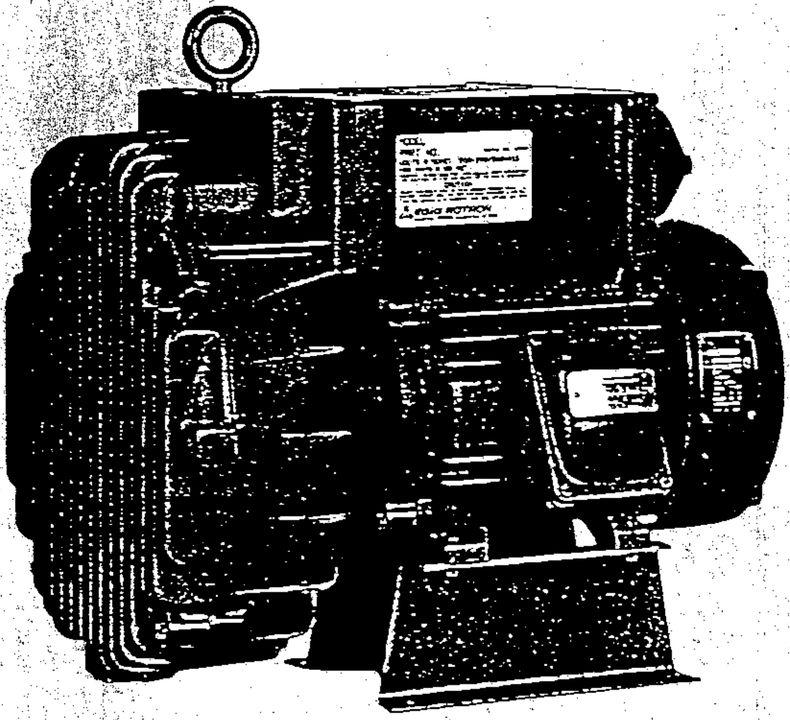
- Manufactured in the USA
- Maximum flow: 920 SCFM
- Maximum pressure: 144" WG
- Maximum vacuum: 115" WG
- Standard motor: 30 HP
- Blower construction – cast aluminum housing, cover, impeller & manifold; cast iron flanges
- UL & CSA approved motors for Class I, Group D atmospheres
- Sealed blower assembly
- Quiet operation within OSHA standards

OPTIONS

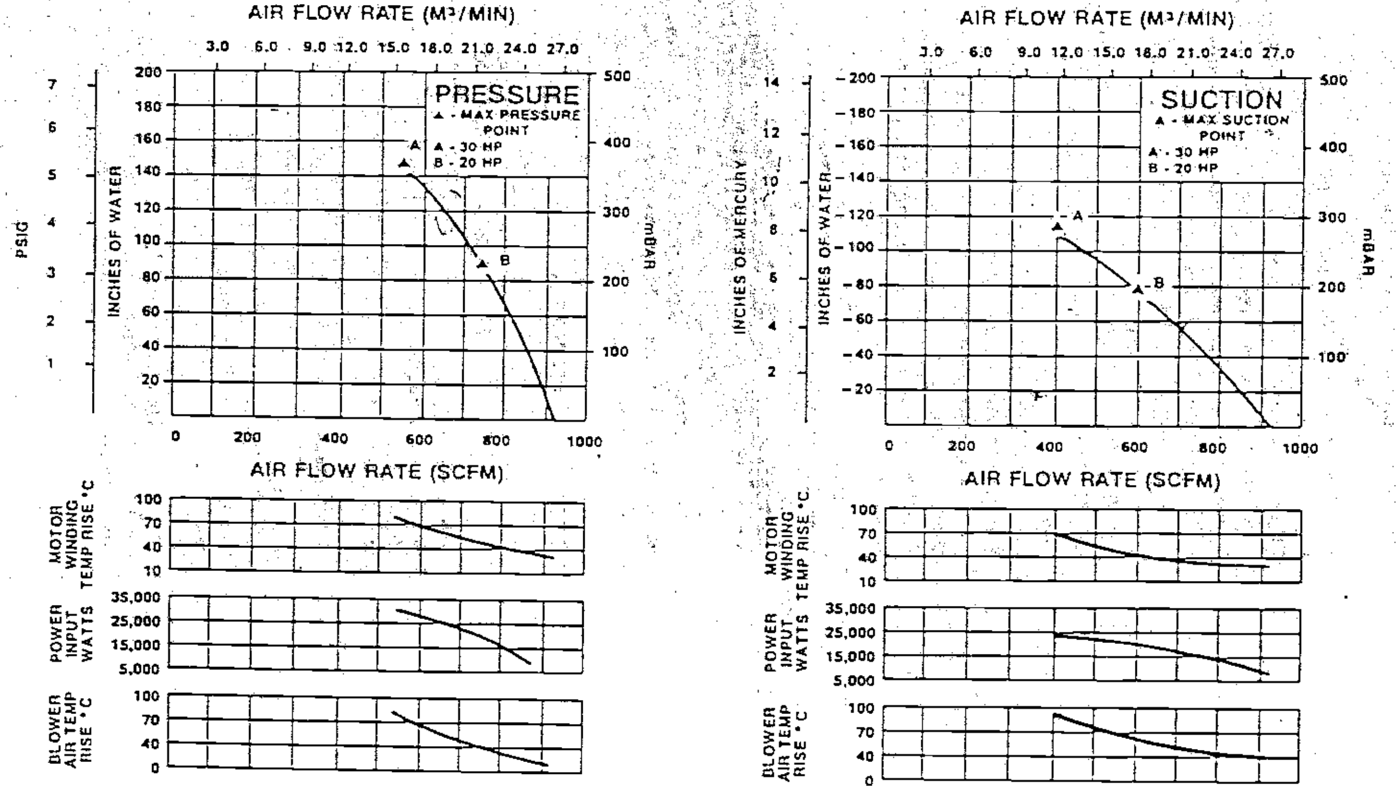
- TEFC motors
- 50 Hz motors
- International voltages
- Other HP motors
- Corrosion resistant surface treatments
- Remote drive (motorless) models

ACCESSORIES

- Moisture serarators
- Explosion-proof motor starters
- Inline & inlet filters
- Vacuum & pressure gauges
- Relief valves
- External mufflers



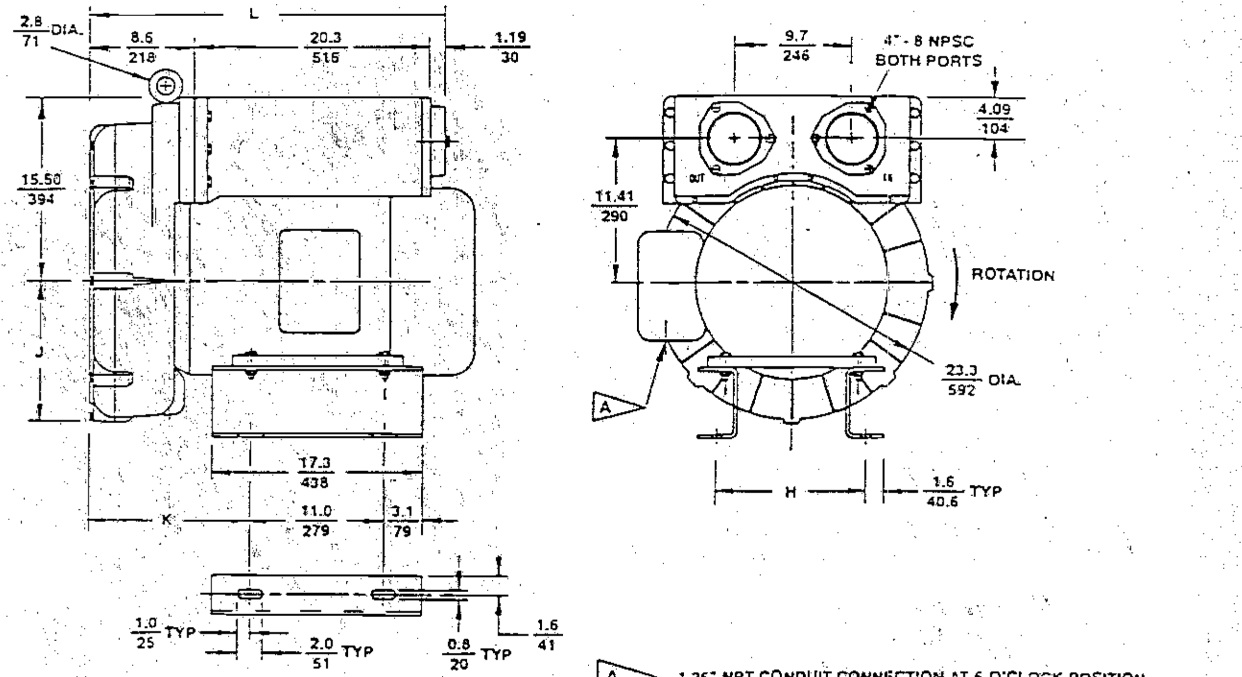
BLOWER PERFORMANCE AT STANDARD CONDITIONS



23 /129

EG&G ROTRON

EN/CP 1
Explosion-Proof Regenerative Blowe



A 1.25" NPT CONDUIT CONNECTION AT 6 O'CLOCK POSITION

DIMENSIONS: $\frac{IN}{MM}$
TOLERANCES: .XX ± $\frac{.1}{2.5}$
(UNLESS OTHERWISE NOTED)

MODEL	L (IN/MM)	K (IN/MM)	J (IN/MM)	H (IN/MM)
EN/CP14DX72WL	31.9/810	13.3/338	12.9/328	12.38/314
EN/CP14BK72WL	30.2/767	12.3/312	12.1/307	8.62/219

SPECIFICATIONS

MODEL	EN14BK72MWL		EN14DX72MWL		EN14DX86MWL	CP14GB72MWLR	CP14GC72MWLR
Part No.	038760		038761		038762	–	038984
Motor Enclosure – Shaft Material	Explosion-proof – CS		Explosion-proof – CS		Explosion-proof – CS	Chem XP – SS	Chem XP – SS
Horsepower	20		30		30	Same as EN14BK72MWL – 038760 except add Chemical Processing (CP) features from catalog inside front cover	Same as EN14DX72MWL – 038761 except add Chemical Processing (CP) features from catalog inside front cover
Phase – Frequency	Three - 60 Hz		Three - 60 Hz		Three - 60 Hz		
Voltage [1]	230	460	200-230	460	575		
Motor Nameplate Amps	50	25	80-70	35	28		
Maximum Blower Amps [3]	60	30	82	41	33		
Inrush Amps	317	159	495-430	215	226		
Starter Size	3	2	3	3	3		
Service Factor	1.0		1.0		1.0		
Thermal Protection [2]	Pilot Duty		Pilot Duty		Pilot Duty		
Bearing Type	Sealed, Ball		Sealed, Ball		Sealed, Ball		
Shipping Weight	680 lb (309 kg)		816 lb (370 kg)		816 lb (370 kg)		

BLOWER LIMITATIONS FOR 60 Hz

Min. Flow @ Max. Suction	600 SCFM @ –80" WG	400 SCFM @ –115" WG	400 SCFM @ –115" WG	600 SCFM @ –80" WG	400 SCFM @ –115" WG
Min. Flow @ Max. Pressure	750 SCFM @ 90" WG	550 SCFM @ 144" WG	550 SCFM @ 144" WG	750 SCFM @ 90" WG	550 SCFM @ 144" WG

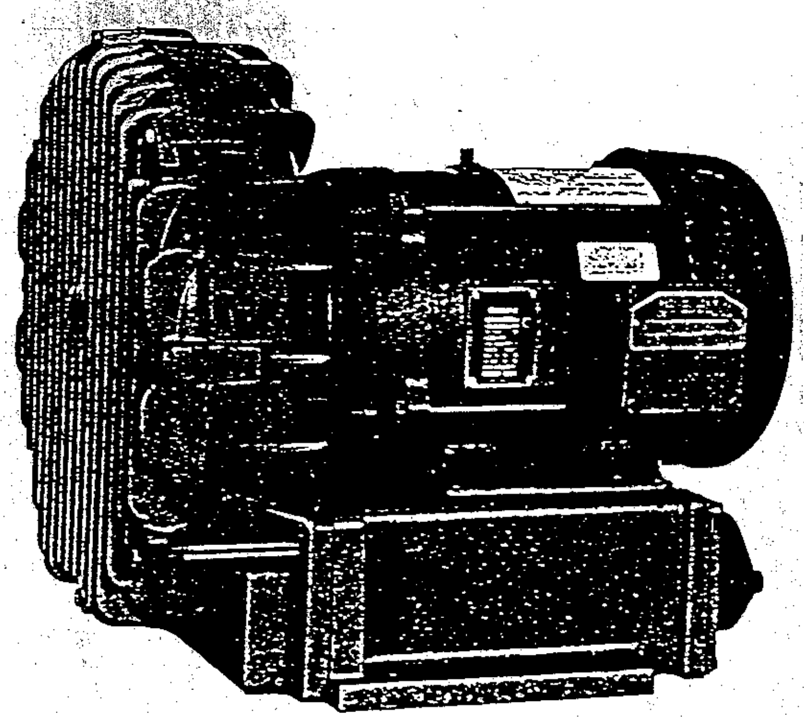
[1] All dual voltage 3 phase motors are factory tested and certified to operate on 200-230/400-460 VAC-3 ph-60 Hz and 220-240/380-415 VAC-3 ph-50 Hz. All dual voltage 1 phase motors are factory tested and certified to operate on 110-120/200-230 VAC-1 ph-60 Hz and 220-240 VAC-1 ph-50 Hz.

[2] Maximum operating temperatures: Motor winding temperature (winding rise plus ambient) should not exceed 140° for Class F insulation or 120° for Class B insulation. Blower outlet air temperature should not exceed 140° (air temperature rise plus ambient).

[3] Corresponds to the performance point at which the blower and / or motor temperature rise reaches the limit of the thermal protection in the motor.

Specifications subject to change without notice. Please contact factory for specification updates.

EN/CP 808
Explosion-Proof Regenerative Blower

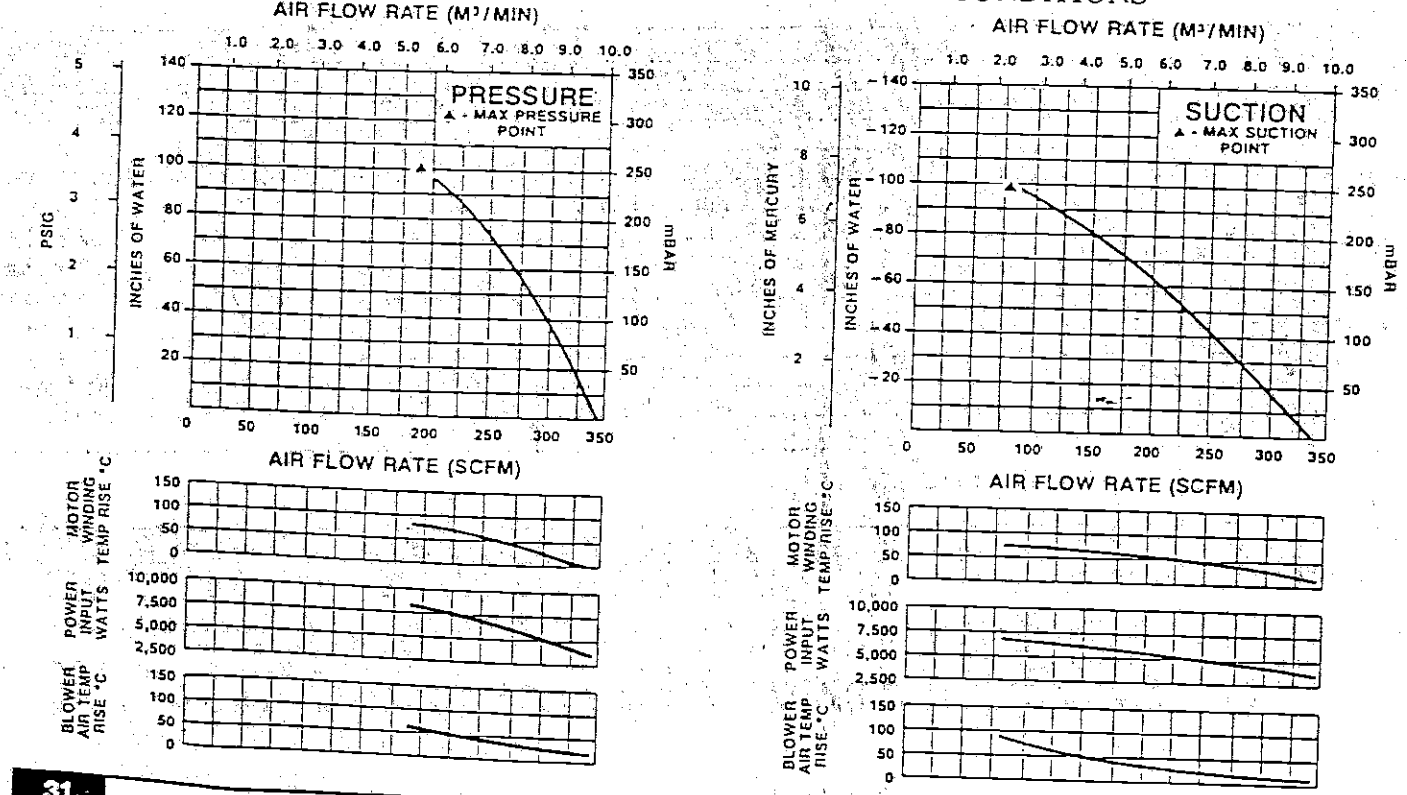


EN FEATURES
- Manufactured in the USA
- Maximum flow: 345 SCFM
- Maximum pressure: 100" WG
- Maximum vacuum: 97" WG
- Standard motor: 7.5 HP
- Blower construction – cast aluminum housing, cover, impeller & manifold; cast iron flanges
- UL & CSA approved motors for Class I, Group D atmospheres
- Sealed blower assembly
- Quiet operation within OSHA standards

OPTIONS
- TEFC motors
- 50 Hz motors
- International voltages
- Other HP motors
- Corrosion resistant surface treatments
- Remote drive (motorless) models

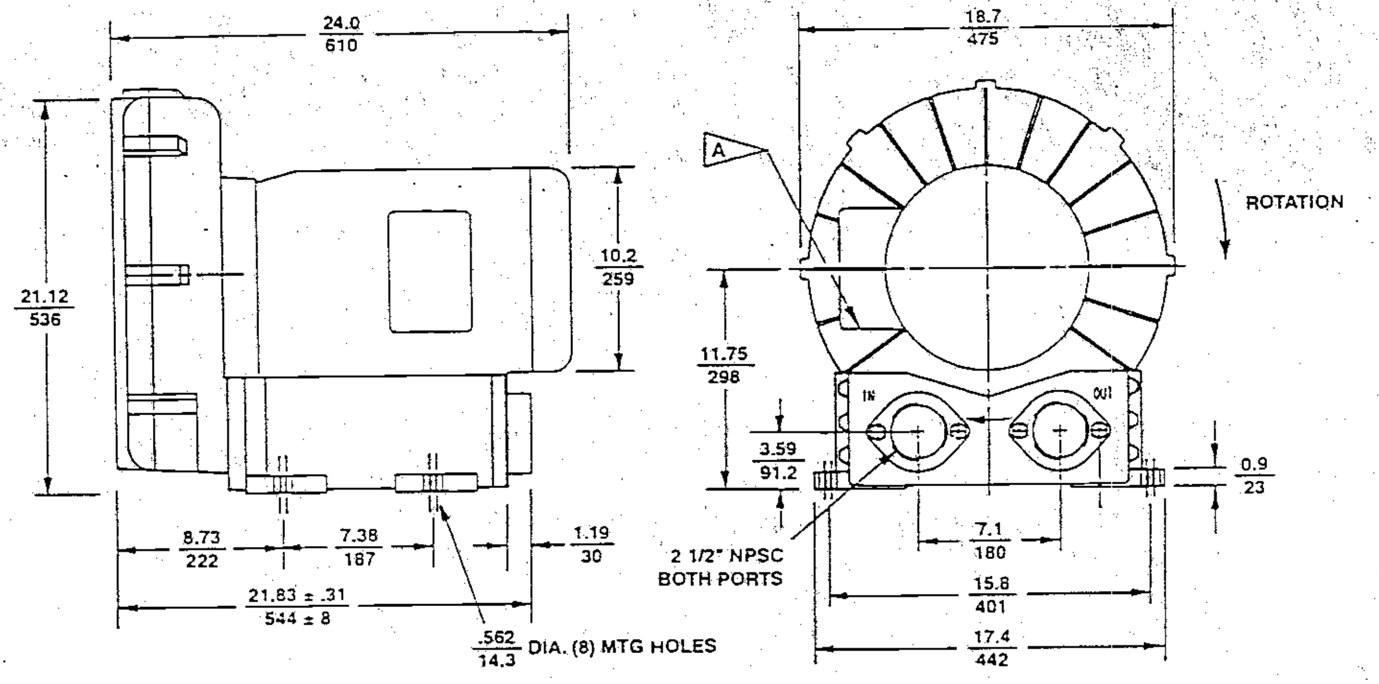
ACCESSORIES
- Moisture serarators
- Explosion-proof motor starters
- Inline & inlet filters
- Vacuum & pressure gauges
- Relief valves
- External mufflers

BLOWER PERFORMANCE AT STANDARD CONDITIONS



23/59

EN/CP 808
Explosion-Proof Regenerative Blower



DIMENSIONS: IN/MM
TOLERANCES: .XX ± 1/2.5
(UNLESS OTHERWISE NOTED)

A 0.75" NPT CONDUIT CONNECTION AT 12 O'CLOCK POSITION

SPECIFICATIONS

MODEL	EN808BA72MXL		EN808BA86MXL	CP808FY72MXLR
Part No.	038729		038731	038976
Motor Enclosure – Shaft Material	Explosion-proof – CS		Explosion-proof – CS	Chem XP – SS
Horsepower	7.5		7.5	Same as EN808BA72MXL – 038729 except add Chemical Processing (CP) features from catalog inside front cover
Phase – Frequency	Three - 60 Hz		Three - 60 Hz	
Voltage [1]	230	460	575	
Motor Nameplate Amps	17	8.5	7.4	
Maximum Blower Amps [3]	26	13	8.1	
Inrush Amps	126	63	56	
Starter Size	1	1	1	
Service Factor	1.0		1.0	
Thermal Protection [2]	Pilot Duty		Pilot Duty	
Bearing Type	Sealed, Ball		Sealed, Ball	
Shipping Weight	304 lb (138 kg)		304 lb (138 kg)	

BLOWER LIMITATIONS FOR 60 Hz

Min. Flow @ Max. Suction	80 SCFM @ –97" WG	80 SCFM @ –97" WG	80 SCFM @ –97" WG
Min. Flow @ Max. Pressure	185 SCFM @ 100" WG	185 SCFM @ 100" WG	185 SCFM @ 100" WG

[1] All dual voltage 3 phase motors are factory tested and certified to operate on 200-230/400-460 VAC-3 ph-60 Hz and 220-240/380-415 VAC-3 ph-50 Hz. All dual voltage 1 phase motors are factory tested and certified to operate on 110-120/200-230 VAC-1 ph-60 Hz and 220-240 VAC-1 ph-50 Hz.

[2] Maximum operating temperatures: Motor winding temperature (winding rise plus ambient) should not exceed 140° for Class F insulation or 120° for Class B insulation. Blower outlet air temperature should not exceed 140° (air temperature rise plus ambient).

[3] Corresponds to the performance point at which the blower and/or motor temperature rise reaches the limit of the thermal protection in the motor.

Specifications subject to change without notice. Please contact factory for specification updates.

$$\int_u^\infty \frac{e^{-x}}{x}\,dx = W(u) = -0.5772 - \log_e u + u - \frac{u^2}{2\cdot 2!} + \frac{u^3}{3\cdot 3!} - \frac{u^4}{4\cdot 4!} + \cdots \qquad (9.17)$$

Equation 9.5a gave the value of u as:

$$u = \frac{1.87 r^2 S}{Tt} \qquad\qquad u = \frac{r^2 S}{4\,Tt}$$

where
r = distance, in ft, from the center of a pumped well to a point where the drawdown is measured

where
r = distance, in m, from the center of a pumped well to a point where the drawdown is measured

If the transmissivity and storage coefficients are known, values for these and other terms can be substituted in the equation to obtain an unknown.

For example, suppose the transmissivity of a confined aquifer is 50,000 gpd/ft (620 m³/day) and the storage coefficient is 5×10^{-4}, a typical value for confined conditions. What would be the specific capacity, Q/s, of a 12-in (305-mm) well after 1 day of continuous pumping? In this case, $r = 0.5$ ft (0.15 m) and $t = 1$ day. First, calculate u:

$$u = \frac{1.87 \cdot (0.5)^2 \cdot 5 \times 10^{-4}}{50{,}000 \cdot 1} \qquad\qquad u = \frac{(0.15)^2 \cdot 5 \times 10^{-4}}{4 \cdot 620 \cdot 1}$$

$$= 4.7 \times 10^{-9} \qquad\qquad = 4.5 \times 10^{-9}$$

Next, the value of $W(u)$ corresponding to this value of u is read from Appendix 9.E. $W(u)$ in this case is 18.60 (18.64). Rearranging Equation 9.5 gives:

$$\frac{Q}{s} = \frac{T}{114.6\,W(u)} \qquad\qquad \frac{Q}{s} = \frac{4\pi T}{W(u)}$$

$$= \frac{50{,}000}{114.6 \cdot 18.60} \qquad\qquad = \frac{4 \cdot 3.14 \cdot 620}{18.64}$$

= 23.5 gpm/ft of drawdown $\qquad$ = 418 m³/day/m of drawdown

Having calculated the specific capacity, the drawdown in the pumped well for any pumping rate is easily determined. If the pumping rate is 200 gpm (1,090 m³/day), then:

$$s = \frac{Q}{Q/s} = \frac{200}{23.5} = 8.5 \text{ ft} \qquad\qquad s = \frac{Q}{Q/s} = \frac{1090}{418} = 2.6 \text{ m}$$

APPENDIX 9.E.

Values of $W(u)$ Corresponding to Values of u for Theis Nonequilibrium Equation

u N	$N \times 10^{-15}$	$N \times 10^{-14}$	$N \times 10^{-13}$	$N \times 10^{-12}$	$N \times 10^{-11}$	$N \times 10^{-10}$	$N \times 10^{-9}$	$N - 10^{-8}$	$N \times 10^{-7}$	$N \times 10^{-6}$	$N \times 10^{-5}$	$N \times 10^{-4}$	$N \times 10^{-3}$	$N \times 10^{-2}$	$N \times 10^{-1}$	N
1.0	33.9616	31.6590	29.3564	27.0538	24.7512	22.4486	20.1460	17.8435	15.5409	13.2383	10.9357	8.6332	6.3315	4.0379	1.8229	0.2194
1.1	33.8662	31.5637	29.2611	26.9585	24.6559	22.3533	20.0507	17.7482	15.4456	13.1430	10.8404	8.5379	6.2363	3.9436	1.7371	.1860
1.2	33.7792	31.4767	29.1741	26.8715	24.5689	22.2663	19.9637	17.6611	15.3586	13.0560	10.7534	8.4509	6.1494	3.8576	1.6595	.1584
1.3	33.6992	31.3966	29.0940	26.7914	24.4889	22.1863	19.8837	17.5811	15.2785	12.9759	10.6734	8.3709	6.0695	3.7785	1.5889	.1355
1.4	33.6251	31.3225	29.0199	26.7173	24.4147	22.1122	19.8096	17.5070	15.2044	12.9018	10.5993	8.2968	5.9955	3.7054	1.5241	.1162
1.5	33.5561	31.2535	28.9509	26.6483	24.3458	22.0432	19.7406	17.4380	15.1354	12.8328	10.5303	8.2278	5.9266	3.6374	1.4645	.1000
1.6	33.4916	31.1890	28.8864	26.5838	24.2812	21.9786	19.6760	17.3735	15.0709	12.7683	10.4657	8.1634	5.8621	3.5739	1.4092	.08631
1.7	33.4309	31.1283	28.8258	26.5232	24.2206	21.9180	19.6154	17.3128	15.0103	12.7077	10.4051	8.1027	5.8016	3.5143	1.3578	.07465
1.8	33.3738	31.0712	28.7686	26.4660	24.1634	21.8608	19.5583	17.2557	14.9531	12.6505	10.3479	8.0455	5.7446	3.4581	1.3098	.06471
1.9	33.3197	31.0171	28.7145	26.4119	24.1094	21.8068	19.5042	17.2016	14.8990	12.5964	10.2939	7.9915	5.6906	3.4050	1.2649	.05620
2.0	33.2684	30.9658	28.6632	26.3607	24.0581	21.7555	19.4529	17.1503	14.8477	12.5451	10.2426	7.9402	5.6394	3.3547	1.2227	.04890
2.1	33.2196	30.9170	28.6145	26.3119	24.0093	21.7067	19.4041	17.1015	14.7989	12.4964	10.1938	7.8914	5.5907	3.3069	1.1829	.04261
2.2	33.1731	30.8705	28.5679	26.2653	23.9628	21.6602	19.3576	17.0550	14.7524	12.4498	10.1473	7.8449	5.5443	3.2614	1.1454	.03719
2.3	33.1286	30.8261	28.5235	26.2209	23.9183	21.6157	19.3131	17.0106	14.7080	12.4054	10.1028	7.8004	5.4999	3.2179	1.1099	.03250
2.4	33.0861	30.7835	28.4809	26.1783	23.8758	21.5732	19.2706	16.9680	14.6654	12.3628	10.0603	7.7579	5.4575	3.1763	1.0762	.02844
2.5	33.0453	30.7427	28.4401	26.1375	23.8349	21.5323	19.2298	16.9272	14.6246	12.3220	10.0194	7.7172	5.4167	3.1365	1.0443	.02491
2.6	33.0060	30.7035	28.4009	26.0983	23.7957	21.4931	19.1905	16.8880	14.5854	12.2828	9.9802	7.6779	5.3776	3.0983	1.0139	.02185
2.7	32.9683	30.6657	28.3631	26.0606	23.7580	21.4554	19.1528	16.8502	14.5476	12.2450	9.9425	7.6401	5.3400	3.0615	.9849	.01918
2.8	32.9319	30.6294	28.3268	26.0242	23.7216	21.4190	19.1164	16.8138	14.5113	12.2087	9.9061	7.6038	5.3037	3.0261	.9573	.01686
2.9	32.8968	30.5943	28.2917	25.9891	23.6865	21.3839	19.0813	16.7788	14.4762	12.1736	9.8710	7.5687	5.2687	2.9920	.9309	.01482
3.0	32.8629	30.5604	28.2578	25.9552	23.6526	21.3500	19.0474	16.7449	14.4423	12.1397	9.8371	7.5348	5.2349	2.9591	.9057	.01305
3.1	32.8302	30.5276	28.2250	25.9224	23.6198	21.3172	19.0146	16.7121	14.4095	12.1069	9.8043	7.5020	5.2022	2.9273	.8815	.01149
3.2	32.7984	30.4958	28.1932	25.8907	23.5881	21.2855	18.9829	16.6803	14.3777	12.0751	9.7726	7.4703	5.1706	2.8965	.8583	.01013
3.3	32.7676	30.4651	28.1625	25.8599	23.5573	21.2547	18.9521	16.6495	14.3470	12.0444	9.7418	7.4395	5.1399	2.8668	.8361	.008939
3.4	32.7378	30.4352	28.1326	25.8300	23.5274	21.2249	18.9223	16.6197	14.3171	12.0145	9.7120	7.4097	5.1102	2.8379	.8147	.007891
3.5	32.7088	30.4062	28.1036	25.8010	23.4985	21.1959	18.8933	16.5907	14.2881	11.9855	9.6830	7.3807	5.0813	2.8099	.7942	.006970
3.6	32.6806	30.3780	28.0755	25.7729	23.4703	21.1677	18.8651	16.5625	14.2599	11.9574	9.6548	7.3526	5.0532	2.7827	.7745	.006160
3.7	32.6532	30.3506	28.0481	25.7455	23.4429	21.1403	18.8377	16.5351	14.2325	11.9300	9.6274	7.3252	5.0259	2.7563	.7554	.005448
3.8	32.6266	30.3240	28.0214	25.7188	23.4162	21.1136	18.8110	16.5085	14.2059	11.9033	9.6007	7.2985	4.9993	2.7306	.7371	.004820
3.9	32.6006	30.2980	27.9954	25.6928	23.3902	21.0877	18.7851	16.4825	14.1799	11.8773	9.5748	7.2725	4.9735	2.7056	.7194	.004267
4.0	32.5753	30.2727	27.9701	25.6675	23.3649	21.0623	18.7598	16.4572	14.1546	11.8520	9.5495	7.2472	4.9482	2.6813	.7024	.003779
4.1	32.5506	30.2480	27.9454	25.6428	23.3402	21.0376	18.7351	16.4325	14.1299	11.8273	9.5248	7.2225	4.9236	2.6576	.6859	.003349
4.2	32.5265	30.2239	27.9213	25.6187	23.3161	21.0136	18.7110	16.4084	14.1058	11.8032	9.5007	7.1985	4.8997	2.6344	.6700	.002969
4.3	32.5029	30.2004	27.8978	25.5952	23.2926	20.9900	18.6874	16.3848	14.0823	11.7797	9.4771	7.1749	4.8762	2.6119	.6546	.002633
4.4	32.4800	30.1774	27.8748	25.5722	23.2696	20.9670	18.6644	16.3619	14.0593	11.7567	9.4541	7.1520	4.8533	2.5899	.6397	.002336
4.5	32.4575	30.1549	27.8523	25.5497	23.2471	20.9446	18.6420	16.3394	14.0368	11.7342	9.4317	7.1295	4.8310	2.5684	.6253	.002073
4.6	32.4355	30.1329	27.8303	25.5277	23.2252	20.9226	18.6200	16.3174	14.0148	11.7122	9.4097	7.1075	4.8091	2.5474	.6114	.001841
4.7	32.4140	30.1114	27.8088	25.5062	23.2037	20.9011	18.5985	16.2959	13.9933	11.6907	9.3882	7.0860	4.7877	2.5268	.5979	.001635
4.8	32.3929	30.0904	27.7878	25.4852	23.1826	20.8800	18.5774	16.2748	13.9723	11.6697	9.3671	7.0650	4.7667	2.5068	.5848	.001453
4.9	32.3723	30.0697	27.7672	25.4646	23.1620	20.8594	18.5568	16.2542	13.9516	11.6491	9.3465	7.0444	4.7462	2.4871	.5721	.001291
5.0	32.3521	30.0495	27.7470	25.4444	23.1418	20.8392	18.5366	16.2340	13.9314	11.6289	9.3263	7.0242	4.7261	2.4679	.5598	.001148
5.1	32.3323	30.0297	27.7271	25.4246	23.1220	20.8194	18.5168	16.2142	13.9116	11.6091	9.3065	7.0044	4.7064	2.4491	.5478	.001021

28/29

	$\times 10^{-15}$	$N \times 10^{-14}$	$N \times 10^{-13}$	$N \times 10^{-12}$	$N \times 10^{-11}$	$N \times 10^{-10}$	$N \times 10^{-9}$	$N \times 10^{-8}$	$N \times 10^{-7}$	$N \times 10^{-6}$	$N \times 10^{-5}$	$N \times 10^{-4}$	$N \times 10^{-3}$	$N \times 10^{-2}$	$N \times 10^{-1}$	N
5.2	32.3129	30.0103	27.7077	25.4051	23.1026	20.8000	18.4974	16.1948	13.8922	11.5896	9.2871	6.9850	4.6871	2.4306	.5362	.0009086
5.3	32.2939	29.9913	27.6887	25.3861	23.0835	20.7809	18.4783	16.1758	13.8732	11.5706	9.2681	6.9659	4.6681	2.4126	.5250	.0008086
5.4	32.2752	29.9726	27.6700	25.3674	23.0648	20.7622	18.4596	16.1571	13.8545	11.5519	9.2494	6.9473	4.6495	2.3948	.5140	.0007198
5.5	32.2568	29.9542	27.6516	25.3491	23.0465	20.7439	18.4413	16.1387	13.8361	11.5336	9.2310	6.9289	4.6313	2.3775	.5034	.0006409
5.6	32.2388	29.9362	27.6336	25.3310	23.0285	20.7259	18.4233	16.1207	13.8181	11.5155	9.2130	6.9109	4.6134	2.3604	.4930	.0005708
5.7	32.2211	29.9185	27.6159	25.3133	23.0108	20.7082	18.4056	16.1030	13.8004	11.4978	9.1953	6.8932	4.5958	2.3437	.4830	.0005085
5.8	32.2037	29.9011	27.5985	25.2959	22.9934	20.6908	18.3882	16.0856	13.7830	11.4804	9.1779	6.8758	4.5785	2.3273	.4732	.0004532
5.9	32.1866	29.8840	27.5814	25.2789	22.9763	20.6737	18.3711	16.0685	13.7659	11.4633	9.1608	6.8588	4.5615	2.3111	.4637	.0004039
6.0	32.1698	29.8672	27.5646	25.2620	22.9595	20.6569	18.3543	16.0517	13.7491	11.4465	9.1440	6.8420	4.5448	2.2953	.4544	.0003601
6.1	32.1533	29.8507	27.5481	25.2455	22.9429	20.6403	18.3378	16.0352	13.7326	11.4300	9.1275	6.8254	4.5283	2.2797	.4454	.0003211
6.2	32.1370	29.8344	27.5318	25.2293	22.9267	20.6241	18.3215	16.0189	13.7163	11.4138	9.1112	6.8092	4.5122	2.2645	.4366	.0002864
6.3	32.1210	29.8184	27.5158	25.2133	22.9107	20.6081	18.3055	16.0029	13.7003	11.3978	9.0952	6.7932	4.4963	2.2494	.4280	.0002555
6.4	32.1053	29.8027	27.5001	25.1975	22.8949	20.5923	18.2898	15.9872	13.6846	11.3820	9.0795	6.7775	4.4806	2.2346	.4197	.0002279
6.5	32.0898	29.7872	27.4846	25.1820	22.8794	20.5768	18.2742	15.9717	13.6691	11.3665	9.0640	6.7620	4.4652	2.2201	.4115	.0002034
6.6	32.0745	29.7719	27.4693	25.1667	22.8641	20.5616	18.2590	15.9564	13.6538	11.3512	9.0487	6.7467	4.4501	2.2058	.4036	.0001816
6.7	32.0595	29.7569	27.4543	25.1517	22.8491	20.5465	18.2439	15.9414	13.6388	11.3362	9.0337	6.7317	4.4351	2.1917	.3959	.0001621
6.8	32.0446	29.7421	27.4395	25.1369	22.8343	20.5317	18.2291	15.9265	13.6240	11.3214	9.0189	6.7169	4.4204	2.1779	.3883	.0001448
6.9	32.0300	29.7275	27.4249	25.1223	22.8197	20.5171	18.2145	15.9119	13.6094	11.3068	9.0043	6.7023	4.4059	2.1643	.3810	.0001293
7.0	32.0156	29.7131	27.4105	25.1079	22.8053	20.5027	18.2001	15.8976	13.5950	11.2924	8.9899	6.6879	4.3916	2.1508	.3738	.0001155
7.1	32.0015	29.6989	27.3963	25.0937	22.7911	20.4885	18.1860	15.8834	13.5808	11.2782	8.9757	6.6737	4.3775	2.1376	.3668	.0001032
7.2	31.9875	29.6849	27.3823	25.0797	22.7771	20.4746	18.1720	15.8694	13.5668	11.2642	8.9617	6.6598	4.3636	2.1246	.3599	.00009219
7.3	31.9737	29.6711	27.3685	25.0659	22.7633	20.4608	18.1582	15.8556	13.5530	11.2504	8.9479	6.6460	4.3500	2.1118	.3532	.00008239
7.4	31.9601	29.6575	27.3549	25.0523	22.7497	20.4472	18.1446	15.8420	13.5394	11.2368	8.9343	6.6324	4.3364	2.0991	.3467	.00007364
7.5	31.9467	29.6441	27.3415	25.0389	22.7363	20.4337	18.1311	15.8286	13.5260	11.2234	8.9209	6.6190	4.3231	2.0867	.3403	.00006583
7.6	31.9334	29.6308	27.3282	25.0257	22.7231	20.4205	18.1179	15.8153	13.5127	11.2102	8.9076	6.6057	4.3100	2.0744	.3341	.00005886
7.7	31.9203	29.6178	27.3152	25.0126	22.7100	20.4074	18.1048	15.8022	13.4997	11.1971	8.8946	6.5927	4.2970	2.0623	.3280	.00005263
7.8	31.9074	29.6048	27.3023	24.9997	22.6971	20.3945	18.0919	15.7893	13.4868	11.1842	8.8817	6.5798	4.2842	2.0503	.3221	.00004707
7.9	31.8947	29.5921	27.2895	24.9869	22.6844	20.3818	18.0792	15.7766	13.4740	11.1714	8.8689	6.5671	4.2716	2.0386	.3163	.00004210
8.0	31.8821	29.5795	27.2769	24.9744	22.6718	20.3692	18.0666	15.7640	13.4614	11.1589	8.8563	6.5545	4.2591	2.0269	.3106	.00003767
8.1	31.8697	29.5671	27.2645	24.9619	22.6594	20.3568	18.0542	15.7516	13.4490	11.1464	8.8439	6.5421	4.2468	2.0155	.3050	.00003370
8.2	31.8574	29.5548	27.2523	24.9497	22.6471	20.3445	18.0419	15.7393	13.4367	11.1342	8.8317	6.5298	4.2346	2.0042	.2996	.00003015
8.3	31.8453	29.5427	27.2401	24.9375	22.6350	20.3324	18.0298	15.7272	13.4246	11.1220	8.8195	6.5177	4.2226	1.9930	.2943	.00002699
8.4	31.8333	29.5307	27.2282	24.9256	22.6230	20.3204	18.0178	15.7152	13.4126	11.1101	8.8076	6.5057	4.2107	1.9820	.2891	.00002415
8.5	31.8215	29.5189	27.2163	24.9137	22.6112	20.3086	18.0060	15.7034	13.4008	11.0982	8.7957	6.4939	4.1990	1.9711	.2840	.00002162
8.6	31.8098	29.5072	27.2046	24.9020	22.5995	20.2969	17.9943	15.6917	13.3891	11.0865	8.7840	6.4822	4.1874	1.9604	.2790	.00001936
8.7	31.7982	29.4957	27.1931	24.8905	22.5879	20.2853	17.9827	15.6801	13.3776	11.0750	8.7725	6.4707	4.1759	1.9498	.2742	.00001733
8.8	31.7868	29.4842	27.1816	24.8790	22.5765	20.2739	17.9713	15.6687	13.3661	11.0635	8.7610	6.4592	4.1646	1.9393	.2694	.00001552
8.9	31.7755	29.4729	27.1703	24.8678	22.5652	20.2626	17.9600	15.6574	13.3548	11.0523	8.7497	6.4480	4.1534	1.9290	.2647	.00001390
9.0	31.7643	29.4618	27.1592	24.8566	22.5540	20.2514	17.9488	15.6462	13.3437	11.0411	8.7386	6.4368	4.1423	1.9187	.2602	.00001245
9.1	31.7533	29.4507	27.1481	24.8455	22.5429	20.2404	17.9378	15.6352	13.3326	11.0300	8.7275	6.4258	4.1313	1.9087	.2557	.00001115
9.2	31.7424	29.4398	27.1372	24.8346	22.5320	20.2294	17.9268	15.6243	13.3217	11.0191	8.7166	6.4148	4.1205	1.8987	.2513	.000009988
9.3	31.7315	29.4290	27.1264	24.8238	22.5212	20.2186	17.9160	15.6135	13.3109	11.0083	8.7058	6.4040	4.1098	1.8888	.2470	.000008948
9.4	31.7208	29.4183	27.1157	24.8131	22.5105	20.2079	17.9053	15.6028	13.3002	10.9976	8.6951	6.3934	4.0992	1.8791	.2429	.000008018
9.5	31.7103	29.4077	27.1051	24.8025	22.4999	20.1973	17.8948	15.5922	13.2896	10.9870	8.6845	6.3828	4.0887	1.8695	.2387	.000007185
9.6	31.6998	29.3972	27.0946	24.7920	22.4895	20.1869	17.8843	15.5817	13.2791	10.9765	8.6740	6.3723	4.0784	1.8599	.2347	.000006439

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water well drilling.

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Appendix 9.E. Continued

u / N	$N \times 10^{-15}$	$N \times 10^{-14}$	$N \times 10^{-13}$	$N \times 10^{-12}$	$N \times 10^{-11}$	$N \times 10^{-10}$	$N \times 10^{-9}$	$N \times 10^{-8}$	$N \times 10^{-7}$	$N \times 10^{-6}$	$N \times 10^{-5}$	$N \times 10^{-4}$	$N \times 10^{-3}$	$N \times 10^{-2}$	$N \times 10^{-1}$	N
9.7	31.6894	29.3868	27.0843	24.7817	22.4791	20.1765	17.8739	15.5713	13.2688	10.9662	8.6637	6.3620	4.0681	1.8505	.2308	.000005771
9.8	31.6792	29.3766	27.0740	24.7714	22.4688	20.1663	17.8637	15.5611	13.2585	10.9559	8.6534	6.3517	4.0579	1.8412	.2269	.000005173
9.9	31.6690	29.3664	27.0639	24.7613	22.4587	20.1561	17.8535	15.5509	13.2483	10.9458	8.6433	6.3416	4.0479	1.8320	.2231	.000004637

NOTE: See page 218 for Theis equation and definitions of terms.

Values of $W(u)$ for u between 1×10^{-15} and 1×10^{-1} computed by R.G. Kazmann assisted by M.M. Evans, U.S. Geological Survey; values for u between 1×10^{-1} and 9.9 adapted from Tables of Exponential and Trigonometric Integrals.

From Water Supply Paper 887, U.S. Geological Survey, 1942.

REVIEW COMMENTS

PROJECT: Ruff Road and Roosevelt Road, Treatment System Demonstrations and Design Verification Study

DOCUMENT: Draft Work Plan **LOCATION:** Fort Richardson, Alaska

U.S. ARMY CORPS OF ENGINEERS CENPA-EN-EE-TE	**DATE:** 02/12/98 **REVIEWER:** Ginter **PHONE:** 753-2805	**Action taken on comment by:** SCHWICHT

Item No.	Drawing Sht. No., Spec. Para.	COMMENTS	REVIEW CONFERENCE A - comment accepted W - comment withdrawn (if neither, explain)	DESIGN OFFICE C - correction made (If not, explain)	Back check by: (Initials)
1	Introduction General	Please separate the discussion of the Ruff Rd Site from the Roosevelt Rd site by using headers between the discussion of the two.	A	C	
2	Page 3-1, Last paragraph	The paragraph says that the trenches will be backfilled with either native soil or gravel with sand. Clarify when each will be used for backfill e.g. The native soil will be used to the maximum extend possible and any additional backfill will be gravel with sand	W		
3	Page 3-4, 2nd paragraph	Note that the pipes will be pressure grouted rather than just grouted	A	C	
4	Page 3-4, 4th paragraph	Clarify what is meant by a qualified DOWL/Ogden JV field representative. What does it take to be qualified?	W		
5	Page 4-1, Section 4.2	Define the acronym ADSCPT	A	C	
6	Page 4-1, Section 4.2	Last sentence. Detail when and if the contaminated soils will be spread beneath the liner versus returned to the trench as backfill.	W		
7	Page 4-2, 2nd paragraph	The operations manual (including emergency procedures) should be on site at all times, not just during start up.	A	C	
8	Biovent System – General	Please include a narrative on the initial system start up and optimization. Is there going to be any testing done initially to determine the area of influence to make sure that the area is receiving an adequate amount of air with out dessicating the soil? Is a respirometry test going to be performed? Is there a target pore volume exchange that you are trying to achieve? If there is a target pore volume removal for the system, that should help determine the air flow rates needed. Is there going to be any background O2 sampling?	A [illegible] MORE [illegible] [illegible]	C	

REVIEW COMMENTS

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9	Biovent System – General	Please provide a table that list the optimum operating conditions for the system, i.e. air flow, soil moisture content, O2 content, etc.	W		
10	Biovent System – General	Provide more details on how the O2 and CO2 samples will be collected. Will the system be shut off and the O2 and CO2 measurements made initially and then after a period of time to determine is respiration is occurring?	A #5	C SEE # 8	
11	Biovent System – General	If we are only concerned about delivering O2 to the microbe population, why are we pulsing the system? The goal is not to remove the diffusion limited contaminants, but enhance biodegradation of the contamination.	W		
12	Page 5-10, 3rd paragraph	It is stated "If significant concentrations of hydrocarbons exist in the exhaust gas, the flow rates will be decreased to only that level required to provide O2 to the microbes". If we are truly doing bioventing at the site, that should be the flow rate that we are aiming for anyway. Any higher flow rate will be unnecessary.	W		
13	Page 5-11, 1st paragraph	If you have a decrease in O2, how do you plan to account for diffusion as part of the O2 reduction.	NOTED	SEE # 8	
14	Page 5-13	I do not see the need for performing a TO-14 test at each sampling event. Since bioremediation is a slower process, and we are only running the system during the summer, you might want to consider one start up and one shut down sample for each season.	NOTED W		
15	Page 5-20, Section 5.2.3.2	The SOW requires the resume of the team members to be submitted, and that the members remain actively involved in the project. Please submit the resumes of the proposed team members.	A	PROVIDED WITH ORIGINAL PROPOSAL	
16	Page 5-25, Case I	We do not want to get involved in inoculating the soil with petroleum degrading microorganisms. We want to encourage the growth of any	A	C	

REVIEW COMMENTS

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		degraders that are presents and add nutrients if necessary.			
17	Drawing C-4	Expand the information contained in the legend. What are the S lines? What is the hatched area?	ADD TO LEGEND A	C	
18	Standard Operating Procedures	In the SOPs it gives the procedures for running an In situ respiration test, but the Work Plan makes no mention of running this test. Clarify if and when this test will be run and include it in the narrative of the Work Plan.	A PART OF #8	C SEE #8	
19	Standard Operating Procedures, Page 32	The Standard Sampling Procedure appears to be for UST removals and there does not appear to be mention of air samples. Please tailor the sampling procedures to the work to be performed at the site.	A	C	
20					

REVIEW COMMENTS

PROJECT: DRAFT WORK PLAN DVS RUFF RD
LOCATION: FT RICH

☐ NP
☐ Air Force
☐ Army
☐

Date:
Reviewer: WEST
Phone: 753 5613

Design Document
☐ D.Memo ☐ Concept
☐ P&S ☐ Prelim.
☐ ☐ Final

☐ Arch./LA
☐ Civ./San.
☐ Mech./Elec.
☐ Struct.

Action taken on comment by: SCHWICHT

Item No.	Drawing Sht. Spec. Para.	COMMENTS	REVIEW CONFERENCE A - comment accepted W - comment withdrawn (If neither, explain)	DESIGN OFFICE C - correction made (If not, explain)	Back check by: (Initials)
1	GEN	THE PLURAL OF SOIL IS SOIL NOT SOILS - CHANGE	A	C	
2	PG 2-1	4th/ PARA - CHANGE "PHTYALATE" TO "PHTHALATE"	A	C	
3	SECT 2	SEPARATE RUFF RD FROM ROOSEVELT RD WITH HEADERS	DUPLICATE	C	
4	PG 2-2	2nd/ PARA - LAST 3 SENT. NEED CLARIFICATION & EXPLAINATION - I.E. LEACHFIELD AT A DEPTH OF — AND PCB REMOVAL ACTIVITY & PCB SAMPLED FOR IN LEACHFIELD AND NOT FOUND - THIS IS NEEDED TO SUPPORT LAST SENTENCE	A	C	
5	GEN	PG 2-3 & OTHERS - REMOVE REFERENCES TO THE SOW.	A	C	
6	PG 2-4	REMOVE LAST SENTENCE	A	C	
7	PG 3-1	LAST PARA - WHAT IS MAGIC ABOUT 3% FINES? GW BY DEFINITION HAS LESS THAN 5% FINES. ALSO THE WAY THE SENTENCE IS WRITTEN IT IS IMPLIED THAT THE NATIVE SOIL MEETS THE GW CLASSIFICATION, IS THIS TRUE.	W		
8	PG 4-2	SEC 4.3.1 PARA 1 - SUGGEST YOU USE "RITE-IN-THE-RAIN" FIELD BOOK	A	C	

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SHT. OF

AC-FFP 3057-84

REVIEW COMMENTS

PROJECT: DRAFT WORK PLAN DVS RUFF RD LOCATION: FT RICH

☐ NP
☐ Air Force
☐ Army
☐

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Action taken on comment by: SCHWICHT

Item No.	Drawing Sht. Spec. Para.	COMMENTS	REVIEW CONFERENCE A - comment accepted W - comment withdrawn (If neither, explain)	DESIGN OFFICE C - correction made (If not, explain)	Back check by: (initials)
9	PG 5-9	SEC 5.1.2 - REMOVE 2nd PARA	A	C	
10	SHT C3	DETAIL 1 & 2 TEXT STATES 10" OF GRAVEL UNDER AND ABOVE PIPE DETAIL SHOWS 6" BELOW 8" ABOVE COORDINATE.	A	C	
11	SHT C3 & C4	USE 95% COMPACTION.	W		
12	SHT C3	DETAIL 7 - TWO NOTES FOR BACKFILL CONTRADICT EACH OTHER, DELETE CONCRETE.	A	C.	
13	SHT C3	DETAIL 8 NOTE ADDRESSING AUGERED HOLE - I DO NOT KNOW OF AN AUGER SIZE SMALL ENOUGH TO ALLOW THIS.	A	C	
14	SHT C4	CONCRETE SLAB - WHAT IS TO BE USED FOR REINFORCMENT #4 BAR 8" SP EW?, WIRE MESH WHAT?	A	C	
15	SHT C4	LUMP NOTES FOR CESS POOL TOGETHER & USE ONE ARROW - WILL BE LESS CONFUSING.	A	C	
16	SHT C4	WHAT IS DEPTH OF EXCAVATION?	A	C	
17	SHT C4	WHAT IS TO BE USED FOR GROUT MIXTURE.	A	C	
18	SHT C4	WHAT WILL SUFFICE AS IMPORT BACKFILL	W		

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SHT. OF

REVIEW COMMENTS

PROJECT: DRAFT WORK PLAN DVS RUFF RD LOCATION: FT RICH

☐ NP	Date:	**Design Document**	☐ Arch./LA
☐ Air Force	Reviewer: WEST	☐ D.Memo ☐ Concept	☐ Civ./San.
☐ Army	Phone: 753 5613	☐ P&S ☐ Prelim.	☐ Mech./Elec
☐		☐ ☐ Final	☐ Struct.

Action taken on comment by:

Item No.	Drawing Sht. Spec. Para.	COMMENTS	REVIEW CONFERENCE A - comment accepted W - comment withdrawn (If neither, explain)	DESIGN OFFICE C - correction made (If not, explain)	Back check by: (Initials)
19	SHT C4	IS SLUDGE REMOVED FROM CESS POOL TO BE ~~[illegible]~~ MIXED WITH CEMENT & ADDED BACK TO CESS POOL? IF NOT, WHAT IS GOING TO BE DONE WITH IT?	A	C	
20	SHT C5	THE NOTE PERTAINING TO SCALE IS MORE APPROPRIATE TO SHTS 2-4	A	C	
21	SHT M1	MOTOR STARTERS FOR MOV'S ARE IN CONTROL PANAL OUTSIDE - WHY DO THEY NEED TO BE EXPLOSION PROOF?	A	MOTOR STARTERS ARE IN CONTROL PANEL & ARE NOT EXPLOSION-PROOF	
~~22~~	~~SHT [illegible]~~	~~DETAIL ?~~			
22	E3	1 A FUSE ON + SIDE OF BLOWER - IS THIS CORRECT?	W		

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APPENDIX C

SITE DRAWINGS FOR RUFF AND ROOSEVELT ROAD
FORT RICHARDSON, ALASKA