COST AND PERFORMANCE REPORT

Solvent Extraction
at Sparrevohn Long Range Radar Station
Alaska

July 1998

Prepared by:
U.S. Army Corps of Engineers
Hazardous, Toxic, Radioactive Waste
Center of Expertise

SITE INFORMATION

IDENTIFYING INFORMATION

Site Name: Sparrevohn Long Range Radar Station (LRRS)
Location: Alaska (approximately 200 miles west of Anchorage)
Technology: Solvent Extraction
Type of Action: Indefinite Delivery Type Remedial Action (IDTRA)

TECHNOLOGY APPLICATION (1)

Period of Operation: Treatability study - 1995; Full-scale operation - June through August 1996
Quantity of Material Treated During Application: 288 cubic yards of soil

BACKGROUND

Site Background (1, 2):

- Sparrevohn LRRS, constructed in 1952, was one of ten Aircraft Control and Warning (AC&W) sites constructed as part of the air defense system in Alaska. The Air Force currently operates the site as a Minimally Attended Radar (MAR) facility staffed by four people.

- The site is located approximately 200 miles west of Anchorage in the Sparrevohn Mountains and is accessible only by air. The site consists of a lower camp (elevation 1,700 feet) that includes support facilities and an upper camp (elevation 3,300 feet) that houses radar equipment.

- In June 1986, soil sampling for polychlorinated biphenyls (PCBs) was conducted at the lower camp in the vicinity of a former transformer pad and drum dump, and field screening for PCBs was conducted at the upper camp. In 1986, Sparrevohn and other bases were beginning to investigate possible PCB contamination in soil, and the sampling was conducted for those efforts to identify potential environmental problems at the bases.

- The results of the laboratory analyses of soils from the lower camp showed concentrations of PCBs ranging from 0.1 to 11,358 milligrams per kilogram (mg/kg); the results of field screening of the upper camp showed contamination with PCBs at concentrations above levels of concern.

- PCB test kits were used in conducting field screening. A positive result indicated that PCBs were present at or above a level of concern. At the time the screening was conducted, field test kits typically identified concentrations of PCBs at levels higher than 10 to 50 mg/kg as positive results (that is, the detection level). Information on the specific detection level for the PCB test kits used at Sparrevohn was not available.

- In 1989 contaminated soil at the lower camp was excavated and shipped off site for disposal; contaminated soil at the upper camp was excavated and transported to the lower camp, where it was stockpiled in a lined, diked containment area.

- Approximately 450 tons of PCB-contaminated soil were removed from the containment area, overpacked, and shipped off site.

- An estimated 600 tons of stockpiled PCB-contaminated soil remained at the site. According to USACE, concentrations of PCBs in the stockpiled soil were estimated at 5 to 500 mg/kg, based on information in manifests for material shipped from the site. No direct sampling of stockpiled soil at the site was performed at that time.

SIC Code: 9711 (National Security)

Waste Management Practice that Contributed to Contamination: Transformer storage, transformer maintenance, and drum storage.

Remedy Selection (1, 2):

- Several remedies were considered for treating the stockpiled PCB-contaminated soil, including thermal desorption, solvent extraction, and soil washing. Solvent extraction was selected over the other technologies on the basis of cost-effectiveness and the logistics of mobilizing on site. For example, solvent extraction was determined to require less equipment and less logistical support — fuel, water, and electricity — than the other technologies. On-site thermal destruction was not feasible because of the high costs of the mobilization and operation of a unit and the relatively low volume of contaminated soil to be treated. In addition, there was a concern that the use of thermal desorption would require that the system perform under stringent conditions to prevent the formation of dioxins and furans. Further, solvent extraction was expected to be more effective than soil washing.

- In addition to considering other technologies such as thermal desorption, soil washing, and solvent extraction, off-site disposal at the Defense Reutilization and Marketing Office (DRMO) at Elmendorf AFB in Anchorage, Alaska was considered. The cost of solvent extraction was found to be less than that of off-site disposal at DRMO. Disposal at DRMO was estimated to cost $0.76 per pound (approximately $3,080 per cubic yard), plus costs for mobilization and demobilization, for a total of $1,908,545. The negotiated cost of solvent extraction was less than half the estimated cost for disposal at DRMO (see the discussion under "Treatment System Costs").

<u>SITE LOGISTICS/CONTACTS</u>

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MATRIX AND CONTAMINANT DESCRIPTION

MATRIX IDENTIFICATION

Soil (ex situ)

CONTAMINANT CHARACTERIZATION

Semivolatiles (halogenated) - PCBs (the specific PCB congeners or group of congeners was not identified.)

CONTAMINANT PROPERTIES

Property	PCBs
CAS No.	1336-36-3
Specific Gravity	1.3 to 1.8 at 60° F
Toxicity	High
Flammability	Low
Solubility	0.04 - 0.2 mg/L (in water @ 20° C)

NATURE AND EXTENT OF CONTAMINATION (1, 2)

- Only limited information is available about the nature and extent of contamination at Sparrevohn LRRS.

- Concentrations of PCBs in untreated stockpiled soil were measured as part of the treatability study. The results of eight composite samples showed PCB concentrations ranging form 13 to 346 mg/kg, with an average of 80 mg/kg.

MATRIX CHARACTERISTICS AFFECTING TREATMENT COST OR PERFORMANCE (1, 2)

- Listed below are the major matrix characteristics affecting cost or performance for this technology and the values measured for each parameter.

Parameter	Value
Soil Classification	Gravel with fines, GM or GP (based on observation)
Clay Content and/or Particle Size Distribution	Not quantified, but likely little or no clay
Hydraulic Conductivity/Water Permeability	Information not available
Contaminant Sorption/Soil Organic Content	Information not available
Lower Explosive Limit	Information not available
Presence of Emulsifying Agents	None
Moisture Content	9%

TREATMENT SYSTEM DESCRIPTION

PRIMARY TREATMENT TECHNOLOGY TYPES

Solvent extraction

SUPPLEMENTARY TREATMENT TECHNOLOGY TYPES

Post-treatment (solids): thermal destruction (residual solvent)

TREATMENT SYSTEM DESCRIPTION (1,3)

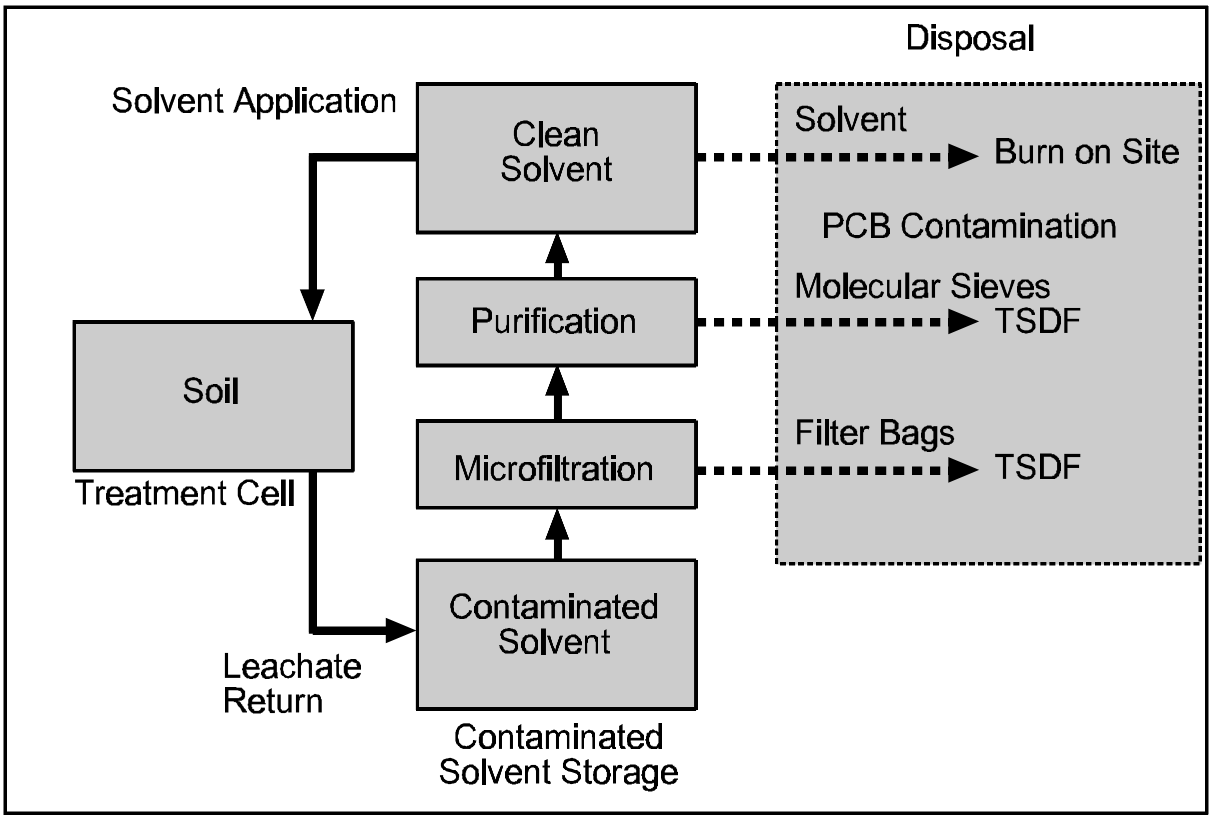

Figure 2. Process Flow Diagram (1)

Construction

- More than 200 tons of equipment and materials were mobilized to the site by air.

- Preliminary activities included construction of a contractor's camp, utilities, and cells for soil treatment and for clean and contaminated soil.

- The solvent extraction system used at Sparrevohn consisted of specially constructed soil treatment cells, storage cells for clean and contaminated solvent, solvent purification equipment (settling, 10-micron-bag filter, and molecular sieve purification stations), and associated process pumps and piping.

- The composition of the solvent used at Sparrevohn was proprietary business information, and was maintained by the treatment vendor. According to the contractor, the solvent is considered a non-hazardous and non-toxic substance.

- Soil treatment cells were constructed in the following steps: 1) the area of each cell was excavated to a depth of approximately two feet, 2) plywood sidewalls were erected on three sides of each cell, with one side left open to facilitate loading, 3) each cell's interior was lined with an impermeable membrane liner, 4) an underdrain system was installed to remove PCB-laden solvent, and 5) the cells were covered after loading to reduce evaporation of solvent and prevent rain from diluting the solvent.

- Five soil treatment cells were constructed, each with dimensions of 36 feet long, 16 feet wide, and 4 feet deep, a volume of approximately 85 cubic yards for each cell. Two additional cells of the same dimensions were constructed to store clean and contaminated solvent.

<u>Operation</u>

- The system operated in fill-and-drain mode. Contaminated soil was loaded into a soil treatment cell, and 3,000 to 4,000 gallons of clean solvent were pumped into the cell to immerse the soil in the solvent. Soil and solvent were held in the cell for one day to allow the PCBs to solubilize in the solvent.

- Contaminant-laden solvent was removed from the cells through the underdrain system, and transferred to the contaminated solvent cell. PCBs were removed from the solvent and concentrated in the molecular sieve medium, while cleaned solvent was collected in the clean solvent storage cell.

- The system treated the soil in batches, with each cell undergoing repeated cycles of fill and drain, until field screening, followed by confirmation sampling and laboratory analyses, showed that the concentration of PCBs in the soil was less than 15 mg/kg. Eight cycles of fill and drain were used for each soil treatment cell.

- At the conclusion of treatment, clean solvent was burned on site. The clean solvent was analyzed to determine that it contained concentrations of PCBs below 2 ppm, as required by the State.

- Solvent-consuming microbes and nutrients were added to the treated soil to promote biodegradation of residual solvent in the soil. According to the contractor, the solvent typically exhibited a half-life of approximately one or two days after such treatment.

OPERATING PARAMETERS AFFECTING TREATMENT COST OR PERFORMANCE (1)

Listed below are the major operating parameters affecting cost or performance for this technology and the values measured for each parameter.

Parameter	Value
Mixing Rate/Frequency	Not Applicable - Fill and drain operating mode
Moisture Content	9% (for all 5 treatment cells)
pH	Information not available
Pumping Time	Information not available
Residence Time/Number of Cycles	1 day/treatment cycle; 8 treatment cycles/batch
System Throughput	288 cubic yards in 5 batches
Temperature of Soil in Treatment Cells	Information not available
Additives and Dosage	Information not available

Closure

- Closure and site restoration activities included: dismantling the soil treatment cells (removing the roofs, puncturing the bottom liners, detaching the liners from the plywood sides, and removing the plywood sides); folding the liner edges over the top of the treated soil; adding a 12-millimeter liner on top of the treated soil; and placing clean soil (soil that had been excavated to construct the cells) over the liner to form a two-foot-thick cap. Remaining liner and piping were left in place with the treated soil. The closed cells were visible above grade as five smoothly graded, rectangular mounds. The molecular sieves and other project-derived wastes (that is, personal protective equipment (PPE) and liner material) were packed in drums and shipped off site for disposal at a facility approved by the U.S. Environmental Protection Agency (EPA). Molecular sieves were shipped to a treatment, storage, and disposal facility (TSDF) of Phillip Environmental and from there to Rollins Environmental for incineration. Additional PPE and stockpiled liner were turned in to the DRMO at Elmendorf Air Force Base for disposal. Solvent drums were crushed and sent to a metal recycler, and other debris were sent to a conventional municipal solid waste landfill in Anchorage, Alaska.

TREATMENT PLAN

- Planning and design of this project were conducted in the following three phases: 1) bench-scale treatability study of solvent extraction; 2) preparation of an engineering evaluation and cost analysis (EE/CA — see previous discussion under Remedy Selection), and 3) preparation of a delivery order (DO) to be issued to a previously selected IDTRA contractor for implementation of the selected remedy.

- The vendor of the solvent extraction process conducted the treatability study at the vendor's facilities, using a 5-gallon sample of PCB-contaminated soil.

- The study showed that concentrations of PCBs were reduced from 350 to less than 15 mg/kg through the application of seven cycles of fill and drain solvent extraction.

- The DO required that the contractor conduct sampling and testing (one sample per 50 cubic yards of soil before treatment); develop a work plan and other related plans; conduct treatment; and dispose of the stockpile of PCB-contaminated soil.

- The U.S. Army Corps of Engineers (USACE), Alaska District, the U.S. Air Force, and state regulators reviewed the plans. Major issues identified during the review included the nature of the solvent to be used, the confirmatory sampling protocol, and the method of disposal of the solvent at the completion of the project.

TIMELINE (1, 2)

Date	Activity
1952	Construction of Sparrevohn LRRS completed
June 1986	Soil sampling for PCBs conducted at lower and upper camps
1989 Construction Season	PCB-contaminated soils excavated at lower and upper camps, all soil from lower camp and some from upper camp shipped off site; and remaining soil from upper camp stockpiled on site
1995	Treatability study of solvent extraction process conducted
July 1995	Delivery order awarded
July 1995 to May 1996	Work plans prepared with approval in May 1996
May 28 to June 13, 1996	Materials and equipment mobilized to site
June 20 to August 12, 1996	Treatment, including confirmational sampling, conducted
August 12 to September 17, 1996	Closure and site restoration activities conducted

TREATMENT SYSTEM PERFORMANCE

PERFORMANCE OBJECTIVES (1, 2)

- A target cleanup level of 15 mg/kg for PCBs in soil was established for this application.

- The contractor was required to perform sampling of the soil at the surface (top) and the bottom of each treatment cell.

- Concentrations of PCBs in the clean solvent were required to be less than 2 mg/liter (mg/L) before the solvent could be burned on site.

TREATMENT PERFORMANCE DATA (1, 2)

- Table TPD-1 shows treatment performance data for each of the five soil treatment cells. Analyses were performed by both an immunoassay procedure and an analytical laboratory procedure (shown in Table TPD-1 as "composite"). The immunoassay procedure was used as a screening procedure to monitor the performance of the extraction system during operation. When screening data indicated that the soil had met the target cleanup level, additional samples were collected and shipped off site for analysis by the analytical laboratory procedure to confirm that the cleanup level had been met. The detection limit for the screening was 10 mg/kg, and for the analytical laboratory was 0.36 mg/kg (the detection limit for the analytical laboratory varied slightly from analysis to analysis).

- Samples of treated soil were collected from both the top and the bottom of each treatment cell for analyses by the off-site laboratory using EPA Method 8080 (3). Originally, the contractor had recommended that samples be collected only from the tops of the cells. However, because of concerns that the solvent might mobilize the PCBs and that the PCBs might concentrate at the bottoms of the treatment cells, samples were collected at both the tops and the bottoms of the treatment cells to confirm that the target cleanup level had been met at both locations.

Table TPD-1. Solvent Extraction Treatment Performance Data, Sparrevohn LRRS [1]

Parameter	Cell 1	Cell 2	Cell 3	Cell 4	Cell 5
PCB Concentration, mg/kg					
Untreated Soil (composite, average)*	80	80	80	80	80
Treated Soil (immunoassay procedure)	<10	<10	<10	<10	<10
Treated Soil (composite from top)	0.55	0.95	3.15	0.98	6.48
Treated Soil (composite from bottom)	0.68	0.99	2.19	8.84	7.88
Treated Soil (Average)			3.27		

* Concentration of 80 mg/kg in untreated soil, on the basis of average of results for eight individual composite samples, as follows: 346, 41, 13, 52, 59, 68, 40, and 28 mg/kg.

- PCBs were measured at levels below the detection limit (detection limit of 0.1 mg/L) in the regenerated (clean) solvent.

PERFORMANCE DATA ASSESSMENT

- The average concentration of PCBs was reduced from 80 mg/kg in untreated soil to 3.27 mg/kg in treated soil (96 percent reduction).

- The concentration of PCBs in treated soil was less than the soil target cleanup level (15 mg/kg) for all five treatment cells.

- The results of the immunoassay screening procedure indicated that the PCB concentrations in the treated soil had met the target cleanup level. The results of the screening were confirmed through off-site analysis which showed PCB concentrations in composite samples from both the top and the bottom of the treatment cells to be below the target cleanup levels.

- Samples were collected from both the top and the bottom of the treatment cells because of concerns that PCBs might concentrate at the bottom of the cells.

- The concentrations of PCBs in treated soil varied among the treatment cells by one order of magnitude (concentrations in composites from the tops of cells ranged from 0.55 to 6.48 mg/kg;

concentrations in composites from the bottoms of cells ranged from 0.68 to 8.84 mg/kg). This variation may be attributed to variations in the actual concentrations of PCBs in the untreated soil. While the average PCB concentration in untreated soil was 80 mg/kg, this was based on a composite of samples with PCB concentrations ranging from 13 mg/kg to 346 mg/kg.

- The concentration of PCBs in clean solvent was less than the concentration of 2 mg/L required by the state for burning the solvent on site. Therefore, spent solvent was burned in onsite burners and did not have to be transported off-site at the end of the application.

Material Balance: The concentration of PCBs in the soil before and after treatment and the weight of PCB extracted from the soil by the solvent and then accumulated in the molecular sieve are summarized below.

Media	Mass	PCB Concentration		Weight of PCB Transferred
		Before Treatment	After Treatment	
Soil	441,000 kg[1]	80 mg/kg	3.27 mg/kg	-33.8 kg
Molecular Sieve	4,772 kg	0 mg/kg	7,090 mg/kg[2]	+33.8 kg

Notes:
Residual solvent PCB concentration assumed to be 0 mg/kg for the purpose of material balance.
[1] Mass of soil based on 288 cubic yards at 125 pounds/cubic foot
[2] Concentration of PCBs in molecular sieve after treatment calculated as the weight of PCBs removed from the treated soil homogeneously distributed in the mass of the molecular sieve.

Removal Efficiencies: The PCB removal efficiency averaged 96 percent, on the basis of a comparison of an average concentration of PCBs in untreated soil of 80 mg/kg with an average concentration of PCBs in treated soil of 3.27 mg/kg.

PERFORMANCE DATA QUALITY (2)

- EPA Method 8080 was used by the laboratory to determine PCB concentrations in the soil and solvents

- The contractor wrote a SAP and a QAPP, which the USACE district, the Air Force, and the ADEC reviewed. Analytical data were reviewed internally by the district, and the USACE division laboratory wrote a chemical quality assurance report that validated the data. The report concluded that overall quality control was satisfactory.

TREATMENT SYSTEM COST

PROCUREMENT PROCESS

- The procurement was conducted under an indefinite delivery type remedial action contract. USACE solicited proposals for the contract, and the contractor was selected on the basis of technical qualifications to perform a variety of remedial actions that might be necessary. Only 8A contractors were evaluated for this contract.

- The contractor submitted a cost proposal for the project, which was issued as a delivery order (DO) against the contract. USACE required a minimum of three bids by any subcontractors in the contractor's proposal. In addition, in this case, USACE required that the contractor prepare a cost for shipment of contaminated soil to DRMO without treatment, for use in comparing costs. The contractor submitted its proposal for the work, and USACE negotiated a firm fixed-price contract for accomplishment of the work. The prime contractor had overall responsibility for the project, including the preparation of all project documents and subcontracting. The treatment subcontractor ran the treatment process and provided technical advice.

TREATMENT SYSTEM COST (1)

- Combination of mobilization and demobilization: $602,530
- Treatment - solvent extraction: $225,649
- The costs presented above are the negotiated costs for treatment (total of $828,179); they were compared with the costs of transfer to DRMO (total of $1,908,545, as discussed under the Treatment Plan section of this document).

COST SENSITIVITIES

- Because of its remote location, the site was accessible only by air. Therefore, transportation costs for both mobilization and demobilization were a major factor in the overall cost of the project.

- For mobilization, over 200 tons of equipment and materials were transported to the site by air.

- For demobilization, efforts were made to reduce the amount of material to be transported off site. For example, the technology achieved a reduction in mass of almost 100 to 1 (contaminants in 441,000 kg of soil transferred to 4,700 kg of molecular sieve) and excess solvent was incinerated on site rather than transported.

REGULATORY/INSTITUTIONAL ISSUES

- The project was managed by the Air Force (611th) under its Installation Restoration Program (IRP). The cleanup was negotiated with ADEC, and target cleanup levels were agreed upon mutually by the Air Force and ADEC. Contractor requirements were identified by examination of applicable codes, regulations, and guide specifications. Plans prepared by the contractor (work plan, SAP, QAPP, health and safety plan, and waste management plan) were reviewed by the USACE district, Air Force, and ADEC. (1,2)

OBSERVATIONS AND LESSONS LEARNED

COST OBSERVATIONS AND LESSONS LEARNED

- Solvent extraction of soil contaminated with PCBs at Sparrevohn LRRS cost $828,179 with a cost of $225,649 for activities directly attributed to treatment. This represents a unit cost of $780 per cubic yard of soil treated (288 cubic yards treated), for activities directly attributed to treatment.

- Because the location of the site was remote and the site was accessible only by air, the mobilization and demobilization costs of $602,530 were relatively high, compared with those costs for a similar operation in a more accessible location.
- Considering mobilization, demobilization, treatment, and disposal costs, solvent extraction was less than 50 percent as costly as off-site disposal through the DRMO (estimated at about $1.9 million).
- On-site thermal destruction of the clean solvent reduced the costs of the demobilization as the solvent did not have to be transported off site.

PERFORMANCE OBSERVATIONS AND LESSONS LEARNED

- Within a three month period (one construction season in Alaska), the solvent extraction system at Sparrevohn reduced the concentration of PCBs to less than the soil target cleanup level of 15 mg/kg for all five treatment cells.
- Solvent extraction reduced the average concentration of PCBs from 80 mg/kg in untreated soil to 3.27 mg/kg in treated soil, representing a 96 percent overall reduction.
- The immunoassay screening procedures used at Sparrevohn indicated that target cleanup goals had been met in the treated soil. In all five cases where the screening procedure indicated that the goals had been met, this was confirmed in the analyses performed by the off-site laboratory.
- A requirement to sample both the top and bottom of the treatment cells was added because of concerns that PCBs would concentrate at the bottom of the cells in this type of application.
- The solvent regeneration system used at Sparrevohn reduced PCB concentrations in the clean solvent to below detectable levels, thereby meeting the requirement for burning the clean solvent on site (below 2 mg/L). Because solvents could be burned on site, no solvent had to be transported off the site as part of the demobilization activities.

OTHER OBSERVATIONS AND LESSONS LEARNED

- The following additional observations and lessons learned were provided by the USACE project manager:
    - The performance of the solvent extraction technology is limited by fines, moisture, and organic content:
        - Treatment of contaminated soils having more than 15 percent clays or fines or high organic content is difficult because contaminants are strongly sorbed to the soil particles (soil particles also form tight aggregates that are difficult to break up).
        - Soils containing more than 20 percent moisture must be dried before treatment (excess water dilutes the solvent, reducing the solubility of the contaminant and transport efficiency).
        - Solvent extraction suppliers require a particle size analysis and information about moisture content, organic content, contaminant identification and concentration, and the target cleanup level to determine the number of wash cycles required and to estimate the cost of treatment.

- The treatment vendor indicated that the solvent extraction technology could be limited by soil moisture content. If the moisture content of treated soils exceeded 20 percent, a solvent dehydration unit would be required to recover or recycle the solvent.

- Solvent extraction vendors recommend a bench-scale treatability test to support the cost estimate.

- The process was flexible and rapid enough to allow additional soil to be treated midway through the project without delaying completion. For example, because of an error in measuring the stockpile of soil, an additional cell (approximately 50 cubic yards) was constructed midway through the project in treating the soil.

REFERENCES

1. Gagnon, Bernard T., P.E. Not dated. Solvent Extraction Treatment of PCB Contaminated Soil at Sparrevohn Long Range Radar Site, Alaska.

2. Gagnon, Bernard T., P.E. 1997. USACE - Alaska District, Comments and Responses on Pre-draft Report. December 2.

3. Berman, Michael H. 1998. Record of Telephone Conversation with Bernard Gagnon. June 19.

ACKNOWLEDGMENTS

This report was prepared for the U.S. Army Corps of Engineers under USACE Contract No. DACA45-96-D-0016, Delivery Order No. 12. Assistance was provided by Tetra Tech EM Inc. and Radian International LLC.