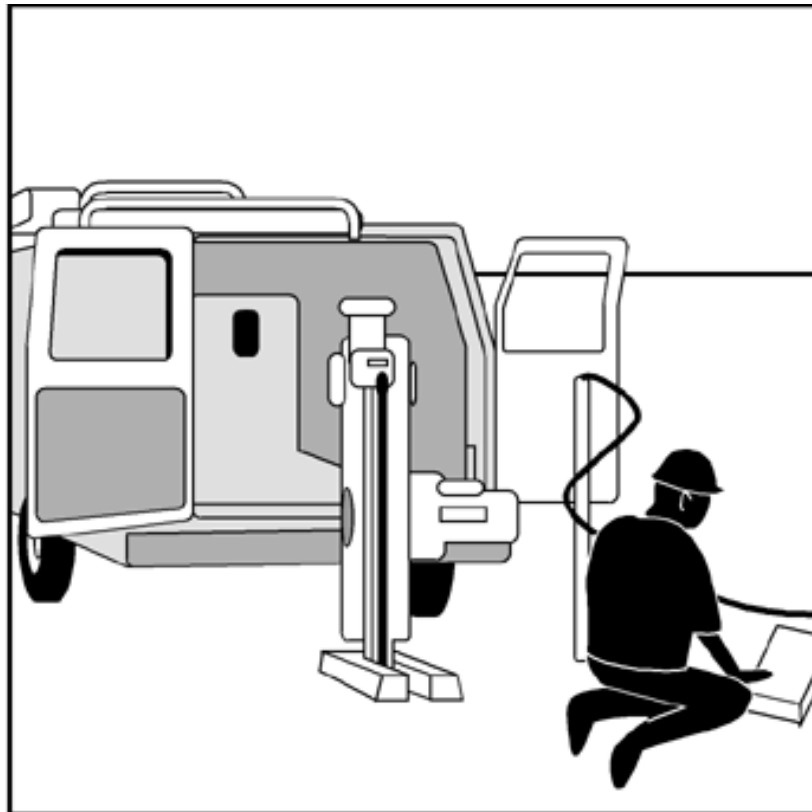




Innovations in Site Characterization

Case Study: Hanscom Air Force Base, Operable Unit 1 (Sites 1, 2, and 3)



Innovations in Site Characterization
Case Study: Hanscom Air Force Base
Operable Unit 1 (Sites 1, 2, and 3)

U.S. Environmental Protection Agency
Office of Solid Waste and Emergency Response
Technology Innovation Office
Washington, D.C. 20460

Notice

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Comments or questions about this report may be directed to the United States Environmental Protection Agency, Technology Innovation Office (5102G), 401 M Street, SW, Washington, D.C. 20460; telephone (703) 603-9910.

Foreword

This case study is the first in a series designed to provide cost and performance information for innovative tools that support less costly and more representative site characterization. These case studies will include reports on new technologies as well as novel applications of familiar tools or processes. They are prepared to offer operational experience and to further disseminate information about ways to improve the efficiency of data collection at hazardous waste sites. The ultimate goal is enhancing the cost-effectiveness and defensibility of decisions regarding the disposition of hazardous waste sites.

Acknowledgments

This document was prepared for the United States Environmental Protection Agency's (EPA) Technology Innovation Office. Special acknowledgment is given to EPA Region 1 (the Office of Site Remediation and Restoration and the New England Regional Laboratory), Tufts University (Center for Field Analytical Studies and Technology), and the staff of Hanscom Air Force Base for their thoughtful suggestions and support in preparing this case study.

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Case Study Abstract

Hanscom Air Force Base Middlesex County, Massachusetts

<p>Site Name and Location: Hanscom Air Force Base Middlesex County, Massachusetts</p>	<p>Sampling & Analytical Technologies: 1. Geoprobe; 2. Bruker Thermal Desorption Probe Head on Gas Chromatography/Mass Spectrometer (Bruker TDGC/MS); 3. Tekmar Purge and Trap Concentrator with Hewlett-Packard GC/MS;</p>	<p>CERCLIS # MA8570024424</p>
<p>Period of Operation: 1941 - 1973 Supported fighter aircraft operations and maintenance; Air Force Research & Development</p> <p>Operable Unit: #01 (Site 1 - Fire Training Area II; Site 2 & 3 - Paint Waste Areas)</p>	<p>4. Ion Signature Technology's Thermal Desorber with Hewlett-Packard GC/MS (Tufts TDGC/MS); 5. Ion Signature Technology's Ion Fingerprint Detection (IFD) Software 6. Field-rugged Inductively Coupled Plasma/Optical Emission Spectrometer (ICP/OES)</p>	<p>Current Site Activities: RI/FS complete, ground water pump and treat operational May 1991, total flow 300 GPM. Focused Feasibility Study.</p>
<p>Point of Contact: Robert Lim US EPA - Region 1 J. F. Kennedy Federal Building Boston, MA 02203-2211 (617) 223-5521 http://clu-in.com/hanscom.htm.</p>	<p>Media and Contaminants: Groundwater and soils at Hanscom Air Force Base are contaminated with chlorinated and aromatic solvents, metals, and petroleum compounds.</p>	<p>Technology Demonstrator: Tufts University, Chemistry Dept. Center for Field Analytical Studies & Technology Medford, Massachusetts 02155 (617) 627-3474</p>
<p>Number of Samples Analyzed during Investigation: A 10-day Adaptive Sampling and Analysis Program produced the following: 601 soil samples screened for volatile organic compounds (VOC) (<1 min/analysis); 158 soil samples for quantitative analysis for VOCs (15 min/analysis); 69 soil samples for simultaneous quantitative analysis of polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs); 121 quantitative soil samples for metals (8 min/analysis after microwave sample digestion).</p>		
<p>Cost Savings: The cost savings using this approach are estimated at 50% over traditional methods.</p>		
<p>Results: Field analytical methods can provide quantitative data to support remedial decisions for contaminated soil. The assessment of contaminated soil was completed in two weeks using an Adaptive Sampling and Analysis Strategy.</p>		
<p>Description: As part of EPA's Environmental Technology Initiative (ETI), Tufts University conducted a demonstration of the ability of field analytical methods to produce data of sufficient quality to support a risk assessment. The specific risk scenario was soil contamination migration to ground water. Action limits were set at the 20 Dilution-Attenuation Factor (DAF) from EPA's Soil Screening Levels. Over a two week period, subsurface soil cores and samples were collected using a Geoprobe. Soil samples were screened with the Bruker Thermal Desorption GC/MS at an average rate of 75 samples/day. Quantitative VOC analyses were performed using conventional (Tekmar) Purge & Trap GC/MS in conjunction with Tufts-developed IFD software to speed processing of the MS signal and data analysis. After extraction, simultaneous quantitative PAH/PCB analyses were performed by Tufts-developed Thermal Desorber GC/MS and IFD data analysis producing data with only a 10-minute run time. Finally, fixed-lab quality data for metals was produced in the field by the use of batched microwave digestion and a field-adapted ICP/OES.</p>		

TECHNOLOGY QUICK REFERENCE SHEET

Case Study Name: Hanscom Air Force Base, Sites 1, 2, and 3

Technology: Geoprobe®			
Summary of Case Study's Performance Information			
Project Role: Collect soil borings		Cost/Performance Information: \$16,500 for 8 days. During that time 61 pushes (1016 linear feet) were made, and 601 screening samples (soils) were collected.	
Total Cost: \$16,500 (subcontracted)			
Project Cost Breakdown			
Instrument Cost: Included in subcontract	Consumables Cost: Disposable cellulose sleeves: \$1 per foot	Labor Cost: Included in subcontract	Waste Disposal Cost: Information not available
Site-Specific Performance Observed: 1016 linear feet collected. Performance generally satisfactory. Due to the sandy nature of the soil, soil samples could not be retained within Geoprobe sleeve when collection of soil from below the water table was attempted. At Site 1, the geology limited the sampling depth to 15-20 feet because the Geoprobe was unable to push through the till layer to reach bedrock. Subsurface materials in others areas consisted of sandy fill material and no hindrance was found in those areas. A total of 61 pushes were performed.			
General Commercial Information (Information valid as of August 1998)			
Vendor Contact: 1-800-GEOPROBE www.geoprobeystem.com	Vendor Information: Geoprobe® Systems 601 N. Broadway Salina, KS 67401	Limitations on Performance: Bedrock drilling; vehicle access to site; and depths >100ft. [Information provided by vendor]	
Availability/Rates: Rent \$1,000 to \$2,000/day	Principle of Operation: Direct push soil probing equipment		Power Requirements: Vehicle or auxiliary engine
General Performance Information			
Rate of Throughput: push up to 200 ft/day		Known or Potential Interferences: Bedrock	
Applicable Media/Matrices: Soil, ground water, and soil gas sampling	Analytes Measurable with Commonly Achieved Detection Limit Ranges: Depends on the specific probe or accessory used	Other General Accuracy/Precision Information: Depends on the specific probe or accessory used	
Wastes Generated Requiring Special Disposal: Limited soil cuttings			

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TECHNOLOGY QUICK REFERENCE SHEET

Case Study Name: Hanscom Air Force Base, Sites 1, 2, and 3

Technology: Bruker Thermal Desorption Probe Head on Gas Chromatograph/Mass Spectrometer (TDGC/MS)			
Summary of Case Study's Performance Information			
Project Role: Screen for VOCs using direct measuring mode. Detections flagged screening interval for quantitative analysis.		Analytical Information Provided: Positive or negative screening result for VOCs.	
Total Cost: Estimated as 601 screening samples x \$33 = \$19,833		Cost Per Sample: Estimated at \$33 per screening result.	
Project Cost Breakdown			
Instrument Cost: 3 week rental-\$12,500/3 weeks (incl. GC/MS)	Consumables Cost: Information not available	Labor Cost: Information not available	Waste Disposal Cost: Information not available
Site-Specific Accuracy/Precision Achieved: Since this technology was used as a screening device, typical precision and accuracy evaluations were not performed. However, the use of a daily standard ensured sensitivity to 10 ppb for 11 target VOC compounds. Additionally, comparison of the screening results from this instrument with confirmatory quantitative analyses found 90% agreement, 4% false positives, and 6% false negatives when results were compared at the 10DAF quantitation limit (which was 1/2 of the 20DAF action level).			Throughput Achieved: Less than 1 minute/screening sample; 75 samples/day; 601 samples total. Turn-around time: results available immediately
General Commercial Information (Information valid as of August 1998)			
Vendor Contact: 978-667-9580 www.bruker.com	Vendor Information: Bruker Analytical Systems, Inc. 19 Fortune Drive Manning Park Billerica, MA 01821	Limitations on Performance: Maximum temperature 240°C with air, 300°C with nitrogen. Extremely polar molecules cannot be analyzed with the same sensitivity.	
Availability/Rates: \$185,000 purchase price	Principle of Operation: Used for rapid screening of Geoprobe cores for VOCs. TD probe head placed over small access holes cut into the cellulose sleeves at 1-ft. intervals. Soil under the probe head is heated and VOCs are swept into the GC/MS for analysis in the SIM mode.	Instrument Weight and/or Footprint: 65 kg 750 x 450 x 350 mm	
Power Requirements: 500 W			
General Performance Information			
Known or Potential Interferences: Excessive water vapor or high levels of contamination			
Applicable Media/Matrices: Soil gas and soil	Analytes Measurable with Expected Detection Limits or Other Analytical Performance Information: VOCs (ppb range), SVOCs (variable detection range)	Other General Accuracy/Precision Information: Accuracy consistent within 30% of the reference concentrations; precision (as determined by RPD on duplicate samples) less than 30% [Information supplied by vendor]	
Wastes Generated Requiring Special Disposal: None			

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TECHNOLOGY QUICK REFERENCE SHEET

Case Study Name: Hanscom Air Force Base, Sites 1, 2, and 3

Technology: Tekmar 3000 Purge and Trap Concentrator (with Hewlett-Packard 5890 II/ 5972 GC/MS)			
Summary of Case Study's Performance Information			
Project Role: Quantitative analysis of VOCs		Analytical Information Provided: 18 VOC analytes quantitated.	
Total Cost: Estimated as 158 samples x \$100 = \$15,800		Cost Per Sample: Estimated at \$100 per sample.	
Project Cost Breakdown			
Instrument Cost: Rental- \$2,700 for 3 weeks	Consumables Cost: Information not available	Labor Cost: Included in cost per sample (above)	Waste Disposal Cost: Information not available
Site-Specific Accuracy/Precision Achieved: Precision was to be evaluated by replicate analysis of 8 site soil samples, however, the samples selected for replicate analysis had very low concentrations of target compounds. Accuracy was assessed by the recovery of 2 surrogate compounds added to each sample. The average recovery (for both surrogate compounds and over 158 samples) was 132%. 82% of surrogate recoveries fell between 30-200%.			Throughput Achieved: 15-20 minutes/sample; 158 samples total. Turn-around time: results available by or before the next day
General Commercial Information (Information valid as of August 1998)			
Vendor Contact: 800-543-4461 www.tekmar.com	Vendor Information: Tekmar-Dohrmann P.O. Box 429576 Cincinnati, OH 45249	Limitations on Performance: Performs in temperatures up to an environmental temperature of 40°C; sample temperature of 200°C; humidity 10-90%	
Availability/Rates: Purchase P&T-- approx. \$12,000, including software & installation	Principle of Operation: Purges volatiles from water or soil onto a sorbent trap which is then heated and the analytes are swept into the GC column.	Power Requirements: 500 W	Instrument Weight and/or Footprint: Purge and Trap - 37 lbs.
General Performance Information			
Known or Potential Interferences: Excessive water vapor (moisture control system set up in instrument)			
Applicable Media/Matrices: Water and soil	Analytes Measurable with Expected Detection Limits or Other Analytical Performance Information: VOCs (ppb range) SVOCs (variable detection range: low molecular weight compounds are more likely to be volatilized than high molecular weight compounds) Turn-around time: results available immediately	Other General Accuracy/Precision Information: Not available	
		Wastes Generated Requiring Special Disposal: Depends on sample; some semi-volatiles may remain in sample and require special disposal procedures	

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TECHNOLOGY QUICK REFERENCE SHEET

Case Study Name: **Hanscom Air Force Base, Sites 1, 2, and 3**

Technology: Thermal Desorber with Hewlett-Packard Gas Chromatography/Mass Spectrometry (TDGC/MS)			
Summary of Case Study's Performance Information			
Project Role: Quantitative analysis of PAH/PCBs	Analytical Information Provided: 22 analytes: 16 PAHs (6 as PAH pairs) + 9 PCB chlorination levels (summed to estimate the sample's total PCB concentration).		
Total Cost: Estimated as 69 samples x \$100 = \$6,900		Cost Per Sample: Estimated at \$100 per sample.	
Project Cost Breakdown			
Instrument Cost: Information not available	Consumables Cost: Information not available	Labor Cost: Included in cost per sample	Waste Disposal Cost: Information not available
Site-Specific Accuracy/Precision Achieved: Because there were few detections of PAH/PCBs in site samples, precision was estimated from the initial (ICV) and continuing calibration verifications (CCV): A total of 8 ICVs & CCVs were run. Of the 176 analytical results (8 runs X 22 analytes per run), 80% had %D ≤ 30%, 14% between 30-40% and 6% had %D > 40%. Accuracy was assessed by the recovery of a surrogate compound added to each sample. The average recovery over 69 samples was 94%, and 92% of the surrogate recoveries fell between 30-200%.			Throughput Achieved: Sample prep time: 1 hr/batch of 20 samples; Analysis time: 10 minute/sample; 69 samples total analyzed
General Commercial Information (Information valid as of August 1998)			
Vendor Contact: Tel: 617-876-0333 Fax: 617-876-0777 ygankin@ionsigtech.com	Vendor Information: Dr. Yuriy Gankin Ion Signature Technology, Inc. P.O. Box 636 Cambridge, MA 02238	Limitations on Performance: GC: 0-55°C; 5-95% humidity; Carrier gas, minimum purity of 99.9995% MS: 15-35°C; Humidity (non-condensing) 25-50% RH	
Availability/Rates: Purchase Thermal Desorber - \$15,000	Principle of Analytical Operation: Ballistic heating allows for a large volume injection of sample (1 to 1000µl) or for thermal desorption of a sorbent trap.	Power Requirements: GC - 120/200V, 220/240V; 47.5-66 Hz MS - 99-127V or 198-254V; 48-66 Hz	Instrument Weight and/or Footprint: GC/MS - 133 lbs, 46.5cm x 77cm x 66cm; the Thermal Desorber sits inside the GC injection port
General Performance Information			
Known or Potential Interferences: moisture, oxygen (traps recommended)			
Applicable Media/Matrices: Soil, Soil gas, Water	Analytes Measurable with Expected Detection Limits: VOCs and SVOCs (ppb range); Turn-around time: results available by or before the next day	Other General Accuracy/Precision Information: High concentrations: RPD<60%; Low concentrations: RPD<100%	
Wastes Generated Requiring Special Disposal: None	Rate of Throughput: 10 minutes/sample for quantitative results; less time for screening result		

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TECHNOLOGY QUICK REFERENCE SHEET

Case Study Name: Hanscom Air Force Base, Sites 1, 2, and 3

Technology: Inductively Coupled Plasma/Optical Emission Spectrometer (ICP/OES)			
Summary of Case Study's Performance Information			
Project Role: Quantitative analysis of Cd and Pb; sample preparation performed by microwave digestion		Analytical Information Provided: 22 inorganic analytes quantitated. Cd and Pb were the only target inorganic analytes for the project; the other 20 analytes were coincidental.	
Total Cost: Estimated as 121 samples x \$275 = \$33,275		Cost Per Sample: Estimated at \$275 per sample.	
Project Cost Breakdown			
Instrument Cost: Information not available	Consumables Cost: \$3,000	Labor Cost: Included in cost per sample (above)	Waste Disposal Cost: Information not available
Site-Specific Accuracy/Precision Achieved: Precision was evaluated by triplicate analysis of 9 site soil samples. 89% of target analyte detections had RSDs less than 30%. 88% of all analyte detections in the 9 replicates had RSDs less than 30%. Accuracy was assessed by laboratory control standards, which were run a total of 21 times. All target analyte recoveries fell within 80-120% of the certified values for the standards.		Throughput Achieved: Sample prep time: 1.5 hr/batch of 20 samples; Analysis time: 8 min/ sample; 121 samples total Turn-around time: results available by or before the next day	
General Commercial Information (Information valid as of August 1998)			
Vendor Contact: 603-886-8400 www.leemanlabs.com	Vendor Information: Leeman Labs 6 Wentworth Drive Hudson, NH 03051	Limitations on Performance: Environmental temperature 60-86F°; Humidity 20-80% (non-condensing); Argon gas should be 99.995% pure; 80-90 psi	
Principle of Operation: Sample is nebulized and heated by the plasma. The excited atoms and ions produce line spectra.	Power Requirements: ICP/OES 110 V, 20 amp; 240 V, 30 amp Water circulator 115V, 15 amp, 60 Hz	Instrument Weight and/or Footprint: ICP/OES: 375 lbs, 54x30x35 (in.) Power supply: 175 lbs, 18 cu. in. Water circulator: 50 lbs, 22x12x22 (in.)	
Known or Potential Interferences: Excessive water vapor			
Applicable Media/Matrices: Water and soil	Analytes Measurable with Expected Detection Limits or Other Analytical Performance Information: Inorganics (ppb to ppm range, depending on the analyte and sample preparation method)		Other General Accuracy/Precision Information: Not available
Wastes Generated Requiring Special Disposal: Depends on sample composition and TCLP results of waste analysis		Rate of Throughput: Depends on how many metals analyzed, and if autosampler is used	

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TECHNOLOGY QUICK REFERENCE SHEET

Case Study Name: **Hanscom Air Force Base, Sites 1, 2, and 3**

Technology: Ion Fingerprint Detection (IFD)TM Software			
Summary of Case Study's Performance Information			
Project Role: Supports component identification in MS analysis		Cost Per Sample: Use of the software reduced GC/MS run times by a factor of 2-4, which increased sample throughput, and thus decreased both direct costs (e.g., labor) and indirect costs (by decreasing turn-around time of results within the context of a dynamic workplan).	
Project Cost: \$20,000 for 2 weeks usage (labor included)			
<p>Site-Specific Accuracy/Precision Achieved: The performance of the IFD software was compared with the data processing software typically supplied with an HP GC/MS system. Of the 158 VOC samples analyzed, 4 samples required re-analysis by IFD to resolve interference or linearity issues, compared to 25 re-analyses required using the traditional software package.</p> <p>The GC/MS total ion current chromatograms from 205 detections of organic compounds were processed by both software systems. For each detection, the quantitative results computed by each software system were compared by calculating the difference between the 2 results. Of the 205 detections, 85% had RPDs \leq 50% and 65% had RPDs \leq 20%.</p> <p>Internal standard data can also be used to assess software performance. The internal standard signal was within the \pm50% difference acceptance range 85% of the time for the IFD software, compared to 78% for the other software.</p>			<p>Throughput Achieved: Quantitative organic analysis by GC/MS performed with run times of 10 minutes/sample.</p>
General Commercial Information (Information valid as of August 1998)			
<p>Vendor Contact: Tel: 617-876-0333 Fax: 617-876-0777 ygankin@ionsigtech.com</p>	<p>Vendor Information: Dr. Yuriy Gankin Ion Signature Technology, Inc. P.O. Box 636 Cambridge, MA 02238</p>	<p>Limitations on Performance: None specified</p>	<p>Rate of Throughput: 10 minutes GC run time for quantitative results; less time for screening results</p>
<p>Availability/Rates: \$10,000 per copy (1-4 copies) \$7,500 per copy (>4 copies)</p>	<p>Principle of Analytical Operation: Complete data analysis system for mass spectrometers, with complete report writing capability. The software uses mathematical algorithms to identify target compounds by deconvoluting their ion signals from non-uniform background interference signals contributed to the total ion current. IFD accurately identifies and quantifies target compounds in the presence of high levels of interferences and with minimal chromatographic separation.</p>		
Software Performance Information			
<p>The IFD software is capable of identifying low concentrations of target analytes in the presence of high levels of matrix interferences. By "seeing through" the matrix interferences, the software reduces the need for sample re-analysis and dilution, and increases confidence in surrogate, internal standard, and target compound identification and quantification.</p>			

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EXECUTIVE SUMMARY

Field analytical instrumentation and methods were used to support a site characterization study at the Airfield at Hanscom Air Force Base (HAFB) Operable Unit 1. HAFB is located in Middlesex County, Massachusetts, and occupies land in the towns of Bedford, Concord, Lexington, and Lincoln. U.S. Air Force military operations began in 1941 and continued through 1973. With the cessation of military flying activities in 1973, the airfield and the surrounding land was given to the Massachusetts Port Authority (MASSPORT), which currently operates a civilian airport as L.G. Hanscom Field. The U.S. Air Force continues to occupy 396 acres and operates the Electronic Systems Division of the Air Force Systems Command at HAFB.

As part of EPA's Environmental Technology Initiative (ETI), a demonstration of a dynamic site investigation using an Adaptive Sampling and Analysis Program was utilized at HAFB for Operable Unit 1. The goal of the HAFB investigation was to demonstrate the ability of field analytical methods to produce data of sufficient quality to support remedial decisions. The specific project objectives used the EPA Soil Screening Level action limits to determine if residual soil contamination posed a risk via the soil to ground water pathway [5]. The HAFB investigation relied on data produced in the field to make decisions as to the location of samples collected and the types of analysis performed. When compared with the traditional site characterization process, the dynamic workplan/adaptive sampling and analysis program for HAFB resulted in a faster and cheaper site investigation. The adaptive sampling and analysis program provided information on a "real-time" basis to support on-site decision making. The field methods were "performance based" and provided data of sufficient quality to achieve site-specific data quality objectives (DQOs), with sample analysis rates that supported the dynamic site investigation process.

Innovative sampling and analytical technologies used at HAFB include Geoprobe; Bruker Thermal Desorption Gas Chromatography/Mass Spectrometry (TDGC/MS); Tekmar Purge and Trap with a Hewlett-Packard (HP) GC/MS; a Tufts designed thermal desorber inlet and HP GC/MS (TDGC/MS); and Ion Fingerprint Detection (IFD) software, as well as an on-site laboratory field rugged ICP/OES. During the HAFB investigation, an average of 75 soil samples per day were screened for volatile organic compounds (VOCs) by the Bruker TDGC/MS. In a two-week period, a total of 601 samples were analyzed. Quantitative VOC analysis of 158 soil samples by the Tekmar purge and trap GC/MS was made to confirm the screening results and to delineate the extent of contamination. Quantitative analyses of 69 soil samples for polychlorinated biphenyls (PCBs) and polycyclic aromatic hydrocarbons (PAHs) were performed by the Tufts TDGC/MS and 121 soil samples for metals were performed by the ICP/OES.

Some important observations and lessons learned during the project were the following:

Field analytical methods employing performance-based methods can produce data of equal quality to commercial laboratories employing standardized EPA methods, can support a dynamic workplan/adaptive sampling and analysis program, and can support cleanup verification programs.

Cost effectiveness is maximized when site DQOs, analytical throughput rates, data turnaround times, sample collection rates, and sample analysis costs are evaluated and optimized to meet the site-specific scientific and engineering questions under investigation prior to the beginning of the field work. TDGC/MS and the mass spectrometry data analysis algorithms allow PCB/PAH analyses to be performed at the same time without the need for sample cleanup and fractionation time. Analytical run times can be reduced from 40 minutes to 10 minutes.

DQOs were met for all target compounds except vinyl chloride. Trade-offs may need to be considered

EXECUTIVE SUMMARY

between achieving low limits of detection for VOC gaseous compounds and meeting DQOs for all other (less volatile) VOC target compounds.

A full copy of the report on which this case study is based, “A Dynamic Site Investigation Adaptive Sampling and Analysis Program for Operable Unit 1 at Hanscom Air Force Base Bedford, Massachusetts” can be downloaded off of the Internet at <http://clu-in.com/hanscom.htm>.

SITE INFORMATION**Identifying Information**

Hanscom Air Force Base (HAFB)
Middlesex County, Massachusetts
Operable Unit: 1 (Sites 1, 2, and 3)
CERCLIS #: MA8570024424
Action Memorandum Date: 8/2/96
ROD Date: N/A

Background [1]

Physical Description: The HAFB site is located in eastern Massachusetts in the towns of Bedford, Concord, Lexington, and Lincoln, see Figure 1. HAFB is approximately fourteen miles northwest of downtown Boston. Although HAFB covers a total of 396 acres, the combined areas of interest in this study total only 20 acres. Operable Unit 1 consists of three sites: Site 1 is situated on the side of a hill, that falls rapidly toward the southeast where the land levels off. Site 2 is located approximately 2,000 feet to the southeast of Site 1, and is situated in a level plain area. Site 3 is located approximately 4,000 feet to the southwest of Sites 1 and 2, and is situated in the same plain as Site 2.

Site Use: From 1941 to 1973 HAFB's primary mission was the support of fighter aircraft operations and maintenance and the support of Air Force Research and Development (R&D). Thereafter, HAFB no longer provided fighter aircraft maintenance and began to support Air Force Command, Control, Communications, and Intelligence activities. The State of Massachusetts obtained control of the airfield in 1974 and renamed it the L.G. Hanscom Field. The airfield is currently operated by the Massachusetts Port Authority (MASSPORT) as a civilian airport. Except for the airfield, the remainder of the base was retained by the Air Force.

Release/Investigation History: Site 1 was used as a fire training area where waste oils, flammables, aircraft wreckage, and fuselages were burned. Sites 2 and 3 are areas where 50-gallon drums containing waste solvents, fuels, and paints were buried. Hazardous waste site investigations for Operable Unit 1 (Sites 1, 2, and 3) began at Hanscom Field in 1982, see Figure 2. In 1987 and 1988, HAFB undertook a removal action that excavated visibly contaminated soils and removed drums from the sites. Approximately 4100 tons of contaminated soil and more than 300 drums were removed from the three sites and sent to an off-site landfill.

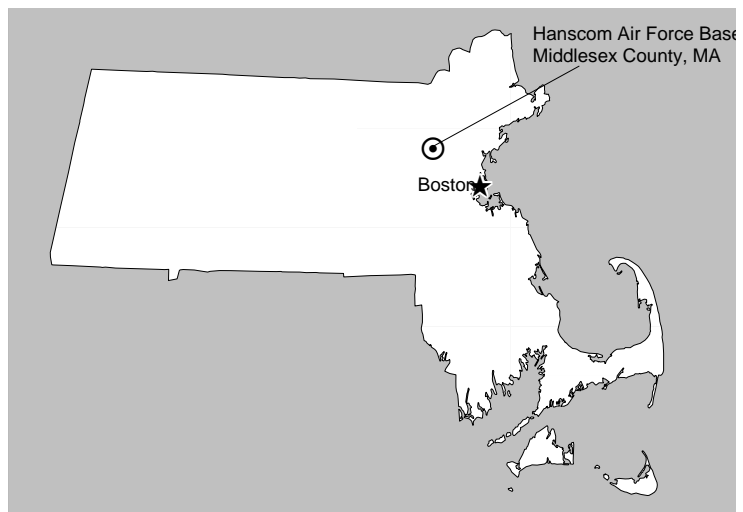


Figure 1: Site Location

Regulatory Context: HAFB and L.G. Hanscom Field were added to the National Priorities List in 1994. A Human Health and Ecological Risk Assessment and Feasibility Study for the airfield is in

SITE INFORMATION

progress.

Site Logistics/Contacts

Federal Lead Agency: U.S. Air Force

Federal Oversight Agency: EPA

Remedial Project Manager:

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 US EPA - Region 1
 J.F. Kennedy Federal Building
 Boston, MA 02203-2211
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 (781) 377-4495

MEDIA AND CONTAMINANTS

Matrix Identification [1]

Type of Matrix Sampled and Analyzed: Subsurface soil

Site Geology/Stratigraphy [2]

Much of HAFB Airfield is built on man-made fill, and Sites 2 and 3 have been converted into recharge pits for the ground water treatment system. The natural geologic setting includes approximately seven feet of sandy fill overlying the topsoil and natural peat deposits that are laterally discontinuous at the west end of the Airfield. North of Pine Hill, five to six feet of sand and silt fill overlies glacial fill. Similar conditions were revealed east of Hartwell's hill, where three feet of fill overlie swamp material. The fill material present in the area of the base consists primarily of natural sand and silt.

Contaminant Characterization [1]

Primary Contaminant Groups: The primary contaminant groups at HAFB are volatile organic compounds (VOCs), polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs), and metals.

Matrix Characteristics Affecting Characterization Cost or Performance

None

MEDIA AND CONTAMINANTS

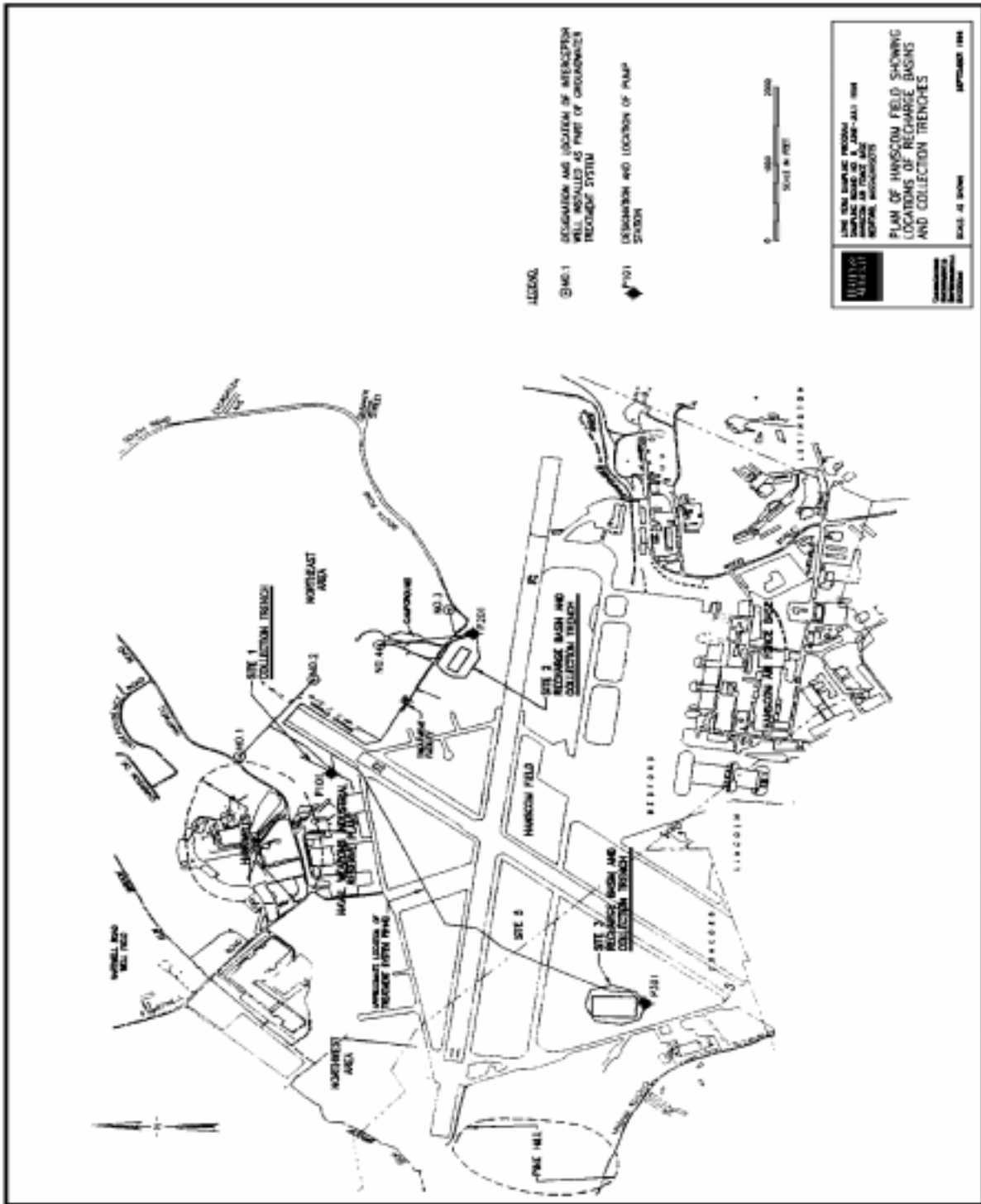


Figure 2: Hanscom Field Sites

SITE CHARACTERIZATION PROCESS**Goal of Site Characterization [1, 3, 4]**

The goal of the Environmental Technology Initiative (ETI) project at HAFB was to demonstrate the capability of field analytical technologies in the context of producing data of sufficient quality to support remedial decisions in a cost-effective manner in the vadose zone at Sites 1, 2 and 3. The specific risk scenario was the threat of ground water contamination via the soil to ground water pathway. The action levels were set at the 20 Dilution Attenuation Factor (DAF) from EPA's Soil Screening Levels [5].

Dynamic Workplan – Adaptive Sampling Strategy [1]

The sampling and analysis program at HAFB was based on a dynamic workplan in which the program itself relied on field analytical instrumentation and methods to generate on-site information on the nature, extent, concentration, and rate of movement of the contamination present at the site. Rather than dictate the details of the sample analyses to be performed, the numbers of samples to be collected, and the location of each sample in the sampling plan, the dynamic workplan specified an initial set of sampling locations at which samples would be collected and analyzed using screening analytical technology. A data quality objective approach then was used to establish the conditions under which additional samples would be collected, and quantitative analyses performed. Adaptive sampling and analysis programs are intended to change or adapt based on the analytical results produced in the field.

The dynamic workplan used at HAFB included the following six steps:

- Step 1: Select the core technical team whose responsibility it is to prepare and carry out the dynamic workplan. The core technical team included staff from HAFB and the Air Force's contractor CH2M Hill, EPA Region I and their contractor Camp Dresser & McKee (CDM), the Massachusetts Department of Environmental Protection (MA DEP), and Tufts University. The core technical team included project managers, risk assessors, hydrogeologists, and quality assurance chemists.
- Step 2: Develop the Initial Conceptual Model and Decision Making Framework. The model contained the best-available information at the start of the project and evolved as field data were produced. Decision making was shared among certain team members. HAFB staff were responsible for sampling decisions, and Tufts staff were responsible for analytical decisions.
- Step 3: Develop Standard Operating Procedures (SOPs). SOPs for sample collection and analysis were produced by the core technical team and approved by EPA before field activities were initiated. The field methods were "performance based" and provided data of sufficient quality to achieve site-specific Data Quality Objectives (DQOs), with sample analysis rates that supported the dynamic site investigation process.
- Step 4: Develop Data Management Plan. Data integration, sampling, and analysis protocols were incorporated into an overall data management plan. Site maps were prepared using Site Planner™ software depicting current information on contamination levels. The maps were used to inform daily operations and the selection of additional sampling locations.

SITE CHARACTERIZATION PROCESS

Step 5: Developed Quality Assurance Project Plan (QAPP). The QAPP defined the responsibility of the technical team and regulators. It described the procedures to be used to monitor conformance with, or documentation and justification of departure from, the SOPs.

Step 6: Prepare Health and Safety Plan. A health and safety plan was produced and included DQOs for the field analytical tools used to monitor worker and community safety.

The team carried out a dynamic site investigation at Operable Unit 1 using the workplan discussed above. In order to effectively implement the sampling strategy, sampling was conducted in rounds. Rounds 1 and 2 were pre-specified in the dynamic workplan and collected concurrently. Round 3 sampling was to be conducted when the results from Rounds 1 or 2 indicated the need for additional samples to adequately identify the spatial distribution of contamination. Round 3 sampling occurred only at Site 1.

The study objectives included the use of field analytical technologies to produce data capable of supporting a risk assessment of threats to ground water from soil contamination. To establish the maximum levels of contamination that could remain in place and not pose a threat to ground water quality, or to ground water users, the DAFs contained in EPA’s Soil Screening Guidance [5] were evaluated. The 20DAF values were selected by EPA as meeting the protective criteria and were established as the action levels for determining the need for an action. The quantitation limits were established at one-half the action level values (i.e. $\frac{1}{2} \times 20\text{DAF} = 10\text{DAF}$) to insure that action levels could be quantitated by the field analytical technologies. For convenience, the 10DAF values were used to produce the site maps. The site-specific action levels (i.e. 20DAF), quantitation limits (QL), and method detection limits (MDL) for the compounds of interest are shown in Table 1.

Table 1: Site-specific Action Levels, Quantitation Limits, and Method Detection Limits

Compound	Action Level 20DAF (mg/kg)	QL 10DAF (mg/kg)	MDL (mg/kg)
Acenaphthene	570	285	0.1
Acenaphthylene	570	285	0.1
¹ Anthracene	12,000	6,000	0.2
Benzene	0.03	0.015	0.003
² Benz(a)anthracene	2	1	0.2
³ Benzo(b)fluoranthene	5	2.5	0.3
³ Benzo(k)fluoranthene	490	245	0.3
Benzo(a)pyrene	8	4	0.1
Cadmium	8	4	0.11
Carbon Tetrachloride	0.07	0.035	0.004
Chlorobenzene	1	0.5	0.008
Chloroform	0.6	0.3	0.008
² Chrysene	1600	800	0.2
Dibenz(a,h)anthracene	2	1	0.2
1,1-Dichloroethane	23	11.5	0.006
1,2-Dichloroethane	0.02	0.01	0.013

SITE CHARACTERIZATION PROCESS

Table 1: Site-specific Action Levels, Quantitation Limits, and Method Detection Limits (continued)

Compound	Action Level 20DAF (mg/kg)	QL 10DAF (mg/kg)	MDL (mg/kg)
1,1-Dichloroethene	0.06	0.03	0.003
cis-1,2-Dichloroethene	0.4	0.2	0.005
trans-1,2-Dichloroethene	0.7	0.35	0.006
Ethylbenzene	13	6.5	0.006
Fluoranthene	43,000	21,500	0.1
Indeno(1,2,3-cd)pyrene	14	7	0.2
Lead	400	200	1.65
Naphthalene	84	42	0.4
¹ Phenanthrene	NA	280	0.2
Pyrene	42,000	21,000	0.1
Total PCBs	NA	0.5	0.2
Styrene	4	2	0.006
Tetrachloroethene	0.06	0.03	0.006
Toluene	12	6	0.010
1,1,1-Trichloroethane	2	1	0.008
Vinyl Chloride	0.01	0.005	0.033
⁴ m-Xylene	210	105	0.016
o-Xylene	190	95	0.003
⁴ p-Xylene	200	100	0.016

Notes: Organics with the same superscript co-elute. EPA has not established a 20 DAF for total PCBs [5], therefore, the site-specific quantitation limit was set as 0.5-mg/kg. No 20DAF concentration was available for lead. One-half of the screening level of 400-mg/kg for ingestion was used based on the Revised Interim Soil Lead Guidance for CERCLA Sites and RCRA Corrective Action Facilities [6].

Source: [1]

Data Quality Objectives [1]

The HAFB site-specific data quality objectives were established to provide data of sufficient quality to support the study objectives. Just before mobilization, the core technical team held its final field investigation planning session at Tufts University. Details of the site investigation objectives, sample collection process, field analyses to be performed, and the framework for making decisions in the field were finalized. HAFB staff assumed primary responsibility for directing the sample collection effort. When questions were raised concerning measured contaminant concentrations at the action level, EPA provided guidance to determine whether additional sampling was required. The work performed was conducted under an EPA-approved workplan. The EPA conducted laboratory audits, reviewed SOPs and MDL studies, and verified the data. Staff from Tufts and CH2MHill prepared chain-of-custody forms and logged information about the samples. Tufts prepared samples for field and off-site laboratory analysis, while CH2MHill was responsible for shipping samples to the off-site laboratory. Field analysis for organics and metals was provided by Tufts, while Spectrum Analytical (Agawam, MA) performed the off-site laboratory analysis.

SITE CHARACTERIZATION PROCESS

To ensure the data quality of the field analytical measurements, the project team developed data quality objectives for organic analyses and inorganic analyses. The data quality objectives are shown in Tables 2 and 3 below.

Table 2: HAFB Data Quality Objectives for Quantitative Analysis of Organics

Data Quality Parameter	Data Quality Objective
<u>Initial Calibration:</u> Five-point calibration	Percent Relative Standard Deviation (%RSD) of average response factor (RF): +/- 30% for 2/3 and +/- 40% for remaining 1/3 target compounds
<u>Continuing RF Calibration:</u> Beginning and end of day	+/- 30% difference between average RF and daily RF from continuing calibration verification (CCV) for 2/3 and +/- 40% difference for remaining 1/3 of target compounds
<u>Method Blank:</u> Beginning and end of day or after analysis of highly contaminated sample	No more than four target compounds with concentrations detected at greater than three times the quantitation limit.
<u>Measurement Precision:</u> Duplicate or triplicates every 20 th sample	When detected concentrations are greater than five times the quantitation limit: Relative Percent Difference (RPD) must be less than 60%. When detected concentrations are less than five times the quantitation limit: RPD must be less than 100% .
<u>Measurement Accuracy:</u> 1) Surrogate fortified samples 2) Field versus laboratory comparison	1) The RPD between known surrogate value and results of surrogate analysis must fall between 30% and 200% 2) When detected concentrations are greater than five times the quantitation limit: RPD must be less than 60% When detected concentrations are less than five times the quantitation limit: RPD must be less than 100%

Source: [1]

SITE CHARACTERIZATION PROCESS

Table 3: HAFB Data Quality Objectives for Metal Analytes

Data Quality Parameter	Data Quality Objective
<u>Initial Calibration:</u> Two-point calibration, a blank and one known high-level concentration	<u>Requirement</u> Average of three solutions
<u>Continuing Calibration Verification:</u> every 10 th sample	Percent recovery +/- 20%
<u>Instrument Blank:</u> every 10 th sample	Concentration below reporting limit
<u>Method Blank:</u> every 20 th sample	Concentration below reporting limit
<u>Measurement Precision:</u> duplicate every 20 th sample	+/- 25% RPD
<u>Measurement Accuracy:</u> 1) Laboratory control check samples (ERA soil and solution) analyzed every 20 th sample 2) Field versus laboratory	1) Percent recovery +/- 20% 2) a) +/- 60% RPD and b) 50% < R < 200% where $R = 100 \times C_{\text{on-site}} / C_{\text{off-site}}$

Source: [1]

CHARACTERIZATION TECHNOLOGIES**Sample Collection [1]**

Geoprobe™ push technology was used to collect soil samples in 4-ft plastic sleeves. Samples were taken in continuous increments in and around each fire training and drum burial pit, from the land surface to the ground water table. Additional samples were taken based on the screening and quantitative results obtained as follows:

- If Gas Chromatography/Mass Spectrometry (GC/MS) screening results indicated non-detectable VOC levels within the 4-ft sleeves from a particular boring, a soil sample for quantitative GC/MS analysis was selected from the 2-ft section of the sleeve nearest to the ground water.
- If only one 4-ft sleeve from a boring produced screening level concentrations at detectable levels, a soil sample was selected for quantitative analysis from the 2-ft section of the sleeve within the area of highest concentration. An additional soil sample was selected for quantitative analysis from the 2-ft section of the sleeve nearest ground water whenever the sample selected by screening was not from the sleeve nearest the ground water level.
- If target compounds were present in multiple 4-ft sleeves within the same boring above ground water, a soil sample was selected for quantitative analysis from the 2-ft section of the sleeve shown to be the area of highest concentration. Additional soil samples were selected for quantitative analysis from the 2-ft section of the sleeve nearest ground water whenever the sample selected by screening was not from the sleeve nearest the ground water level. Supplementary samples were selected for quantitative analysis to determine the extent of contamination from these boring locations.

Field Analytical Technologies [1]

Bruker Thermal Desorption Gas Chromatograph / Mass Spectrometer (TDGC/MS)

The Bruker GC/MS was used with a thermal desorption (TD) sampling probe to perform screening analyses for VOCs. The technology allows direct volatile vapor sampling analysis of soil samples without extraction. A sampling probe was held directly over one-inch holes that were cut in the 4-ft Geoprobe™ sample sleeves, and drew vapors directly into the mass spectrometer. The MS was operated in the continuous direct measuring mode, simultaneously monitoring eleven targeted VOCs, with three ions measured for each analyte. The TD sampled the vapor for 30 sec (if screen was positive) to 1 min (if screen was negative), with the MS readout shown instantly on the instrument's monitor. An average of 75 soil samples per day were screened over a ten-day period, for a total of 601 soil samples screened for VOCs.

Tekmar 3000 Purge and Trap Concentrator with Hewlett-Packard 5890 II / 5972 GC/MS

This technology was utilized for quantitative VOC analyses. The Tekmar Purge and Trap system was used to extract VOCs by mixing the soil sample with reagent water in a sparging vessel and then purging the sparging vessel with an inert gas. The extracted VOCs were concentrated on a sorbent trap that was then thermally desorbed to transfer the VOCs to the GC inlet. The Purge and Trap GC/MS system produced quantitative VOC data for 158 samples over ten days with a 15-min per sample analysis time. Ion Fingerprint Detection algorithms (see below) were used to expedite the analysis, increase sensitivity, and reduce the need for reanalysis for dilutions.

Tufts Thermal Desorption GC/MS

This sample introduction system was utilized for quantitative analyses of PCBs and PAHs. The thermal desorber sits in-place of the syringe injection GC inlet and was used to introduce a large volume of sample extract into the GC/MS. Soil samples were extracted with solvent and a portion of the solvent extract was deposited into a glass sleeve, which was then placed into the TD. The TD was ballistically heated to 280°C which caused sample analytes to be desorbed and transferred to the GC column for separation and MS analysis within 15 minutes. The 50-100 µL injections that are possible with the thermal desorber maintained the required detection levels even though only two grams of sample were extracted. Quantitative PCB and PAH data were obtained for 68 soil samples in 10 minutes per analysis. The Ion Fingerprint Detection (IFD) software (see below) was used to allow compound identification and quantitation in the reduced run time.

Ion Fingerprint Detection (IFD) Software

The Ion Fingerprint Detection™ data analysis software package was developed at Tufts University and is commercially available through Ion Signature Technology. It was used on the quantitative GC/MS systems for the identification and quantitation of analytes. This package provides the capability of extracting between two and ten characteristic fragment ions produced in mass spectrometry from targeted organic compounds. Based on a set of mathematical algorithms, compound identity and concentration are determined. Most MS data analysis software packages can extract individual ion fragments, however the underlying mathematical algorithms unique to the IFD software facilitate compound identification for these samples regardless of matrix interferences. IFD provides the technology necessary to reduce long chromatographic run times from 30-40 minutes to 10 minutes.

Leeman PS-1000 Inductively Coupled Plasma / Optical Emission Spectrometer (ICP/OES)

This technology was used for the quantitative analysis of trace metals contamination in samples. Soil samples were extracted using a microwave acid digestion and Teflon membrane filtration procedure. The sample digestion procedure employed a 50 percent 3:2 HNO₃:HCl acid mixture, as opposed to concentrated HNO₃. A comparison study [1] determined that the 50 percent 3:2 HNO₃:HCl acid digestion procedure had benefits such as improved analyte stabilities and recoveries of certified performance evaluation samples (especially for silver and antimony), while producing equivalent recoveries and precision for lead determinations in actual field samples. The sample extracts were then analyzed by ICP/OES in eight-minute analysis times. The ICP/OES in this case was modified to provide field ruggedness. Movable parts were pneumatically locked in place, the chassis was ruggedized to stabilize the instrument during field transport, and the nebulizer was upgraded to a system that can handle samples with high dissolved solids and digestate acid concentrations. The ICP/OES processed a total of 121 soil samples.

Sample Collection [1]

There were more samples collected than were projected in the sampling plan, indicating that better delineation was needed for organic contaminants in and around the three sites. The total number of projected samples to be screened for VOCs was 585, and 601 samples, or 2.7 percent more, were actually screened. Higher than projected numbers of samples were quantitatively analyzed for both VOCs and PCB/PAH, 15.3 and 61.9 percent more, respectively. It is interesting to note that although no samples were projected to be analyzed for PCB/PAH at Sites 2 and 3, a total of 12 and 10 samples, respectively, were actually analyzed at those sites. There were fewer samples analyzed for metals than projected. The need for greater than projected numbers of samples for organics analysis indicated a need for expanded characterization at each of the three sites for VOC and semi-volatile organic compound (SVOC) contamination.

Sampling Results [1]

Samples were collected from 23 boring locations at Site 1, shown in Figure 3. Quantitative analysis of 51 samples taken from three borings showed levels of chlorinated VOCs and benzene, toluene, ethylbenzene, and xylene (BTEX) compounds that equaled or exceeded the 20 DAF action level. Analyses of samples taken below four feet in depth in only one of those borings showed above 20DAF levels of chlorinated VOCs and BTEX compounds. No metals contamination that exceeded the 20DAF action level was detected at Site 1. Figure 3 also shows the concentration contours for a representative chlorinated VOC, cis-1,2-dichloroethene (cis-1,2-DCE).

At Site 2, 58 soil samples were collected from 18 boring locations, shown in Figure 4, for quantitative analysis. Analyses of samples taken above eight feet in depth from only three of these showed VOC contamination in excess of the 20DAF action level. Below eight feet in depth, contamination was found in samples from only two of the three borings that had contained contamination above eight feet. However, VOC contamination above the action level was found in three additional borings. Concentrations of metals were below the action level in all borings. Figure 4 displays the concentration contour intervals for a representative BTEX compound, toluene.

At Site 3, samples were collected in 25 boring locations, shown in Figure 5, and 49 samples were quantitatively analyzed for VOCs. Above action level VOC contamination was detected in three of the borings at depths less than eight feet, and in only one boring at depths greater than eight feet. Metals contamination in excess of the action level was found in four of the borings, and Figure 5 shows the cadmium concentration contour plot.

Based on the sampling results obtained at the three sites, volumes of soil contaminated with VOCs were estimated using site mapping software. For each boring, the screening data were used to estimate the vertical distance between points of contamination and non-measurable levels. Thus, the x-z and x-y coordinates were determined by using a combination of quantitative and screening data. From this, contaminated soil volumes were estimated by linearly interpolating between soil concentrations above the action level and non measurable levels for each x-z and x-y coordinate. Approximately 28,000, 243,000, and 66,000 cubic feet of soil are estimated to be contaminated for Sites 1, 2, and 3, respectively.

Figure 3: Cis-1,2-DCE Concentrations (in ppb) Above 4 Feet at HAFB Site 1

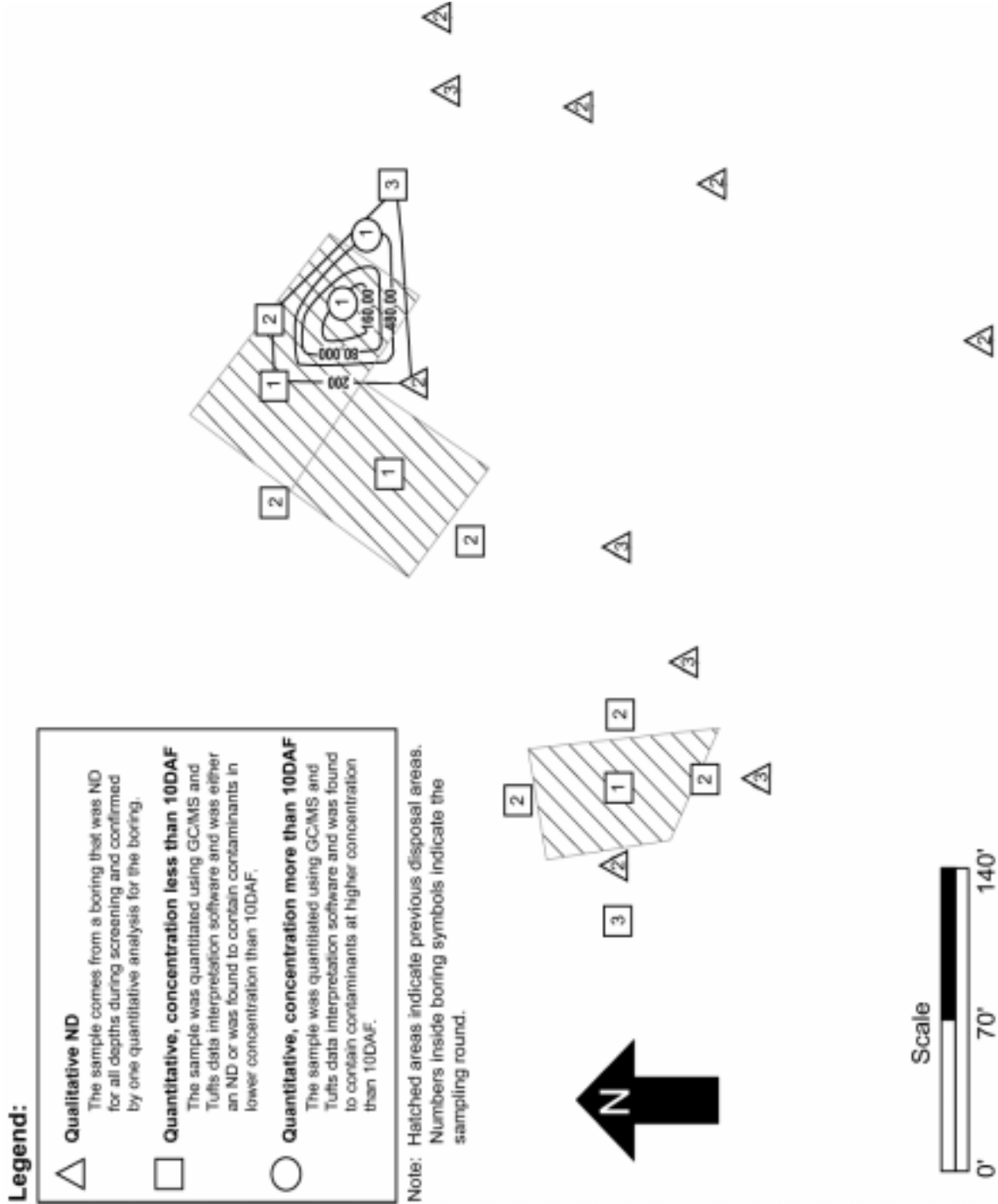


Figure 4: Toluene Concentrations (in ppb) Below 8 Feet at HAFB Site 2

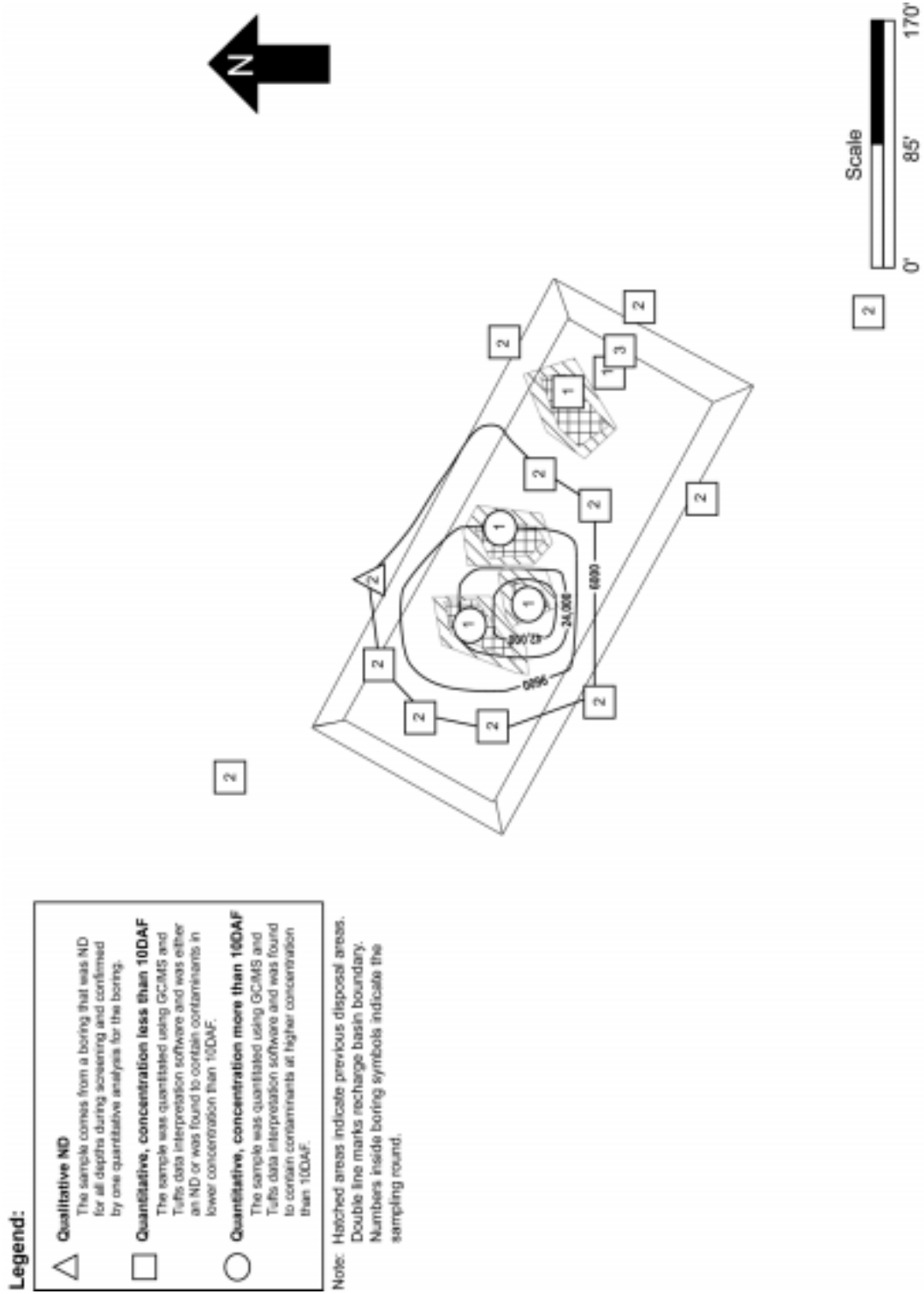
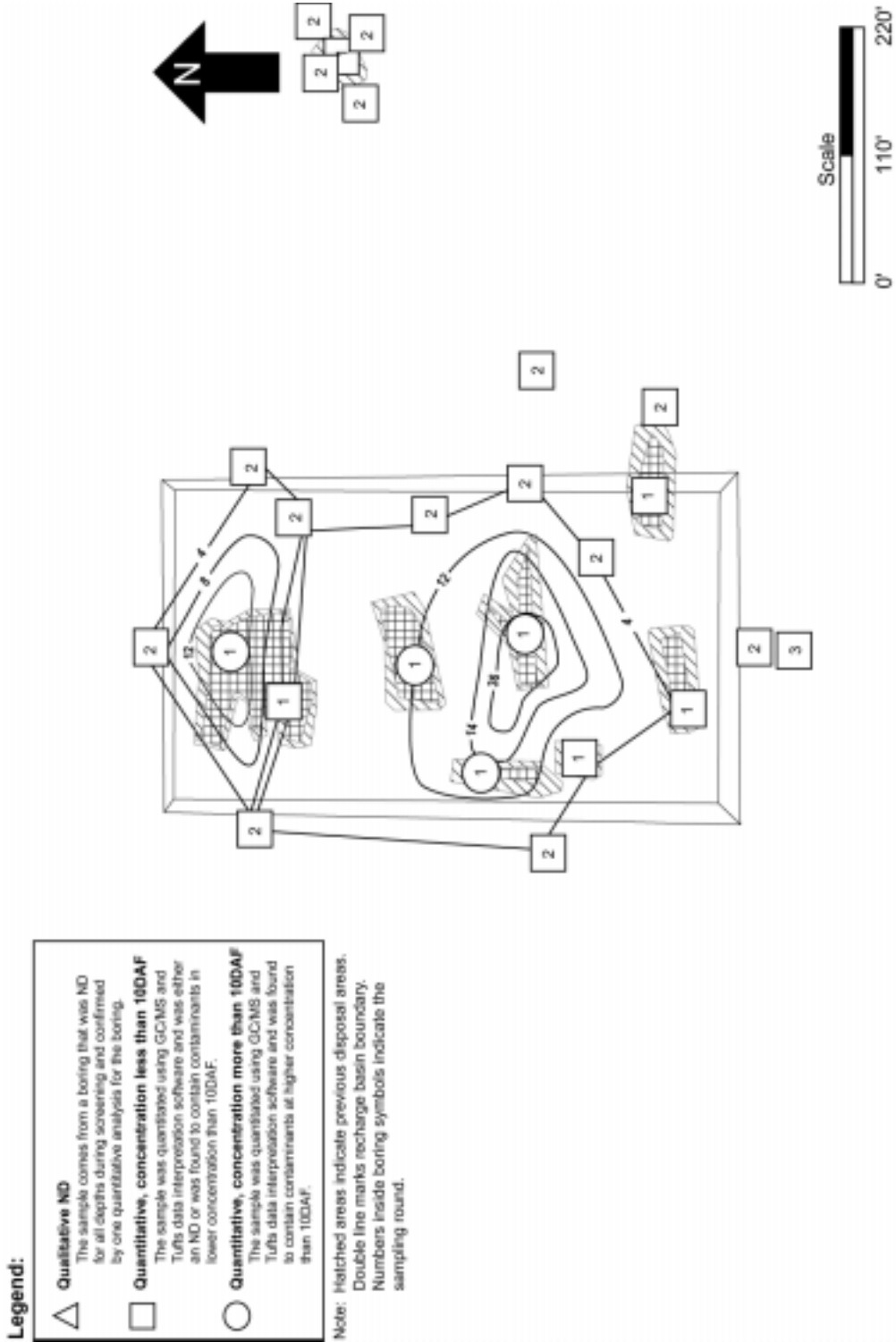


Figure 5: Cadmium Concentrations (in ppb) At HAFB Site 3



Method Detection Limit (MDL) Studies [1]

An MDL study was undertaken to verify that VOC concentrations below the action limits could be detected by the Tekmar Purge and Trap GC/MS. The MDL study was performed at the end of the field investigation, rather than at the beginning, due to logistical difficulties. An MDL for each compound was determined by calculating the standard deviation of seven replicate analyses of the lowest calibration standard (20 ppb), and then multiplying the standard deviation value by 3.14. All VOC MDLs were found to be below the 10DAF quantitation limit, except for the MDLs of vinyl chloride and 1,2-dichloroethane. It was agreed that the 1,2-dichloroethane data were sufficient for confidence of detection at the 20DAF action level, but the vinyl chloride data were unusable.

An MDL study was performed on the Tufts TDGC/MS system for PCB and PAH compounds before the field investigation and prior to initial calibration. Seven soil samples were fortified with 300 ppb of PAHs and Aroclor 1248 and analyzed by the TDGC/MS. The MDL was calculated using 3.14 times the product of the relative standard deviation and the concentration injected. The calculated MDLs for all compounds were well below the 10DAF quantitation limit.

An instrument detection limit (IDL) study was also performed for the field-rugged ICP/OES technology prior to the field investigation. Although cadmium and lead were the only target metals for the HAFB project, the IDL study involved 22 metals and metalloids to explore the capabilities of the instrumentation. MDLs were calculated from the results of the IDL study, and the results showed that the MDLs for the target metals, cadmium and lead (0.11 mg/kg and 1.65 mg/kg, respectively), were well below the 10DAF quantitation limits.

VOC Screening Method vs. VOC Quantitative Method [1]

The Bruker TDGC/MS screening results were used to determine if additional sample borings were necessary and which samples required further analysis. For each sample where the TDGC/MS rapid screening results indicated the presence of VOCs, quantitative analysis by Tekmar Purge and Trap GC/MS was performed on those samples to confirm the results. Whereas screening procedures involved the collection and analysis of sample vapors from over a nickel-sized hole in the sample borings, quantitative GC/MS data was acquired from the analysis of 5-g soil samples. If no VOCs were detected by screening throughout an entire sample boring, a sample for quantitative VOC analysis was taken from the boring sleeve just above the ground water level (as discussed within the Sample Collection section on page 9). In this way, some samples determined to be negative for VOCs by the screening method were also analyzed by the quantitative VOC method.

Table 4 presents an evaluation of VOC screening results relative to quantitative results. Of the total number of soil samples screened for VOCs (601), 144 were quantitatively analyzed. Additionally, 14 soil QC samples were analyzed by both methods. Ninety percent (142/158) of the quantitative results agreed with the screening results at or above the 10DAF quantitation limit concentration levels (refer to Table 1). Four percent (6/158) of the samples had screening results which indicated the presence of VOC compounds at or above the 10DAF levels, but the quantitative method indicated no detectable VOC concentrations at these levels (false positive screening results). For six percent of the samples (10/158), the screening TDGC/MS did not detect VOCs at the 10DAF levels, but VOCs were detected by the Tekmar Purge and Trap GC/MS system at or above the 10DAF levels (false negative screening results).

Table 4: Agreement of Screening Results with Quantitative Analysis for VOCs

Level of Interest	Confirmation	False Positive	False Negative
Quantitation Limit (10DAF)	90%	4%	6%

Source: [1]

Instrument Calibration [1]

For quantitative VOC analysis with the Tekmar Purge and Trap GC/MS, the initial calibration DQOs required that the %RSD of the response factors generated from each of the five calibration points be less than or equal to 30 percent for two-thirds of the 18 VOC compound results, and less than or equal to 40 percent for the remaining one-third of the compounds. The DQO requirements for continuing calibration verification (CCV) performance specified that the percent difference (%D) between the average response factor from the initial calibration (RF_{cal}) and the continuing calibration response factor be less than or equal to 30 percent for two-thirds of the compound results, and less than or equal to 40 percent for the remaining one-third.

The field data generally met the DQO requirements for initial and continuing calibrations for VOC compounds with the exception of vinyl chloride. This compound exceeded the 40 percent upper limit for one out of the three initial calibrations and for six out of the 10 CCVs. The problem with vinyl chloride may have been due to its 100- to 1000-fold greater volatility relative to the other 17 VOC compounds. Not a single detection of vinyl chloride was found for any soil sample at the achieved detection limit of 33 ppb, but this achieved detection limit was substantially higher than the 10DAF detection limit goal of 5 ppb for vinyl chloride. The data for vinyl chloride were judged uninformative, but since all data for the other 17 VOC compounds were acceptable and useable for supporting site decision making, the deficiency of vinyl chloride data was not found to impede this stage of the site investigation. Table 5 presents the results of initial and continuing calibration tests for VOCs. Exceedances of the 40 percent DQO criteria were caused by vinyl chloride, with trichloroethene causing an additional exceedance during a second run of the CCV standard on the 28th.

The DQOs established for initial and continuing calibration for PCB and PAH analyses using the Tufts TDGC/MS were the same as those for VOCs. The %RSD for the initial calibration must be less than or equal to 30 percent for two-thirds of the PCB/PAH compound results, and less than or equal to 40 percent for the remaining one-third of the compounds; and for CCVs, the %D between the average response factor from the RF_{cal} and the continuing calibration response factor must be less than or equal to 30 percent for two-thirds of the compound results, and less than or equal to 40 percent for the remaining one-third. Two initial calibrations and six continuing calibration verifications were performed in the field for PCB and PAH analysis. Initial calibration DQOs were met for all of the 22 analytes measured. Continuing calibration verification DQOs were not met for two out of the six CCVs, where some analytes (typically PAHs) fell outside of the 40 percent difference criteria. This was likely due to a leak that developed in the TD unit which affected responses for many compounds.

Table 5: Initial and Continuing Calibration Summary for VOCs

DQO Goal	DQO Criteria	Date in August 1996										
		21st	22 nd	22 nd	23 rd	24 th	26 th	27 th	28 th	28 th	29th	30th
		Number of VOC Compounds Meeting Criterion (Percent of Total Meeting Criterion) ³										
%RSD for IC ¹	≤30%	18 (100%)	-	-	-	-	17 (94%)	-	-	-	18 (100%)	-
	≤40%	0 (0%)	-	-	-	-	0 (0%)	-	-	-	0 (0%)	-
	>40%	0 (0%)	-	-	-	-	1 (6%)	-	-	-	0 (0%)	-
%D for CCV ²	≤30%	16 (89%)	17 (94%)	16 (89%)	18 (100%)	15 (83%)	-	17 (94%)	12 (67%)	12 (67%)	14 (78%)	13 (72%)
	≤40%	2 (11%)	0 (0%)	1 (6%)	0	2 (11%)	-	0	5 (28%)	4 (22%)	4 (22%)	5 (28%)
	>40%	0 (0%)	1 (6%)	1 (6%)	0	1 (6%)	-	1 (6%)	1 (6%)	2 (11%)	0	0

Notes:

¹ Percent Relative Standard Deviation for Initial Calibration

² Percent Difference for Continuing Calibration Verification

³ Total number of VOC compounds was 18

Percentages may not total to 100% due to rounding. A '-' indicates that the test was not performed that day.

Source: [1]

For quantitative metals analysis by ICP/OES, calibration DQOs required that the percent recoveries of the initial calibration verification (ICV) samples and the CCV samples must fall within 80-120 percent of the reference value for each analyte in the standard solution comprising the calibration verification samples. The percent recoveries for ICVs and CCVs were well within the specified DQO for, not only the two target metals (cadmium and lead), but also for the other 20 metal and metalloid analytes detectable by the ICP/OES.

Method Blanks [1]

The DQO for organic analyses required that blanks be analyzed at the beginning and end of every day, and after the analysis of highly contaminated samples. The blanks must not contain more than four target compounds, and their concentrations must be less than three times the quantitation limit.

Method blank criteria for organics were met after methylene chloride was excluded as a target compound. Despite the use of a fume hood in the field laboratory, blank analyses revealed that high background levels of methylene chloride from its use as the extraction solvent for the PAH/PCB analyses performed in the same trailer caused cross-contamination of VOC samples.

The DQO for metals analysis required that ICP/OES instrument blanks and method blanks be analyzed after every 10th and 20th sample, respectively. The DQO required that corrective action be

taken if blank results found analyte concentrations at or above the reporting limit. ICP/OES blanks consistently met the DQO criteria and no problems were encountered.

Precision [1]

Measurement precision DQOs for quantitative organics analyses using the Tekmar Purge and Trap with GC/MS on field samples required that duplicates or triplicates be analyzed every 20 samples. For duplicate samples, the measure of precision was the RPD. For triplicate samples, the corresponding measure was the relative standard deviation (RSD). If the detected analyte concentrations were less than five times the quantitation limit ($5 \times \text{QL}$), the RPD (for duplicates), or RSD (for triplicates) must be less than 100 percent. When analyte concentrations were greater than $5 \times \text{QL}$, the RPD or RSD was to be less than 60 percent. The procedure for selecting replicates resulted in six VOC samples analyzed in duplicate, and two samples analyzed in triplicate. This precision DQO for analytes detected in these samples was met 78 percent of the time.

Low VOC concentrations (near the MDL and well below the 10DAF QL) in the samples selected as replicates contributed to the occasional failure to achieve this DQO. No replicate samples had VOC analyte concentrations greater than $5 \times \text{QL}$. Additionally, workload considerations demanded that replicates sometimes were not analyzed on the same day as the original sample and a marked decline in VOC concentrations was apparent with even a single day of sample storage. Although replicate sample results were not compared to the initial results, but only to back-to-back runs of the replicate sample, sample storage caused a noticeable deterioration of data quality. VOC replicates run on the same day as the initial sample had a much greater likelihood of meeting the DQO for replicate precision.

Measurement precision DQOs could not be evaluated for PCB and PAH analyses because the field samples selected for replicate analyses had no detectable PCBs or PAHs.

The measurement precision DQOs for metals analysis by field ICP/OES required that replicates be analyzed every 20th sample, and the resulting RPD or RSD be less than 25 percent. For the target metal cadmium, only two samples from the nine replicate samples had detectable concentrations of cadmium. Triplicate RSDs for these two replicates both met the DQO. For lead, the other target metal analyte, seven of the nine replicates had detectable amounts of lead. Five of those seven triplicates met the DQO with RSDs of less than 25 percent, and one replicate just “missed” with an RSD of 27 percent.

Accuracy [1]

Surrogates and Controls

In the HAFB investigation, matrix spikes were not used; however, surrogate recoveries were evaluated as a measurement accuracy DQO for organic analyses. This DQO required that all samples for quantitative VOC analysis be fortified with two surrogate compounds, and the recoveries of the surrogates were to fall between 30-200 percent. Samples for PAH/PCB analysis were fortified with a single surrogate compound, the recovery of which was to fall within the same range. The surrogate recovery DQO was met for 82 percent of the quantitative VOC analyses, and 92 percent of the PAH/PCB analyses.

The accuracy DQOs for metals analysis required that laboratory quality control standards be analyzed regularly, and the percent recoveries fall within 80-120 percent of the certified value. Two different controls were used during the field work. An aqueous control standard was analyzed at the beginning and end of each day to serve as an instrumental control. A solid soil-based standard was digested and analyzed every 20th sample to serve as a control to evaluate the digestion procedure. The aqueous control was run a total of 12 times over the work period, and the soil-based control was run nine times. For the target metal analytes (cadmium and lead), all (100%) of the control measurements, both aqueous and soil-based, met the DQO. If all 22 analytes for which the ICP/OES was calibrated are considered, 92 percent of all aqueous and 59 percent of all soil-based control measurements met the DQO.

Field versus Laboratory Comparison

Another DQO related to measurement accuracy required that comparison between field results and off-site laboratory results be performed. The sample selection procedure for organics called for the fifth sample and every tenth subsequent sample to be sent for off-site laboratory analysis, and this resulted in 14 samples sent for comparison VOC analysis. The accuracy DQO required that the comparison must agree with less than a 60 percent RPD if the analyte concentrations were greater than five times the quantitation limit, and with less than a 100 percent RPD if the concentrations were less than five times the quantitation limit.

Only three of the samples selected in this manner had detectable levels of VOC constituents; the other 11 samples were non-detect for VOCs by both the on-site and off-site laboratory methods. The results for the VOC data comparison for these three samples appear in Table 6. These results are noteworthy for two important reasons: Due to the presence of interferences, Samples S2-B2-(20-22) and S3-B1-(13-15) required 5:1 and 50:1 dilutions, respectively, before analysis by the off-site laboratory. For Sample S2-B2-(20-22), this resulted in several compounds being diluted below the resulting MDL for the off-site laboratory (50 ppb). In contrast, because of the use of the Ion Fingerprint Detection software's algorithms which are able to "look through" interfering ion signals without the need for dilution, reportable quantitative results for these VOC compounds were obtained in the field. Dilution of samples in the field was required only when very high levels of an analyte exceeded the quantitation range of the MS detector. A reduced need for dilution produced lower detection limits and more accurate analyte quantitation with the field equipment. Secondly, it has been well-documented that VOCs are lost in transport and/or storage by the time off-site laboratories analyze the samples [8, 9]. Field analysis of VOCs may therefore produce results which are more reliable and more representative of *in situ* soils. This likely explains the ability of the field laboratory to detect low levels of VOC constituents in Sample S3-B23-(13-15) whereas the off-site laboratory did not, and the generally higher concentrations of VOC analytes as reported by the field laboratory. For these reasons, although the DQO for the comparison between field and off-site lab results for VOCs was not achieved, this was not considered by any means a reason to lose confidence in the field-generated data.

The sample selection procedure resulted in five samples being sent for PCB/PAH analysis by an off-site laboratory. The field versus off-site laboratory accuracy DQO for PCBs and PAHs could not be evaluated because none of these samples contained these analytes above detection limits.

Table 6: Field versus Laboratory VOC Data Comparison

Sample ID	Compounds	Field (ppb)	Laboratory (ppb)
S2-B2-(20-22)	1,1-dichloroethene	30	< 50
	1,1-dichloroethane	41	< 50
	cis-1,2-dichloroethene	560	< 50
	1,1,1-trichloroethene	300	250
	toluene	37,000	2,000
	tetrachloroethane	120	< 50
	ethylbenzene	990	240
	m/p-xylene	7,400	1,200
	o-xylene	2,200	480
	S3-B1-(13-15)	toluene	280,000
ethylbenzene		3,000	14,500
S3-B1-(13-15)	m/p-xylene	320,000	58,700
	o-xylene	83,000	25,500
S3-B23-(13-15)	1,1-dichloroethene	15	< 10
	carbon tetrachloride	6	< 10
	tetrachloroethane	23	< 10
	ethylbenzene	7	< 10
	o-xylene	17	< 10

The measurement accuracy DQO for target metals in a field versus off-site laboratory comparison required that the RPD be less than 60 percent, and that the ratio of the field result to the off-site result be between 0.5 and 2 (i.e., the field result could not be less than half, or more than double, the off-site result). Eleven samples were submitted to the off-site laboratory for comparison of lead and cadmium results. Lead results were obtained for all 11 samples, and the DQO was met for 10 of the 11 comparisons. Cadmium results were comparable for only one sample, and for that sample, the DQO was achieved. Cadmium was frequently detected by the field ICP/OES in the other samples, but at levels which were below the detection limit of the off-site laboratory.

COST COMPARISON

Since the investigation at HAFB was conducted as a demonstration under an ETI grant, the actual costs incurred were not representative of those that would be incurred in a full site investigation. A cost estimate was prepared, however, to highlight some of the costs that might be incurred in a comparable site investigation using field analytical technologies and an on-site laboratory. The cost estimate, shown in Table 7, also provides a comparison between the estimated costs of the dynamic investigation and those that might be seen using the more traditional approach with off-site laboratory support. All labor costs associated with collecting samples and obtaining analytical results are included in this cost estimate.

For both of the traditional scenarios, the number of samples collected and the types of analyses performed are the same as in the HAFB investigation. It is assumed that the first traditional scenario will require two rounds of sampling, each with a separate mobilization. In this scenario, the data turnaround time is assumed to be two to four weeks. The second traditional scenario is based on expediting the data turnaround time, and a 50 percent surcharge is assumed to obtain data within two days. It is also assumed that the sampling and analysis will be conducted in one mobilization and the field team is held on site until the laboratory results are received. Thus, it is assumed that 21 days will be needed to complete the investigation (11 days more than the 10 days actually used in the HAFB investigation).

The analysis shown in Table 7 suggests that a traditional approach to collecting data in a site investigation might cost between 36 and 57 percent more than the estimated cost of the HAFB investigation. Clearly, analytical costs make up the largest share of these costs, and the 50 percent surcharge paid for quick turnaround on the results has a significant impact on the total cost. When the effect of this surcharge is combined with the cost of holding the field team on site, the cost of conducting an investigation using the second traditional scenario might be more than double the cost of the HAFB investigation.

In the analysis provided below, two categories of costs are not addressed, yet such costs may have a significant impact on the cost of the overall investigation. First, several different technologies may be used to collect soil samples, other than the Geoprobe that was used at HAFB. Given the geological setting at HAFB, an example of a likely alternate would be a hollow stem auger. Whether the cost of collecting samples with an auger is higher or lower than those associated with the Geoprobe would depend on site-specific factors, such as the local availability of well operators and the geology of the site. Second, because of the dynamic nature of the HAFB investigation, it is likely that more effort will be required from mid- to high-level management than would be expected in a traditional investigation. In the HAFB investigation, the project manager was available every day to review the previous day's analytical results and make decisions regarding that day's sampling efforts. Additionally, the EPA remedial project manager spent at least two days of each week at the site, participating in the decision making process. Such participation is not likely for a traditional investigation.

COST COMPARISON

Table 7: Cost Comparison between Traditional and Dynamic Field Investigations

Traditional Investigation Scenario 1 Off-Site Analysis Data Turnaround 2-4 Weeks		Traditional Investigation Scenario 2 Off-Site Analysis Data Turnaround 2 Days		HAFB Investigation On-Site Analysis Data Turnaround Next Day	
VOC Screening Analysis 601 Site Samples 60 QC Samples	\$39,065 \$3,900	VOC Screening Analysis 601 Site Samples 60 QC Samples	\$58,598 \$5,850	VOC Screening Analysis 601 Site Samples	\$19,833
VOC Quantitative Analysis 158 Site Samples 16 QC Samples	\$19,750 \$2,000	VOC Quantitative Analysis 158 Site Samples 16 QC Samples	\$29,625 \$3,000	VOC Quantitative Analysis 158 Site Samples 16 QC Samples	\$15,800 \$1,600
PCB Quantitative Analysis 68 Site Samples 7 QC Samples	\$6,800 \$700	PCB Quantitative Analysis 68 Site Samples 7 QC Samples	\$10,200 \$1,050	PCB and PAH Quantitative Analysis 68 Site Samples 7 QC Samples	\$6,800 \$700
PAH Quantitative Analysis 68 Site Samples 7 QC Samples	\$9,860 \$1,015	PAH Quantitative Analysis 68 Site Samples 7 QC Samples	\$14,790 \$1,523		
Metals Quantitative Analysis 121 Site Samples 12 QC Samples	\$36,300 \$3,600	Metals Quantitative Analysis 121 Site Samples 12 QC Samples	\$54,450 \$5,400	Metals Quantitative Analysis 121 Site Samples 12 QC Samples	\$33,275 \$3,300
Analytical Cost Mobilization Cost Remob to Collect Quant Samples 3 Additional Field Days	\$122,990 \$5,000 \$5,000 \$6,000 \$3,186	Analytical Cost (50% surcharge) Mobilization Cost 11 Additional Field Days Sample Shipping	\$184,486 \$5,000 \$22,000 \$3,186	Analytical Cost Field Laboratory/ Instrument Mobilization Cost	\$81,308 \$10,000
Total Project Cost	\$142,176	Total Project Cost	\$214,672	Total Project Cost	\$91,308

OBSERVATIONS AND LESSONS LEARNED

Summarized below are key findings learned while conducting the HAFB investigation.

Dynamic Workplans and Field Analytical Methods

1. Successful hazardous waste site investigations should be focused with goals and objectives clearly defined. A dynamic workplan provides an alternative to the traditional approach. It relies, in part, on an adaptive sampling and analysis strategy. An adaptive sampling and analysis program requires analytical methods and instrumentation that are field-practical and can produce data fast enough to support the dynamic workplan process.
2. Successfully implementing dynamic workplans requires that the project manager invest a significant level of resources at the planning stage and during the field investigation. At HAFB, the USAF manager was on-site every day, and the EPA remedial project manager (RPM) was present for at least three days of each week. Furthermore, the technical team should be in daily communication with the person assigned the responsibility for making all final field decisions.
3. Field analytical methods can support a dynamic workplan/adaptive sampling and analysis program by providing near “real-time” information with which site managers can make daily decisions on sampling locations and analytical requirements.
4. Performance-based field analytical methods are selected and refined to produce data quality as required to address site-specific project needs. In some cases, field methods can produce data quality equal to, or surpassing, that generated by fixed (traditional) laboratories employing standardized EPA methods. The analyses performed during this study generally met the study DQOs, and were comparable to those used with standard laboratory methods.
5. Cost effectiveness is maximized when site DQOs, analytical throughput rates, data turnaround times, sample collection rates, and sample analysis costs are evaluated and optimized to meet the site-specific scientific and engineering questions under investigation prior to the beginning of the field work. The use of field analytical methods with an adaptive sampling and analysis plan can result in a higher percentage of the samples collected and analyzed containing target compounds, which may decrease the number of uninformative sample results.
6. VOC losses during sample processing may be less when field analytical methods are used to support a field investigation or cleanup verification program. The longer the sample holding time and the lower the VOC concentration, the more accentuated the difference between on- and off-site analytical results.

Field Instrument and Method Performance

1. TDGC/MS and the IFD Software (mass spectrometry data analysis algorithms) allow more samples to be analyzed per day than current MS vendor data analysis systems, probabilistic library sample identification matching routines, forward/backward regression search routines, or compound identification through the standard EPA/NIST library matching data systems.

OBSERVATIONS AND LESSONS LEARNED

2. The IFD Software can be used to obtain compound selectivity rather than adjusting the gas chromatography operating conditions. This decreases the per sample analysis time and increases the number of samples that can be analyzed per day per instrument over standard GC/MS instruments. The Software algorithms which “look through” non-target MS ion signals can unambiguously determine compound identity, minimizing masking of low-concentration target compounds by high-concentration matrix interferences. In this context, low-level target compounds are not lost because of the need to dilute the sample. Use of the Software algorithms makes sample dilution less necessary, keeping detection limits low and saving time and money.
3. TDGC/MS provides increased method detection limits over standard syringe sample introduction techniques for GC/MS and comparable detection limits with GC with electron capture detection (ECD) without the need for a sample preconcentration step.
6. TDGC/MS and the IFD Software allow PCB and PAH analyses to be performed in one analysis without the need for sample cleanup and fractionation time.
7. DQOs were met for all target compounds except vinyl chloride. A trade-off may need to be considered between achieving low limits of detection for VOC gaseous compounds and meeting DQOs for all other (less volatile) VOC target compounds.
8. A 50 percent 3:2 HNO₃:HCL mixture produced a more stable environment than concentrated HNO₃ for the digestion of all Target Analyte Metals with the exception of mercury for quantitative ICP/OES analysis.
9. Microwave digestion as a sample preparation method for metals analysis is more practical for field application than open vessel acid digestion, and recoveries are comparable to what can be obtained in a fixed laboratory.

Mobile Laboratory Set-up and Operation

1. A minimum of one week is required to install and calibrate all field instruments. MDL studies should be performed prior to beginning field work.
2. Depending on the number of field instruments, separate electrical services should be provided per instrument complement.
3. Line voltage regulators are recommended to protect instruments and computers from line voltage surges or brownouts.
4. Instrument backup or a service repair plan should be incorporated into the workplan as ‘contingency planning.’ For example, the thermal desorber carrier gas leakage problem was addressed by using the Tekmar purge and trap system for the HAFB investigation. Later, the new electrically controlled injection valve system of the thermal desorber was found to be more rugged than the manual valve unit.
5. Sample pretreatment for SVOC samples should be separated from the VOC sample analysis area to eliminate sample cross-contamination during the sample extraction process. Good

OBSERVATIONS AND LESSONS LEARNED

ventilation in a field laboratory is critical to prevent sample cross-contamination and exposure of personnel to hazardous vapors.

6. All instruments can be electronically linked to a data management computer system for ease of data review and site map generation.

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