Case Study Abstract

Refueling Loop E-7, Source Area ST20 Bioventing Treatment at Eielson Air Force Base, Alaska

Site Name: Eielson Air Force Base Source Area ST20	**Contaminants:** Total Petroleum Hydrocarbons (TPH) and Benzene, Toluene, Ethylbenzene, Xylenes (BTEX) - Soil TPH levels averaged 1,500 mg/kg - Contamination is concentrated in areas greater than 5.25 feet below ground surface	**Period of Operation:** Status - Ongoing Report covers - 7/91 to 7/94
Location: Fairbanks, Alaska		**Cleanup Type:** Field Demonstration
Vendor: Ronald M. Smith Battelle-Pacific Northwest Labs Richland, WA	**Technology:** Bioventing - Bioventing conducted in conjunction with several soil warming techniques - Four experimental plots tested: passive warming, active warming, surface warming, and control	**Cleanup Authority:** CERCLA and State: Alaska - Federal Facilities Agreement - ROD Date: 9/92
SIC Code: 9711 (National Security)		**Point of Contact:** Capt. Timothy Merrymon 354 CES/CEVR 2258 Central Ave., Suite 1 Eielson AFB, Alaska 99702
Waste Source: Spills and Leaks of JP-4 Jet Fuel	**Type/Quantity of Media Treated:** Soil - Thickness of contamination in saturated zone - 6.1 meters - Soil consists of interbedded layers of loose to medium dense gravel and sands with varying amounts of silt to 6-9 feet - Underlain by 600 feet of medium dense to dense sandy gravel - No permafrost encountered at site	
Purpose/Significance of Application: Bioventing with various soil warming techniques to demonstrate technology effectiveness in a subarctic environment.		

Regulatory Requirements/Cleanup Goals:
- TPH - 200 mg/kg in soil
- Benzene - 2 lbs/day in extracted soil gas
- Remedial activities to be conducted in accordance with a Federal Facilities Agreement between U.S. Air Force, U.S. EPA, and the Alaska Department of Environmental Conservation

Results:
- Bioventing project not complete at time of this report
- Preliminary results indicate that bioventing with soil warming stimulates in situ biodegradation year round in a subarctic environment
- Active warming achieved higher biodegradation rates than passive or surface warming
- Ambient air samples showed no detectable concentrations of benzene 4 feet and 6 feet above ground level

Cost Factors:
- Estimated Capital Costs - $758,077 (including floating fuel collection devices, soil bioventing equipment, composting site development, mobilization, groundwater remediation and engineering design)
- Estimated Annual Operations and Maintenance (O&M) Costs - $177,160 (O&M of three components - floating fuel (5 year duration), soil bioventing (10 year duration), groundwater monitoring (30 year duration), including sample analysis and monitoring of each component)

Refueling Loop E-7, Source Area ST20 Bioventing Treatment at Eielson Air Force Base, Alaska (Continued)

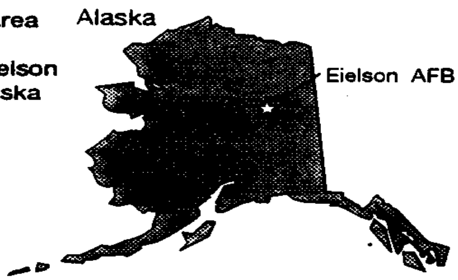
Description:
As a result of spills and leaks of JP-4 jet fuel at a refueling complex at Eielson Air Force Base (AFB) in Fairbanks, Alaska, soil was contaminated with total petroleum hydrocarbons (TPH) and benzene, toluene, ethylbenzene, and xylenes (BTEX). In November 1989, Eielson AFB was added to the National Priorities List (NPL) with the fuel-saturated area within the Refueling Loop E-7, Source Area ST20 designated as CERCLA Operable Unit 1. A field demonstration of bioventing and three soil warming techniques began in July 1991 including active warming, passive warming, and surface warming. Specific cleanup goals include TPH (200 mg/kg in soil), and benzene (2 lbs/day in extracted soil gas).

The field demonstration of the bioventing system was on-going as of July 1994. Available respiration test data for oxygen consumption rates confirmed the occurrence of biological degradation processes. Preliminary results indicate that bioventing with soil warming achieves biodegradation year round in a subarctic environment. ~~Active warming was found to achieve a higher biodegradation rate than passive or surface warming.~~ It was noted that biodegradation is enhanced by adequate soil oxygen, moisture, and nutrient levels; that injection wells are impractical at source areas with a naturally high concentration of iron in the groundwater; and that high soil moisture content interferes with soil gas monitoring and reduces the number of soil gas monitoring points that can be sampled.

The estimated capital cost of this application was approximately $758,000 and the estimated annual operations and maintenance costs are $177,160. Full-scale remedial activities at the site will be conducted in accordance with a Federal Facilities Agreement between the U.S. Air Force, U.S. EPA, and the Alaska Department of Environmental Conservation.

SITE

Refueling Loop E-7 Complex, Source Area ST20, CERCLA Operable Unit 1, Eielson Air Force Base, Alaska



TECHNOLOGY APPLICATION

In situ bioremediation (bioventing) of a JP-4 fuel spill in a subarctic environment.

SITE CHARACTERISTICS

Site History/Release Characteristics

- Eielson AFB is located 26 miles southeast of Fairbanks, Alaska and approximately 100 miles south of the Arctic Circle.
- Eielson AFB was constructed in 1944 and encompasses approximately 19,790 acres; 3,651 acres improved or partially improved; 16,139 acres undeveloped land encompassing forests, wetlands, lakes, and ponds.
- Eielson's primary mission since the early 1960s has been to provide tactical air support in direct support of Army ground elements assigned to Alaska.
- Past practices have caused groundwater and soil contamination.
- Floating petroleum products were encountered in 1972 in a 6-m test hole at the ST20 E-7 aircraft refueling pump house.
- Field investigations conducted in 1989 around the pump house identified an area of petroleum, oils, and lubricants (POL) contamination with floating product.
- The source area was determined to be the ST20 E-7 Complex, one of three active refueling complexes located at the south end of the runway.
- The complex consists of the asphalt pad centered along the taxiway with adjacent areas of gravel and grass, served by a fuel pump house (Building 1315), three 190,000-L defueling USTs, and several fueling and defueling transfer pipes.
- The initial date of operation is unknown.
- The actual source of contaminants is JP-4 fuel spills in the refueling area and leaks of JP-4 fuel from delivery lines for buried storage tanks. Fueling operations remain vital to the ongoing missions of the Base and will continue to serve as a part of future Base operations.
- Eielson AFB was added on the National Priorities List (NPL) in November 1989.
- The fuel-saturated area was assigned to CERCLA Operable Unit 1.

Contaminants of Concern

Total Petroleum Hydrocarbons (TPH)
Benzene
Toluene
Ethylbenzene
Xylene

Contaminant Properties

Properties of contaminants focused upon during remediation are provided below.

Property	Units	Benzene	Ethylbenzene	Toluene	Xylenes*
Empirical Formula		C_6H_6	C_8H_{10}	C_7H_8	C_8H_{10}
Density @ 20°C	g/cm³	0.88	0.87	0.87	0.87 (avg)
Melting Point	°C	5.5	-95	-95	-47.9 to 13.3
Vapor Pressure (20°C)	mm Hg	50	8.5	26	7.7
Henry's Law Constant (atm)(m³)/mol		5.59 x 10-3	6.43 x 10-3	6.37 x 10-3	7.04 x 10-3
Water Solubility	mg/l	1,750	152	535	198
Octanol-Water Partition Coefficient	Kow	132	1410	537	1830
Organic Carbon Partition	ml/g	83	1,100	300	240
Ionization Potential	ev	9.24	8.76	8.5	8.56
Molecular Weight		78.12	106.18	92.15	106.18

*All 3 isomers (M,O,&P)

Nature & Extent of Contamination

- Three static recovery wells were installed in the ST20 E-7 pump house test hole area and operated until February 1988, recovering 3,350 L of JP-4 fuel.
- Ten monitoring wells and numerous product probes were installed as part of the 1989 field investigation.
- Product measurements in 1993 indicated that the area extent of the measurable product has decreased, but product thickness has increased slightly from 1989 at well 20M04.
- Smearing of the floating product caused by seasonal changes in the water table is expected to have occurred.
- The downgradient extent of benzene concentrations in groundwater appears to be naturally degrading.
- The average contamination level is 1,500 mg total hydrocarbon per kg soil.
- The majority of the jet fuel is concentrated in areas below 5.25 feet.
- Figure 1 shows the approximate area of contamination.

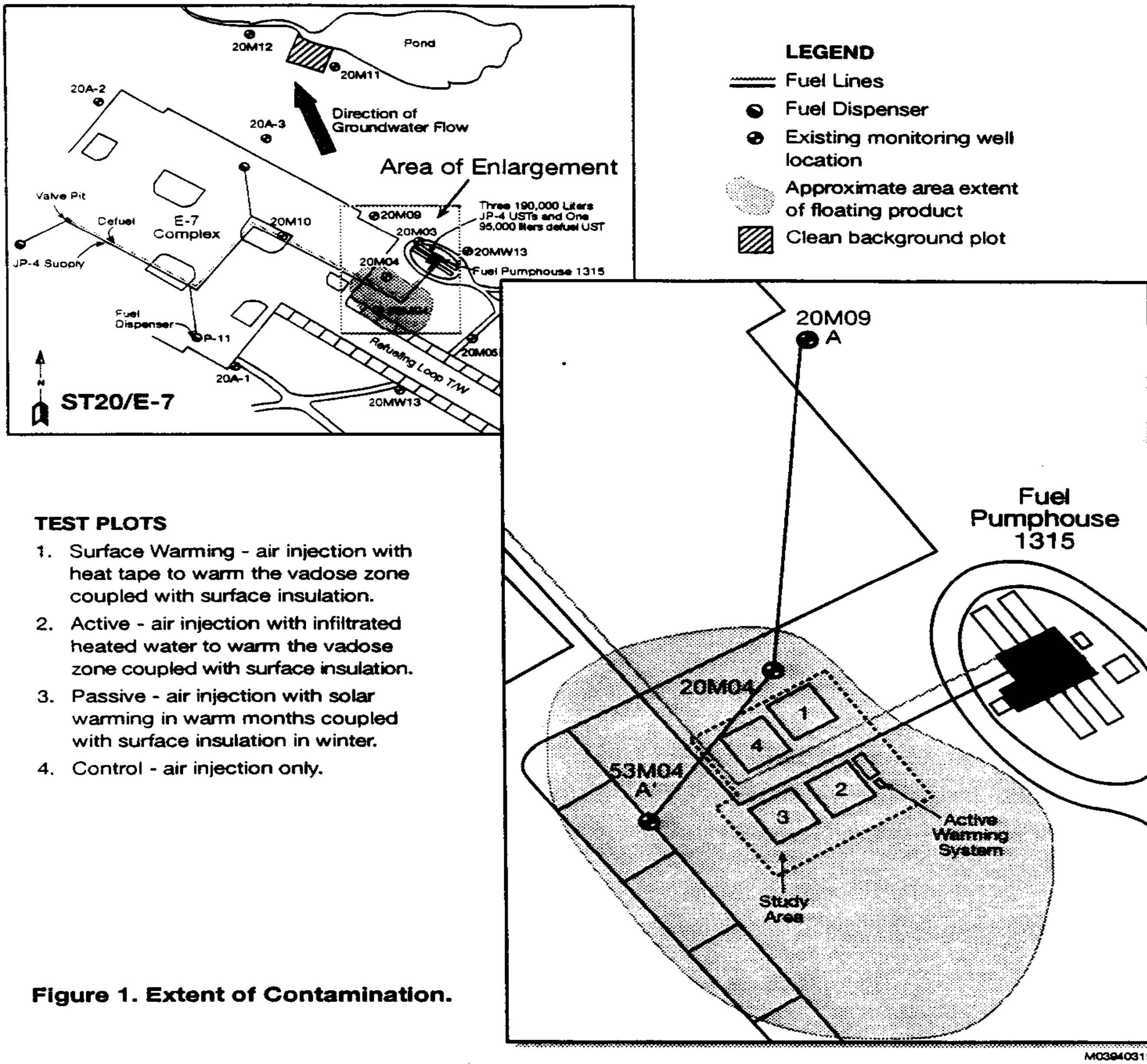


Figure 1. Extent of Contamination.

Contaminant Locations and Geologic Profiles

Topography is generally flat and somewhat featureless with elevations ranging from 550 to 525 feet above mean sea level, sloping downward to the north-northwest.

Soil conditions at E-7 generally consist of interbedded layers of loose to medium dense gravel and sands with varying amounts of silt to approximately 2 meters below ground surface (bgs).

Sandy gravel is generally encountered at a depth of between 2.5 and 3 m. The upper 2.5 and 3 m consists of a variety of lithologies including silty gravel, sandy gravel, gravelly sand, sand, and silty sand. These units generally average 1-m thick. Silty sands and gravels are underlain by medium dense to dense sandy gravel more than 200 meters deep. Permafrost was not encountered during subsurface investigations.

The water table elevation at the site can fluctuate seasonably as much as 0.5 meters. Groundwater was encountered at depths between 1.7 and 2.6 meters bgs. Groundwater flow is generally to the north northwest. There is potential for interaction with surface water in the downgradient Refueling Loop ponds.

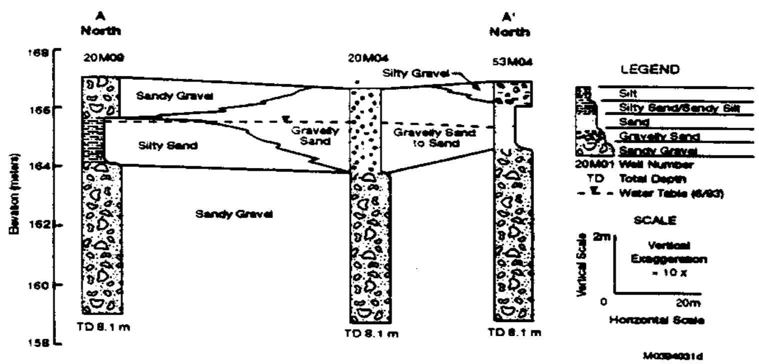


Figure 2. Cross Section A-A' for ST20 E-7 Complex

Nearby surface water bodies are used for local fishing and as possible sources of drinking water for moose. Three main base water supply wells are also located directly down gradient from ST20-E7. Residences start at approximately 1 to 1.2 miles from the ST20. The taxiway loop within ST20 is an airstrip which is in constant use. Hangars and alert hangars surround the site.

Site Conditions

The climate in the Eielson area is characterized as subarctic. Summer high temperatures are typically in the low to mid-eighties. Winter low temperatures are typically well below zero with moderate snowfall. Annual precipitation is 14 inches, annual lake evaporation is 10 inches, and net precipitation is 4 inches. The annual average wind speed is 5 mi/hr.

Key Soil or Key Aquifer Characteristics

Saturated Zone Data	Value
Thickness of Contamination	6.1 m
Aquifer Thickness	91.4 m
Pore-Water Velocity	10.0 cm/d
Hydraulic Conductivity	4 ft/d to 1000 ft/d
Effective Porosity	30.0%
Total Porosity	43.7%
Bulk Density	1.60 g/cm3

Aquifer Test Data at well 54M01 (ST20)	Value
Hydraulic Conductivity	1,480 ft/day
Horizontal Gradient	0.001
Storage Coefficient	0.07
Aquifer Thickness	20 ft
Effective Porosity	0.30

The average soil temperature during summer months is 40 °F. The silt content of the soil is 10%.

TREATMENT SYSTEM

A bioventing system has been operating at ST20 E-7 since July 1991 to investigate the feasibility of executing enhanced *in situ* bioremediation (bioventing) of soil contaminated with JP-4 fuel in a subarctic environment. Bioventing involves the aerating of subsurface soils to maximize biodegradation of biodegradable compounds while minimizing volatilization. Forced air *in situ* is used as a source of oxygen to promote microbial growth and the degradation process. Bioventing in conjunction with methods of soil warming at the source area have enhanced the biodegradation rate of JP-4 jet fuel in the soil.

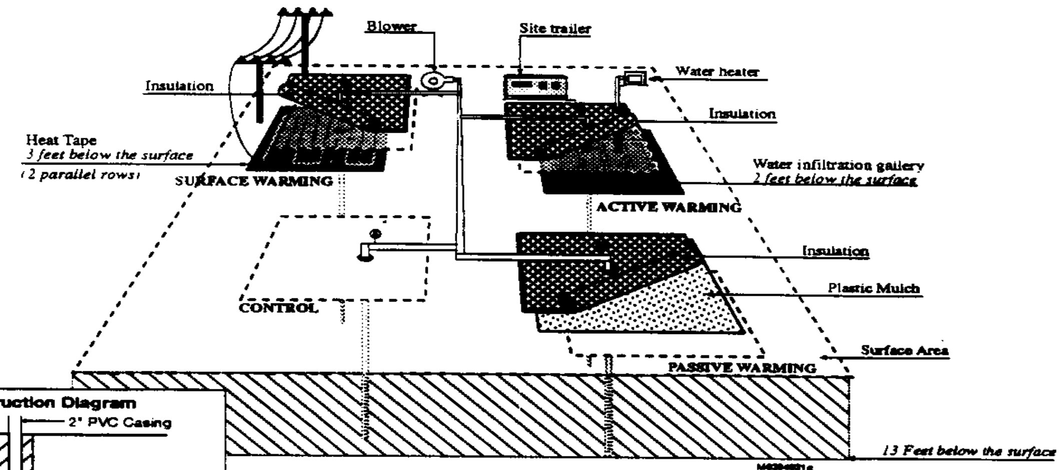


Figure 3

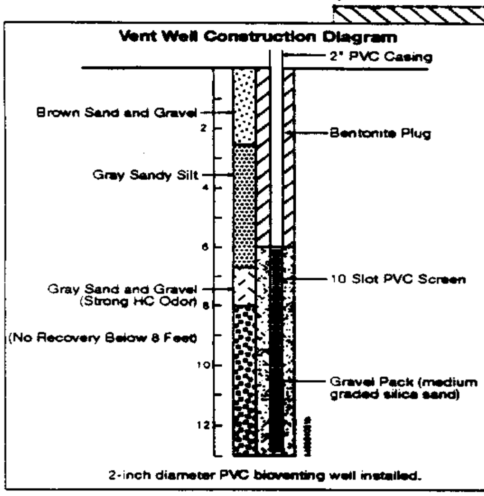


Figure 1 in conjunction with Figure 3 show the bioventing system.

The original system was composed of several groups of vadose wells on a 30' grid connected to centrifugal blowers by insulated above-ground piping.

In 1992, the air injection system was modified replacing the grid system of air injection wells with one deeper well in the center of each of the test plots. Additionally, a fourth test plot was added that uses a buried heat tape to heat vadose zone soils.

PERFORMANCE

Performance Objectives

- To determine the effectiveness of the bioventing process in a sub-arctic environment and to evaluate potential enhancement of the process through soil warming.
- To prevent further degradation of the groundwater quality by significantly reducing the amount of petroleum product floating on the groundwater.

Treatment Plan

- It is estimated that 99% of the volatile petroleum hydrocarbons can be degraded through bioventing.
- All groundwater with a concentration of benzene in excess of 5 µg/l is targeted for cleanup. The remediation goal is to reduce the benzene concentration to below the drinking water standard of 5 µg/l.
- Bioventing at ST20 E-7 is being conducted as a three-year study which began in July 1991.
- To determine the effectiveness of bioventing in conjunction with soil-warming methods in a subarctic environment, the source area is divided into four 50-foot-square experimental plots.
- The plots are set up to test the effectiveness of three different types of soil warming, and are compared to the fourth control plot (Figure 1) which is maintained under ambient soil temperature conditions.
- One plot utilizes Passive Warming in which solar warming in late spring, summer, and early fall is enhanced by plastic sheeting placed over the ground surface of the plot. Insulation is used to cover the plot to help retain heat during late fall and the dark winter months.
- A second plot utilizes Active Warming in the vadose zone by infiltrating heated groundwater through soaker hoses buried 2 feet below ground surface. Water at 35°C is added an approximate rate of 1 gallon per minute through five parallel hoses spaced 10 feet apart. This plot is also covered by insulation year round.
- The third plot is a Surface Warming test plot using heat tape to add direct heat to the vadose zone soils. The heat tape is buried in parallel lines 5 feet apart, 3 feet below the surface, and delivers heat at a rate of 6 W/ft.
- The fourth plot is the contaminated Control plot which is biovented with no artificial method of heating. Air at ambient temperatures is simply injected into the contaminated soil.
- A Background plot of uncontaminated soil located away from the study area is also used for comparison.
- Air injection wells are installed in the center of each plot. The wells are screened from 6.5 ft to 13 ft to allow for deeper air injection. The air injection system was reconfigured in 1992 to inject air in the deep bioventing wells only at an average flow rate of 5 cubic feet per minute. Prior to 1992, a 30 foot grid system of shallower air injection wells operating at 2.5 cfm was used.
- Major operation and maintenance at ST20 include weekly sampling of soil gas concentrations, regular monitoring of soil temperature, and replacing the insulation material on the Active and Passive Warming plots as needed.
- Treatment of extracted soil gas is not anticipated.

The following assumptions were used:

- VOCs are released into the atmosphere at low rates during bioventing.
- No off-gas treatment or odor control was considered because flow rates are low.
- An air flow exchange rate of 0.6 pore volumes per day is sufficient to promote microbial activity.
- The effective porosity is 0.30.

Performance Measures

Each experimental plot has multi-level soil gas monitoring wells and multi-level soil temperature probes. Oxygen, carbon dioxide, and total petroleum hydrocarbons in the soil are measured regularly in order to estimate bacterial growth. Approximately once a month, the air injection system is turned off, and the oxygen levels are measured to see how quickly the microorganisms in the soil use the oxygen. Changes in soil gas concentrations of oxygen and carbon dioxide are monitored and compared with the Background plot to determine a relative biodegradation rate.

Preliminary conclusions show that bioventing in conjunction with soil warming is stimulating *in situ* biodegradation year round in this subarctic environment. Active warming maintains soil temperatures above ambient temperatures and thus increases biodegradation rates. The externally heated experimental plots are maintaining more higher, summer-like temperatures than the control plot, despite ambient air temperatures as low as -20°C.

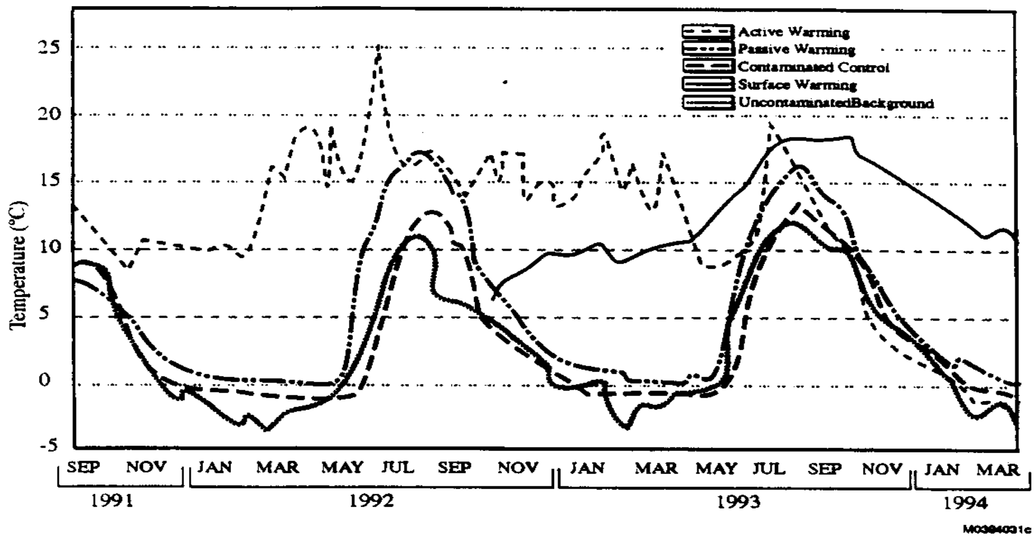


Figure 4. Soil temperature in the four test plots and the background area.

In the sixteen-month period from August 1991 to November 1992, the average respiration rates in the three original test plots are listed in the following table. The biodegradation rate in the Active Warming test plot is over twice the rate measured in the Control test plot:

Biodegradation
August 1991 to November 1992

Test Plot	Average Respiration Rates [mg/kg/day]	Hydrocarbon Removal [mg/kg]
Active	4.6	2,100
Passive	1.3	600
Control	1.6	750

Figure 5 summarizes the average biogradation from October 1991 to January 1993. Here the average biodegradation rates in the Active, and Surface Warming test plots are significantly higher than the rate measured in the Control test plot:

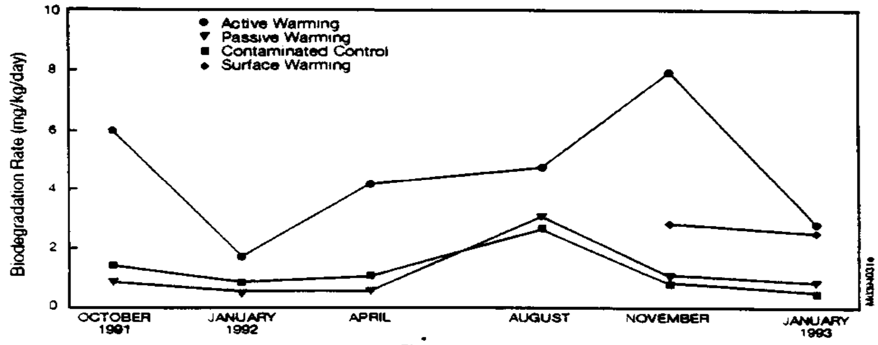


Figure 5

- A preliminary comparison of soil gas measurements taken from the Passive Warming test plot at the beginning of the bioventing demonstration and six months later shows a 60% to 97% decrease in total hydrocarbon vapor concentrations.
- Contaminant concentrations in soil and groundwater have been analyzed. The draft results indicate that the concentrations of benzene in groundwater samples collected from wells at ST20 (E-7) in 1993 were generally lower (maximum 200 µg/L) than those observed in samples collected at the time of the last sampling round in 1989 (maximum 12,000 µg/L). After the bioventing treatability study is completed during the 1994 field season, Eielson AFB may continue remediation at the site using bioventing.
- Surface emissions sampling has shown that benzene emissions are on the order of 0.00035 lbs/area/day, well below the Alaska State Department of Environmental Conservation limit of 4 lbs/area/day. Total TPH emissions were measured at 8.6 lbs/area/day versus 135 lbs/area/day of hydrocarbon removed through biodegradation.
- Soil vapor extraction testing has shown that removal of hydrocarbons due to biodegradation is an order of magnitude greater than hydrocarbon removal due to volatilization.

COST

The three-year bioventing system at ST20 E-7 is being conducted as a joint Air Force/EPA study. Battelle is the prime contractor for the Air Force and EPA component of the joint study.

Since the Eielson AFB Bioventing remediation is currently being conducted as study project, the system capital and operating do not accurately reflect the cost of remediating the ST20 E-7 site through bioremediation. An estimate of the costs involved if bioventing is chosen as the alterative for remediation of Eielson AFB source areas has been prepared by Battelle Pacific Northwest Labs and is summarized below. It should be noted that these costs are for multiple sites under arctic conditions. A more general cost for bioventing on a per cubic yard basis is found in *Bioventing Performance and Cost Summary*.

Capital Cost

Component Description	Category Subtotal
Floating Fuel	
Passive collection trenches installation	$14,500
Product collection pipes/sumps/pumps/storage	20,500
Soil Remediation - Bioventing	
Injection wells (30-35)	52,500
Above ground manifold system	140,000
Injection blowers	4,500
Trailer	6,000
Installation/Electrical/I&C	98,865
Start-up/Shakedown	10,000
Composting site development	16,180
Compost excavated soils	1,400
Groundwater Remediation	$3,000
Subtotal	$367,445
Mobilization & General Requirements @ 15%	55,167
Subtotal	$422,562
Contingencies	
Bid Contingency @ 10%	42,256
Scope Contingency @ 20%	84,512
Subtotal	$549,330
Other Costs	
Administrative @ 5%	27,467
Services During Construction @ 10%	54,933
Legal @ 5%	27,467
Implementation Cost Total	$659,197
Engineering Design @ 15%	98,880
	758,077

Annual Operations & Maintenance Cost

Component Description	Quantity	Unit price	Component Cost	Category Subtotal
Floating Fuel (5 Years Total Duration)				$21,000
Operating labor - 4 hours per week	208 hr	40	8,300	
Electric power	1 ls	5,000	5,000	
Trench maintenance	1 ls	500	500	
Monthly monitoring	96 hr	50	4,800	
Data management/Reporting	48 hr	50	2,400	
Soil Remediation - Bioventing (10 Years Total Duration)				$104,160
Fence and sign maintenance	48 hr	40	1,920	
Operating labor - 8 hours per week	416 hr	40	16,640	
Electric power	1 ls	20,000	20,000	
Monthly monitoring	240 ls	50	12,000	
Data Management/Reporting	192 hr	50	9,600	
Sample analysis	20 ea	1,200	24,000	
Maintenance	1 ls	1,000	1,000	
Groundwater Monitoring (30 Years Total Duration)				$52,000
Semi-annual sampling for VOCs	40 hr	50	2,000	
Data Management/Reporting	20 hr	50	1,000	
Sample Analysis	40 ea	1,200	48,000	
Well Maintenance	1 ls	1,000	1,000	
TOTAL				$177,160

REGULATORY/INSTITUTIONAL ISSUES

- Eielson Air Force Base is implementing remedial design and remedial action (RD/RA) activities at the Refueling Loop E-7 complex, designated Source Area ST20 (E-7), in accordance with the Federal Facilities Agreement between the United States Air Force, the Environmental Protection Agency (EPA), and the Alaska Department of Environmental Conservation (ADEC).
- The system is being operated on a test portion of the site by Battelle Columbus [sponsored through the United States Air Force Armstrong Laboratory, the United States Air Force Center for Environmental Excellence (AFCEE), and EPA].
- The Air Force has been designated as the lead government agency in cleanup efforts at Eielson AFB, Alaska. As the lead agency, the Air Force must ensure public involvement in all site-related decisions at Eielson AFB.
- No permitting will be required for purge water from the monitoring wells. Eielson AFB will provide for any required water treatment during well purging.
- Eielson AFB will be responsible for analysis and disposal of any soil or groundwater wastes generated.
- At the completion of the project all equipment will be left in place and will be turned over to the Air Force for continued operation.
- Administrative permits are not required for any treatment process carried out on the Base.
- Bioventing is expected to achieve the Alaska DEC ARAR for soil of 200 ppm TPH within 10 years.
- Recovered fuel is not a hazardous waste.
- Bioventing meets air discharge limits specified by the State.
- Institutional controls such as access restrictions, use of personal protective equipment, and continued use of the Base water treatment plant must be considered to prevent exposure to contaminated media during and after remedial activities.
- The ST20 refueling complexes contain active underground fuel tanks, piping, and pump houses. Special flight-line security passes are required for access, and additional security restrictions are imposed during Base exercises.
- The aquifer is used as the only source of potable drinking water source for the nearby community of Moose Creek.

SCHEDULE

Figure 6 shows the schedule of activities.

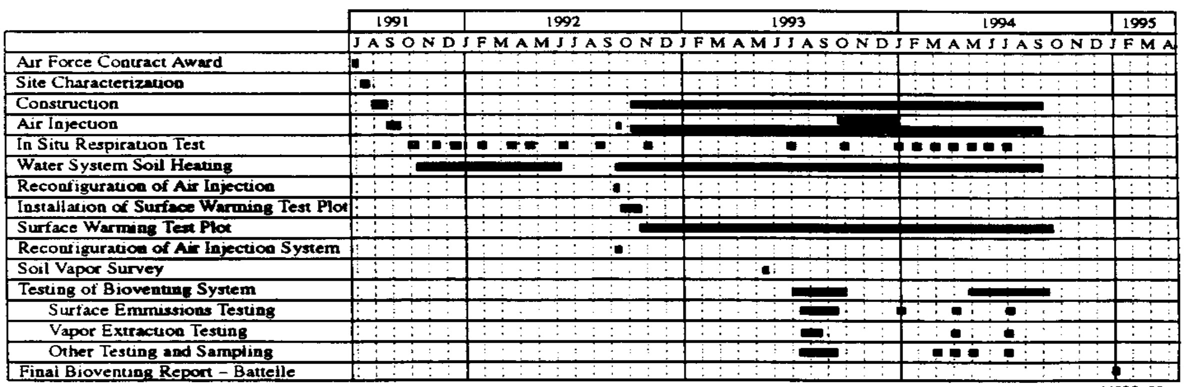


Figure 6. Interim Remediation Schedule.

LESSONS LEARNED

Implementation Considerations

- The ST20 refueling complexes contain active underground fuel tanks, piping, and pump houses. Special flight-line security passes are required for access, and additional security restrictions are imposed during Base exercises.
- The short construction season and arctic conditions affect implementation, operation, and maintenance.
- Base snow removal plowing services for site access roads must be coordinated.
- A bioventing system may be configured in several different ways to enhance biodegradation. The optimal configuration of any given site will depend on site-specific conditions and remedial objectives.
- The groundwater has naturally high concentrations of metals, including iron, arsenic, and manganese. Because the concentration of iron in the water is high, the introduction of oxygen or air into the groundwater could cause precipitation and fouling of equipment, wells, or the aquifer itself.

Technology Limitations

- Bioventing is an innovative technology, and data on effectiveness and time to achieve cleanup goals are limited. The reliability and effectiveness of bioventing depend on oxygen, nutrients, moisture, and microbial populations present in the soil.
- Injection wells may be impractical from a maintenance standpoint at sources areas with a naturally high content of iron in the groundwater.
- High soil moisture content especially in the Active Warming plots interferes with soil gas monitoring and reduces the number of soil gas monitoring points that can be sampled. In general, the deeper monitoring points where the most contamination is present are the most difficult to sample. The use of heat tape may prove to be the preferred means of soil warming since the problem of high soil moisture content is avoided.
- Many types of batteries, as well as the electronics in many field instruments can be adversely affected by the cold. Manufacturers literatures must be consulted for operating ranges. Additional time must also be allotted in the morning to check out and warm-up field equipment.

Future Technology Selection Considerations/Alternatives

SVE/Bioventing/Sparging:

- SVE is a reliable, proven technology for VOC remediation.
- SVE and bioventing are expected to remove a high percentage of the volatile compounds and perhaps up to 50 percent of the residual contamination.
- Bioventing may release VOCs into the air at a very low rate.
- Air sparging releases volatile compounds to the SVE system. Catalytic oxidation of SVE off gas thermally destroys organic contaminants.
- High-iron content in groundwater may limit feasibility of sparging using air.

Removal:

- The removal alternative provides the greatest protection to future groundwater users in the shortest time frame through source removal (active skimming and excavation) and groundwater extraction.
- Active skimming reduces the source of groundwater contamination by removing up to 50% of the floating fuel. However, residual fuel contaminants may continue to leach to groundwater.
- Groundwater extraction is proven for removing contaminant mass, but not for aquifer restoration.
- Excavating "hot spots" eliminates current and future exposure from concentrated areas of contamination, but lower levels of contamination in soil may be widespread.
- VOCs will be released to the air during excavation, composting, and air stripping.
- In addition, underground fuel lines, utilities, and fuel storage tanks may pose a hazard during excavation.

SOURCES

Major Sources For Each Section

Site Characteristics	1, 2, 3, 4, 5, 7, 8, 10
Treatment System	1, 5, 6, 9
Performance	1, 3, 5, 6, 9, 12, 15
Cost	1, 13, 14, 15, 16, 18
Regulatory/Institutional Issues	1, 5, 6, 8, 10, 14
Schedule	1, 6, 15
Lessons Learned	1, 5, 11

REFERENCES

Administrative Record Code [Information Repository, Eielson Air Force Base, AK]	Document Description
1. 003473	U.S. Air Force. 1992. Environics TOC Task 3 Bioventing Feasibility Study: Eielson Air Force Base. Annual Report, December 1992. In preparation for the U.S. Air Force by BATTELLE Columbus Division, Columbus, Ohio.
2. 003286	U.S. Air Force. 1992. OUIB Record of Decision, Eielson Air Force Base, Alaska. September 1992.
3. 003742	U.S. Air Force. 1993. Remedial Investigation/Feasibility Study. Operable Unit 1 Management Plan, Eielson Air Force Base, Alaska. Draft Final, May 1993. U.S. Air Force Environmental Restoration Program.
4. 003838	U.S. Air Force. 1993. Operable Unit 1 Remedial Investigation Report, Volume 1, Text and Appendixes, Eielson Air Force Base, Alaska. Draft, August 1993. U.S. Air Force Environmental Restoration Program.
5. 003853	U.S. Air Force. 1993. Operable Unit 1 Feasibility Study, Volume 3: Text and Appendixes, Eielson Air Force Base, Alaska. Draft, November 1993. U.S. Air Force Environmental Restoration Program.
6. 003830	U.S. Air Force. 1993. Interim Remedial Action. Remedial Design: OUIB Source Area ST-20 (E-7). Draft, September 1993. Prepared for Eielson Air Force Base through Armstrong Laboratory, Brooks Air Force Base, San Antonio, Texas.

7. 003926 — U.S. Air Force. 1993. Management Action Plan, Eielson Air Force Base, Alaska. Revision, 17 December 1993. U.S. Air Force Environmental Restoration Program.

8. 002694 — 343d Fighter Wing. Eielson Air Force Base Community Relations Plan for Environmental Restoration. October 1991. Eielson Air Force Base Installation Restoration Program.

9. 003375 — 343d Fighter Wing. Fact Sheet: Bioventing. December 1992. Eielson Air Force Base Installation Restoration Program.

10. On File in Information Repository — U.S. Air Force. Base-General Information for DPM FY-93 U.S. Air Force Scoring Exercise. DPM Information Packet based on Site 20 data. Completed on 5 January 1994 by 354 CES/CEVR, Eielson Air Force Base, Alaska. Submitted to Engineering Science, Fairfax, Virginia.

NOTE: A final report from Battelle summarizing the results and conclusions of the Site 20 bioventing research project will be prepared by December 1994.

Additional Sources of Information

11. Office Copy — Vogel, Catherine M. Soil Bioventing Under Arctic Conditions. The Military Engineer Magazine, August 1993.

12. Correspondence [Project File] — Kittel, Jeffrey A. Letter from Jeffrey Kittel of Battelle (Columbus, OH) in response to a request from Capt. Catherine Vogel of HQ AFCESA/RAVW (Tyndall AFB, FL), dated 31 December 1993. SUBJECT: Estimate to Complete the Bioventing Field Research Project at Site 20, Eielson AFB, AK.

13. Correspondence [Project File] — Battelle. Faxed submittal from Battelle (Columbus, OH) to Lafayette Turner of AFDTC/PKRA (Eglin AFB, FL), dated 5 March 1993. SUBJECT: Full-scale Bioventing Demonstration in Alaska, Environics Task Order Contract Task 3, Contract No. F08635-90-C-0064. Proposal for completion of the above referenced task (includes proposed funding).

14. Correspondence [Project File] — Vogel, Catherine M. Fax from Capt. Catherine Vogel at AL/EQ (Tyndall AFB, FL) to Dave Blevins of 354 CES/CEVR (Eielson AFB, AK), dated 8 March 1993. SUBJECT: FY 92 Bioventing Funding. Fax includes copies of the Battelle bills (monthly invoices) for 3 September 1992 through 25 February 1993.

15. Monthly Status Reports [Project File] — Battelle. Copies of Monthly Status Reports from Dr. Robert E. Hinchee of Battelle (Columbus, OH) to Capt. Catherine Volge of AL/EQW (Tyndall AFB, FL) for August 1992 through December 1993. SUBJECT: [Thirteenth through Twenty-Ninth] Monthly Status Report, Full-Scale Bioventing Demonstration in Alaska, Task 3, Contract F08635-90-C-0064.

16. Report — Bioventing Performance and Cost Summary, February 1994. Air Force Center for Environmental Excellence, Brooks AFB, Texas.

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REVIEW

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