Case Study Abstract

Underground Storage Tanks (USTs)
Land Treatment at Lowry Air Force Base (AFB), Denver, Colorado

Site Name:
Lowry Air Force Base

Location:
Denver, Colorado

Contaminants:
Benzene, toluene, ethylbenzene, and xylenes (BTEX) and Total Petroleum Hydrocarbons (TPH)
- Contaminated soil - BTEX < 100 mg/kg; Total Recoverable Petroleum Hydrocarbons (TRPH) up to 11,000 mg/kg; 3,100 mg/kg average
- Stockpiled soil - average TRPH of 3,983 mg/kg

Period of Operation:
Status - Ongoing
Report covers - 7/92 to 9/93

Cleanup Type:
Full-scale cleanup (interim results)

Vendor:
Engineering Science, Inc.
1700 Broadway, Suite 900
Denver, CO 80290

SIC Code:
9711 (National Security)

Technology:
Land Treatment
- Soil spread on plastic sheeting to thickness of 14 to 18 inches
- One-time addition of ammonium nitrate nutrients (C:N:P ratios of 200:10:1)
- Soil aerated twice a month (April-November)
- Soil moisture content 10%-15%

Cleanup Authority:
State: Colorado

Point of Contact:
Lt. Tom Williams
3415 CES/DEV
Lowry AFB, CO 80230

Waste Source:
Underground Storage Tank

Purpose/Significance of Application:
Land treatment to remediate soils contaminated with heating oil which contained relatively high concentrations of TPH and relatively low concentrations of soluble contaminants (e.g., benzene).

Type/Quantity of Media Treated:
Soil
- Soil type firm sandy clay and medium to coarse-grained sand
- Soil moisture content ranged from 6% to 11%
- 5,400 yd^3 treated plus three additional truckloads of contaminated soil

Regulatory Requirements/Cleanup Goals:
- Treated soil - TPH < 500 mg/kg; TRPH < 500 mg/kg; and BTEX < 100 mg/kg
- Cleanup conducted under EPA and State of Colorado Underground Storage Tank Regulations and the Colorado Department of Health's Remedial Action Category III (RAC III) action levels

Results:
- Land treatment project was not complete at time of this report
- No TRPH, BTEX, or TPH data are available at this time
- Total Extractable Petroleum Hydrocarbon levels as of September 1993 ranged from 1,300-1,700 mg/kg

Cost Factors:
- Total Capital Cost - $104,257 (including site work, permitting, construction/mobilization/demobilization, pilot testing, project management); pilot testing was $76,000 of the total capital costs
- Estimated Annual Operating Costs - $18,460 per year (including laboratory charges, maintenance, monitoring)

Case Study Abstract

Underground Storage Tanks (USTs)
Land Treatment at Lowry Air Force Base (AFB)
Denver, Colorado (Continued)

Description:
As a result of a leak of heating oil from an underground storage tank (UST) at Lowry Air Force Base in Denver, Colorado, soil at the site was contaminated with total petroleum hydrocarbons (TPH) and benzene, toluene, ethylbenzene, and xylenes (BTEX). An estimated 10,500 gallons of fuel oil were released. The USTs in the area were removed and the contaminated soil was excavated. Land treatment was selected for the excavated soil; treatment of about 5,400 cubic yards began in July 1992 and is ongoing at the time of this report. For this land treatment application, nutrients (ammonium nitrate) were added in a one-time application, the soil is tilled twice a month, and soil moisture content is kept between 10 to 15% by weight. The target cleanup levels for the soil are TPH to less than 500 mg/kg; Total Recoverable Petroleum Hydrocarbons (TRPH) to less than 500 mg/kg, and BTEX to less than 100 mg/kg. The cleanup is being conducted under the authority of the Colorado Department of Health Underground Storage Tank Program.

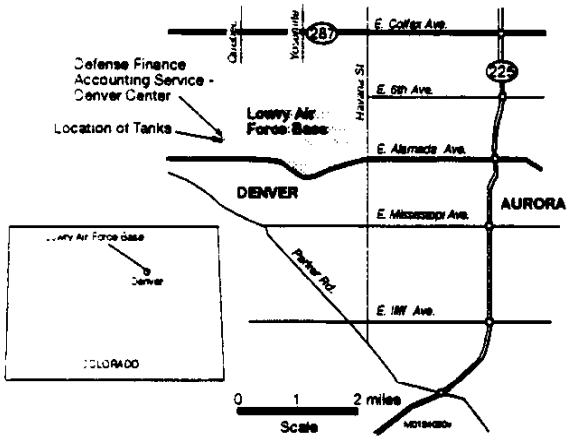
The estimated completion time for the land treatment operation was two years. However, as of September 1993, the treatment had not been completed. While no TPH, TRPH, or BTEX data were available at the time of this report, levels of Total Extractable Petroleum Hydrocarbons (TEPH) sampled as of September 1993 showed levels in the range of 1,300 to 1,700 mg/kg. These data and the results of a pilot test, which showed a general decrease in TEPH over time, appear to indicate that land treatment will be effective, though no projections for a completion date are available at this time.

The total capital cost for this project is $104,257 including $76,000 for pilot testing, and the estimated annual operating costs are $18,640. Available information to date indicates that the credibility of the land treatment soil assessment would have been improved if an adequate, random sampling program had been used for sample collection. In addition, laboratory analysis should have been consistent throughout the pilot test or an explanation of inconsistencies provided.

TECHNOLOGY APPLICATION ANALYSIS

SITE

Figure 1



TECHNOLOGY APPLICATION

This analysis covers the use of landfarming to bioremediate soils contaminated with heating oil. The treatment began 1 July 1992 and is currently ongoing. This analysis covers performance through September 1993.

SITE CHARACTERISTICS

Site History/Release Characteristics

- The Defense Finance Accounting Service - Denver Center (DFAS-DE) is located on Lowry Air Force Base (AFB) at the east edge of the City of Denver, Colorado.
- This project was carried out in response to a suspected release of petroleum hydrocarbons (heating fuel oil) from an UST at the DFAS-DE adjacent to building 444.
- A suspected leak of 10,500 gallons of heating fuel oil was discovered by a discrepancy in inventory measurements during February 1992. In response to the suspected release, an emergency UST removal and site assessment project was performed.
- Underground storage tank (UST) removal efforts commenced March 2, 1992, with uncovering of the suspected leaking UST (Tank 424). The soil above the tank was free of hydrocarbon odor.
- Leakage was confirmed by visual inspection of the removed tank on March 16, 1992.
- Initial notification of the release was provided in a letter dated April 7, 1992, to the CDH Underground Tank Program.

Contaminants of Concern

- Contaminants of greatest concern in the soil are BTEX (benzene, toluene, ethyl benzene, and xylenes) and heating oil.

Properties of contaminants focused upon during remediation are:

Property	Units	Benzene	Ethylbenzene	Toluene	Xylenes*
Empirical Formula		C_6H_6	C_8H_{10}	C_7H_8	C_8H_{10}
Density @ 20°C	g/cm^3	0.88	0.87	0.87	0.87
Vapor Pressure @ 20°C	mm Hg	100	10	36.7	10
Henry's Law Constant @ 25°C	(atm)	5.59×10^{-3}	6.43×10^{-3}	6.73×10^{-3}	7.04×10^{-3} $(m^3)/mol$
Water Solubility @ 20°C	mg/l	1,800	200	500	200
Log Octanol-Water Partition Coefficient; Log Kow		2.13	3.15	2.69	2.77-3.2
Site Specific Soil-Air Partition Coefficient; Kh /Kd	ug/l air / mg/kg soil		0.48	3.42	0.77
Organic Carbon Partition Coefficient; Koc	ml/g	83	1,100	300	240
Ionization Potential	ev	9.25	8.76	8.82	8.56
Molecular Weight		78.12	106.18	92.15	106.18

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

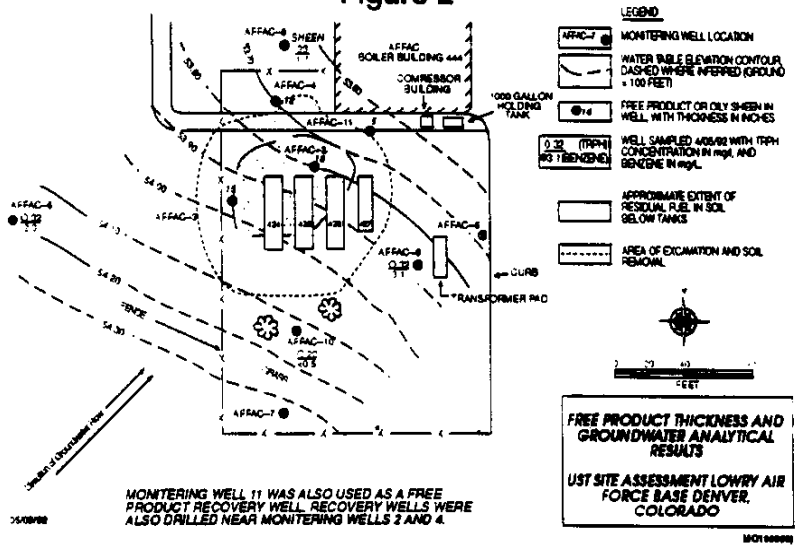
Nature & Extent of Contamination

- 4 USTs (Tanks 424, 425, 426, and 427) were removed.
- It was determined that only Tank 424 leaked.
- Tanks 424, 425, and 426 had a capacity of 24,000 gallons each. Tank 427 had a 6,000 gallon capacity. All 4 tanks were steel.
- Components of the heating fuel oil did not significantly affect the groundwater. Heating fuel oil contains relatively low concentrations of soluble components (such as benzene) compared to lighter petroleum fractions such as gasoline. Groundwater treatment was not deemed necessary, but it was monitored during remediation activities.
- Groundwater benzene concentrations from 4 monitoring wells ranged from 1.7 to 3.1 µg/L. Concentrations of toluene, ethylbenzene, and xylenes were well below State standards and MCLs. Low TRPH concentrations (0.3 mg/L or less) were measured in 3 wells; 23 mg/L of TRPH was observed in the downgradient well.

Contaminant Locations and Geologic Profiles

Remedial investigation field activities at the site included:

Figure 2 Plume (Plan View)



Hydrogeologic Units

- Thicknesses of unconsolidated alluvium >80 feet occur at the location of the DFAS-DE tanks.
- A layer of moist, firm sandy clay occupies the top 10 to 15 feet.
- The next 15 to 80 feet is a medium to coarse-grained sand.
- Aquifer is a water table aquifer.
- Groundwater gradient is roughly 0.4%.
- Approximately 9,000 cubic yards of soil was removed from the excavation. This soil was a combination of course-grained sand and sandy clay.
- Approximately 3,000 cubic yards of sandy clay soil excavated from above the tanks was stockpiled separately and used for backfill of the excavation.
- Clean fill from offsite was used to backfill remainder of the excavation.

Site Conditions

- Elevation is about 5,390 feet.
- Average annual air temperature is 50°F. Diurnal temperature fluctuation averages 29°F. Record high 105°F; record low temperature -30°F.
- 14.81 inches precipitation/year; 58.3 inches of snow/year.
- On the average, the first freeze is around October 12 and the last freeze is around May 5.
- Direction of groundwater flow is from the southwest to the northeast.

Key Soil or Key Aquifer Characteristics Measured

Property	Units	Range or value
Soil moisture content (landfarm)	%	6% to 11%
Hydraulic conductivity	cm/s	1.8 to 78.4 X 10-4
Depth to groundwater	feet	45
Aquifer thickness	feet	>35
Depth to bedrock	feet	>80

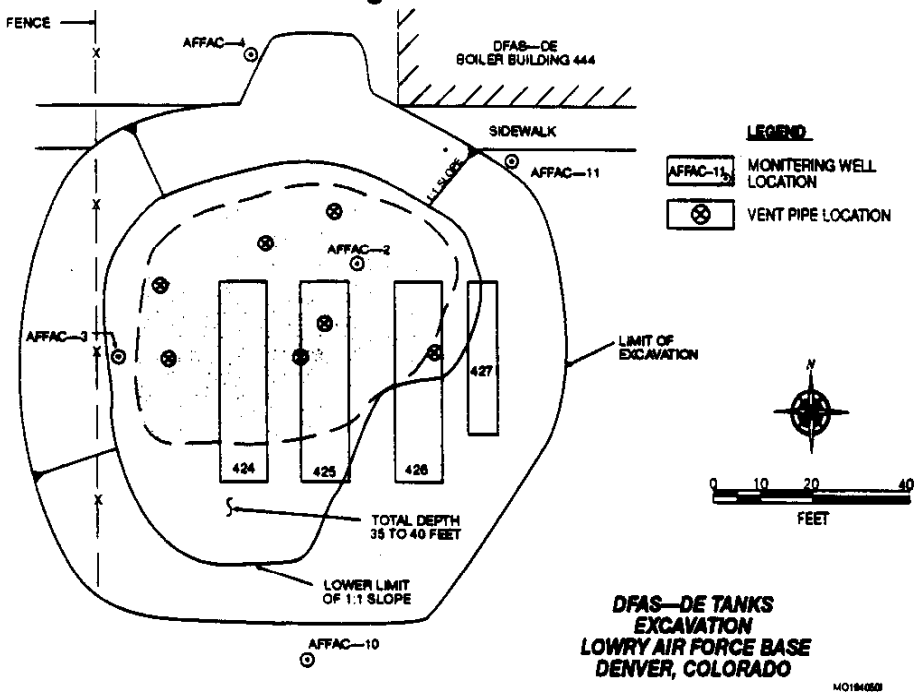
TREATMENT SYSTEM

Three remediation technologies are being used to remediate this site. The three technologies selected complement each other and are not competitive, one with another.

- Landfarming for the soil removed from the excavation.
- Bioventing for the soil remaining in the excavation.
- Product only pumping for the free product found floating on the water table.
- This report addresses landfarming only.

Extent of Excavation

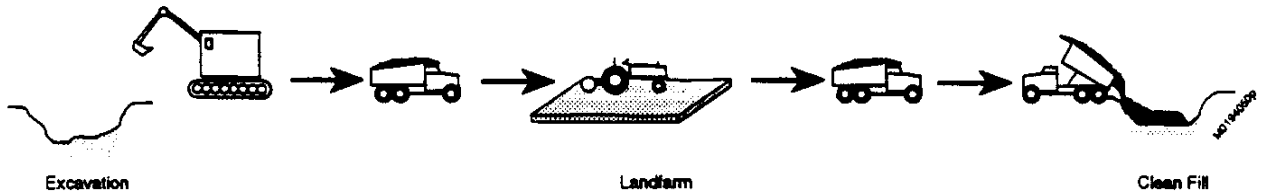
Figure 3



Overall Process Schematic

Figure 4

Process Flow



Key Design Criteria

- Soil berms, 2 feet wide by 2 feet high, were constructed on plastic sheeting used for the landfarming operation and the edges rolled back over the berms.
- Contaminated soil was spread on the plastic sheets to a thickness of 15 inches. Orange synthetic mesh fencing 3 to 4 feet high was installed around the landfarm for security and to prevent animal intrusions.
- The application of agricultural fertilizers to soil used in landfarming operations had C:N:P ratios of 200:10:1 as recommended for hydrocarbon biodegradation. Ammonium nitrate nutrients with this ratio were applied and tilled into the soils once.
- Optimum moisture for biodegradation ranges from 10 to 15% by weight. Moisture was added to the landfarming soils during the dry summer months to maintain this range.
- Based on Lowry AFB soil and contaminant conditions, a minimum landfarming treatment period of 12 to 18 months was expected for reduction of heating oil residuals from 3,100 mg/kg to <500 mg/kg.
- Assuming that a maximum of 10% by weight of the heating fuel oil will volatilize, 1.9 tons of total volatile hydrocarbons could volatilize to the atmosphere during the anticipated landfarming treatment term.

Key Monitored Operating Parameters

- A pilot test was performed to verify treatability.
- TRPH concentrations are used to monitor microbial activity, verify biotreatment of the soil, and document removal of petroleum hydrocarbons from the soil. When TRPH concentrations have been reduced to 500 mg/kg, a letter will be sent to the CDH to confirm successful treatment.

The Treatment System

- A pilot test was conducted over a six month period in 1992 to assess the effectiveness of providing soil amendments to aid in the treatment process.
- 5,400 cubic yards of petroleum contaminated soil was removed from the excavation.
- Soil was removed from below the tanks to a depth of 35 to 40 feet below ground surface.
- Soil that was saturated with fuel oil or had olfactory or PID indications of hydrocarbons present was excavated by a track hoe, hauled to a treatment location on an abandoned paved airstrip, and stockpiled on plastic sheets.
- The stockpiled soils had an average TRPH concentration of 3,100 mg/kg (the maximum observed was 11,000 mg/kg). BTEX was <100 mg/kg.
- The soil is being remediated using above ground biotreatment (landfarming). In landfarming, soil microbes use petroleum hydrocarbons as their primary carbon source. Soil tilling supplies sufficient oxygen to the soils for biodegradation and produces a homogeneous mixture of soil, moisture, and added nutrients. Nutrients including available nitrogen (N), phosphorous (P), and various trace elements were added once by application of an agricultural fertilizer in aqueous solution.
- The thickness of the stockpiled soils during treatment was 14 to 18 inches.
- The soil was aerated with a farm plow to provide oxygen to the soil bacteria. Soil Tilling is performed twice a month from April to November.

PERFORMANCE

Performance Objectives

- There are no RODs or FFAs. However, compliance with EPA and State of Colorado UST regulations is required.
- The soils biotreatment operations will be completed when composite soil samples indicate TRPH concentrations have been reduced to less than 500 mg/kg.

Treatment Plan

- The soil is being remediated using above ground *(ex situ)* biotreatment (landfarming).
- The remediated soils will be used for fill material on Lowry AFB property after soils biotreatment is completed.

Operational Performance

DFAS-DE FULL SCALE LANDFARM SOIL SAMPLING RESULTS

First Samples		Latest Samples	
Dates: Sample I.D.	April 23-27,1992 TRPH* (mg/kg)	Dates: Sample I.D.	Sept. 2, 1993 TEPH† (mg/kg)
AFFAC-SP3	5,400	LF-9/2/93-1	1,700
AFFAC-SP4	5,300	LF-9/2/93-2	1,300
AFFAC-SP5	5,300	LF-9/2/93-3	1,400
AFFAC-SP6	1,200		
AFFAC-SP7	1,700		
AFFAC-SP8	1,300		
AFFAC-SP9	11,000		
AFFAC-SP10	660		
Mean	3,983		1,467

* Total recoverable petroleum hydrocarbons
† Total extractable petroleum hydrocarbons

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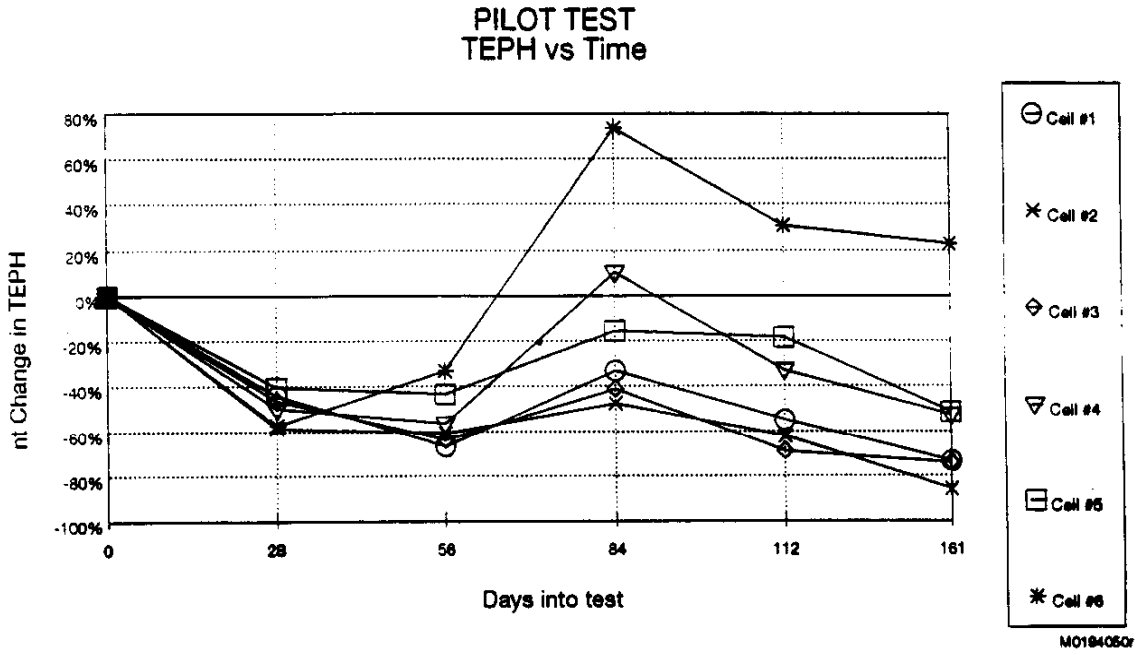
Eight samples of soil stockpiled from the excavation were analyzed for TRPH before being removed to the landfarm. The data labeled "First Samples" in Figure 5 presents this data.

- On September 2nd soil samples from 3 locations in the 100,000 sq. ft. landfarm were analyzed for TEPH. The data labeled "Latest Samples" presents this data.
- The samples from April 1992 indicate that the contaminated soil was not homogeneous before it was placed for landfarming.
- It is difficult to determine the average level of TEPH for the landfarm from only the three samples that were taken on 2 September, 1993.
- Three additional truck loads of diesel contaminated soil were added to the landfarm subsequent to this sampling. This contaminated soil resulted from a 150 gallon diesel fuel spill from a delivery truck.

- **Pilot Test**

  The results of the pilot study showed an uncharacteristic increase in TEPH between weeks 8 and 12. Except for this all samples show a general decrease in TEPH over time. No reason for the increase between weeks 8 and 12 was given.



Treatment Performance

- 9,000 cubic yards of soil were removed from the excavation. 3,000 cubic yards of this were clean soil removed from over the tanks.
- The landfarming project is not complete at this time and the evaluation of the performance of this treatment method is incomplete.
- The data presented in Figure 5, however, suggests that the performance of the landfarming project will be satisfactory.

COST

Capital Costs

Site Work	$14,600
Permitting & Regulatory	$1,500
Startup Costs	$2,400
Subtotal	$18,500
Engineering	$1,500
Project Management	$6,000
Pilot testing	$76,000
Construction/Mobilization/Demobilization	$1,480
Fees @ 1.5%	$277
Cumulative Subtotal	$104,257
Total Capital Costs	$104,257
Annual Capital Cost (over 2.5 years)	$41,700

Estimated Operating Costs (per year)

Laboratory Charges	$500
Maintenance Labor & Parts	$16,640
Monitoring	$1,500
Subtotal	$18,640
Total Annual Operating Cost (estimated)	$18,640
Total Annual Operating & Capital Costs (estimated)	$60,340
Cost/Ton (estimated)	$17

Cost Sensitivities

Effects of Assumption Changes

The estimated cost is subject to the following sensitivities:

	$/ton
• An increase in the landfarm treatment time of 40% (to 3.5 years)	Added $2

REGULATORY/INSTITUTIONAL ISSUES

- The USTs were removed in conformance with American Petroleum Institute Recommended Practice 1604 and the National Fire Protection Association Code 30.
- The EPA and the State of Colorado reviewed all documents produced by this project including the Quarterly Monitoring Reports. In addition, Lowry AFB personnel meet with the EPA and the State of Colorado once/month. Local communities are invited to the monthly environmental meetings.

Cleanup Criteria

The Colorado Department of Health (CDH) Remedial Action Category III (RAC III) Action Levels are:

Compound	mg/kg
Total (Recoverable) Petroleum Hydrocarbons (TRPH)	500
Total Benzene, Toluene, Ethylbenzene, and Xylenes (BTEX)	100

- The CDH's "Basic Standards for Ground Water" includes:

	µg/L
benzene	1
toluene	1,000
ethylbenzene	680
xylenes	none

- The MCL standard for benzene is 5 µg/L, the MCL for xylenes is 10,000 µg/L, but there is no MCL for TPH.
- Shallow groundwater beneath Lowry AFB is not being used as a drinking water supply and there is little or no likelihood that this will change.
- Target Cleanup Levels/Criteria:

Contaminant	mg/L
TPH	500

SCHEDULE

- Landfarming began treatment on 1 July 1992.
- As of September 1992, the estimated time of completion was 2 years.
- As of April 1994 treatment is not complete.

LESSONS LEARNED

Key Operating Parameters

- The key operating parameters are soil moisture, soil oxygen content and temperature.
- The credibility of the 2 September 1992, landfarm soil assessment would have been improved had an adequate, random sampling program been applied at that time. The variability of the TRPH analysis in the initial landfarm soil sample could have been used to determine the number of samples required for the later sampling program.
- The sample collection and laboratory analysis should have been consistent throughout the pilot test or an explanation provided for the inconsistency in the data.

Implementation Considerations and Technology Limitations

- Adequate space for landfarming is required.
- Time is required for biotreatment. For example, it is slower than other treatment method, such as incineration.
- Soils must be excavated for landfarming to be used.

Future Technology Selection Considerations

- Both landfarming (above ground bioremediation) and *in situ* bioventing appear to have been successful at this site, but data, thus far, is not sufficient to make a judgment as to which process performed better.

SOURCES

Major Sources For Each Section

Site Characteristics:	1, 2, 6 and 7
Treatment System:	1 and 7
Performance:	1, 3, 4 and 5
Cost:	8
Regulatory/Institutional Issues:	1
Schedule:	1 and 8

Chronological List of Sources and Additional References

1. *Underground Storage Tanks Site Assessment Report and Corrective Action Plan*, Lowry Air Force Base, Denver, Colorado, prepared for Headquarters Air Training Command/DEV, Randolph AFB, Texas, and Armstrong Laboratory/OEB, Brooks AFB, Texas, prepared by Engineering-Science, Inc., May 1992.
2. *Underground Storage Tanks Site Assessment Report and Corrective Action Plan*, Appendices, Lowry Air Force Base, Denver, Colorado, prepared for Headquarters Air Training Command/DEV, Randolph AFB, Texas, and Armstrong Laboratory/OEB, Brooks AFB, Texas, prepared by Engineering-Science, Inc., June 1992.
3. *Quarterly Monitoring Report, Lowry Air Force Base*, Denver, Colorado, prepared for Headquarters Air Training Command/DEV, Randolph AFB, Texas, and Armstrong Laboratory/OEB, Brooks AFB, Texas, prepared by Engineering-Science, Inc., October 1992.
4. *Quarterly Monitoring Report-January 1993*, Lowry Air Force Base, Denver, Colorado, prepared for Headquarters Air Training Command/DEV, Randolph AFB, Texas, and Armstrong Laboratory/OEB, Brooks AFB, Texas, prepared by Engineering-Science, Inc., January 1993.
5. *Quarterly Monitoring Report-November 1993*, Lowry Air Force Base, Denver, Colorado, prepared for Headquarters Air Training Command/DEV, Randolph AFB, Texas, and Armstrong Laboratory/OEB, Brooks AFB, Texas, prepared by Engineering-Science, Inc., December 1993.
6. *RREL Treatability Data Base*, Version 4.0, EPA, November 15, 1991.
7. *Basics of Pump-and-Treat Ground-Water Remediation Technology*, EPA/600/8-90/003, Robert S. Kerr Environmental Research Laboratory, Ada, OK 74820, March, 1990.
8. *Personal Communication with Kent Friesen*, Engineering-Science, Inc., 1700 Broadway, Suite 900, Colorado 80290 (Phone, 303/ 831-8100).

ANALYSIS PREPARATION

This analysis was prepared by:

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REVIEW

Project Manager
This analysis accurately reflects the performance and costs of this remediation

X _____

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