Procedures Manual for the Environmental Survey and Clearance of a Construction Site

Interim Draft Final

October 1999

SFIM-AEC-ER-TR-200008
Distribution Unlimited

REPORT DOCUMENTATION PAGE

Form Approved
OMB No. 0704-0188

1. REPORT DATE *(DD-MM-YYYY)*
October 1999

2. REPORT TYPE
Interim Draft Final

3. DATES COVERED *(From - To)*

4. TITLE AND SUBTITLE
Procedures Manual for the Environmental Survey and Clearance of a Construction Site

5a. CONTRACT NUMBER

5b. GRANT NUMBER

5c. PROGRAM ELEMENT NUMBER

5d. PROJECT NUMBER

5e. TASK NUMBER

5f. WORK UNIT NUMBER

6. AUTHOR(S)

7. PERFORMING ORGANIZATION NAME(S) AND ADDRESS(ES)
Argonne National Laboratory

8. PERFORMING ORGANIZATION REPORT NUMBER

9. SPONSORING/MONITORING AGENCY NAME(S) AND ADDRESS(ES)
U.S. Army Environmental Center
SFIM-AEC-ER
E5179 Hoadley Road
Aberdeen Proving Ground, MD 21010-5401

10. SPONSOR/MONITOR'S ACRONYM(S)
USAEC

11. SPONSOR/MONITOR'S REPORT NUMBER(S)
SFIM-AEC-TR-200008

12. DISTRIBUTION/AVAILABILITY STATEMENT
Distribution Unlimited

13. SUPPLEMENTARY NOTES

14. ABSTRACT
This manual establishes preconstruction investigation and clearance screening procedures as required by AR 415-15. Following these procedures will minimize risks to future occupants and personnel working on construction projects at Army installations that might contain ordnance and explosive waste and hazardous substances. This manual outlines screening procedures that will identify areas at Army installations that might be contaminated with hazardous materials, i.e., volatile (VOC) and semivolatile organic compounds (SVOC), pesticides, toxicologically significant inorganics and ordnance and explosives (OE) so construction at these areas can be avoided. Information contained herein will improve the safety of construction projects and decrese the risk of injury to the military, civilian and contractor personnel involved in them. This manual is designed to guide installation personnel and the construction project manager from the initial site recommendation stage, and in cases where OE has been located or contamination detected, to final clearance. This manual recommends investigative techniques and instruments, describes their strengths, weaknesses and applicability to particular site conditions; discusses health and safety procedures for personnel; and provides a Data Quality Objectives Model to aid in evaluating proposed construction projects.

15. SUBJECT TERMS
Preconstruction site survey; preconstruction assessment; preconstruction sampling and analysis; screening procedures for identification of VOC, SVOC and OE; storage and handling of investigation-derived waste; detecting and avoiding OE and chemical warfare agent and clearing; risk assessment procedures and methods; construction site approval determinations; geophysical tools; soil gas sampling technologies.

16. SECURITY CLASSIFICATION OF: a. REPORT	b. ABSTRACT	c. THIS PAGE	17. LIMITATION OF ABSTRACT	18. NUMBER OF PAGES	19a. NAME OF RESPONSIBLE PERSON
U	U	U	UU	141	Jeff Armstrong
					19b. TELEPHONE NUMBER *(Include area code)* 410-436-1510

Disclaimer

Procedures Manual for the Environmental Survey and Clearance of a Construction Site

Interim Draft Final

Prepared by
Argonne National Laboratory

for the
U.S. Army Environmental Center

October 1999

SFIM-AEC-ER-TR-200008
Distribution Unlimited

CONTENTS

CONTENTS (Cont.)

CONTENTS (Cont.)

FIGURES

FIGURES (Cont.)

TABLES

NOMENCLATURE AND DEFINITIONS

ACRONYMS AND INITIALISMS

AEC	U.S. Army Environmental Center
AR	Army Regulation
CBDCOM	Chemical and Biological Defense Command
CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
CERCLIS	Comprehensive Environmental Response, Compensation, and Liability Information System
CFR	*Code of Federal Regulations*
CM	countermine
CMS	corrective measures study
COC	constituent of concern
COE	U.S. Army Corps of Engineers
CSET	construction site evaluation team
CWA	chemical warfare agent
DOD	U.S. Department of Defense
DOE	U.S. Department of Energy
DOT	U.S. Department of Transportation
DPDO	Defense Property Disposal Office
DQO	data quality objective
DRMO	Defense Reutilization and Management Office
EBS	environmental baseline survey
EMMI	Environmental Monitoring Methods Index
EOD	explosive ordnance disposal
EPA	U.S. Environmental Protection Agency
EPIC	Environmental Photographic Interpretation Center
FS	feasibility study
GIS	geographic information system
HASP	health and safety plan
HAZWOPER	Hazardous Waste Operations and Emergency Response standard
HQDA	Department of the Army headquarters
IDW	investigation-derived waste
IIA	initial installation assessment
IRDMIS	Installation Restoration Data Management Information System
IRP	Installation Restoration Program

MACOM	Major Command
MEAP	mobile environmental analysis platform
MILCON	military construction
NPL	National Priorities List
OE	ordnance and explosives
OSHA	Occupational Safety and Health Administration
PA	preliminary assessment
PRG	preliminary remediation goal
QA	quality assurance
QC	quality control
RBC	risk-based concentration
RCRA	Resource Conservation and Recovery Act
RCRIS	Resource Conservation and Recovery Information System
RFA	RCRA facility assessment
RFI	RCRA facility investigation
RI	remedial investigation
RPD	relative percent difference
RPMP	Real Property Management Plan
RTAP	real-time analytical platform
SAP	sampling and analysis plan
SBDCOM	U.S. Army Soldier and Biological Chemical Command
SI	site investigation
SSL	soil screening level
SVOC	semivolatile organic compound
TSD	treatment, storage, and/or disposal
USGS	U.S. Geological Survey
VOC	volatile organic compound

DEFINITIONS

Ordnance and explosives — In accordance with Army policy, this term includes:

a. Live conventional ammunition, live ammunition components, or explosives that have been lost, abandoned, discarded, buried, fired, thrown from demolition pits or burning pads, or shot off ranges. Such ammunition, ammunition components, and explosives are no longer under accountable record control of any DOD Organization or activity;

b. Chemical warfare materiel (chemical agents or military munitions containing chemical agents, see Army Regulation 50-6[1]); and

c. Explosive soil.

Chemical agent — In accordance with Army policy, this term refers to a chemical substance that is intended for use in military operations to kill, seriously injure, or incapacitate a person through its physiological effects. Excluded from consideration are industrial chemicals, control agents, chemical herbicides, smoke, and incendiary materials (Army Regulation AR 50-6[1]).

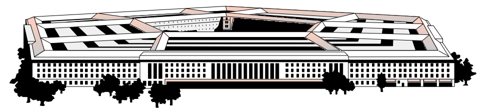
Chemical warfare agents (CWAs) — In accordance with Army Regulation and Pamphlet 385-61,[2,3] this term includes the chemical agents in the U.S. military stockpile, namely the blister agents H, HD, and HT (sulfur mustards) and L (lewisite), and the nerve agents GS (tabun), GB (sarin), and VX. Chemical agents can also include agents expected to be present in only relatively small quantities in the Army inventory, such as nerve agent GD (soman) and any experimental chemicals of similar toxicity to the aforementioned.

Explosive soil — In accordance with Army policy, this term refers to mixtures of explosives in soils, sands, clays, or other media at concentrations such that the mixture itself is explosive. Furthermore, soil containing 10% or more by weight of any of the explosives listed below (or a mixture of any listed below) is considered “explosive soil.”

Ammonium nitrate	Comp A series	Comp 8 series	Comp C series
CH-6	Cyclotol	DATB	Destex
Dina	Dipam	DNB	DNT
EDNA	Expl D	H-6	HBX-3
HMX	LX-04	LX-07	LX-09
LX-10	LX-11	LX-14	IX-I7
MINOL	Nitroguanidine	Octol	PBX-9007
PBX-9010	PBX-9011	PBX-9025	PBX-9404
PBX-9407	PBX-950I	PBXC-116	PBXC-117
PBXN-3	PBXN-4	PSXN-5	PBXN-6
PBXN-101	PBXN-102	PBXN-103	PBXN-IO5
PBXN-106	PBXW-108	PBXW-109	Pentolite
Picramide	Picratol	RDX	TATB
Tetryl	TNB	TNETB	TNT
Tritonal			

Soil containing explosives not listed above must be tested to determine explosives concentrations necessary to qualify as explosive soil. A test protocol consisting of the Bureau of Mines Zero Gap Test and Deflagration to Detonation Transition (DOT) Test is one acceptable method.

1 INTRODUCTION



1.1 Purpose of Manual

This manual establishes preconstruction investigation and clearance screening procedures, as required by Army Regulation (AR) 415-15.[4] These procedures need to be followed to ensure that (pursuant to Chapter 15-12, "Construction Site Selection Surveys," of AR 200-1)[5]: "Every effort will be made to ensure that builders and future occupants of military facilities will not be exposed to environmental health and safety risks. . . ." Following these screening procedures will minimize risks to future occupants and personnel working on construction projects at Army installations that might contain ordnance and explosive waste and hazardous substances. (In this construction clearance manual, the term "ordnance and explosives" [OE] as defined in the Nomenclature and Definitions section is used in lieu of the phrase "ordnance and explosive waste" found in AR 415-15.) A good source for current army regulations can be found on the Web at the following address: http://www.usapa.army.mil.

AR 210-20 specifies that via the Real Property Master Plan (RPMP) planning process, Army installation commanders must "establish a vision and future direction for efficiently managing and acquiring or reducing real property at Army installations in order to support effectively the mission, management process, and community aspirations."[6] The RPMP planning process is meant to chart a long-term strategy for providing facilities and services for soldiers and their families, while still supporting current and future missions. In some cases, the continuous improvement of installations will require the construction of facilities on relatively undisturbed and uncontaminated Army-controlled property. In other cases, realizing the goals of an RPMP will necessitate the construction of facilities on Army-controlled "brownfields" (i.e., abandoned areas with little or no contamination). In either case, the screening procedures discussed in this manual will help optimize the use of such-controlled real property consistent with AR 405-70.[7]

With the passage of Public Law 100-526; the Base Realignment and Closure Act, as amended; and the Community Environmental Response Facilitation Act of 1992, the identification, cleanup, and transfer or lease of excess Army property have become an Army priority. Real property transactions covered by Section 15-6 of AR 200-1 are acquisitions, sales divesting title, transfers of jurisdiction between agencies, and leases. It is Army policy to prepare an environmental baseline survey (EBS) to determine the environmental conditions of properties being considered for outgrants and disposal. In some cases, a thorough evaluation of the environmental condition of a prospective construction site, as advocated in this manual, can help simplify real property transactions in the future, since many of the requirements of an EBS are satisfied by the record search, visual site inspection, environmental survey, data review, and data archiving that are accomplished in the evaluation.

The audience for this document is Major Commands (MACOMs) and engineering and construction project managers responsible for

- Military construction, Army;
- Minor military construction, Army;
- Family housing construction projects; and
- All other construction projects on Army installations.

1.2 Scope of Manual

This manual outlines screening procedures that will identify areas at Army installations that might be contaminated with hazardous materials such as volatile organic compounds (VOCs), semivolatile organic compounds (SVOCs), pesticides, toxicologically significant inorganics, and OE, so construction at these areas can be avoided. The proponent of a construction site shall allocate the funds for this screening survey from Operation and Maintenance accounts. In some cases, as a result of the preconstruction evaluation process, sites or portions of sites that would be eligible for evaluation or remediation through the Installation Restoration Program (IRP) or other Army programs may be discovered.[8] To avoid construction activities on problem areas at an installation, the manual advocates reliance on a thorough search of historical records and aerial photographs, and it downplays the use of intrusive techniques. Should intrusive techniques be required, the manual provides specific information on using soil sampling and analysis methods, detecting chemical warfare agents (CWAs), identifying and clearing OE, and using geophysical and soil gas investigation methods.

Information contained herein will improve the safety of construction projects and decrease the risk of injury to the military, civilian, and contractor personnel involved in them. This manual is designed to guide installation personnel and the construction project manager from the initial site recommendation stage, and, in cases where OE has been located or contamination has been detected, to final clearance. Investigative and clearance procedures may be conducted by qualified contractors. The manual recommends investigative techniques and instruments, and it describes their strengths, weaknesses, and applicability to particular site conditions. It also discusses health and safety procedures for personnel involved in the investigation and clearance of sites. The manual introduces a modification of the Data Quality Objectives Model to aid in evaluating proposed construction projects. Although the investigation techniques described in this manual can be used to safely conduct the survey of a prospective construction site, the first and recommended option at any site where OE could be present is to avoid construction at that site.

1.3 Regulatory Requirements for Site Approval and Classification

AR 415-15[4] requires that all proposed construction sites undergo a site approval process, as follows:

2-2 Site approval

a. All proposed construction projects in the approved Real Property Master Plan (RPMP) Short Range Component will identify site locations in accordance with the installation RPMP and receive MACOM approval per AR 210-20. Site approval denotes that the project's location conforms to land planning principles, the planned development of the installation and that any special criteria (such as safety or environmental protection) have been considered and deficiencies have been or will be rectified or a waiver will be obtained.

b. Organizations which select MILCON sites will conduct an environmental survey and categorization before site selection.

MACOMs are required to review each military construction (MILCON) project before submitting the project to Department of the Army Headquarters (HQDA) to ensure, among other things, that "(6) the site is free from pollutants, contaminants, and ordnance and explosive waste that would impact start of construction" (AR 415-15, Subsection 3-3).

Appendix F, "Environmental Protection," of AR 415-15 provides additional guidance on how the MACOM can initiate the site approval process. Under Section F-2, "Environmental Considerations," the installation commander and MACOM are charged with conducting an environmental survey of a proposed location and certifying what is termed the "site categorization," as follows:

d. Pre-construction site selection. The installation commander arranges for an environmental survey of a proposed site before site selection. The MACOM certifies the site categorization.

e. Site categorization. Sites are classified into the three following categories:

(1) Category I. There is no reason to suspect contamination will be encountered during construction.

(2) Category II. There is no known contamination, but there remains some potential that contamination may be encountered during construction.

(3) Category III. The site is known to be contaminated or there is a strong suspicion contamination will be encountered during construction.

f. Ordnance and explosive waste. If historical research of a prospective site indicates the possibility of the presence of ordnance and explosive waste, the site will be classified as a Category III site. Even though the site is classified as Category III, it may still be a feasible construction site because of the nature of the unexploded ordnance contamination (for example inert) or the capability to clear the construction site.

1.4 Site Survey and Classification

The construction site survey and clearance process is organized as a series of steps, as shown in Figure 1.1. The process involves a preconstruction site assessment that includes a review of records, an examination of aerial photographs, and a site surface inspection to determine the former usage of the site and its potential for contamination. The procedures for performing the preconstruction assessment are contained in Chapter 2 of this manual. After the preconstruction site review, the proposed construction site is classified as Category I, II, or III. When the preconstruction assessment has been completed and the site has been classified, additional environmental survey and clearance steps are performed as indicated in Figure 1.1.

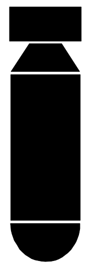
1.4.1 Category I

For sites classified as Category I, the results of the preconstruction assessment can be recorded in the environmental documentation associated with the construction project.

1.4.2 Category II

Sites classified as Category II (i.e., sites that have the potential to be contaminated) must be investigated with an environmental survey technique. In general, a soil sampling and analysis survey is required. In some cases, a geophysical survey (methods to be selected from among the techniques described in Appendix A) and a soil gas sampling and analysis survey (methods to be selected from among the techniques described in Appendix B) can be used in addition to the above survey to evaluate a Category II site.

1.4.3 Category III



Sites that are known to be contaminated or to contain possible OE (including soil mixed with high concentrations of explosives) are classified as Category III sites. Construction projects planned on or near the following types of sites, as revealed by a review of archival information, should be closely evaluated, with a bias for designating the site as Category III:

- Army airfields,
- Naval air stations,
- Marine Corps air stations,
- Air Force bases,
- Practice bombing ranges/precision bombing ranges,
- Rifle ranges,
- Coastal artillery batteries,
- Prisoner of war camps,
- Arsenal/ordnance plants,
- Survival training areas,
- Camps, and
- Forts.[9]

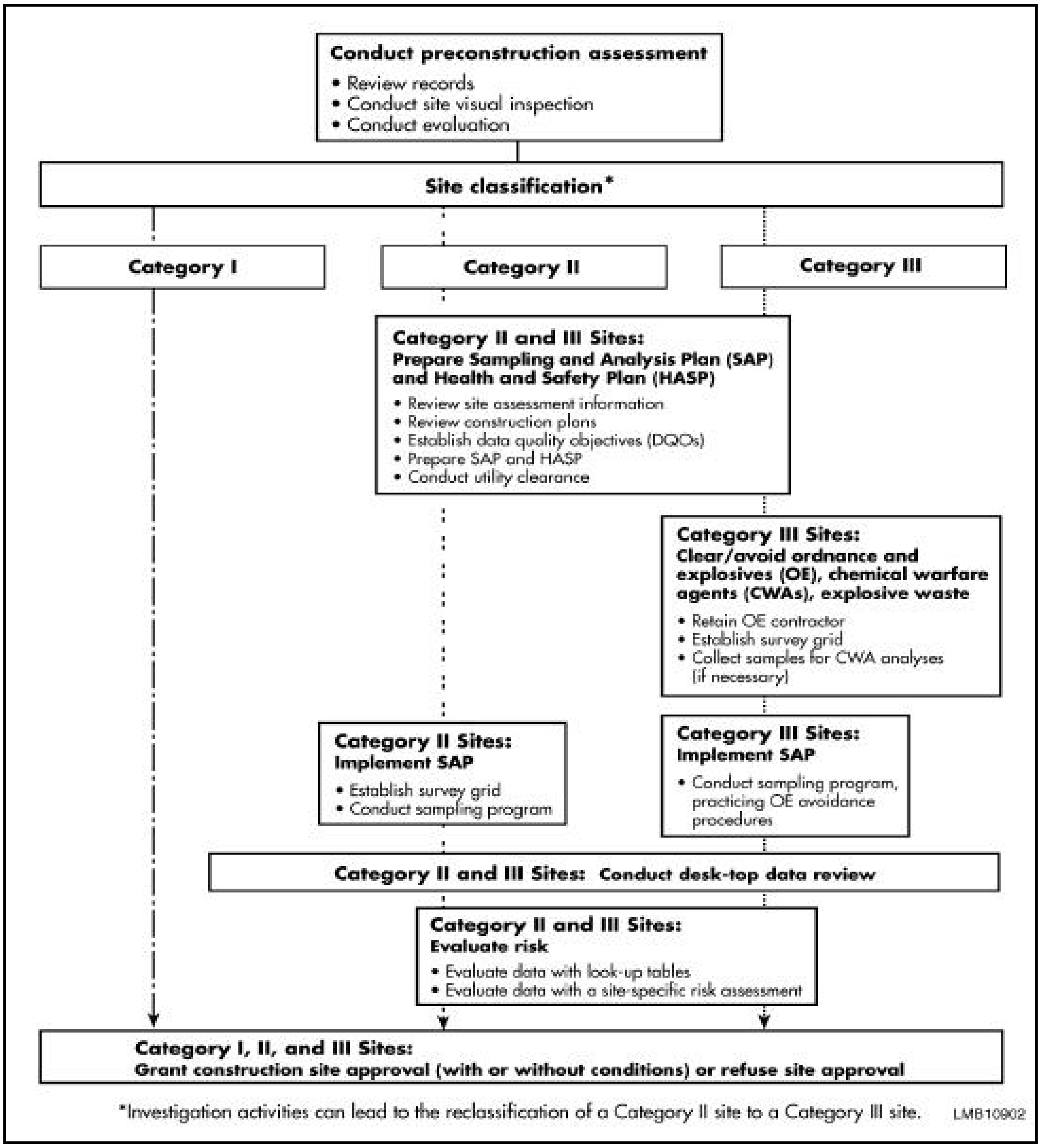


FIGURE 1.1 Conceptual Elements of Preconstruction Investigation

Sites that are known to have CWAs or munitions that may contain CWAs are also classified as Category III sites.

Survey and clearance procedures for Category III sites must be conducted by specially trained personnel. Category III sites must be investigated with environmental survey techniques including, as a minimum, a geophysical survey and a soil sampling and analysis survey. A soil gas sampling and analysis survey and environmental geophysical survey can also be used to help evaluate the suitability of a Category III site for construction.

Category III sites pose significant hazards to both the construction site evaluation team and the construction staff. The investigation and clearance procedures for these sites will be developed on a site-specific basis by the installation, in coordination with U.S. Army representatives having a core competence in the detection and handling of OE and CWAs (e.g., the U.S. Army Corps of Engineers [COE] Mandatory Center of Expertise located at the U.S. Army Engineering and Support Center, Huntsville, Alabama). Remediation and clearance of Category III sites will be conducted in compliance with applicable U.S. Army, federal, state, and local environmental laws and regulations. Investigation and clearance of such sites may require extensive field surveys (including geophysical analysis, soil sampling and analysis, and groundwater sampling and analysis). Implementation of the surveys may require coordination with state and federal environmental agencies. Completion of the preconstruction survey and remediation of a Category III site and its vicinity could encompass a number of months. Investigations need to be site-specific and focus on constituents of concern (COCs). As is the case for Category II sites, the details of the particular construction project will guide the design of the survey and clearance procedures.

The application of geophysical methods and soil gas sampling and analysis to Category II and III sites will depend on site-specific characteristics, such as geology, soil type, depth to groundwater, and the type of suspected contamination. This geological and contaminant information will have been collected during the preliminary site assessment (records review) and will provide guidance for the selection and design of the soil sampling and analysis methods and geophysical and soil gas survey methods. The environmental survey methods also will be based on specific details of the proposed construction project, including its size and the locations and depths of soil excavations (e.g., foundations, conduit and utility lines, and subsurface dewatering requirements). The results of the preconstruction site survey are recorded on DD Form 1391-EF and in Paragraph D9, “Summary of Environmental Consequences,” of the Detailed Justification.

Information gleaned from archival sources during the site survey and classification process should be retained and integrated into installationwide information systems. For example, information gathered during site survey and classification for a given construction site may reveal the location(s) of now-abandoned manufacturing operations or testing/training ranges. These potential contamination sources should be delineated on information systems, such as an RPMP based on a geographic information system (GIS), or be otherwise recorded so that the construction

DD Form 1391-EF

This is the MILCON programming form prescribed by the U.S. Department of Defense (DOD). It includes the following documentation:

- Justification
- Analysis of deficiency
- Alternatives considered, with related economics
- Functional requirements
- Criteria to be used
- Related acquisitions
- Utility impacts
- Environmental documentation
- Completed and required coordination actions.

site evaluation team (CSET) does not have to "reinvent the wheel" when future construction sites are proposed.

1.5 Environmental Survey Techniques

A number of environmental survey techniques can be used to support construction site clearance. One or more of the following methods should be used:

- Environmental geophysical sampling,
- Soil gas sampling, and
- Environmental media sampling and analyses.

At first glance, environmental geophysical sampling and soil gas sampling may seem to be the most cost-effective survey techniques. However, in many cases, the costs of performing geophysical and soil gas surveys may exceed the costs associated with conventional environmental media sampling and analyses. In particular, the use of direct push sampling technologies and the decreasing analytical costs at both fixed-site and on-site analytical laboratories make conventional environmental media sampling and analyses competitive and, in some cases, less expensive than geophysical and soil gas surveys. Some Category II and III sites may have contaminants or geological conditions for which geophysical and soil gas methods would not be effective survey techniques. For example, this situation would occur for nonvolatile contaminants (e.g., metals, explosives, radiological contaminants), biological (infectious) contaminants, and contaminated groundwater occurring at depths below the effective range of geophysical and soil gas survey methods. (Note: The soil gas survey methods referred to here involve the placement of soil gas extraction/monitoring points or soil gas collectors containing specialized adsorbent material within or on soil at the investigation site. Collected soil gas and adsorbent material containing soil gas are then typically analyzed either on-site or at an off-site fixed laboratory. Some CWAs are highly volatile and could be monitored in situ by using these survey methods. However, in general, these in situ soil gas survey methods are used to collect and analyze VOCs.)

Geophysical methods and soil gas sampling can be applied to a wide range of potential contamination scenarios that could occur on or near a Category II site. Furthermore, if OE might be present, geophysical methods (i.e., surveys with magnetometers) used to locate, avoid, and remove OE are required.

This worker is using ground penetrating radar to perform a survey.

In some situations, however, specific sampling and laboratory analyses of affected soil and groundwater and comparisons of analytical results with risk-based concentrations (RBCs), preliminary remediation goals (PRGs), site screening levels (SSLs), or site- and exposure-specific screening levels are needed. In addition, as discussed in Section 5.1.1, in some cases, the concentrations of CWAs in environmental media must be evaluated against appropriate screening standards. Such comparisons constitute a well-developed technical approach routinely used in the U.S. Army IRP; CERCLA (Comprehensive Environmental Response, Compensation, and Liability Act) cleanup programs; and RCRA (Resource Conservation and Recovery Act) corrective action programs. By comparing environmental media (soil, sediment, surface water, groundwater, and air) sampling results to RBCs, PRGs, SSLs, or site- and exposure-specific screening levels, investigators can determine whether a site represents an unacceptable risk to construction personnel and end users of the subject property. In contrast, soil gas results and the identification of geophysical anomalies cannot be as readily compared with risk-based criteria. The decision to include this specific sampling in the site investigation would be made on the basis of information collected in the preconstruction assessment (Chapter 2) and the details of the planned construction.

1.6 Summary

In summary, the steps in the proposed construction site environmental survey and the corresponding manual guidance sections are as follows:

- Preconstruction Assessment (Chapter 2),
- Preconstruction Sampling and Analyses (Chapter 3),
- OE/CWA Detection (Chapters 5 and 6),
- Desk-Top Data Review (Chapter 7), and
- Construction Site Determination and Approval (Chapter 8).

2 PRECONSTRUCTION ASSESSMENT

2.1 Introduction

A preconstruction assessment is required for most construction sites. Such a preliminary site investigation should be performed by the installation during the site selection process, before the project is designed. In some cases, installation master plans may include zoning maps with Category I, II, and III zones already delineated. As a result, the classification of a site as a Category I, II, or III may already have been established by the master plan, so the investigators' primary role would be to verify that the hazard category has not changed since the master plan was prepared.

A preconstruction assessment involves the following tasks:

- Installation historical records review,
- Aerial photographs review,
- Site visual inspection, and
- Data review and evaluation.

The primary objectives of the preliminary site investigation tasks are to:

- Develop an understanding of past site activities and disposal practices that might have resulted in site contamination,
- Identify possible contaminant receptors on site or in adjacent areas, and
- Provide a preliminary identification of contaminant pathways.

2.2 Review of Installation Historical Records

Available historical records can provide information regarding past construction at a site and former land use. Records describing past installation activities may be available in the reports described in this section or in others found in the installation's library or museum. Both text records and photographs should be reviewed. Interviews with long-time installation personnel are also a means to determine historical usage of an area and the likelihood of contamination. Table 2.1 lists particularly useful documents that are usually available at an installation. Key documents are discussed in the following subsections.

2.2.1 Initial Installation Assessment Documents

Many of the documents prepared in the early phases of the IRP by the U.S. Toxic and Hazardous Materials Agency (precursor to the U.S. Army Environmental Center [AEC]) will contain information on environmental contamination caused by past operations at the installation, with an emphasis on substances that might migrate off the installation. These early documents include initial installation assessments (IIAs). An IIA is generally the best source of information regarding contaminated sites on an installation and is usually available in the

TABLE 2.1 Documents That Could Contain Information on Site Use

Document	Information
Initial installation assessment (IIA)	Site history; locations of testing and training areas, landfills, ordnance storage and disposal units, waste surface impoundments, fuel storage tanks, spills, and septic tank/leach fields
Installation Restoration Program (IRP)-related documents, including: • CERCLA 103© notification forms • CERCLA and RCRA corrective-action-related project documents authored by the installation • Aerial photographic interpretive reports, including Installation Assessment Relook Program working documents	Information noted for IIA above and analytical data on environmental media; hydrography; geology; hydrogeology; climate; ecological and human receptors; contaminant migration pathways; and locations of stains and ground scars, stressed vegetation, and other anthropogenic signatures on the ground surface
Installation master plans	Former and present land use; locations of testing and training areas, impact areas, and ordnance storage units
Army Center for Health Promotion and Preventive Medicine (formerly Army Environmental Hygiene Agency) documents, including: • Solid waste engineering surveys • Hazardous waste surveys and compliance audits • Industrial hygiene surveys • Geohydrological investigations	Information noted for IIA above
Archeological studies	Locations of prehistoric and historic archeological sites, landfills, and former weapons training areas
RCRA Part B permit application	Information noted for IIA above
State and federal regulator sources, including: • CERCLA preliminary assessments and site investigation reports • RCRA facility assessment reports • CERCLIS and RCRIS databases found at www.epa.gov/enviro/index_Java.html	Information noted for IIA above
National Environmental Policy Act (NEPA)-related documents, including: • Environmental impact statements • Environmental assessments	Information noted for IIA above

Environmental Office of the Directorate of Engineering and Housing. In some cases, a second IIA document may update or address information gaps in the first document. IIA documents examine current and historical:

- Industrial operations,
- Lessee industrial operations,
- Laboratory operations,
- Materiel proof and surveillance testing and ranges,
- Defense Reutilization and Management Office (DRMO) [formerly Defense Property Disposal Office (DPDO)] property salvage areas,
- Training areas and activities,
- Toxic and hazardous materials handling and storage,
- Petroleum, oil, and lubricants handling and storage, and
- Sewage treatment plants and sludge drying areas.

Current and past practices for disposal of industrial waste, wastewater, and solid waste are reported on in IIAs, along with the histories of demolition and burning ground areas and other demilitarization activities. The information on managing wastes and hazardous materials presented in IIA reports had been obtained by reviewing installation, U.S. Environmental Protection Agency (EPA), and other governmental agency files; interviewing installation personnel; evaluating aerial photographs; and conducting on-site inspections. The conclusions and recommendations in the IIA report determined whether additional investigations were conducted under the IRP. Examples of IIA report information on potentially contaminated sites are presented in Figure 2.1 and Table 2.2.

The evaluation team should be aware that site usage may have changed since IIA reports were prepared. In some cases, it may be prudent to reexamine the source material used to prepare the IIA reports to ensure that no significant changes have occurred since the IIA reports were prepared. Source records can be found in the National Archives; U.S. Center of Military History; history offices and centers for the Army, Air Force, Navy, and Coast Guard; and Smithsonian Historical Information and Research Center.

The evaluation team should also be aware that a number of DOD statutes, directives, and regulations require DOD to address risks to human health and the environment from military munitions. Several DOD directives and regulations focus on operating practices at active military ranges. For example, DOD Directive 6055.9-STD, Chapter 12, requires that range operators maintain permanent records of “known and suspected” ranges and that munitions must be recorded “by nomenclature, hazard, quantity, exact locations, and dud rates.”[10] This type of information could be useful when evaluating the suitability of a prospective construction site.

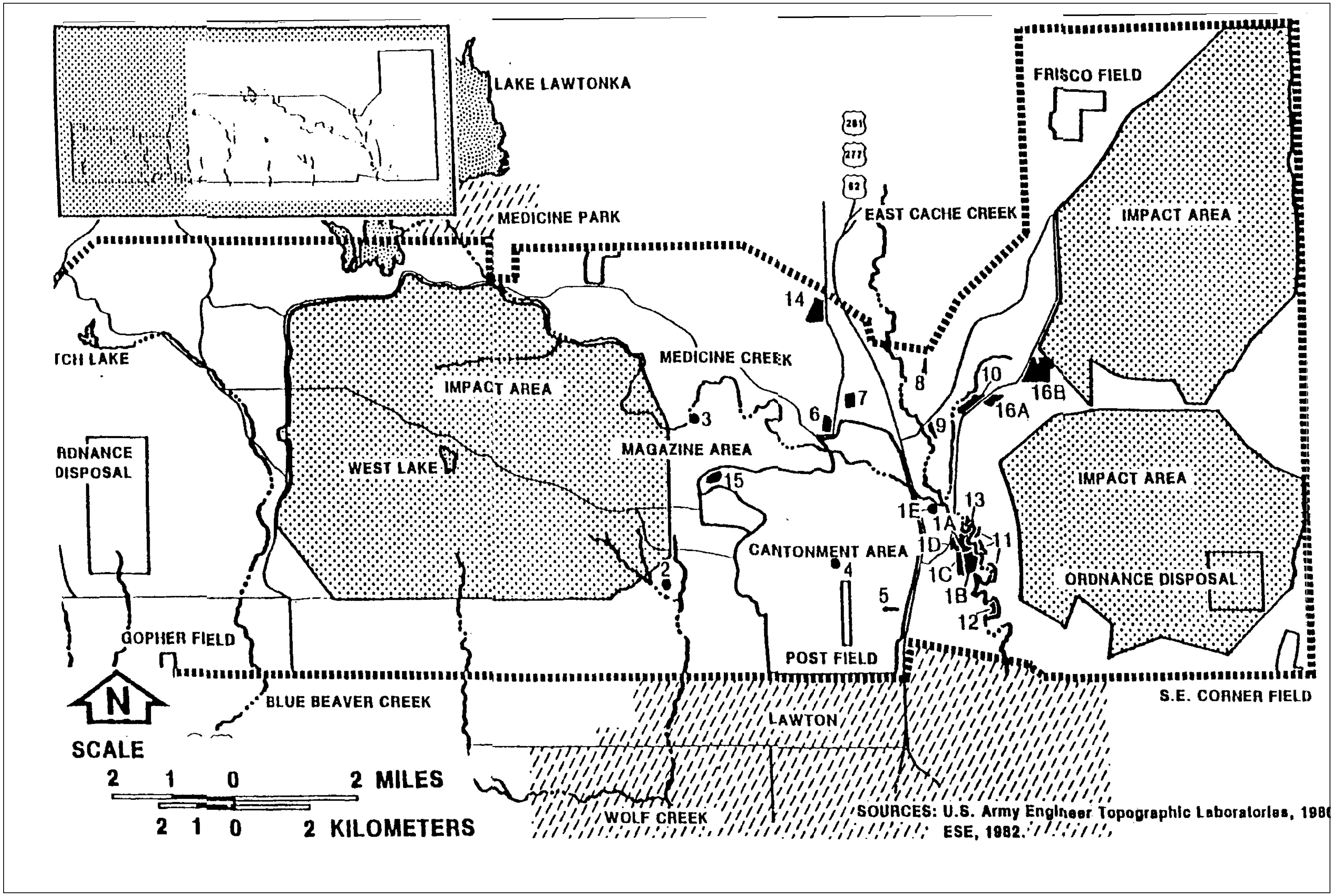


FIGURE 2.1 Landfill Location Map from IIA Document (Source: Environmental Science and Engineering, Inc., 1982, *Installation Assessment of Fort Sill*, Okla Report No. 318, prepared by ESE, Gainesville, Fla., for Commander, Fort Sill, Fort Sill, Okla, and U.S. Army Toxic and Hazardous Materials Agency, Aug.)

TABLE 2.2 Example Landfill Data for Fort Sill

Landfill Number	Location	Date Opened	Date Closed	Type of Refuse	Type of Disposal	Miscellaneous
1A 1B 1C 1D 1E	East side of can-tonment area near Cache Creek	1870* 1880* 1890* 1900* 1870*	1880* 1890* 1900* 1920* 1880*	Household debris, military articles, personal items	Surface dump, Burn areas	Areas dated from material recovered in salvage archaeology efforts.
2	West side of can-tonment area	ca. 1917		Same as above	Surface dump	Dump for Camp Doniphan, WWI era.
3	Heyles Hole, Medicine Creek	?	?	Approximately 1 million rounds of defective 45-75 cartridges	Dumped into hole in creek bottom	Probably one-time dumping operation. Discovered in 1910.
4	Gunnery Hill	1920*	1940's	Unknown	Surface dump on hillside - refuse was burned	
5	Sitting Bear Creek	1880's	1945*	Rubbish and oil	Surface dump	Area filled in and covered with soil about 1975.
6	See Fig. 2-1	1940's	early 1950's	Unknown	Trench landfill	1st post landfill, WWII era.
7	See Fig. 2-1	1950*	Post 1955	Unknown	Trench landfill	Area currently used to burn diseased elm trees.
8	See Fig. 2-1	Pre-1965	1970	Unknown, grease pit	Trench landfill	
9	See Fig 2-1	1970	1971	Unknown	Trench landfill	
10	See Fig 2-1	1971	Present	Rubbish, garbage	Trench landfill	
11	Cache Creek	1970	?	Construction debris	Fill in old creek channel and cover with soil	
12	Cache Creek	?	Present	Construction debris	Fill in old creek channel and cover with soil	
13	Cache Creek	?	Present	Leaves	Surface dump	
14	See Fig 2-1	?	Present	Limbs and stumps	Surface dump	Piles of limbs and stumps are dumped over a large field. May be for wildlife habitat.
15	See Fig 2-1	?	?	Unknown	Unknown	Noted on map dated April 19, 1971, as a "classified material waste area."
16A 16B	See Fig 2-1	N/A	N/A	N/A	N/A	Future landfill site
17	Campe Eagle (not located on map)		ca. 1968/69	Garbage	Single trench	

? = Unknown, * = Approximate, N/A = Not applicable.

Areas used for testing or training could contain OE on the surface. Shown here is a projectile lying in a mountainous area. A pen is placed in front of it to indicate size.

2.2.2 Installation Restoration Program Documents

These documents will be available if the IIA document recommended further investigation, if the sited is listed on the Superfund National Priorities List (NPL), or if the site is required to conduct corrective action as part of a RCRA permit. IRP-related documents contain the results of soil and groundwater sampling and analysis at specific sites subject to CERCLA or RCRA corrective action. A list of chemicals detected at various U.S. Army installations is also available in the AEC Installation Restoration Data Management Information System (IRDMIS) database.

IRP documents evaluate suspected contaminated sites at an installation for their potential to release hazardous constituents. Limited sampling and analyses of environmental media may also have been conducted during the environmental survey to verify the presence of contamination. A full-scale remedial investigation/feasibility study (RI/FS) and RCRA facility investigation/corrective measures study (RFI/CMS) of a contaminated site are usually conducted if the installation is subject to the requirements of CERCLA and RCRA. These reports are available in the installation's Environmental Office of the Directorate of Engineering and Housing.

Typically, state or federal regulators are responsible for generating the documents that initiate CERCLA and RCRA corrective action requirements. Sites that may be candidates for a CERCLA investigation or RCRA corrective action may be listed on two databases maintained by the EPA: Comprehensive Response, Compensation, and Liability Information System (CERCLIS) and Resource Conservation and Recovery Information System (RCRIS). These databases can be found on the Web at http://www.epa.gov/enviro/index_Java.html.

A preliminary assessment/site investigation (PA/SI) report is written for sites listed in CERCLIS to identify the high-priority sites posing threats to human health and the environment. The EPA evaluates a site for its potential to release hazardous substances during the PA/SI. The PA is designed to collect and document readily available information in order to distinguish between sites that pose little or no threat to human health and the environment and sites that require further investigation. The SI is conducted to identify which sites have a high probability of qualifying for the NPL. As a result, the PA/SI can provide useful information for the preconstruction assessment.[11]

In many ways, a RCRA facility assessment (RFA) can be likened to the PA/SI. An RFA is conducted at sites seeking a RCRA permit. The RFA is typically conducted by the state or federal regulator and represents an attempt to identify any locations where solid wastes or hazardous wastes were handled at any time in the history of a facility. Thus, the RFA may provide useful information regarding waste handling practices in proximity to a prospective construction site.[12]

2.3 Review of Aerial Photographs

A number of public sources of aerial photography exist. Commercial sources also are available. Table 2.3 lists these sources, types of data, and source locations. The U.S. Geological Survey (USGS) source noted in Table 2.3 is an excellent starting point because it can provide a summary of all of the aerial photographs generated by U.S. government agencies for a desired area.

The U.S. Army entered into an interagency agreement with the EPA to have a number of installations examined by the EPA's Environmental Photographic Interpretation Center (EPIC). As a result, depending on the installation, EPIC-authored reports, referred to as Installation Assessment Relook Program working documents, may be available for the preconstruction assessment. In some cases, Relook Program documentation is integrated into the IIA reports. Installation historical aerial photographs are also useful in determining the historical usage of an area. Aerial photographs may also be available from the Environmental Office of the Directorate of Engineering and Housing and from the Department of Public Works.

It is advisable to review aerial photographic documentation with someone knowledgeable about discerning land disturbances on aerial photographs to ensure that the interpretation provided in the narrative is accurate. The aerial photographic report may provide conclusive information for the proper categorization of a site and its vicinity. However, neither the aerial photographic information nor the

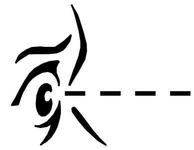


TABLE 2.3 Sources of Remote-Sensing Data Such as Aerial Photographs and Satellite Imagery

Data	Source	Location	Comments
Aerial photographs	Earth Science Information Center/ U.S. Geological Survey (ESIC/USGS) http://nsdi.usgs.gov/nsdi/products/aerial.html	507 National Center, 12201 Sunrise Valley Drive, Reston, VA 22092; (703) 648-5963	National high-altitude photography (NHAP); can conduct computer searches of available aerial photographs
Aerial photographs and satellite imagery	EROS Data Center and EOSAT LANDSAT Customer Service http://-edcwww.cr.usgs.gov/content_products.html	Sioux Falls, SD 57198; EROS (605) 594-6151; EOSAT (605) 594-2291	Aerial photographs and space imagery (manned flights, LANDSAT [thematic mapper and multispectral scanners]); can conduct computer searches of available imagery, provide digital satellite imagery data
Aerial photographs	U.S. Soil Conservation Service (SCS)	P.O. Box 30010, Salt Lake City, UT 84130; (801) 524-5856	Varied aerial coverage (including historical) of the U.S.
Aerial photographs	U.S. Army Corps of Engineers (COE/USACE)	Various COE District Offices	Aerial photographs for various areas of the U.S.
Aerial photographs	U.S. Fish and Wildlife Service (USFWS) http://www.fws.gov/search/index.html	9720 Executive Center Drive, Suite 101, Monroe Bldg., St. Petersburg, FL 33702; (813) 893-3624 and other offices	Aerial photographs used to prepare wetland inventories for the U.S.
Aerial photographs	U.S. Environmental Protection Agency (EPA) Environmental Photographic Interpretive Center (EPIC)	Bicher Road, Bldg. 166, Vint Hill Farms Station, Warrenton, VA 22186; (703) 349-8970	Aerial photographs and imagery
Satellite imagery	National Oceanic and Atmospheric Administration (NOAA) http://psbsgil.nesdis.noaa. gov:80-80	9015 Junction Drive, Annapolis, MD 20701; (301) 436-6990	Low-resolution weather satellite images; some satellites are capable of imaging true infrared

TABLE 2.3 (Cont.)

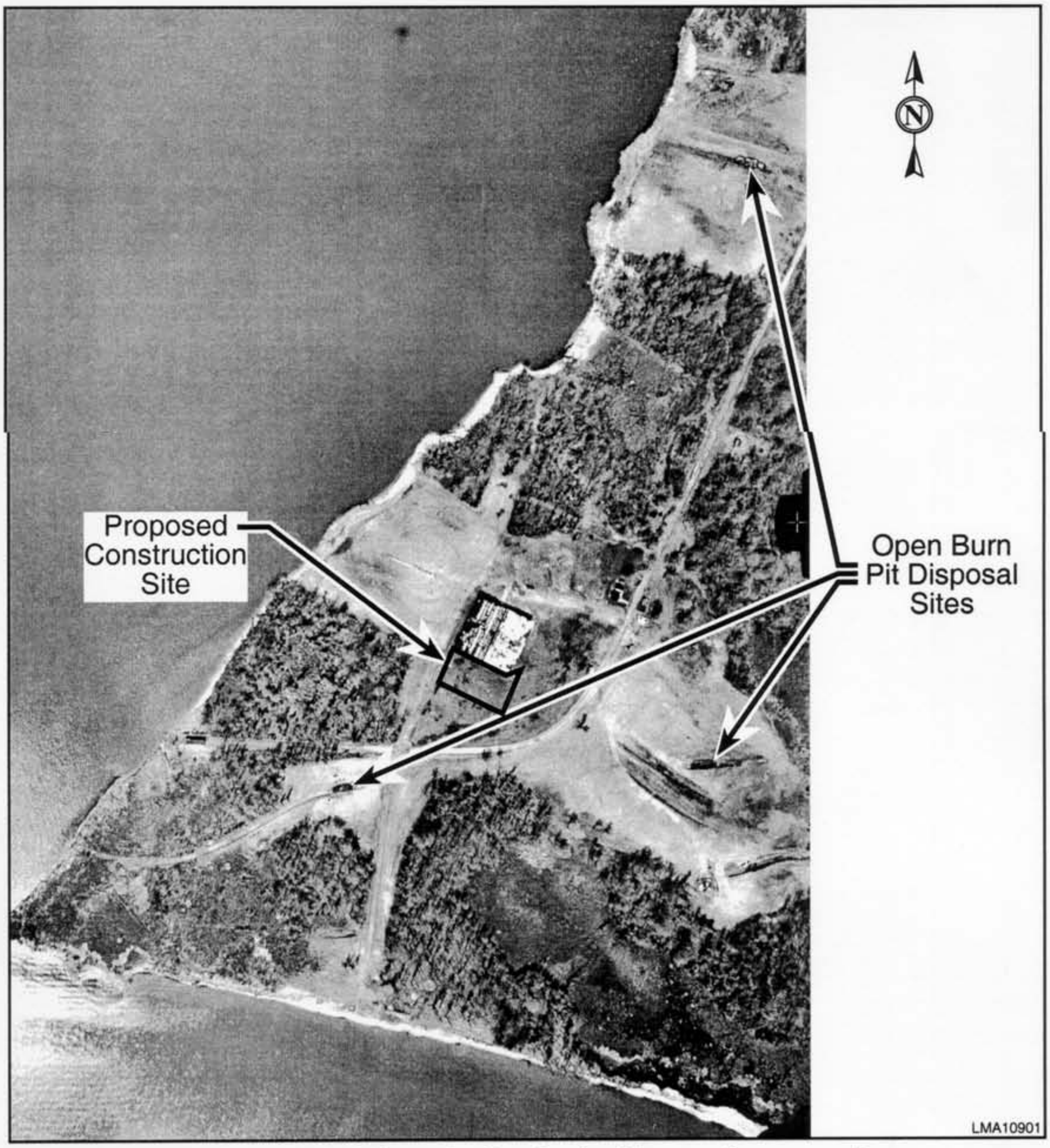
Data	Source	Location	Comments
Aerial photographs	Defense Mapping Agency (DMA) http://wwww.gcrio.org/ DifHolding/GCRIO067. html	DMA Office of Distribution, Attn: DDCP, Washington, DC 20315; (202) 227-2495	Unclassified and declassified aerial photographs of U.S. and world
Aerial photographs	Various state transportation, environmental, and soil conservation offices	Various state governmental offices	Aerial photographs that cover entire states, counties, or specific programs; regional SCS offices frequently have historical aerial photographs
Aerial photographs	County tax or property appraisers offices	Various local county governmental offices	Relatively up-to-date (i.e., no more than 5 years old) aerial photographs at large scale

review of archival records can take the place of a site visual inspection.

2.4 Site Visual Inspection

A visual site inspection must be conducted to obtain evidence of potential contamination. Before conducting the inspection, the investigator should consider how the results should be recorded and preserved. A variety of media can be used, including voice/sound recordings, handwritten notes coupled with handwritten notes on maps, photographs (film and digital), and GIS. Typically, investigators use the handwritten notes option to record the results of site inspections. These draft results can then be refined as final environmental documentation in support of the AR 415-15 site approval and classification process. If resources permit and if a GIS infrastructure is available, it is recommended that site inspection results be preserved by using reports, photographic images (film or digital), and the installation's GIS.

Ideally, the investigator should stake out the rough outline of the construction project "footprint" of the prospective building site to identify portions of the site that are likely to be physically disturbed during construction. The site inspection should be conducted under the supervision of environmental personnel who are experienced in identifying anthropogenic contamination sources such as unusual odors, stained soils, stressed vegetation, leachate seeps, or unnatural land features that may be related to human sources. All questionable features should be marked in the field with flags and recorded on a site map of appropriate scale. As noted above,



Aerial photographs can be helpful in evaluating the significance of past operations at a prospective construction site.

results can also be recorded by using digital imagery and GIS. (For example, in the 1965 aerial photograph shown, the proposed construction site is delineated. The photograph was used to locate three former open burning waste disposal pits and to verify that no similar open burning activities occurred at the prospective construction site.) The surface of the proposed site should be walked on by personnel. All areas of the proposed site must be covered. Any evidence that suggests the prospective construction site was used for activities involving the handling of hazardous substances will place the site in Category II or III, and the site will require further investigation.

2.4.1 Unnatural Surface Features

Man-made structures or debris and unnatural surface features, such as subsidence, depressions, or disturbed areas, also should be marked in the field by flags and recorded on a site map.

The color and consistency of any waste or debris should be noted. In those areas where there are no known hazards associated with buried OE, the subsurface may be explored with a shovel or hand auger to reveal the cause of unnatural surface features. Personnel from the Environmental Office of the Directorate of Engineering and Housing or other personnel experienced in site safety should be present when any subsurface exploration is conducted. Subsurface exploration should not be conducted in areas suspected of containing OE until the area has been cleared of OE, unless avoidance techniques (such as geophysical magnetometric surveys) have preceded the intrusive exploration.

Unnatural subsidence features should be noted during the site visual inspection.

Soil staining and leachate seeps could indicate a contamination source.

2.4.2 Cleared or Stressed Vegetation

Dead or suppressed vegetation, or the conspicuous presence or absence of vegetation, may indicate contamination at a site. Since many contaminants kill or hinder plant growth, areas of stressed vegetation will require further investigation to determine the source of stress. Infrared aerial photographs are very useful for indicating areas of stressed vegetation. The conspicuous presence of vegetation in an otherwise barren area may indicate that sewage sludge or other wastes with a high nitrogen and/or phosphorus content have been disposed of at the site.

2.4.3 Soil Staining, Seeps, and Leachate

Stained or discolored soils should be noted on a site map. Soil with stains indicative of contamination is often found in well-defined drainage ways. Any odors associated with stained soil should be noted, and further investigation is required if there is no apparent natural cause of soil discoloration. Seeps, or naturally occurring discharges of groundwater, are typically found at the base of embankments, along stream channels, or in road cuts. Seeps or springs are sometimes identified in the IIA or EPIC reports. Seeps should be observed during the site inspection to determine whether unusual colors or odors are associated with the discharge. If a seep contains leachate, which is groundwater or surface water that has migrated through a subsurface source of contamination, the seep discharge will have an odor and usually have visible discoloration and/or a metallic or petroleumlike sheen.

2.5 Preconstruction Evaluation

On the basis of the records review and visual site inspection, the evaluation team must determine whether there is any reason to suspect that contamination has occurred as a result of past activities in an area. If not, the site should be classified as Category I, and the gathered information should be recorded in environmental documentation associated with the site. If there is any reason to suspect that a site contains contamination, it must be classified as Category II or III and investigated by following the required procedures described next.

3 PRECONSTRUCTION SAMPLING AND ANALYSES

3.1 Technical Approach

Category II and III sites must be investigated further before construction can be approved. In general, investigation activities should focus on the collection of data necessary to substantiate the absence of risk or to otherwise manage risk to construction workers and end-users.

This manual advocates sampling and analyzing environmental media and comparing the results with pre-established environmental screening levels such as PRGs, RBCs, or SSLs. Such a comparison can be the primary means to appraise risks associated with a prospective construction site. Alternatively, if resources permit, the CSET can work with appropriately trained health risk assessors to develop other generic screening levels on an installation-specific basis to address the unique exposure scenarios for military construction sites. However, even if PRGs, RBCs, or SSLs are to be used as part of the categorization process, the CSET is still urged to seek the assistance of risk assessment professionals for the site categorization process.

This generalized technical approach (that is, the comparison of media-specific contaminant concentrations to media-specific PRGs, SSLs, or RBCs) is based on precedents established in the U.S. Army IRP and the nation's two primary investigation/remediation programs: the CERCLA program and the RCRA corrective action program. However, whereas the CERCLA and RCRA programs default to the collection of numerous environmental media samples and the performance of detailed and/or site-specific risk assessments, this manual advocates the collection of a minimal number of environmental media samples and, whenever possible, the comparison of analytical results to RBCs, PRGs, or SSLs found in convenient "look-up" tables.

Because such look-up tables were derived by using default exposure assumptions, they should be used only in accordance with the table-specific rules, and only when the default assumptions are equivalent to or more conservative than site-specific conditions. In cases when the look-up table rules cannot be followed (for example, exposure scenarios that differ from the default exposure assumptions in the table), or when site conditions indicate that adequate protection of workers or the community would not be achieved by using the default exposure assumptions, a site-specific risk assessment must be conducted. It is recommended that an experienced risk assessment professional be used whenever such look-up tables are used or when a site-specific risk assessment is performed.

The technical approach that follows is based on data quality objectives (DQOs). The DQO process is a management tool based on the scientific method. It was developed by the EPA and adopted by both the U.S. Department of Energy (DOE) and DOD to facilitate the planning of environmental data collection activities.[8,13] The DQO process enables planners to focus their efforts by specifying the intended use of the data (the decision), the decision criteria (action level), and the decision maker's tolerable decision error rates.

Preliminary Remediation Goals (PRGs). PRGs are described in Part B of the EPA's Risk Assessment Guidance for Superfund (RAGS).[14] PRGs are used at the scoping phase of the risk assessment process. The residential soil PRG given in RAGS is derived from an estimate of the potential ingestion of soil. For industrial/ commercial land uses, a soil PRG is calculated on the basis of soil ingestion, as well as inhalation of volatiles released from soil and/or inhalation of airborne particulate matter. EPA Region IX supports the use of PRGs, with the modification that skin contact and inhalation (of volatiles or particulates) are also included as components of both residential and industrial soil PRGs.[15,16] Region IX also has a separate pathway-specific PRG for inhalation of contaminants in ambient air. The PRG methodology requires the use of certain chemical-specific data, such as diffusivity coefficients, to calculate a volatilization factor for each chemical contaminant. A nonchemical-specific "particulate emission factor" is used for chemicals that are not volatile.

Risk-Based Concentrations (RBCs). EPA Region III[17] supports the use of RBCs, which are similar to PRGs. EPA Region III calculates a soil ingestion RBC for noncarcinogens (for children only) and for carcinogens (age-adjusted for a 30-year exposure period) but does not include inhalation or dermal contact as additional exposure pathways for contaminated soil. However, Region III calculates a pathway-specific RBC (inhalation only) for ambient air, as well as an RBC based specifically on ingestion of edible fish.

Soil Screening Levels (SSLs). The EPA's Office of Solid Waste and Emergency Response has developed soil screening guidance that is used to derive risk-based site-specific SSLs.[18] SSLs are concentrations of contaminants in soil that would be protective for residential exposure scenarios. For contamination of surface soils, SSLs are derived for two pathways: ingestion of soil and inhalation of fugitive dusts. For subsurface soils, SSLs are also derived for two pathways: inhalation of volatiles released from the soil and ingestion of groundwater contaminated as a result of the migration of chemicals through the soil to the underlying aquifer."[19]

Although the DQO process typically results in statistical/probabilistic sampling methods for data collection, not every problem necessarily has to be evaluated by using probabilistic techniques. Investigators are encouraged to review the document entitled *Guidance for the Data Quality Objectives Process*, EPA/600/R-96/055, by the EPA Office of Research and Development, to obtain more information about designing probabilistic sampling programs as part of a construction clearance exercise. This construction clearance manual recommends using the DQO process as a planning tool even if a statistical data collection design is not going to be used.

The DQO process consists of seven steps (Table 3.1). Although it is pictured as a linear process, in practice, it is an iterative process, in that the output from each step may result in the reconsideration of decisions made in previous steps. During the first six steps of the DQO process, the CSET should develop the decision performance criteria that will be used to design the sampling and analysis plan (SAP). The final step of the DQO process involves preparing the SAP.

The steps in the DQO process can be adapted to help prepare an SAP to satisfy the requirements of AR 415-15 (Table 3.2). Steps 1 and 2 of the traditional DQO process are, in effect, already established by AR 415-15 as follows. Step 1 is to state the problem. AR 415-15 requires the CSET, installation commander, and MACOM to submit an approved site plan that includes a MACOM statement that a hazardous and

TABLE 3.1 The DQO Process

Step 1 State the problem	Describe the problems to be studied. Review prior studies and existing information to gain a sufficient understanding to define the problems.
Step 2 Identify the decision	Identify what questions the study will attempt to resolve and what actions may result.
Step 3 Identify the inputs to the decision	Identify the information that needs to be obtained and the measurements that need to be taken to resolve the decision statement.
Step 4 Define the study boundaries	Specify the time periods and spatial area to which the decision will apply. Determine where and when data should be collected.
Step 5 Develop a decision rule	Define the statistical parameters of interest, specify the action level, and integrate the previous DQO outputs into a single statement that describes the logical basis for choosing among alternative solutions.
Step 6 Specify tolerable limits on decision errors	Define the decision maker's tolerance for making an incorrect decision on the basis of data that inaccurately estimates the true state of nature.
Step 7 Optimize the design	Evaluate information from the previous steps and generate alternative data collection designs. Choose the most resource-effective design that meets all DQOs.

toxic materials survey has been done, indicating the site is suitable for construction (AR 415-15, Subsection 5-5, predesign activities). Note that site suitability relates to the risk to construction workers and future users. Step 2 is to identify the decision. Ask the question, "Is the site free from hazards that would affect the start of construction, or can hazards be cleared or managed in such a way that construction can proceed?" Since these first two steps are common to all construction clearance projects, the modified DQO process starts by making Step 3 "Identify the inputs to the decision" into Step 1.

Table 3.2 is provided as an example of how the DQO process can be used to help guide the preparation of a construction site clearance SAP. For more information on the DQO process, refer to the DOE Office of Environmental Management home page on DQOs at http://etd.pnl.gov: 2080/DQO/. It discusses:

- Why to use the DQO process;
- Steps in the DQO process;
- Case studies of the DQO process; and
- DQO resources, including software, references, newsletters, and links to other Web pages that contain statistical information useful in implementing the DQO process.

TABLE 3.2 Modified DQO Process for the Development of Category II and Category III Sampling and Analysis Plans

State the problem		AR 415-15 requires the evaluator, installation commander, and MACOM to submit an approved site plan that includes a MACOM statement that a hazardous and toxic materials survey has been accomplished, indicating the site is suitable for construction (AR 415-15, Subsection 5-5, predesign activities).
Identify the decision		Is the site free from hazards that would affect the start of construction, or can hazards be cleared or managed in such a way that construction can proceed?
Step 1	Identify the inputs to the decision	Inputs include determinations regarding: • Presence/absence of OE and explosive waste (see Chapter 4), • Presence/absence of CWAs (see Chapter 5); • Identity of constituents of concern (COCs), and • Action levels (the threshold values that provide the criteria for choosing between alternative actions) for COCs.
Step 2	Define the study boundaries	Study boundaries include: • Spatial boundary of the proposed construction site; • Temporal boundary (the term of construction activities or, in the case of a perceived risk to end users, the "life" of the project, if construction proceeds); • Concentrations of COCs in environmental media; • Areas of the site where human receptors derive their exposure; and • Presence of OE, explosive waste, and CWAs that could also "bound" the study.
Step 3	Develop a decision rule	The decision rule requires the consensus of the evaluator and installation and MACOM decision makers and can be generally stated as follows: • If they are detected, clear the OE, explosive waste, or CWAs from the proposed construction site or do not approve site for further characterization. • If the concentration(s) of COC(s) within the proposed construction site is (are) greater than the action level, remove the soil from the site; otherwise, manage the risk or do not approve the site for construction.
Step 4	Prepare the Sampling and Analysis Plan	Choose the most resource-effective SAP design that meets all the DQOs.

The CEST should seek input on the DQO process from stakeholders (the public, Army personnel, Restoration Advisory Boards, Technical Review Committees, etc.) The input should address key elements in the construction site clearance process, such as the sampling approach, analytical methods, COCs, and action levels. A priori "buy in" of the DQOs and technical approach used for the construction site clearance process may "smooth" future sales, outgrants, and leases of real property.

3.2 Step 1: Identify the Inputs to the Decision

For Category III sites, input for Step 1 involves determining whether OE (including CWAs), if present, can be cleared so that site characterization can continue. In general, for site characterization, the only recommended step that can be taken at Category III sites where OE is present is to use anomaly avoidance when conducting sampling. If a site requires that OE be cleared for the sole purpose of conducting sampling and characterization during pre-construction, construction at that site should be avoided. Alternatively, the CSET may determine that (1) characterization can continue if the evaluation team practices OE avoidance techniques as sampling proceeds (Chapters 4 and Chapter 5) or (2) the proposed construction site cannot be approved.

For Category II sites and "cleared" Category III sites, Step 1 includes identifying COCs and establishing how action levels for the COCs are to be selected.

3.2.1 Identify COCs

The nature of the activities that occurred at the site under investigation can be used to help identify COCs. For example, COCs for a site used to store dry cleaning solutions would include VOCs and nonvolatile organics. COCs for a site used to perform maintenance on batteries would be inorganic compounds. COCs for a site used to store treated wood products would be SVOCs and inorganic compounds (compounds found in wood preservatives).

Broad analytical categories that typically might include the COC of interest include these:

- CWAs (see Section 1.4.2)
- CWA degradation products (e.g., lewisite oxide, inorganic arsenic, EA-2192).[19]
- Nonhalogenated VOCs (e.g., benzene, xylene, toluene),
- Nonhalogenated SVOCs (e.g., phenol),
- Halogenated VOCs (e.g., trichloroethene),
- Halogenated SVOCs (e.g., pentachlorophenol, hexachlorobenzene),
- Polynuclear aromatic hydrocarbons (e.g., fluoranthene, benzo[a]pyrene),
- Insecticides/herbicides (e.g., DDT);

- Metals (e.g., arsenic, cadmium, chromium),
- Radionuclides (e.g., strontium-90),
- Other inorganics (e.g., asbestos, cyanide, fluoride),
- Explosives (e.g., RDX, HMX), and
- Total petroleum hydrocarbons.

In some cases, the CSET may be able to focus on a particular analytical category (e.g., metals) or a particular analyte (e.g., lead) in determining the applicable COC for a site. In other cases, the CSET may have to resort to a "shotgun" approach and develop a more expansive list of COCs (e.g., metals, halogenated organics, and insecticides/ herbicides) when crafting the SAP because there is not enough information available to focus on any particular analyte. In general, analytical costs are incurred on the basis of analytical categories rather than individual analytes. As a result, the CSET should strive to limit the number of COCs to those analytes that are reasonably expected to be present on the site on the basis of its history.

3.2.2 Determine Action Levels

Action levels are the threshold values that establish the criteria for choosing between alternative actions. For the purpose of this manual, alternative actions are to approve the site for construction, with or without contingencies (e.g., removal of contaminated soil), or not approve the site for construction. Action levels can be based on regulatory thresholds or standards; RBCs, PRGs, or SSLs derived from standardized default assumptions; or site-specific risk assessments. In some cases, it may behoove an installation to have a custom set of action levels developed, especially if an unusual future land use is expected for a number of prospective construction projects. Whenever possible, the CSET should use lists of standardized action levels to derive action levels for the construction site evaluation, so the costs of conducting site-specific risk assessments can be avoided. The CSET should use tables that provide action levels that are appropriate for the anticipated land use of the proposed construction site. Action levels for an industrial exposure scenario tend to be higher than action levels for a residential exposure scenario. For example, the October 1997 version of the EPA Region III RBC table reports arsenic RBC values of 3.8 and 0.43 mg/kg for industrial and residential land use, respectively. Because such tables are periodically updated, the CSET should seek current information sources. For example, the following Web sites offer up-to-date versions of standardized PRG tables:

- Region 9 PRG table at http://www.epa.gov/region09/ under "Solid and Hazardous Waste Programs"
- Region 3 RBC table at http://www.epa.gov/reg3hwmd/risk/ under "Risk Assessment"
- EPA SSLs at http://www.epa.gov/oerrpage/superfnd/resources/.

States or EPA regions that host the installation may also have developed standardized RBC tables that can be used to derive action levels.

The rough boundaries of the proposed site should be delineated as part of the evaluation process.

Despite the many positive aspects associated with standardized action levels, the conservatism built into such action levels can, in some cases, overestimate the risks associated with some exposure scenarios. As a result, the CSET may want to work with experienced risk assessment professionals to perform site-specific risk assessments to more accurately appraise risks associated with a prospective construction site. An example of a site-specific risk assessment used for construction site clearance is provided in Appendix C. Two sources that can be used to prepare site-specific risk assessments are the *CERCLA Baseline Risk Assessment: Reference Manual*, DOE/EH-0484, published by DOE in March 1995, and *Understanding Superfund Risk Assessment*, OSWER-9285-7-06FS, published by the EPA in 1992.

3.3 Step 2: Define Study Boundaries

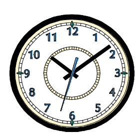
Defining the boundaries of the SAP for Category II and III sites is critical, because by properly bounding the SAP, the collection of unnecessary data can be avoided.

3.3.1 Spatial Boundary

In general, the spatial boundary of the study area where samples are to be collected is determined by the spatial extent of the proposed construction site. In evaluating the spatial boundary of the study area, the CSET is encouraged to physically stake out at least the rough boundaries of the proposed construction site. When possible, the CSET should divide the study area into strata that have relatively homogeneous characteristics. By using the results of the archival record search, the CSET may be able to stratify or segregate the site into subsets that exhibit homogenous characteristics that could influence the outcome of the study. For example, the CSET may be able to stratify the site into areas that are going to be disturbed (and thus present the opportunity for the exposure to site-specific contaminants), such as the "footprint" of a planned building, and perimeter areas that will remain undisturbed, such as a mature-growth forest or wetland.

By dividing the site into subsets of data, the evaluator may be able to reduce the complexity of the problem, the variability within subsets, and the number of samples needed to appraise the risks associated with a site.

3.3.2 Temporal Boundary



The temporal boundary is the time frame during which decisions regarding the site apply. In general, samples are collected and data are evaluated only once — before construction of a site — and they are chiefly meant to evaluate risks during site construction. However, in some cases, the temporal boundary may involve the end users of the site. For example, when a risk assessment is being performed, the use of industrial exposure scenarios may be appropriate for construction workers (because they may be present at the site only during work hours). However, the use of residential exposure scenarios may be more appropriate if a proposed site is to be used as base housing or as a barracks. Thus, in some cases, the time frame for decisions regarding site risks could involve both pre- and postconstruction time periods.

3.3.3 Areas Where Exposure to COCs Occurs

Typically, the DQO process requires a scale of decision making to be defined. This scale should represent the smallest, most appropriate subset of a population for which decisions will be made within spatial and temporal boundaries. In the case of construction clearance, the scale of decision making corresponds to the size of the area where the target receptors derive the majority of their exposure. For example, construction workers at a given construction site may derive the majority of their exposure from excavating the building footprint. Thus, from the perspective of the construction site workers, the important element in the characterization effort is determining the concentrations of COCs within the building footprint. However, in some cases, a proposed project could result in longer exposure than would be experienced by a construction worker. For example, a prospective barracks or family housing structure could result in the almost continuous occupation of a prospective building site. In such cases, the CSET should include areas vicinal to the building footprint in the characterization effort, since long-term site occupants could be exposed to COCs in such perimeter areas.

3.4 Step 3: Develop a Decision Rule

The development of a decision rule is site specific. The decision rule requires the consensus of the evaluator, installation commander, and MACOM decision makers. However, a generic decision rule that flows from AR 415-15 and the DQO process can be developed.

1. If detected, clear the OE, explosive waste, or CWAs from the proposed construction site. Practice OE avoidance and conduct the SAP, or do not approve the site for further characterization.

2. If the concentration(s) of COC(s) within the proposed construction site is (are) greater than the action level, remove the soil from the site; otherwise, manage the risk or do not approve the site for construction.

The strict interpretation of the second item above would require a decision whenever an action level is exceeded. However, the CSET should keep in mind that, as described in Section 3.2.2, action levels overestimate the risks associated with some exposure scenarios. Thus, a slight exceedence of an action level in, for example, one sample, may not automatically require hot spot removal, risk management, or the disapproval of a construction site. The CSET should consult with risk assessment professionals regarding such minor exceedences to determine if the site-specific exposure scenario differs from the assumption rules keyed to the action level being exceeded. For example, the exposure duration for workers building footers for a transmission tower that is to be constructed in two weeks would be considerably different than the duration for an industrial exposure scenario that presumes an 8-hour/day, 40-hour/week work week.

3.5 Step 4: Prepare a Sampling and Analysis Plan

Category II sites and cleared Category III sites require the execution of an SAP to ascertain whether the site is suitable for construction activities. The CSET may or may not integrate geophysical studies and soil gas studies into the SAP. Geophysical and soil gas studies may be appropriate for investigating the contamination scenarios, particularly when these techniques are used to focus the collection and analysis of environmental media samples. However, as a minimum, this manual recommends the collection of at least some environmental media samples to evaluate a proposed site for construction clearance.

A SAP for a Category II site should address the following elements:

- Sample numbers, types, and locations;
- Sampling procedures and equipment decontamination procedures;
- Storage and handling of investigation-derived waste (IDW);
- Sample handling and, if applicable, sample packaging and shipment;
- Sample analysis;
- Sample documentation;
- Quality assurance/quality control (QA/QC) procedures; and
- Records management.

3.5.1 Sample Numbers, Types, and Locations

The numbers, types, and locations of samples collected depend on site-specific considerations. In general, the most common environmental medium from which samples for a construction site are collected is soil. However, in some cases, the evaluation of a construction site may also involve the collection of samples from other environmental media. An example is an evaluation of surface-water features that channel rainfall runoff away from a given construction site.

Sample numbers and locations can be derived in a number of ways. The September 1994 EPA document, *Guidance for the Data Quality Objectives Process*, can help the CSET select sample numbers and locations on the basis of probabilistic considerations. The CSET urged to refer to this DQO guidance if statistical rigor is required for a construction clearance operation. For example, the CSET could use the DQO process to develop a sample design that is based on the collection of sample results and that can eventually be used for deriving COC mean values and comparing them with action levels.

The CSET could also forgo a statistical sampling design and rely on comparing the data on the COCs from each sample point with action levels. Sample numbers and locations could be based on the spatial extent of the proposed construction site and the depth to which the site is to be disturbed by construction activities. For example, if a building footprint is 100 by 100 ft, the team could establish a grid over the area to be disturbed and, by using a systematic sampling design, sample at each node of the grid (e.g., every 10 ft). Alternatively, the CSET could number the nodes of the grid and then use a random number table to select an appropriate number of nodes for sampling.

Still another option is to use a "worst case" approach to select sample locations. In such an approach, those areas most likely to contain the most elevated concentrations of COCs (for example, areas where soil is stained or where historical COC releases have occurred) are targeted for sampling. The rationale for using a worst case approach is that if action levels are not exceeded in those locations expected to represent the most elevated concentration(s) of COCs, it would be unlikely that any other location at the prospective site would represent a risk to construction workers or future users.

3.5.2 Sampling Equipment and Equipment Decontamination

Sampling procedures and equipment depend on the type of sample medium and desired sample depth. The CSET can select from among a wide variety of sampling techniques. Table 3.3 summarizes a number of useful technologies.

Equipment decontamination should take place in areas specially designated for this activity that are located separately from the sample handling and storage area. The equipment decontamination procedure should be sufficient to remove environmental media and COCs from the sampling equipment to prevent cross-contamination between sampling locations. The following decontamination sequence is offered as an example of an acceptable decontamination protocol.

At the decontamination area, reusable equipment will be hand-washed in the following sequence:

- Thoroughly brush-clean with a phosphate-free detergent (such as Alconox),
- Rinse with tap water,
- Rinse with distilled and deionized water, and
- Rinse with methanol and air-dry.

3.5.3 Storage and Handling of Investigation-Derived Waste

When executing an SAP, the CSET should strive to minimize the generation of IDW. As noted in Table 3.3, a number of sampling techniques minimize or even preclude the generation of IDW. Sampling methods with such minimal impact to environmental media should be used whenever possible. In general, for Category II sites, the CSET can probably safely return any IDW to the source area. For example, cuttings from borings or surficial soil sample collection locations can be

TABLE 3.3 Field Sampling and Collection

Technique/Instrumentation	Analytes	Maximum Depth	Production Rate	Investigation-Derived Waste Volume	Technology Status	Relative Cost per Sample
Drilling Methods — Unconsolidated Formations						
Hollow-stem auger	All	●	●	△	III	●
Direct mud rotary	All	■	●	△	III	●
Directional drilling	All	●	●	△	III	△
Solid flight and bucket augers	All	●	●	△	III	●
Jetting methods	2, 4-6, 10, 11	●	■	△	III	■
Sonic drilling	All	■	■	■	II	△
Drilling Methods — Consolidated Formations						
Direct air rotary with rotary bit/downhole hammer	2, 4-6, 10, 11	■	●	△	III	●
Cable tool	2, 4-6, 10, 11	■	△	●	III	●
Rotary diamond drilling	2, 4-6, 10, 11	■	△	△	III	△
Drive Methods						
Cone penetrometer	All	●	■	■	III	●
Direct push sampler	All	●	■	■	II	■
Sampling Installations for Portable Samplers						
Driven wells	All	●	■	■	III	■
Single riser/limited interval wells	All	●	■	△	III	●
Nested wells/single borehole	All	●	△	△	II	●
Nested wells/multiple boreholes	All	●	△	△	II	●
Portable In-Situ Groundwater Samplers and Sensors						
Direct drive samplers	All	●	●	■	II	■
Passive multilayer samplers	1, 3	●	●	■	II	■
Fixed In-Situ Samplers						
Multilevel capsule samplers	All	●	●	●	II	●
Multiple-port casings	All	●	●	●	II	■
Passive multilayer samplers	1, 3	●	●	■	II	■
Destructive Sampling Methods						
Coring and extraction	All	●	●	●	II	■
Temporary installations	All	●	●	●	III	■
Hand-Held Methods						
Scoops, spoons, and shovels	All	△	■	■	III	■
Augers	All	△	■	■	III	■
Tubes	All	△	■	■	III	■
Power-Driven Soil Samplers						
Split and solid barrel	All	△	■	■	III	■
Rotating core	2, 4-6, 10, 11	△	●	●	II	●
Thin-wall open tube	All	△	■	■	III	●
Thin-wall piston/specialized thin wall	All	△	■	■	III	●

TABLE 3.3 (Cont.)

Technique/Instrumentation	Analytes	Maximum Depth	Production Rate	Investigation-Derived Waste Volume	Technology Status	Relative Cost per Sample
			Portable Positive Displacement			
Bladder pump	All	■	■	●	III	●
Gear pump	All	●	●	●	I	●
Submersible helical rotor pump	All	●	●	●	I	▵
Gas-driven displacement pumps	All	●	●	●	III	■
Gas-driven piston pumps	All	■	●	●	II	▵
			Other Portable Groundwater Sampling Pumps			
Suction-lift pumps (peristaltic)	All	▵	●	●	III	■
Submersible centrifugal pump	All	■	●	●	III	▵
Inertial-lift pumps	All	●	●	●	II	■
			Portable Grab Samplers			
Bailer	All	■	●	▵	III	■
Pneumatic depth-specific samplers	All	■	●	■	II	●
Mechanical depth-specific Samplers	All	■	●	▵	III	■

LEGEND

Maximum Depth: ■ = 100 feet plus, ● = Up to 100 feet, ▵ = Up to 25 feet.

Production Rate: ■ = Available quickly, ● = Available in a short amount of time, ▵ = Available after an extended wait.

Investigation-Derived Waste Volume: ■ = Small, ● = Medium, ▵ = Large.

Technology Status: III = Commercially available and routinely used field technology, II = Commercially available technology with moderate field experience, I = Commercially available technology with limited field experience.

Relative Cost per Sample: ■ = Least expensive, ● = Midrange expensive, ▵ = Most expensive.

Analytes: 1 = Nonhalogenated VOCs, 2 = Nonhalogenated SVOCs, 3 = Halogenated VOCs, 4 = Halogenated SVOCs, 5 = Polynuclear aromatic hydrocarbons (PAHs), 6 = Pesticides/herbicides, 7 = Metals, 8 = Radionuclides, 9 = Other inorganics (asbestos, cyanide, fluorine), 10 = Explosives, 11 = Total petroleum hydrocarbons, and 12 = Specific analyte (named in matrix).

Source: Adapted from Federal Remediation Technologies Roundtable, Field Sampling and Analysis Technologies Matrix home page, http://www.frtr.gov/site, accessed September 1998.

A variety of sampling methods can be used.

returned to the borehole. In a similar fashion, if "minimum impact" decontamination liquids such as distilled water, tap water, phosphate-free detergent, and ethanol are used, the spent liquids can be poured onto the ground in the area being investigated.

As discussed in Chapters 4 and 5, IDW from Category III sites should be handled with scrupulous care because of the potential presence of CWAs, OE, and explosive waste. Site-specific IDW handling requirements will likely be required until the CSET determines that the IDW is free from CWA and OE hazards. IDW from Category III sites deemed to be free from such hazards can also be returned to the source area. In some cases, IDW may need to be put in containers until such decisions are made.

3.5.4 Sample Handling and, If Applicable, Sample Packaging and Shipment

3.5.4.1 Sample Labeling

At the time of sampling, each sample should be assigned a unique sequential number that will be permanently affixed to the sample container. The sample label should include the following information:

- Project name,
- Project number,
- Location,
- Date and time of sample collection,

In some cases, investigation-derived waste may need to be put in containers until decisions regarding disposal are made.

- Analyses to be performed,
- Preservatives (for water samples),
- Sample number, and
- Number of containers for the sample.

3.5.4.2 Sample Containers, Preservatives, and Sample Holding Times

Before use, all sample containers should be cleaned in accordance with EPA and AEC protocols. Certified, precleaned sample containers may be obtained from a number of sources. The sample containers, preservatives, and sample holding times to be used for aqueous and solid samples are described thoroughly in COE Engineering Manual 200-1-3, *Requirements for the Preparation of Sampling and Analyses Plans*, published in September 1994.

3.5.4.3 Sample Chain of Custody, Packaging, and Transportation

Throughout the investigation of a construction site, the possession and holding of samples will be regulated through chain of custody procedures, including the use of chain of custody documentation and the affixing of custody seals. A person is considered to have custody of a sample if that sample is (1) actually in the person's possession, (2) within sight after being in the person's possession, and/or (3) in the person's possession at one time but moved to a locked area to prevent tampering. Chain of custody begins when sample containers are prepared and a sample is collected.

When applicable, all sample containers will be packaged and transported in a manner that will protect the integrity of the sample and ensure against any detrimental effects from possible leakage.

Packaging procedures will vary, depending on the suspected contaminant concentrations and the U.S. Department of Transportation (DOT) hazard class. In general, the off-site laboratory will provide instructions on packaging and shipping requirements.

3.5.5 Sample Analysis

As the SAP is being prepared, the evaluator needs to determine whether environmental media samples are to be analyzed on site or off site. For installations with a significant number of planned construction projects, it may be cost-effective to establish an on-site analytical laboratory. However, because of the costs involved with the procurement, maintenance, and operation of the sophisticated analytical equipment typically required to generate analytical data of credible quality, it may be more cost-effective for the evaluator to use contractor-operated, off-site analytical laboratories.

Analytical methods are approved procedures for measuring the presence and concentrations of COCs. In selecting an analytical method, the CSET must ensure that results from the analytical laboratory satisfy the DQOs for the project. In particular, the CSET must ensure that the data produced are of known and documented quality and that concentrations of COCs below the action levels can be achieved.

The CSET can refer a number of sources to when trying to select the appropriate analytical method. A useful starting point is the EPA's Environmental Monitoring Methods Index (EMMI) system, an automated inventory of the EPA's official methods compendium. The EMMI is updated on a semiannual schedule. The most recent version of the compendium is on the Web at http://www.epa.gov/epahome/index.

3.5.6 Sample Documentation

To ensure compliance with minimum QA/QC standards, appropriate documentation procedures must be followed for each sample. Proper record keeping requires that field sampling logs, chain of custody forms, and sample labels be prepared and maintained. Field sampling logs must include (as a minimum) the following information for each sample:

- Project or installation for which the sample is being collected,
- Sampling date and time,
- Sampling location or source,
- Field sample number,
- Analyses required for the contents of each container,
- Field data (if applicable),
- Name of sampler,
- Sample depth,
- Sampling technique, and
- Preservative used (if applicable).

3.5.7 QA/QC Procedures

Regardless of whether on-site, in-house analytical capability or off-site, fixed laboratory capability is used, the CSET must ensure that all decisions regarding a construction site are based on data of known quality. As discussed in Chapter 6, this manual advocates the performance of a data quality assessment known as a desk-top review. Performance of a desk-top review is predicated on the assumption that the CSET have access to a laboratory report with QC summary results and that a number of QA/QC samples have been collected. As a minimum, the project team should collect and have analyzed duplicate samples (samples run by the same laboratory), field blanks (blanks to determine if contaminants are artificially introduced in the field), and trip blanks (blanks to determine if contaminants are artificially introduced during shipment). A good rule of thumb is to collect and analyze one duplicate sample for every 10 samples collected. Field blanks can be collected at the beginning, middle, and end of the project. One trip blank should accompany each sample shipment.

Additional discussion on QA/QC procedures and the evaluation of the QA/QC samples noted above is included in Chapter 6.

3.5.8 Records Management

Bound logbooks will be used for all record keeping, both in the field and in the laboratory. Bound logbooks will provide a chronological sequence of when data were recorded. All logbooks will contain a unique document control number. As a minimum, all pages with information recorded on them will be numbered. To facilitate data validation, each person who makes an entry in a logbook must sign and date the entry. All entries must be recorded in indelible ink. Corrections to entries will be made by drawing a line through the incorrect entry, recording the correct information, and initialing and dating the corrected entry. Logbooks containing information specific to the project will be archived at a document control center at the host installation.

4 HAZWOPER STANDARD

Activities to be conducted at individual prospective construction sites should be evaluated to determine if they fall under the *Code of Federal Regulations* (CFR), Title 29, Section 1910.120, "Hazardous Waste Operations and Emergency Response," the HAZWOPER standard. The applicability of the HAZWOPER standard depends on whether the work sites are regulated and whether a worker could be exposed to health and safety hazards as a result of operation. If it is determined that an operation falls under the scope of HAZWOPER, the evaluator must determine which elements of the HAZWOPER standard must be followed. If the HAZWOPER standard is implemented, the Occupational Safety and Health Act stipulates that, in the case of overlap or conflict with another standard, the more protective standard applies.

Figure 4.1 has been included to help the evaluator determine whether HAZWOPER is applicable for the sampling activities associated with a given prospective construction site.[20]

A number of scenarios can trigger the applicability of HAZWOPER. In some cases, a prospective construction site may be located on or near an uncontrolled hazardous waste site on the installation. For example, the proposed construction site may be on an installation or portion of an installation listed on the NPL. Alternatively, a proposed construction site may be located on a RCRA corrective action cleanup site. Or it may be - located on a RCRA treatment, storage, and/or disposal (TSD) facility with operations that involve hazardous wastes. Perhaps the most far reaching HAZWOPER trigger noted is a site at which the investigation of areas of known or suspected contamination is required to determine the presence of hazardous substances. Evaluations of Category II and III sites are conducted because there are suspicions about the presence of hazardous substances. Thus, in general, sampling activities at Category II and III sites should always be conducted under the umbrella of a HAZWOPER-compliant program.

HAZWOPER compliance involves a number of elements including, but not limited to, the following:

- 9 CFR 1910.120 b(1)(I), which requires employers to establish a written health and safety program;
- 29 CFR 1910 e(1)(I), which requires the training of site personnel; and
- 29 CFR 1910.120(f), which requires participation in a medical surveillance program.

In addition to complying with the programmatic, training, and medical surveillance requirements noted above, sampling activities at a prospective construction site require the preparation and approval of a site-specific health and safety plan (HASP). The components of the site-specific HASP must address the following elements:

- A safety and health risk or hazard analysis for each site task and operation mentioned in the work plan;

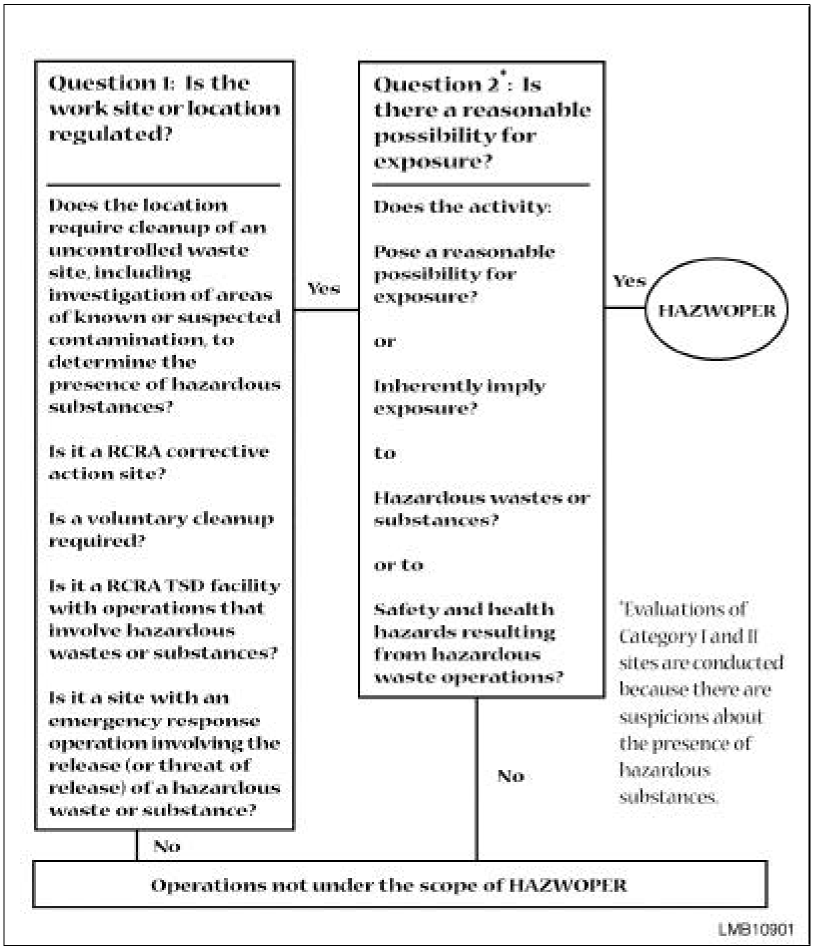


FIGURE 4.1 Determining HAZWOPER Scope (Source: Adapted from Reference 20)

- Employee assignments;
- Personal protective equipment to be used by employees for each site task and operation being conducted;
- Medical surveillance requirements;
- Frequency and types of air monitoring and environmental sampling techniques and instrumentation to be used, including methods of maintenance and calibration of monitoring and sampling equipment;
- Site control measures;
- Decontamination procedures;
- An emergency response plan;
- Confined space entry procedures (if applicable); and
- A spill control program.

The site-specific HASP must be made available to contractors, subcontractors, employees, Occupational Safety and Health Administration (OSHA) personnel, other federal officials, and state and local officials.

5 DETECTING AND AVOIDING OE/CWAS AND CLEARING CATEGORY III SITES

5.1 Evaluating the Feasibility of Clearing a Category III Site

As noted in AR 415-15(f), the potential presence of OE as revealed by historical research is sufficient justification for classifying a prospective site as Category III. However, classification as Category III does not preclude approval of site construction, because AR 415-15 specifies, "Even though the site is classified as Category III, it may still be a feasible construction site because of the nature of the unexploded ordnance contamination (for example inert) or the capability to clear the construction site."

5.1.1 CWA Monitoring and Clearance

AR 415-15 does not explicitly mention CWA-related compounds. Nevertheless, identifying whether or not CWA-related compounds are present is implied in Subsection 3-3(a)(6), which requires the evaluation team to ensure that the "site is free from pollutants or contaminants that would impact the start of construction." Prospective construction sites where CWAs could be present will be classified as Category III sites. The potential presence of CWAs at a prospective construction site requires the evaluation team to consult with a host, tenant, or private sector expert having a core competence in the sampling and analyses of these compounds.

CWAs include lethal chemical agents, blister agents, incapacitating agents, tear-producing and vomiting compounds, and binary components. Lethal chemical agents include choking, nerve, and blood agents such as phosgene, sarin, and hydrogen cyanide, respectively. Blister agents include such compounds as distilled mustard, lewinstein mustard, and nitrogen mustard. Incapacitating agents produce effects that can last for hours or days after exposure and include compounds like 3-quinuclidnyl benzilate (BZ). Tear-producing and vomiting agents are colloquially referred to as riot control agents. Vomiting agents are no longer authorized for use by U.S. forces in combat or in training. The standard tear-producing agents currently in the U.S. Army inventory include compounds like mace (CN) and bromobenzylcyanide (CA).[21]

Although some Army-sanctioned analytical methods can be used to analyze CWA degradation compounds, there are no standardized analytical methods to analyze CWA compounds at low detection limits. However, the U.S. Army — chiefly the Soldier and Biological Chemical Command (SBCCOM), which was formerly called the Chemical and Biological Defense Command (CBDCOM) — is involved in a program to identify the universe of CWA analytical techniques currently in use throughout the Army. These efforts may or may not lead to the development of Army-approved analytical methods for analyzing CWAs in the future. In the interim, evaluation teams that need to sample and analyze a site for CWAs are urged to refer to the CBDCOM point of contact: Thomas Sekula, phone: (410) 436-8441, e-mail: Thomas.Sekula @sbccom.APGEA.ARMY.MIL.

Although no low-detection-limit CWA analytical methods are sanctioned for use Army-wide, a number of analytical

A Real Time Analytical Platform (RTAP) contained in the truck on the left is being used to monitor chemical warfare agents during intrusive sampling.

methods are being used by specific organizations within the U.S. Army. For example, in a memorandum of agreement between the U.S. Army Engineer and Support Center, Huntsville, Alabama, and the Edgewood Chemical and Biological Center (formerly the U.S. Army Edgewood Research, Development and Engineering Center), two pieces of CWA detection equipment in support of remediation projects are mentioned: mobile environmental analysis platform (MEAP) and real-time analytical platform (RTAP).[22] MEAP and RTAP could be used to provide low-level monitoring and detection of CWAs during the clearance of a prospective construction site.

The United States Army Center for Health Promotion and Preventive Medicine (USA CHPPM) recently authored a document that evaluates the currently available data and scientific methods for assessing potential chronic human health risks from residual CWAs in environmental media. The data evaluated were then used to calculate health-based environmental screening levels (HBESLs). HBESLs were developed for two common theoretical exposure scenarios, residential and industrial, by using three current EPA chronic risk assessment methods and common default and chemical-specific parameters. Soil RBCs, PRGs, and SSLs for the vesicant CWAs sulfur mustard (HD) and lewisite and for the nerve agents tabun (GA), sarin (GB), soman (GD), and VX were developed (http://www.chppm-www.apgea.army.mil/hrarcp/pages/caw/home.htm).[16] (Note that throughout the CHPPM document, it states that ongoing scientific research and literature reviews may require future updates and/or reevaluations of information and that the RBCs, PRGs, and SSLs developed should be used carefully and only when a number of conditions are met. The CSET is urged to refer directly to the noted document to obtain more detailed information on health-based screening levels for CWAs.

The conventional OE avoidance/ clearance and contaminant sampling activities described in Chapters 3 through 7 can proceed once a Category III site is deemed by recognized experts to be clear of CWAs.

5.1.2 OE Identification and Avoidance and Site Clearance

In some cases, even if OE is present at a site, construction can safely proceed if at least a portion of the Category III site is cleared of OE. Determining the feasibility of clearing a given prospective construction site depends on site-specific factors including the availability of alternative construction sites, the cost of clearing the proposed site, and other mission-related requirements. In some cases, the cost of clearing a proposed construction site of OE may not be cost effective (see text box). If the evaluation team determines that clearance of OE from a Category III site is not feasible, the location, form, and boundaries of the Category III land tract should be established and recorded in an authoritative installation record repository. Several of the geophysical techniques detailed in Appendix A can be used to help delineate the land tract.

Execution of a Category III site SAP can proceed while the evaluation team is determining whether or not the site should be cleared. However, because of the hazards associated with intrusive characterization activities (such as installing borings and monitoring wells and collecting soil samples where OE and explosive waste could be present), the evaluation team should rely on nonintrusive characterization techniques to optimize the locations and depths at which a minimum number of intrusive samples can be collected. Appendices A and B describe a number of useful nonintrusive characterization techniques.

Intrusive characterization activities at Category III sites require the involvement of either a DOD or a private sector expert with a core competence in OE remediation. Installations may or may not have access to OE expertise from host or tenant groups. The CSET should be cautioned that major differences exist between OE remediation and the traditional military missions of explosive ordnance disposal/countermine (EOD/CM). EOD efforts typically focus on the surface or near-surface clearance of OE. EOD/CM missions usually involve emergency response and minefield breaching — missions that focus on speed and the clearance of a pathway through an area and

> **Costs for Subsurface Remediation**
>
> The technologies currently used for subsurface OE remediation require walking with metal detection devices, placing a flag at each location where metal is detected, and manually digging up detected objects — traditional “mag and flag.” These techniques are not cost effective for large areas of land or feasible for all terrain. Most important, mag and flag surveys are plagued by excessive false alarm rates. At some sites, more than 100 subsurface nonordnance items (clutter) have been flagged and excavated for each actual ordnance item found and removed. Under normal circumstances, OE remediation costs can be as high as $20,000 per acre (Reference 23, page 10).

are generally designed for OE avoidance. In contrast, OE remediation can involve the detection and removal of OE deeply buried in the subsurface (see text box).[23] As a result, in some cases, the CSET may need to outsource OE remediation work.

OE Remediation

OE remediation involves a complex set of tools, skills, personnel, training, and requirements. Skills include a knowledge of ordnance-recognition and associated computer software, precise mapping, subsurface geophysical methods for detection and characterization, OSHA safety training, explosives handling, blaster skills, and data management. OE remediation also requires the expertise to handle complex legal, policy, and safety problems when OE sites are being transferred to private use. OE remediation could employ EOD-style surface clearance tools, but only as a first step (Reference 23).

5.2 Outsourcing OE Remediation Work

Should outsourcing for OE detection, avoidance, and clearance be required, the CSET can obtain assistance from the COE Mandatory Center of Expertise located at the U.S. Army Engineering and Support Center in Huntsville, Alabama. Although no template work plan for OE clearance and sampling was available from this Center at the time this construction clearance manual was prepared, an example of a site-specific scope of work prepared by the Center is included in Appendix D.

5.3 Avoiding OE While Integrating the Plans

In some cases, the CSET may want intrusive samples to be collected and analyzed before OE is cleared from a Category III site. Intrusive sampling on a Category III site can be executed safely as long as "safe" sampling locations have been identified by a competent OE contractor. The parallel performance of OE avoidance, sampling, and analysis activities requires integrating the SAP, HASP, and OE remediation contractor project documents.

The blended documentation should address key elements such as

- Chain of command,
- Emergency response,
- Standard operating procedures for OE, and
- Avoidance at target sample locations, etc.

The CSET should note that requirements and guidance for the remediation of active and inactive testing/training ranges contaminated with OE are contained in AR 385-64.[24]

6 DESK-TOP DATA REVIEW

In general, items to keep in mind when conducting a desk-top data review include the overall data collection system, field sampling and sample handling, and laboratory performance.

When evaluators review the overall data collection system and field sampling activities, they should check:

- Have the correct sampling procedures been followed?
- Do sample numbers reported on a laboratory report match site locations?
- Have the proper analytical methods been used?
- Have the correct analytes been reported?
- Do the reported detection limits meet the project requirements (i.e., are detection limits as low as action levels)?

If there are duplicate sample results, the relative percent different (RPD) between the two results should be calculated thus:

$$RPD = \frac{\text{Difference between sample duplicate results}}{\text{Mean of duplicate results}} \times 100$$

A good rule of thumb is that for a pair of results that are more than five to ten times the detection limits, the RPD between the two results should be not greater than 50% for soil samples or greater than 35% for water samples. Poor precision may indicate a poor sampling technique (particularly improper homogenization of the sample before it was split) or poor laboratory performance.

Field, trip, and equipment blanks should also be checked to see if there is any contamination being introduced into the overall data collection and management system. A comparison of blank samples can be valuable for tracing the source of contamination. For example, contaminants found in equipment blanks but missing from trip and field blanks suggest contaminant introduction at the analytical laboratory. In some cases, common laboratory contaminants, such as acetone, are also found at contaminated sites, a situation that requires a determination of whether the detected analyte is "real." Information gathered from the preconstruction assessment can help the evaluator determine whether detected contaminants are real or artifacts of the overall data collection and management system.

Laboratory performance should also be checked. Whether an analysis is conducted on site or off site, the analytical results should be accompanied by the documentation necessary to establish the quality of the data. If possible, documentation packages from the laboratory (whether on or off site) should include a case narrative describing any problems that the laboratory encountered. The following results, as recorded in the laboratory documentation, should also be checked:

- Sample holding times,
- Performance evaluation sample results,
- Laboratory control sample results,
- Method blank results, and
- Surrogate recoveries.

7 RISK ASSESSMENT PROCEDURES

Proposed constructions sites can vary significantly in terms of environmental setting; history; physical and chemical characteristics of COC-, OE-, and CWA-related hazards; and the risks that the site may pose to end users. This manual recognizes this diversity and provides for a tiered approach to the evaluation of those risks by using either look-up tables or a site-specific risk assessment.

7.1 Using Look-up Tables

The CSET is urged to consult with a risk assessment professional when performing risk assessments. In some cases, a risk assessment professional may recommend the use of look-up tables to evaluate risks posed by COCs in environmental media at proposed construction sites. Three different look-up tables were introduced in Section 3.1: PRGs, RBCs, and SSLs. In addition, CWA-related HBESLs were introduced in Section 5.1.1. Each look-up table has rules of use and assumptions underlying the development of the protective levels it reports. As a result, the RBC, PRG, and SSL values for any particular compound tend to differ (see Table 7.1). In addition, SSLs were developed by the EPA for the evaluation and cleanup of contaminated soil at Superfund sites where future residential land use is anticipated. In contrast, RBCs and PRGs were developed for the evaluation and cleanup of contaminated soil at sites where either residential or industrial future land use is anticipated. By consulting with a risk assessment professional, the CSET can develop the best match between the exposure scenario at the prospective construction site and a given look-up table.

PRGs, RBCs, and SSLs are periodically updated. The following URL addresses have the most current versions of the relevant look-up tables:

- PRGs: http://www.epa.gov/region09/ under "Solid and Hazardous Waste Programs,"
- SSLs: http://www.epa.gov/oerrpage/superfund/resources/,
- RBCs: http://www.epa.gov/reg3hwmd/ under "Risk Assessment."

Once a risk assessment professional has approved a given risk assessment approach, the CSET can reuse the approach in cases where the exposure scenario of a prospective construction site is similar.

Proposed Construction Site Fort XYZ

EPA Region III RBCs

Sample No. 1 COC	Result (mg/kg)	Industrial Soil Ingestion (mg/kg)	Residential Soil Ingestion (mg/kg)
White phosphorus	1.0	41	1.6
1,1,2,2-Tetrachloroethane	1.0	29	3.2
Cadmium	20.0	1,000	39
Benzene	15.0	200	22
Arsenic	0.22	3.8	0.43

Reported results for sample No.1, the sample with the highest concentrations of the COC, are well below the RBC levels developed by EPA Region III and adopted by the evaluation team. As a result, the evaluation team has determined that there are no unacceptable risks from the COC at the proposed construction site (EPA Region III RBC Table, October 22, 1997).

Analytical results deemed usable after the desk-top review can be compared with appropriate look-up tables. For example, in the look-up table in the text box, the points of exposure are assumed to be located within the area of the proposed construction site where the highest concentrations of the COCs have been detected. Concentrations of the COCs should be compared with values in the look-up table, which in this case are RBCs.

If statistical rigor is required and if there are sufficient data, the evaluation team may choose to compare values in the look-up table with statistical limits (for example, 95% upper confidence levels of the mean value of a COC).

7.2 Using a Site-Specific Risk Assessment

In some cases, the assumptions that form the basis of look-up tables typically available in the literature may be overly conservative and not reflect site-specific circumstances. As a result, the evaluation team may elect to perform a site-specific risk assessment. An example of a site-specific risk assessment approach used to evaluate a construction site at Aberdeen Proving Ground, Maryland, is included in Appendix C.[25]

TABLE 7.1 Comparison of RBC, PRG, and SSL Values for Various Compounds

Chemical Abstract Service No.	Compound	Generic SSL[a] "Ingestion" (mg/lb)	EPA Region III RBC "Soil Industrial" (mg/kg)	EPA Region IX PRG "Industrial Soil" (mg/kg)
71-43-2	Benzene	22	200	1.4
1336-36-3	PCBs	1	2.9[a]	1.3
79-34-5	1,1,2,2-Tetrachloroethane	3	29	87
79-01-6	Trichloroethylene	58	520	6.1
7440-38-2	Arsenic	0.4	3.8	3.0
7440-39-3	Barium	5,500	140,000	100,000
18540-29-9	Chromium (VI)	390	6,100	64
7439-92-1	Lead	400	No value reported	1,000
7440-02-0	Nickel	1,600	41,000	37,000
7440-66-6	Zinc	23,000	610,000	100,000

[a] Except for Archolor 1016, which is 82.

8 CONSTRUCTION SITE APPROVAL DETERMINATIONS

On the basis of the results of the preconstruction assessment, SAP, desk-top data review, and risk assessment, the CSET should have sufficient information to determine whether approval can be granted for a prospective construction site. In some cases, site approval may be granted without conditions. For example, no conditions would be necessary for a Category I site. In some cases, a Category II site might be reclassified as a Category I site on the basis of the results of an environmental survey technique. In some cases, site approval might be contingent upon conditions such as the removal of OE and/or all metal contacts detected within 2 feet of the subsurface before construction. Contingent approval might also involve a requirement to identify and remove OE in 2-foot “lifts” before - excavation of a building footprint. Contingent approval might also involve a number of conditions and physical and institutional controls to be enforced after construction is completed, including these:

- Periodic review of the site after construction is completed (contingent approval might require periodic sampling for COCs or surface sweeps by a competent OE expert to detect and remove OE/metal contacts after the site has been constructed);

- Requirements for OE escort, excavation permits, and HAZWOPER health and safety plan approval from a controlling authority who is aware of the site hazards if surface soil in the proximity of the site is to be disturbed;

- Site user outreach programs that could incorporate elements such as educational materials, liability waivers, and access permits;

- Restrictions imposed to limit the age of site users; and

- Access control features, such as signs notifying personnel of hazardous areas or fencing to restrict access to hazardous areas (hazards could result from OE or elevated COCs in soil) at the site.

9 REFERENCES

1. U.S. Department of the Army, 1995, *Nuclear and Chemical Weapon and Materiel Chemical Surety,* Army Regulation 50-6, U.S. Army Headquarters, Washington, D.C.

2. U.S. Department of the Army, 1997, *The Army Chemical Agent Safety Program,* Army Regulation 385-61, U.S. Army Headquarters, Washington, D.C.

3. U.S. Department of the Army, 1997, *Toxic Chemical Agent Safety Standards,* Pamphlet 385-61, U.S. Army Headquarters, Washington, D.C.

4. U.S. Department of the Army, 1994, "Army Military Construction Program Development and Execution," Army Regulation 415-15, U.S. Army Headquarters, Washington, D.C., Aug. 30.

5. U.S. Department of the Army, 1997, "Environmental Protection and Enhancement," Army Regulation 200-1, U.S. Army Headquarters, Washington, D.C., Feb 21.

6. U.S. Department of the Army, 1993, "Master Planning for Army Installations," Army Regulation 210-20, U.S. Army Headquarters, Washington, D.C., July 30.

7. U.S. Department of the Army, 1993, "Utilization of Real Property," Army Regulation 405-70, U.S. Army Headquarters, Washington, D.C., Sept. 15.

8. U.S. Department of the Army, 1998, *U.S. Army Environmental Restoration Programs Guidance Manual,* April.

9. U.S. Department of the Army, 1995, *Procedures for Conducting Preliminary Assessments at Potential Ordnance Responses Sites,* Interim Guidance, Draft ETL 1110-1-165, U.S. Army Engineering and Support Center, Ordnance and Explosives Center of Expertise, Huntsville, Ala., April.

10. U.S. Environmental Protection Agency, 1995, "Military Munitions Rule: Hazardous Waste Identification and Management," 60 *Federal Register* 56468, 56467.

11. U.S. Environmental Protection Agency, 1991, *Guidance for Performing Preliminary Assessment under CERCLA, 9345.0-01A,* Office of Solid Waste and Emergency Response.

12. U.S. Environmental Protection Agency, 1986, *RCRA Facility Assessment Guidance,* OSWER Directive No. 9502.00-05, Oct.

13. Bottrell, D., et al., 1995, "Streamlined Approach for Environmental Restoration (SAFER)," *Federal Facilities Environmental Journal* 6(1):67–77, spring, U.S. Department of Energy, Office of Environmental Restoration, Washington, D.C.

14. U.S. Environmental Protection Agency, 1991, *Risk Assessment Guidance for Superfund: Volume 1 Human Health Evaluation Manual (Part A)*, EPA/540/1-89/002, Office of Emergency and Remedial Response, Washington, D.C.

15. U.S. Environmental Protection Agency, 1996, *EPA Region IX Preliminary Remediation Goals (PRGs),* Aug. 1. [S.J. Smucker, EPA Region IX, San Francisco, Calif.]

16. U.S. Environmental Protection Agency, 1998, *Region IX PRGs,* May 1, http://www.epa.gov/region09/waste/sfund/prg/intro.htm. [S.J. Smucker, EPA Region IX, San Francisco, Calif.]

17. U.S. Environmental Protection Agency, 1996, *EPA Region III Risk-Based Concentration Table, Background Information. Development of Risk-Based Concentrations*, April 30, http://www.epa.gov/reg3hwmd/risk/guide4.htm (retrieved March 31, 1997). [R.L. Smith, EPA Region III, Office of Superfund Programs, Philadelphia, Penn.]

18. U.S. Environmental Protection Agency, 1996, *Soil Screening Guidance: Users Guide,* EPA/540/R-96/018, Office of Solid Waste and Emergency Response, Washington, DC.

19. USA CHPPM, 1999, *Derivation of Health-Based Environmental Screening Levels for Chemical Warfare Agents: A Technical Evaluation*, U.S. Army Center for Health Promotion and Preventive Medicine, Toxicology and Risk Analysis Section, Life Sciences Division, Oak Ridge National Laboratory, Oak Ridge Tenn., March.

20. U.S. Department of Energy, 1996, *Handbook for Occupational Health and Safety during Hazardous Waste Activities,* June.

21. U.S. Department of the Army, Marine Corps, 1996, *Technical Aspects of Military Significant Chemical Agents/Compounds,* Army Field Manual (FM) 3-9, Marine Corps Warfighting Publication (MCWP) 3-3, Air Force Manual (AFM) 355-7, AFJPAM 32-4008, initial draft, Washington, D.C.

22. U.S. Department of the Army, 1995, *Memorandum of Agreement between Chemical Support Division, U.S. Department of the Army, Edgewood Research, Development and Engineering Center, and the U.S. Army Engineer Division, Huntsville, Alabama,* June 7.

23. U.S. Department of Defense, 1998, *Report of the Defense Science Board Task Force on Unexploded Ordnance (UXO) Clearance, Active Range UXO Clearance, and Explosive Ordnance (EOC) Programs,* Office of the Under Secretary of Defense for Acquisition and Technology, Washington, D.C. April.

24. U.S. Department of the Army, 1997, "U.S. Army Explosive Safety Program," Army Regulation 385-64, U.S. Army Headquarters, Washington, D.C., Nov. 28.

25. Reed, L.L., et al., 1997, *Soil Contaminant Levels and Associated Risks to Construction Workers at the Construction Site for Work Request CEQ 37CE, Edgewood Area, Aberdeen Proving Ground, Maryland,* prepared by Center for Environmental Restoration Systems, Argonne National Laboratory, Argonne, Ill., June 30.

APPENDIX A:

GEOPHYSICAL TOOLS

APPENDIX A:

GEOPHYSICAL TOOLS

A.1 INTRODUCTION

Surface environmental geophysical investigations can be used at Category II and III sites to assess natural hydrogeologic conditions, detect contaminants within the natural system, and, most importantly for preconstruction environmental investigations, map or locate the presence of buried wastes, pipes, and utility lines. This appendix describes the specific geophysical tools and their application to construction site environmental investigations.

A.1.1 Background

Geophysical methods measure intrinsic physical properties of the underlying soil and bedrock that arise from natural geologic conditions or anomalous areas associated with past activities. These measured physical properties provide insight into subsurface conditions and, in some cases, a cross-sectional view. Electromagnetic (EM) and magnetic techniques operate on a subset of physical properties found useful for preconstruction environmental site investigations. These properties include EM wave propagation, EM induction, and localized distortions in the earth's magnetic field produced by buried ferrous (iron) objects. The primary applications resulting from these types of measurements include the following:

- Locating buried waste and disposal trenches and

- Mapping underground utility pipes, cables, drums, storage tanks, and buried foundations.

Electromagnetic and magnetic methods can also be used to characterize natural soil, bedrock, and hydrogeologic conditions, as well as to map contaminant plumes.

A.1.2 Techniques

Specific geophysical techniques and instrumentation commonly used for preconstruction environmental site investigations (and discussed in this appendix) are:

- GPR: Ground penetrating radar, EM wave propagation;

- FEM: Frequency domain electromagnetic system, EM induction;

- MAGs: Magnetometers, both total field and gradiometer, magnetics; and
- MDs: Metal detectors, EM induction.

GPR, FEM, and MD methods use electromagnetic properties to characterize the subsurface, whereas MAG techniques map localized distortions in the earth's magnetic field. Both FEM and MD methods use EM induction, and MD can be thought of as a specialized aspect of this technique. The application and characteristics of individual techniques are summarized in Tables A.1 and A.2. Conceptual illustrations of the principles employed by each technique are given in Figures A.1 and A.2, and survey results for each technique are shown in Figures A.3 and A.4.

These methods and instruments are well suited to locating buried waste and underground utilities, as well as to mapping areas containing disturbed soils. As a group, these techniques are noninvasive and can be used to rapidly gather subsurface information that will minimize digging or trenching operations. Although other geophysical techniques are currently available (e.g., seismic and resistivity), and newer methods are being developed (two- and three-dimensional resistivity), the geophysical methods described here offer the widest range of application to preconstruction environmental site investigations.

A common aspect of each of these four methods is the ability to provide continuous, or nearly continuous, data acquisition along a survey line. This capability is critical for successful detection and location of smaller objects (targets), such as a single steel drum. In many cases, data are obtained in real time and require minimal processing other than plotting and contouring. Preliminary results can often be interpreted directly in the field. The user is cautioned, however, that initial interpretations may ultimately be changed, depending on the availability of other critical information such as other environmental surveys or a historical record.

A.1.3 Other Considerations

Geophysical methods, like any other investigative technique, have certain advantages and limitations that will most likely be site specific. No single, universally applicable geophysical method will work at every site each time. Thus, the project manager must understand the advantages and limitations of each method and, in conjunction with the geophysical contractor, carefully select the appropriate method or methods most likely to work at a given site.

The success of a geophysical survey program depends primarily on two factors: (1) availability of background information for the site and (2) adequate definition of the target(s) to search (see Chapter 2). Historical information (verbal or written) indicating past activity, utility and sewer plans, and aerial photographs often prove critical in defining where to survey and suggesting what might be found. Knowing specific parameters of the target (e.g., physical makeup, size,

TABLE A.1 General Applications of Geophysical Methods[a]

Geophysical Method	Buried Trenches	Pipes and Cables	Drums and Tanks	Buried Foundations
GPR	2	2	3	2
FEM	3	2	2	2
Magnetometers[b]	2	1	3	1
Metal detectors	2	3	3	2

[a] Applicability of method for target type: 1 = successful in some instances; 2 = successful in many instances; 3 = successful in most instances.

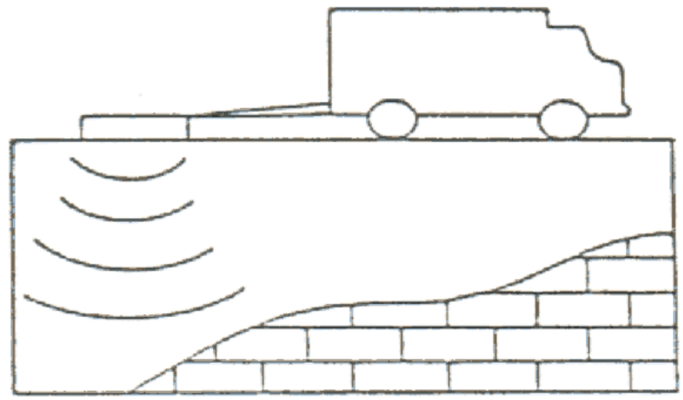
[b] Magnetometers require the presence of ferrous material or the mineral magnetite.

TABLE A.2 Characteristics of Specific Geophysical Methods

Method	Method Responds to	Depth	Station or Continuous Mode	Limitations
GPR	Changes in dialectric constants and electrical conductivity; both metallic and non-metallic objects	1 to 30 ft Very site specific	Continuous mode	Strongly dependent upon soil conditions
FEM Electrical Conductivity	Changes in soil/rock electrical conductivity, ferrous and non-ferrous metals			Soil moisture and proximity to metal buildings, fences, etc.
EM-38		5 ft	Both	
EM-31		20 ft	Both	
GEM System		5-30 ft	Both	
MAG	Ferrous metal and changes in the magnetic content of soils or rock; proportional to mass of target	Up to several 10s of feet, depending on mass of target		Interference from metal building, fences, power lines
Proton Precess			Station	
Fluxgate			Both	
Alkali Vapor			Both	
Metal Detectors	Both ferrous and nonferrous metals	Up to 10 ft, depending on size of target	Both	Interference from other metallic objects
EM-61		10 ft for drums	Continuous	Cleared area
GEM System		10s of feet	Both	

GPR

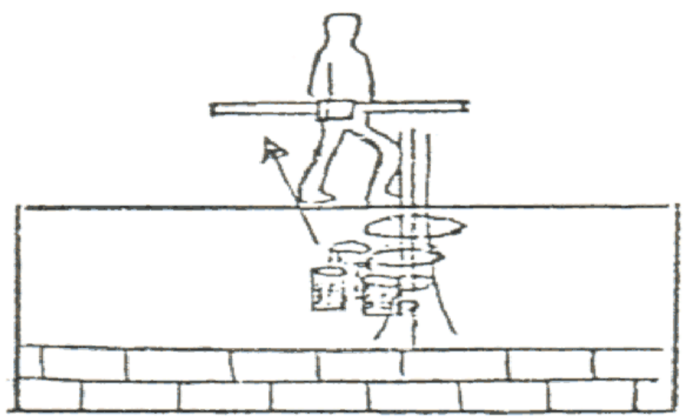
A



GPR: Uses reflected high frequency electromagnetic waves to create a picture-like cross-section of the subsurface.

FEM

B

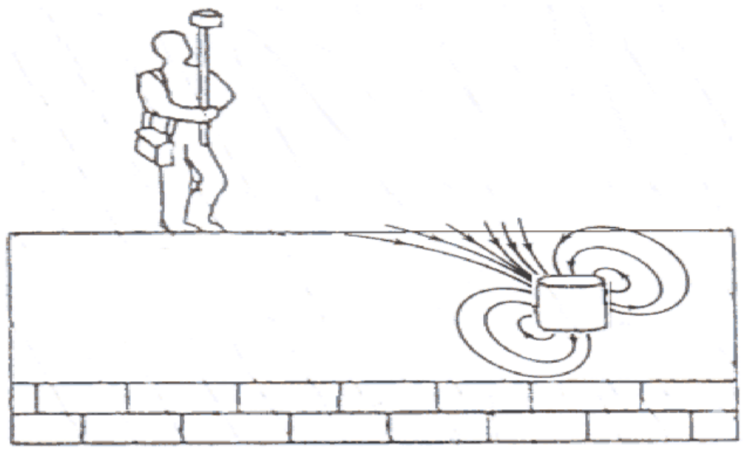


Measure the electrical conductivity of soils or rocks by inducing electromagnetic currents in the subsurface. The method can also be used to detect buried metallic items (both ferrous and non-ferrous)

FIGURE A.1 Principles of Ground-Penetrating Radar (GPR) and Frequency Domain Electromagnetics (FEM)

MAG

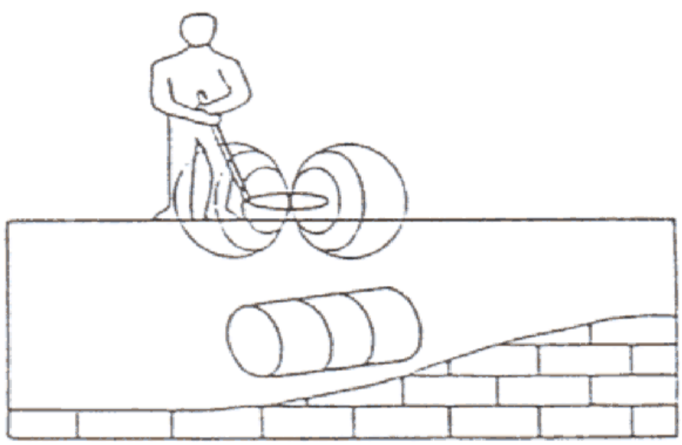
A



Magnetics measures the intensity of the earth's magnetic field. Localized pertubations caused by buried ferrous (iron) debris are used to map the position of these objects.

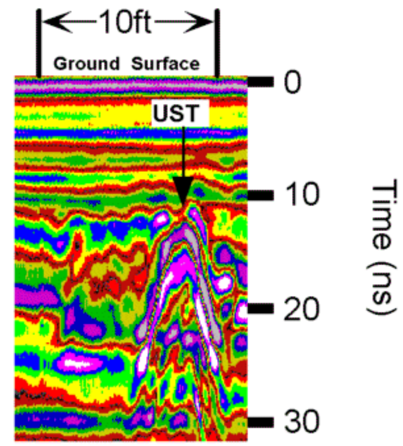
MD

B

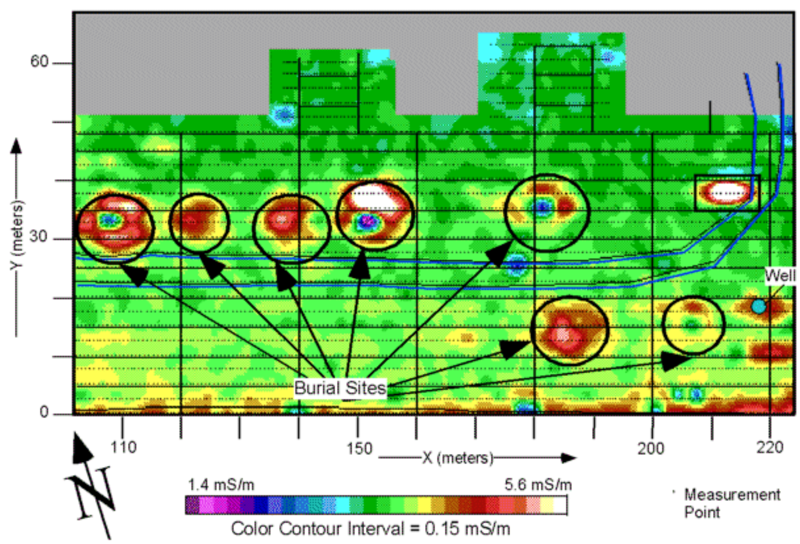


Metal detectors are used to locate buried metallic objects, both ferrous and non-ferrous, by inducing electromagnetic currents within the buried metal.

FIGURE A.2 Principles of Magnetics (MAG) and Metal Detection (MD)

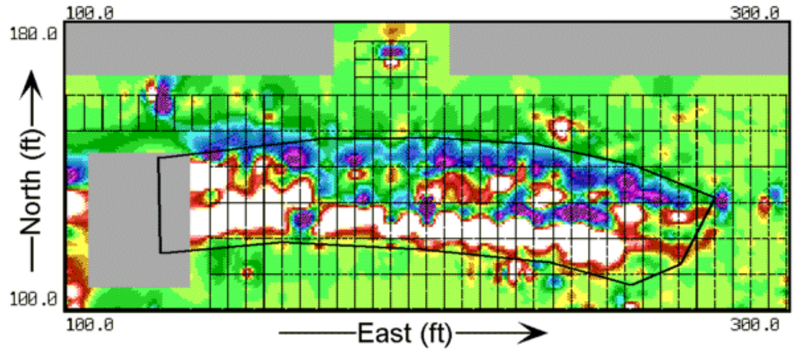


GPR profile over a buried storage tank (UST) showing the characteristic hyperbola signature.

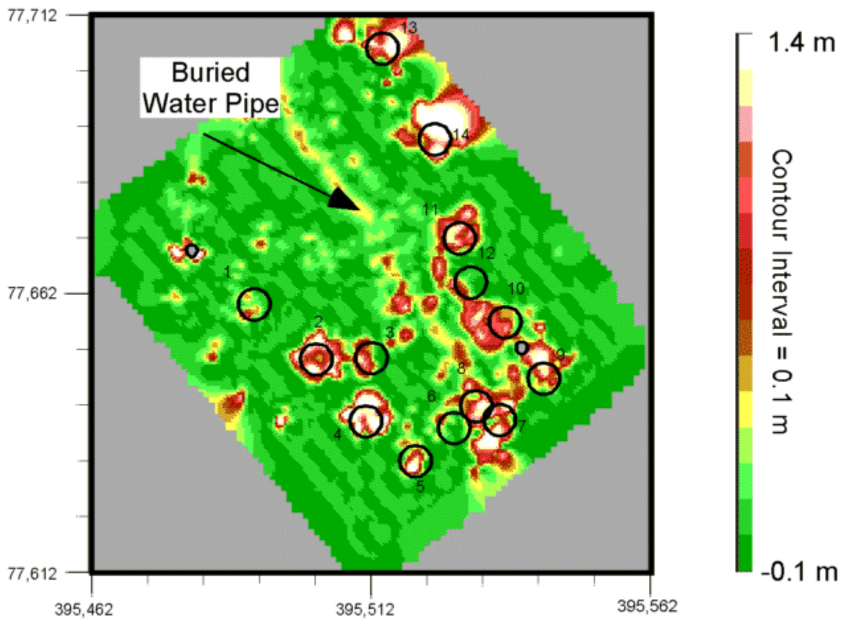


EM-31 conductivity survey over burial pits. The locations of several pits are indicated by the black circles

FIGURE A.3 Examples of GPR and EM-31 Surveys (Top, GPR Profile over a Buried Tank; Bottom, EM-31 Conductivity Survey over Burial Pits)



Magnetometer survey over a burial trench. A continuous profiling mode was used. The paired highs (reds) and lows (purples) are typical of magnetic anomalies.



EM61 survey over burial pits. The EM61 data have been converted to depth of burial.

FIGURE A.4 Examples of Magnetometer and EM-61 (Metal Detector) Surveys over Burial Sites (Top, Magnetometer Survey; Bottom, EM-61 Survey)

expected burial depth) will allow the geophysical contractor to select the appropriate tools and survey parameters for the job. For example, is the target the location of trenches and burial pits, or is the target individual items buried within these sites? Being able to address these types of questions before the geophysical survey is conducted will help ensure the success of the project.

Brief descriptions of individual geophysical survey techniques and limitations of those techniques are provided in the following sections.

A.2 GROUND-PENETRATING RADAR

GPR surveys can be used to locate buried objects that may include (but are not limited to) drums, pipes, and tanks. GPRs transmit an electromagnetic pulse into the ground and record the reflected energy generated by this pulse along a line of profile. A two-dimensional (2-D) cross-sectional image of the subsurface is generated by the GPR survey, which can be thought of as a slice-view of the subsurface.

A.2.1 Instrumentation

GPR systems consist of an electronic control system to transmit an EM pulse into the ground, transmitting and receiving antennas, and a recording system. GPR data are recorded to either a graphic chart recorder or a digital data storage device. The latter is preferred because the digital data can be further processed to enhance the GPR image, aiding in the identification of specific targets. Older GPR equipment tends to be somewhat bulky and will generally require a vehicle in which to mount the control electronics and the recorders. Newer systems, however, can be carried by a single person using a backpack or harness that holds the electronics. The GPR antenna can be either hand-towed or vehicle-towed along a traverse line at a constant rate of speed.

Most GPR systems have only a single antenna that serves as both the transmitter and receiver. These types, called monostatic systems, offer easier setup and use and are sufficient in most cases. Bistatic systems use separate antennas for the transmitter and receiver, usually with a fixed offset between the antennas that is both site- and target-specific. In some cases, the capability of bistatic systems to be tuned to a specific target or target depth will provide the best results (Daniels 1990).

A.2.2 Applicable Systems

Manufacturers such as GSSI, MALA, Sensors, and Software produce commercial GPR systems that have been generally positively accepted for environmental geophysics uses. Although each system may have individual strengths and weaknesses with regard to a given site, the most critical factors in GPR surveying are the capability of the geophysicist and site conditions.

A.2.3 Principle of Operation

GPR systems fall into two general classes, continuous wave (CW) and pulse systems. For CW systems, a sinusoid of a single frequency is transmitted into the ground, and the amplitude and phase of the return signal are recorded and interpreted. CW systems operate in what is called the frequency domain, that is they only consider the spectral response of the subsurface to a given imparted frequency. In practice, CW systems are rarely used in GPR investigations (Daniels 1990), so they are not discussed further in this document.

A pulse system transmits a single positive/negative paired amplitude pulse into the ground and measures the back scatter, or reflected energy (echo), generated by that pulse for a fixed length of time. Unlike CW systems, pulse systems operate in the time domain, have the ability to display the result in real time, and use a transmitted signal that is broadband in nature (contains many frequency components). Pulse systems are the most widely used GPRs and are discussed in more detail in the following sections.

High-frequency EM pulses are transmitted into the ground and the reflected energy is recorded along a line of profile. A single GPR measurement is called a scan line and contains the reflected information recorded at a single horizontal position for a given length of time. Thousands to hundreds of thousands of scan lines comprise a single GPR profile section, giving the illusion of nearly continuous, horizontal coverage of the subsurface. These collated scans lines are plotted in either variable amplitude (gray or color scale) or as wiggle plots on a 2-D cross section. The resulting profile section depicts both horizontal and vertical variations in the reflected GPR wave (radar wave) character.

A reflection of the radar wave occurs whenever the transmitted EM pulse encounters an object that has a different electrical impedance, or contrast, than the material through which the wave is propagating (Daniels 1990). Electrical contrasts can occur from natural geologic conditions, such as mineralogy, bedding, cementation, moisture, clay content, voids, and fractures, which can yield measurable reflected energy. Stronger contrasts in electrical properties are found when buried metallic items (e.g., pipes, drums) are encountered. Nonmetallic buried items may also produce a radar wave reflection and thus be detectable.

The target being searched for often is relatively small (from inches to several feet in width), and the corresponding reflection off that target takes on a characteristic hyperbolic shape (see Figure A.3). The hyperbolic shape occurs because as the GPR antenna traverses over the target, the time it takes for the radar wave to travel to and from the target becomes progressively less until a minimum is reached when the GPR antenna is directly overhead. Thus, the peak of the hyperbola pinpoints both the horizontal and vertical position of the buried target along the profile line.

A.2.4 Units of Measurement

The horizontal axis of a GPR 2-D cross section is usually presented in units of distance or station number and the vertical axis in units of time. Here, the time units are in nanoseconds (1 nanosecond equals 10^{-9} second, i.e., one-billionth of a second). The time scale can be converted to depth by making assumptions about, or measurements of, the velocity of the radar wave in the subsurface. In some cases, a GPR survey line can be conducted across a buried object of known depth in order to determine an appropriate time-to-depth conversion. The resulting depth scale is often nonlinear because the velocity of the radar wave varies with depth (e.g., in going from the unsaturated to the saturated zone).

A.2.5 Resolution and Target Detection

The GPR method has the highest resolution of all of the surface geophysical methods, ranging from less than an inch to several feet, depending on the size and depth of the target, the type of antenna used, and the traverse speed. Because of this high resolution, GPR can be used to accurately locate buried objects. Typical GPR signatures over various buried objects are depicted in Figure A.5.

The resolution power of a GPR system is governed primarily by the frequency of the antenna and the electrical nature of the subsurface. In general, greater vertical resolution is obtained with higher-frequency antennas. This resolution does, however, come at the cost of reducing the depth of penetration of the radar wave. The presence of electrically conductive soils often forces the use of a lower-frequency antenna than is desired in order to scan to the required depths.

A.2.5.1 Antennas

GPR systems generally can use a wide selection of antennas, with frequencies ranging from less than 100 MHZ (1 MHZ = 1,000 hertz) to 1 GHz (1 GHz = 1,000 MHZ). Most systems use antennas from 80 to 500 MHZ.

Most radar antennas have a beam width of approximately ±45° fore and aft and ±22° side to side. Although reflections can occur from anywhere within this zone, many reflection surfaces, such as stratified soil and rock, are generally planar and will reflect energy reasonably upward to

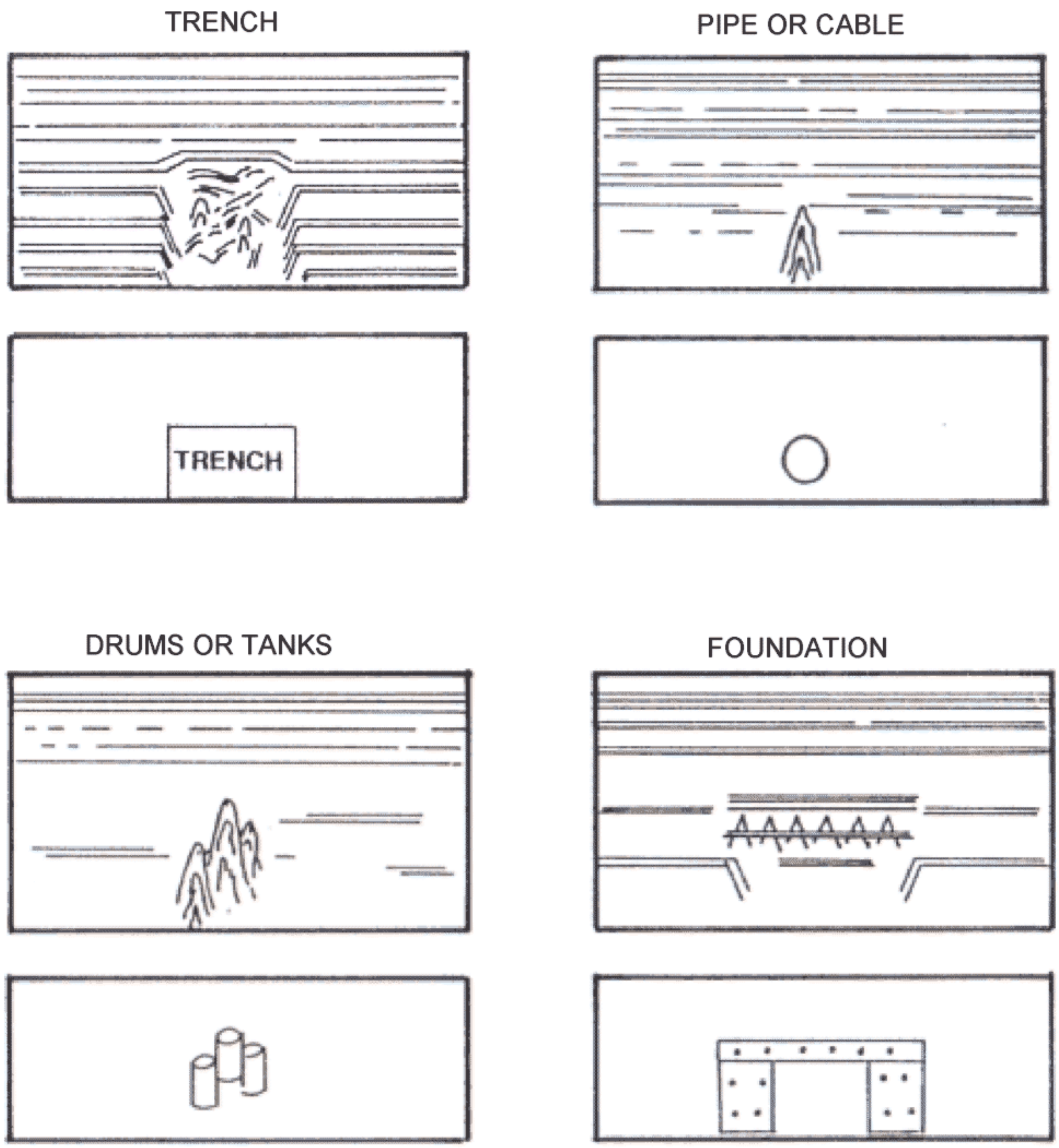


FIGURE A.5 Generalized GPR Response for Various Targets

the antenna. For practical purposes in shallow surveys, the width of GPR scans is essentially an area directly beneath the antenna.

The speed at which the antenna is moved across the survey line depends on what the objectives and targets are. Reconnaissance radar data can be obtained at speeds up to 10 mph or more. However, more detailed data are generally required for preconstruction environmental site investigations, and to obtain the required detail, the antenna must be towed at much slower speeds (1 to 2 mph). Small targets (less than one-half foot in size) require even slower survey speeds (0.25 to 1 mph).

For most geologic conditions, large trenches, and long pipes or utilities, antennas in the 80- to 300-MHz frequency range prove suitable. In order to detect smaller targets that are approximately the same size as the antenna (such as a single 55-gal drum), the antenna must be centered less than one-half an antenna width (about 1 to 2 ft) from the centerline of the target. Antennas in the 80- to 500-MHz frequency range might be suitable for targets of this size. Small, discrete targets require antennas in the 500- to 900-MHz range. The GPR antenna must essentially pass directly over a target in order to detect it.

A.2.5.2 Depth of Radar Wave Penetration

Depth of penetration of the radar wave is highly site specific and depends primarily on the electrical conductivity and scattering potential of the underlying soil or rock. Although radar penetration to more than 100 ft in soil and rock has been reported, penetration depths of 10 to 30 ft are more typical. In silts and clays, penetration may be limited to a few feet or less. Radar penetration typically works better in coarse and dry soils (sands and gravels) and rock; poorer results are obtained in wet, fine-grained clayey (electrically conductive) soils. Radar will function in saturated soil conditions and in freshwater rivers and lakes. High-specific-conductance pore fluids can greatly diminish radar performance, even making radar totally ineffective under certain conditions. These conditions are typically associated with salt water and inorganic contaminants, such as those found at a landfill.

A.2.5.3 Target Identification

An object of a specific size that is detectable when buried beneath 2 ft of sandy soil may not be detectable when buried in clayey soil. No comprehensive study of target size versus depth response as a function of soil conditions and antenna frequency has been published

The target size versus depth of detection response for radar is not a direct relationship and is complicated by several factors: soil conditions, antenna frequency, and target composition. In practice, individual drums have been detected at 10 ft with both 80- and 300-MHZ antennas under controlled test conditions (Horton et al. 1981). Small-diameter pipes and even 1/8-in.-diameter grounding wires (18 in. deep) have been detected by radar when the antenna passes perpendicular to the pipe or wire.

A.2.6 Applications

The primary applications of the GPR survey technique to preconstruction environmental site investigations include the following:

- Locating and defining boundaries of buried disposal sites;
- Locating drums, tanks, pipes, cables, and foundations; and
- Locating unexploded ordnance (UXO).

A.2.6.1 Locating and Defining Boundaries of Buried Disposal Sites

Burial or disposal sites (pits or trenches) can have the following, or a combination of the following, responses on a GPR profile:

- A change in penetration depth. Penetration depth will be shallower over the disposal site if it contains more clay cover or a higher moisture content than adjacent soils or rock. Note that the converse may also occur.
- A chaotic pattern of reflections caused by disturbed soils and debris in the disposal site. This condition is most obvious if adjacent soils are uniform and undisturbed.
- Dipping reflections or diffraction patterns associated with the slopes of the trench or pit can sometimes be seen directly and may sometimes make it possible to estimate the depth of the trench's bottom.

A.2.6.2 Locating Drums, Tanks, Pipes, Cables, and Foundations

Buried drums, tanks, pipes, and cables will generally produce hyperbolic-shaped reflections on radar profiles when the antenna crosses perpendicular to the target. Hyperbolic-shaped reflections found on parallel survey lines and forming linear trends are probably caused by pipes and cables. Local hyperbolic-shaped reflections may be caused by drums and tanks. Plotting the location of each hyperbolic-shaped reflection will aid in identifying the locations of pipes and cables or drums and tanks. A buried foundation will usually be associated with a change in reflection amplitude, a distinctive change in pattern from the surrounding soils, and/or contain diffracted events near the edge. In addition, if a shallow concrete slab is reinforced with rebar, multiple, closely spaced hyperbolic reflections may be present on the GPR section because of the rebar (Daniels 1990).

A.2.6.3 Locating Unexploded Ordnance

When detected, UXO will appear as hyperbolic events on the GPR section (see Figure ??). Although 200- to 500-pound bombs may be encountered, most UXO items are small and difficult to detect by means of GPR. Compounding this problem is the fact that UXO can be buried relatively deep (up to 16.5 ft in clayey soils for a 155-mm shell; Henegar 1976) and is thus undetectable by GPR methods. Another complicating factor is that hyperbolic reflections from buried cobbles or boulders are often similar in appearance to those from UXO, leading to a higher false-positive rate than desired.

A.2.7 Limitations of GPR

The limitations to the GPR method fall into the following general classes: depth of penetration, target size, and masking of target response by natural or anthropogenic conditions. Some of the more common limitations that occur with the GPR method are listed below:

- Metal at or near the surface may cause the GPR section to exhibit a “ringing” phenomenon (multiple, high-amplitude reflectors), which masks the reflected energy when the antenna passes over the metal. For example, a wire coat hanger can produce a considerable ringing effect.

- Caution should be used in interpreting hyperbolic signatures as buried debris because many natural objects, such as boulders, tree roots, and animal burrows, will also produce a hyperbolic reflection.

- Depth of penetration is very site specific and may be less than 3 ft in fine grained clayey soils or in electrically conductive soils. A single drum may not be detected if buried under several feet of moist clayey soils.

- Most lower-frequency antennas (less than 100 MHZ) are not fully shielded and will radiate EM energy upward as well as down into the ground. Interference effects from overhead trees and power lines, as well as from adjacent buildings, fences, and vehicles, can obscure the GPR section.

- Because the radar antenna must be coupled directly to the ground, traverse lines must be relatively clear of obstructions such as parked vehicles, drums, brush, and piles of debris.

- The survey line spacing must be tight enough for a given target size. A buried target may not be detected if it is located a distance off the survey line and to the side of the antenna.

- A fairly rough ground surface may produce perturbations in the radar reflections that may be confused with targets. Such surface conditions must be noted and caution must be exercised during data analysis.

- GPR cannot be used immediately adjacent to or over salt water.

A.3 FREQUENCY DOMAIN ELECTROMAGNETIC METHODS

Frequency domain electromagnetic (FEM) methods are used to measure the electrical conductivity of soils and rock and locate zones of increased metal content (Geonics 1980). The resulting data are displayed as either profile XY plots, or the collected profile data are collated, gridded, and contoured to generate an anomaly map. A primary advantage of FEM systems over traditional magnetometers is that FEM systems are sensitive to all metals (brass, copper, steel), not just ferrous metal.

A.3.1 Instrumentation

A FEM system consists of a transmitter and a receiver coil pair separated at some fixed distance. The transmitter and receiver are usually mounted on a rigid boom so that a single person can conduct the survey. Data are recorded with a dedicated data logger and downloaded to a personal computer for display and interpretation. In some cases, such as when working over water or snow-covered areas, the FEM system may be mounted on a boat or sled.

A.3.2 Applicable Systems

FEM systems applicable to preconstruction environmental site investigations are available from Geonics (EM-31 and EM-38) and Geophysical Survey Systems, Inc. (GSSI) (GEM-300 system). The EM-31 consists of a 13-ft-long boom housing the transmitter and receiver coils and is designed to investigate to depths of approximately 20 ft. The EM-38 has a shorter boom (3.5 ft long) and is used for localized survey work to a depth of about 5 ft, much as a metal detector is used. Both the EM-31 and EM-38 use a fixed frequency to transmit the inducing current.

The GEM-300 system, a newer instrument, differs from the Geonics systems by having the ability to vary the frequency used to transmit the inducing current. This feature allows the depth of investigation to be varied and permits tuning of the instrument to provide the best electromagnetic response from targets. The GEM-300 is a portable, lightweight (6.4 kg/14 lb) system that simultaneously measures up to 16 user-defined frequencies between 330 and 20,000 Hz with a fixed coil separation.

A.3.3 Principle of Operation

Electrical currents are induced into the ground by the transmitter coil, and the strength of the secondary magnetic field generated by these currents is measured. Two components of the secondary magnetic field are recorded: (1) the quadrature-phase component, which is used to measure the electrical conductivity of the subsurface, and (2) the inphase component, which is used for metallic detection because of its extreme sensitivity to large metallic objects (Geonics 1991). The electrical conductivity of the ground is nearly linearly proportional to the strength of the quadrature-phase component and is given in units of millisiemens per meter (mS/m). The in-phase measurement is the ratio between the secondary magnetic field and the primary field and is expressed in parts per thousand (ppt) or parts per million (ppm).

Conductivity values obtained during EM surveys represent weighted mean values of all the layer conductivities from the ground surface to the maximum depth that is sensed by the EM instrument (McNeill 1980). If the underlying rock or sediment is uniform, the measured conductivity value will be the true conductivity. At sites where electrically conductive pore fluids are present, the specific conductance of the pore fluid will dominate the measurement. The amount of contribution to the measured conductivity from a single layer depends on its conductivity, depth, and thickness. Deeper layers contribute less to the final weighted value than near-surface layers. For example, the EM-31 has a depth of investigation of approximately 20 ft, but the greatest contribution to the conductivity measurement will be from material at depths of 12 ft or shallower.

FEM systems can be used to collect data in either a station mode or profile mode. In the station mode, the operator stops to take a measurement at specified intervals. Station mode is used mostly for regional, reconnaissance surveys. In the profile mode, data are collected at specific time intervals (sample rate) while the operator is walking a profile line. The recording system allows the operator to denote fiducial points (locations of known x and/or y position) along the profile so that the position of the sample point can be determined. The sampling rate can vary, and for detailed surveys, a rate of three samples per second may be used. While station measurements can be effective for locating a burial trench of substantial size, the more continuous coverage provided by profiling is much more suitable for detailed (high-resolution) surveys to identify targets such as individual drums and for mapping areas in which complex cultural conditions are expected.

Survey speeds for continuous-mode data collection are generally in a range of 1 to 2 mph (walking speed or slower). Faster speeds may be acceptable during a reconnaissance survey over a large area (several acres) where the target itself is large (hundreds of feet).

A.3.4 Units of Measurement

The electrical conductivity of the ground measured by FEM systems is given in mS/m, and the metallic content is given in ppt or ppm. Profile and grid coordinates are usually in distance units, although in some cases, station numbers are used.

A.3.5 Resolution and Target Detection

FEM systems cover a small area to either side of the traverse line. For example, a 55-gal drum at a depth of 2 to 4 ft can be detected at about 3 ft on either side of the survey line. This capability implies a 6-ft-wide band of coverage for a drum located 2 to 4 ft below the surface with an EM-31. In general, smaller targets require more closely spaced survey lines. Wider spaced survey lines can be used in locating larger targets, such as buried tanks. Figure A.6 shows typical FEM responses for buried targets of various dimensions and types.

EM response to buried metal is a function of the area of the metal and its orientation with respect to the flux field from the EM. For example, a 55-gal drum makes a relatively good EM-31 target because it has a large surface area in which eddy currents can be induced. An equal amount of metal compressed into a smaller sphere would not be detected by EM-31 because the target would have too little cross-sectional area. On the other hand, the EM-38 or GEM system would detect such a sphere quite well if it was not too deep.

The detection depths quoted by the manufacturer of the EM-38 and EM-31 are 5 and 20 ft, respectively. This rating implies that 70% of the instrument's response is caused from the materials that lie between the surface and the specified maximum depth. The response curves versus depth are nonlinear, with the majority of the response coming from the shallower portions of depth (Geonics 1980). These depth considerations are for geologic conditions and do not apply to discrete targets such as drums.

A.3.6 Applications

The primary applications of the FEM survey technique to preconstruction environmental site investigations are:

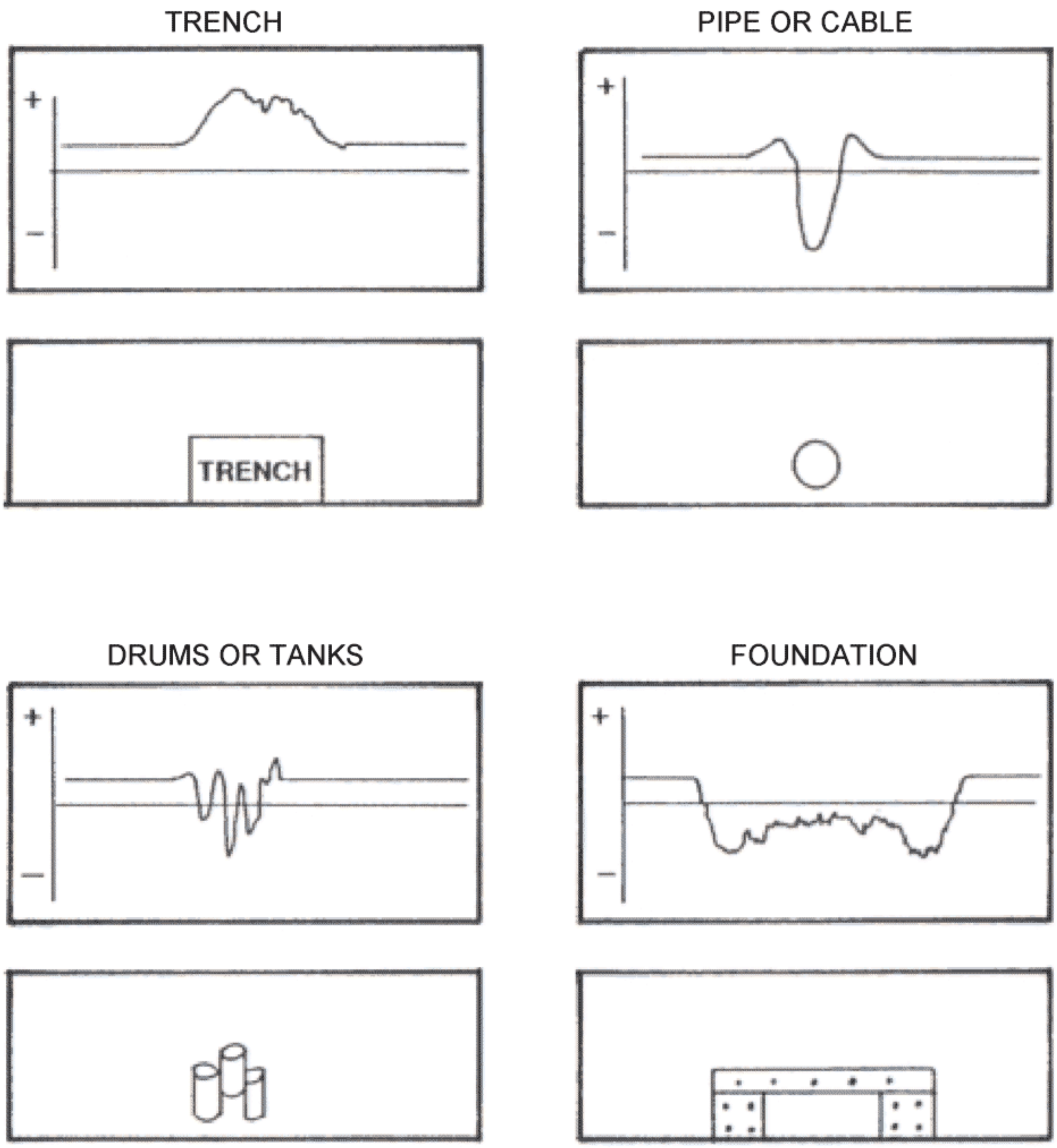


FIGURE A.6 Generalized Response for Frequency Domain Electromagnetic Surveys

- Locating and defining boundaries of buried disposal sites;
- Locating drums, tanks, pipes, cables, and foundations; and
- Locating UXO.

A.3.6.1 Locating and Defining Boundaries of Buried Disposal Sites

Buried disposal sites can be located and defined with EM primarily on the basis of what the sites contain. Trenches with substantial elevated specific conductance because of the presence of inorganics, such as general landfill material and metal debris, can easily be detected. In some cases, disturbed soil associated with a burial trench and the increased moisture in the trench may be detected, even though specific conductance and metal content is low. Trenches with sufficient buried metals are easily detected; however, trenches with small amounts or small pieces of metal may not be detected. In Figure A.3, anomalies observed on an electrical conductivity map generated from an EM-31 survey show locations of several burial sites.

A.3.6.2 Locating Drums, Tanks, Pipes, Cables, and Foundations

Metal pipes, cables, drums, tanks, or steel reinforcement bars in foundations are usually readily detected. Sufficient amounts of metals cause a noticeable change in the magnitude or an erratic response of the out-of-phase conductivity component. However, the in-phase component is recommended for most metal detection work. Point-source or localized anomalies suggest the presence of drums and tanks, while anomalies forming linear trends indicate the presence of pipes and cables. An out-of-phase pipe response is quite distinctive. Foundations with extensive rebar would cause an erratic response from the FEM.

FEM systems can be an effective tool for locating buried pipes or utilities because the character of the conductivity anomaly depends on the orientation of the sensor boom relative to the metallic source. For data collected along profiles oriented perpendicular to the pipe, the resulting anomaly is diagnostic in shape and consists of a central minimum bounded by two maxima, with the anomaly minimum centered over the pipe (Geonics 1991). Nonmetallic pipes or underground tanks may also be detected with a FEM system if the electrical character of the soils was sufficiently altered during burial.

A.3.6.3 Locating Unexploded Ordnance

In general, FEM systems such as the EM-31 are not applicable for a UXO search unless the UXO is buried in clusters. UXO is generally small and can be buried relatively deep (up to

16.5 ft in clayey soils for a 155-mm shell) [Henegar, 1976]. The EM-38 and GEM systems are much more sensitive to small targets and could be used as a metal detector for locating UXO at shallow depths. EM-38 has a disadvantage because it is sensitive to local changes in soil conditions (e.g., change in percentage of clay or moisture content), which may mask a metal target response.

A.3.7 Limitations of FEM Methods

Limitations of FEM systems include the following:

- FEM techniques are sensitive to interference caused by nearby metal fences, vehicles, and buildings. EM-31 can generally be used to within 20 to 30 ft of metal fences (15 ft if caution is exercised and corrections are made to the data). EM-38 can be operated to within 6 ft of fences (3 ft if caution is used and corrections are made to the data).

- EM measurements may prove ineffective immediately adjacent to, or over, salt water because of a nonlinear response that results in unstable electrical conductivity measurements.

- The EM-31 tool will not detect individual UXO-sized targets.

A.4 MAGNETOMETERS

A magnetometer (MAG) measures the intensity of the earth's magnetic field. It is very sensitive to ferrous (iron) objects but is not sensitive to nonferrous metal, such as aluminum, brass, and copper. For natural soils and rock, the MAG essentially senses the magnetite (a magnetic mineral) content. Discrete magnetic targets can cause localized and measurable distortions in the magnetic field, and thus be detectable. In a magnetometer survey, data are collected on either profiles or grids and displayed as either XY profile plots or contoured anomaly maps.

A.4.1 Instrumentation

MAGs used for preconstruction site investigations are portable devices consisting of a sensor head and supporting electronics. In some systems, data are stored to either an internal or external digital recording system. Other systems only produce an audible tone or use an analog readout. The sensor head is mounted either on a wand (swept near ground surface) or pole (6 to 10 ft above ground), depending on the MAG type and survey needs. In some instances, several sensors are used together as either a magnetic gradiometer or as a multisensor array (which increases the swath coverage of a single pass).

The six types of MAGs are fluxgate, proton precession, optically pumped (alkali vapor), superconducting quantum device (SQUID), fiber-optic, and electron tunneling. The first three of these types are the most commonly used for preconstruction site investigations, primarily because of their commercial availability. The latter three types are still mostly in the research stage, although SQUID devices are slowly gaining use in places where extremely sensitive magnetic measurements are required (e.g., UXO detection).

Fluxgate MAGs are solid-state devices that measure a component of the earth's magnetic field (usually the vertical component). A wire-wrapped core of soft magnetic material is periodically saturated by a magnetic field generated by an excitation current in the wire. The core's magnetic permeability is correspondingly changed, and the flux caused by the ambient magnetic field induces a voltage proportional to its strength in a secondary pickup coil.

Proton precession MAGs use the precession, or oscillation, of spinning protons to measure the earth's magnetic field. Protons in a hydrocarbon fluid contained in the sensor head are momentarily aligned with a strong direct-current magnetic pulse. When the magnetic pulse is turned off, the protons precess like miniature gyroscopes about the ambient magnetic field, generating a signal frequency in the wire coil that is proportional to the ambient magnetic field strength (Breiner 1973).

Optically pumped MAGs operate on a principle similar to that of proton precession devices but use the atom of a specific gas (usually cesium, helium, or rubidium). An external, circularly polarized light source excites (pumps) the atom from its ground state to multiple energy states. In this state, the atoms precess about the ambient magnetic field at a frequency proportional to the magnetic field strength.

A.4.2 Applicable Systems

Fluxgate systems are available from Foerster (FEREX or Mk-26) and Schonstedt (MAC-51B). These models use a pair of fluxgate sensors and audible and/or analog displays. The Foerster unit is used primarily for ordnance detection, and the Schonstedt system is marketed as a cable and magnetic locator.

Proton precession and optically pumped MAGs are available from both Scintrex and Geometrics. Both use digital data recording and can be operated as either gradiometers or total field instruments.

A.4.3 Principle of Operation

The primary objective of MAG surveys, as applied to preconstruction environmental site investigations, is to measure localized distortions in the earth's magnetic field produced by targets such as buried waste. A magnetic body, when buried in the subsurface, will usually have a smaller magnetic field induced in it by the earth's magnetic field, as illustrated in Figure A.7. This induced magnetic field constructively and destructively adds with the earth's primary field, producing localized perturbations.

Two basic measurement techniques are used: (1) total field measurements and (2) gradient measurements, or magnetic gradiometry. A total field measurement is a single scalar value that includes the intensity of the earth's magnetic field at a point. Contributing to the total field measurement are magnetic fields from nearby buildings, fences, or power lines, as well as from nearby buried ferrous metal or iron-rich strata (if present). A gradiometer measurement uses the difference between two simultaneously obtained total field measurements. This process is accomplished by using two or more sensors that simultaneously measure the earth's magnetic field and that are separated by a fixed distance (usually 2 to 4 ft vertically).

An advantage of total field MAGs over gradiometers is that the former are inherently more sensitive (assuming that both total field and gradient MAGs have the same basic sensor sensitivity). The response of a discreet target such as a 55-gal drum will decrease as the reciprocal of the distance (between MAG and sensor) to the third power, whereas for a gradiometer, the response will vary as a reciprocal of the distance to the fourth power. Gradiometer surveys can more accurately locate small targets buried at shallow depths, take measurements closer to metal buildings or fences, and are insensitive to natural changes in the earth's field.

The effectiveness of total field MAGs can be reduced or totally inhibited by noise or interference caused by time-variable changes in the earth's magnetic field or by spatial variations due to magnetic minerals in the soil, steel debris, pipes, fences, buildings, and passing vehicles. A base station MAG (a second stationary MAG) can be used to reduce the effects of natural noise by subtracting the base station values from those of the search MAG (Breiner 1973). This procedure can minimize any errors due to slow natural changes of the earth's field with time. Spatial changes due to cultural noise, however, remain a problem with total field measurements. Many of these problems can be avoided by use of gradiometer measurements and proper field techniques.

MAGs are operated in either station or continuous profiling mode. Typically, proton precession MAGs (both total field and gradient) require the operator to stop to take a station measurement; fluxgate and optically pumped MAG systems permit the continuous acquisition of data. While station measurements can be effective for locating larger targets, such as a burial trench containing a number of drums or substantial scrap steel, continuous recording systems offer the greatest advantage for detailed (high-resolution) surveys to identify local targets such as individual drums.

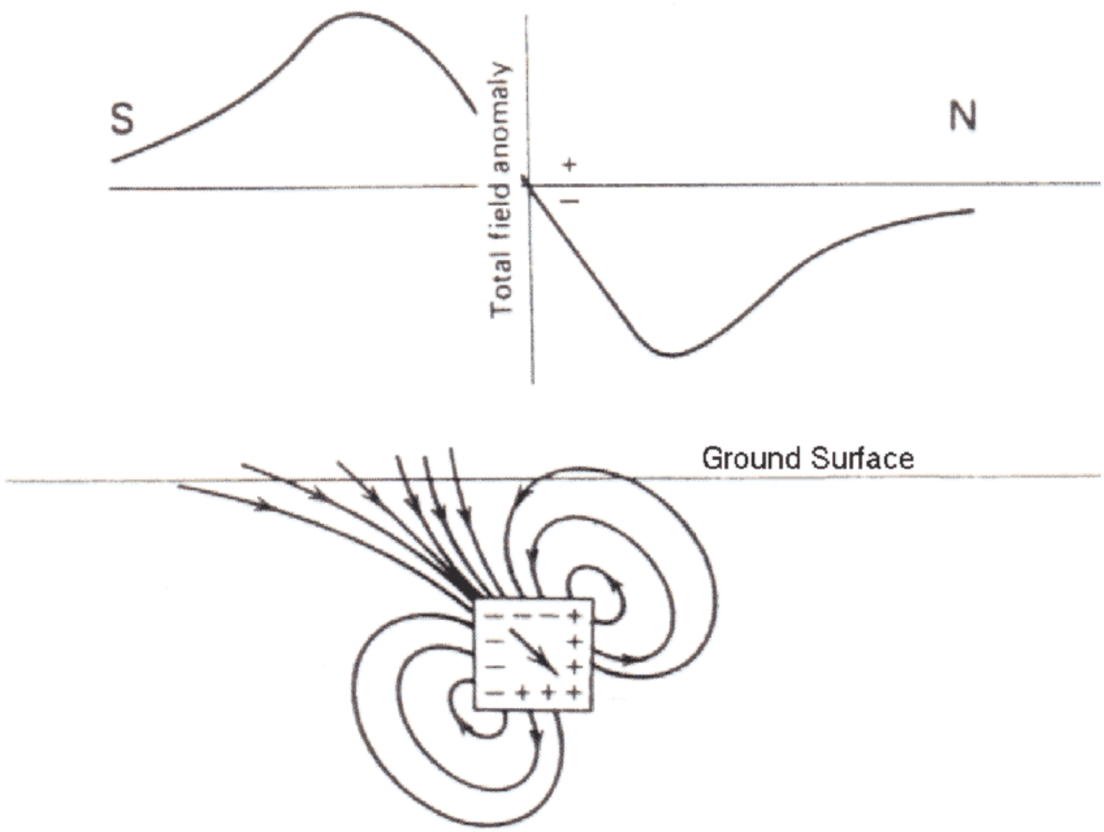


FIGURE A.7 Magnetic Response for a South-North Traverse over a Buried Ferrous Object in an Inclined Magnetic Field (Mid Latitudes, Northern Hemisphere) (Location of Object Is in Strong Gradient Area between the Relative High and Low Magnetic Anomalies)

Continuously sensing instruments that only offer an audible tone or analog readout are often used in sweeping motion while the operator moves forward. This procedure allows the operator to cover a larger swath. The instrument may also be held steady while the operator walks the survey line at a constant speed and while the results are recorded on a strip chart recorder.

Continuous reconnaissance MAG data can be obtained at speeds up to 10 mph or more by using a vehicle. When detailed data are required, the survey will typically be run at much slower speeds, 1 to 2 mph. Micro-searches for very small targets require much slower speeds (0.25 to 1 mph).

A.4.4 Units of Measurement

The intensity (magnetic flux density), or some component of the intensity, of the earth's magnetic field is measured (Dobrin and Savit 1988). The conventional unit for field intensity is the tesla (T), though it is sometimes given in oersteds (Oe), or, in older literature, as gauss. Because the intensity of the earth's magnetic field is approximately 1/2 Oe, while desired measurement levels are often less than a thousandth of this amount, MAG surveys are presented in units of nanoteslas (nT), where one nT equals 10^{-9} T (or 10^{-5} Oe). Magnetic surveys are also commonly given in units of gamma, where 1 gamma equals 1 nT. Magnetic gradient surveys are given in nT or gammas per unit distance.

A.4.5 Response

A total field MAG response is proportional to the mass of the ferrous target and inversely proportional to the distance to the target. Other factors affecting the response are the shape (elongation) of the target and its orientation with respect to the earth's magnetic field. For example, a 55-gal drum makes a relatively good target because it has a sufficiently long dimension that will distort the earth's magnetic field. An equal amount of metal compressed into a sphere would not be detected as readily by a MAG. In Figure A.8, typical MAG responses over various buried objects are depicted.

A.4.5.1 Size of Target Versus Depth of Detection

The response of a MAG for a given target size and depth of burial is illustrated in Figures A.9 and A.10, which show the response of a total field MAG and a gradiometer, respectively, for five different target masses: 1, 10, 100, and 1,000 lb of iron, and a 55-gal drum.

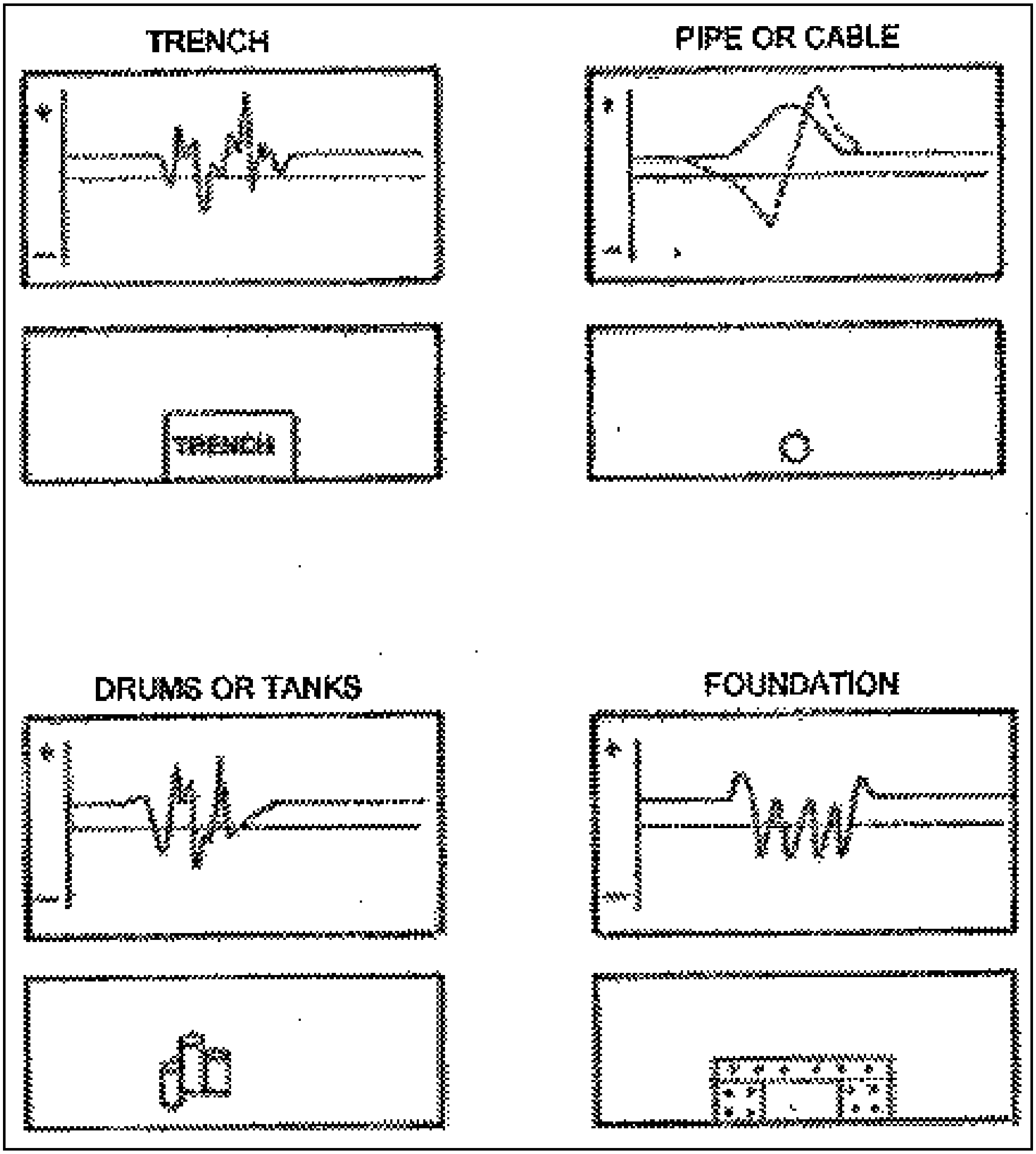


FIGURE A.8 Generalized Magnetometer Response over Various Objects

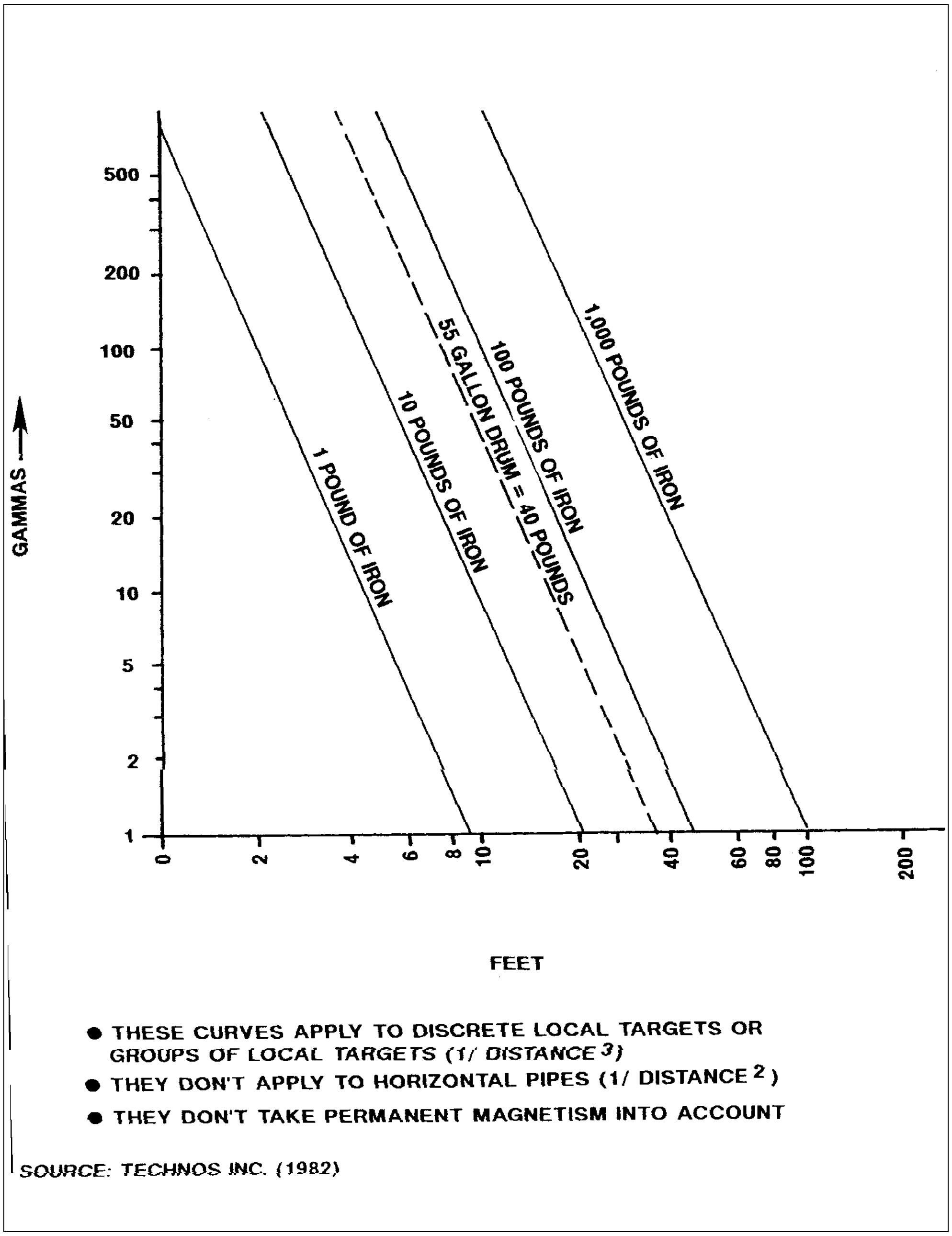


FIGURE A.9 Total Field Magnetometer Response (Gammas) for Different Targets at Different Depths

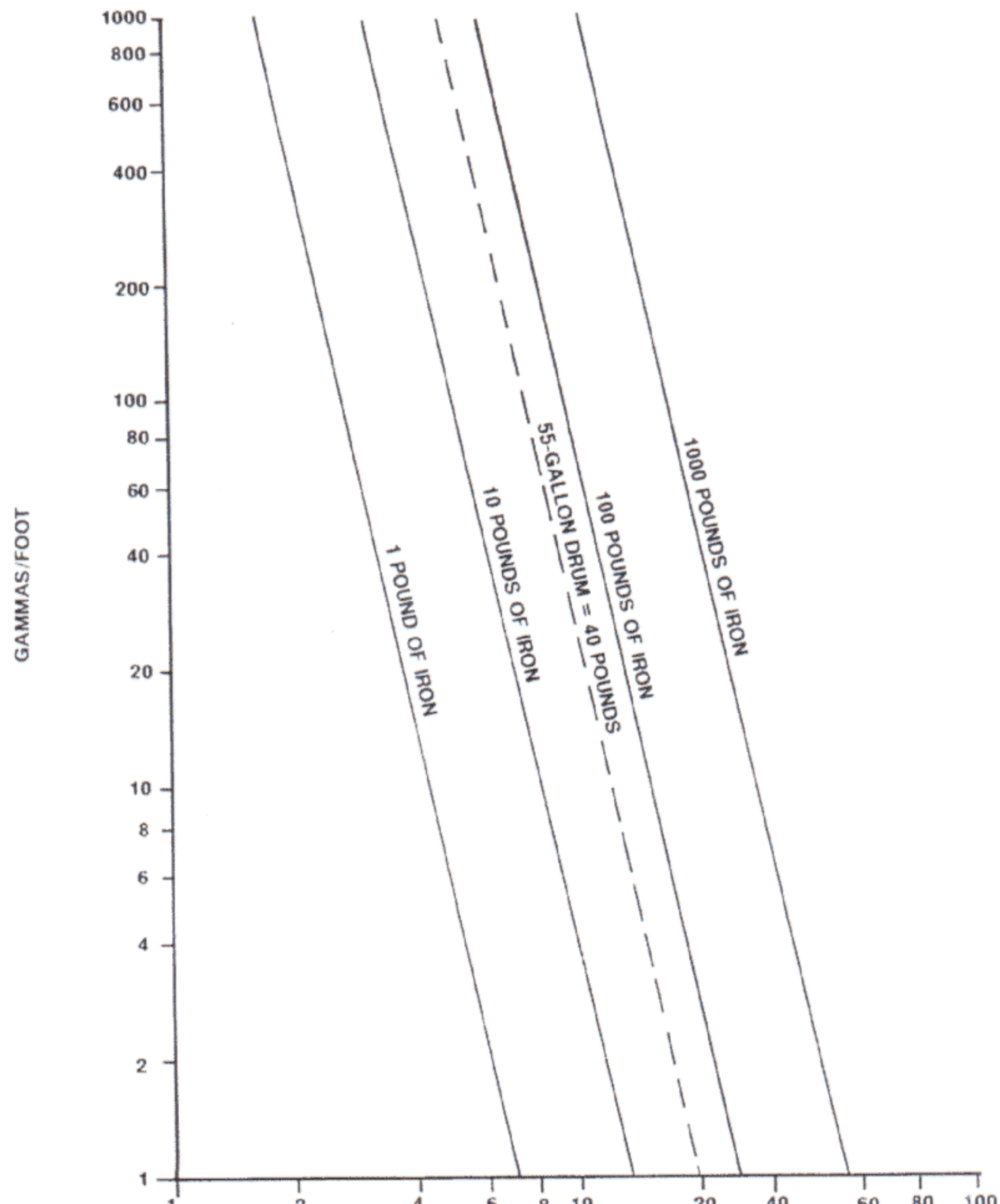


FIGURE A.10 Magnetic Gradiometer Response (Gammas per Foot) for Different Targets at Different Depths

As shown in the graphs, a 55-gal drum can be detected at a greater distance with a total field MAG (about 20 ft) than with a gradiometer (about 12 ft) for a given level of response. The target size versus depth response for any ferrous metal object can be estimated on the basis of these graphs by approximating the weight of the object. These graphs assume a relatively compact target (square or sphere). The magnitude of the anomaly can be greater for more elongated objects aligned with the earth's field.

A.4.5.2 Signature of Buried Targets

The magnetic anomaly of a buried object is generally complex and will have both high and low components relative to the ambient field (Figure A.8). This condition is a result of the interaction between the earth's magnetic field and the induced magnetic field of the object. Depending on the location, the object's magnetic field will either add to, or subtract from, the earth's magnetic field. A characteristic of most magnetic anomalies is the occurrence of a paired set of high and low peaks, where the strong gradient between the peaks (not the peaks themselves) indicate the position of either the edge of the object, or the object itself is small enough in size (see Figure A.7). A situation further complicating the interpretation of magnetic anomalies is that the magnitude and shape can vary considerably, depending on target shape, orientation, and degree of permanent magnetism. A target may not be detectable if it is capable of having a remnant (or permanent) magnetism that cancels out the magnetic field induced by the earth.

A.4.5.3 Survey Coverage

For all practical purposes, a MAG survey will cover only a small area to either side of the survey line. For example, a 55-gal drum at a depth of 2 to 4 ft can be detected only about 3 ft on either side of the survey line. This range implies a 6-ft-wide band of coverage for a drum buried 2 to 4 ft below the surface when a fluxgate gradiometer is being used. In general, small targets require more closely spaced survey lines, and more widely spaced survey lines can be used for locating large targets (such as underground storage tanks and burial pits).

A.4.6 Applications

A.4.6.1 Locating and Defining Boundaries of Buried Disposal Sites

Buried disposal pits can be located and defined with MAGs if the pits contain ferrous metal or if the disturbed area has altered the natural magnetite (magnetic mineral) content of the soil. A MAG traverse over such sites will result in noticeable variations in magnetic field intensity.

A.4.6.2 Locating Drums, Tanks, Pipes, Cables, and Foundations

Drums, tanks, pipes, and cables can be found with a MAG only if they are made of ferrous metal. Foundations can be found if they are reinforced with steel bars or if the emplacement has altered the natural magnetic properties of the soil.

A.4.6.3 Locating UXO

A magnetometer is useful for locating UXO items only when they are made of ferrous metal. However, it is one of the most sensitive methods that can be used for small ferrous targets such as UXO. Since buried UXO items are generally small and can be relatively deep (up to 16.5 ft in clayey soils for a 155-mm shell; Henegar 1976), they may be somewhat difficult to detect. The size of a buried target generally dictates the level of effort needed to detect and locate that target. In the case of buried ordnance, particularly items that are relatively small, such as hand grenades and small shells, a micro-search should be carried out. The MAG must be run on closely spaced survey lines, since spacing depends on target size. Also, the MAG must be moved very slowly along the survey line (0.25 to 1 mph).

A.4.7 Limitations and Environmental Interferences

All MAGs are susceptible to magnetic interference from steel fences, vehicles, buildings, underground utilities, and, in some cases, natural soil conditions. Gradiometers tend to be less sensitive to these features than total field MAGs. Alternating-current power lines interfere with proton precession MAG surveys.

Total field MAGs require a base station MAG to monitor short-term variations in the earth’s magnetic field. If unaccounted for, these variations could appear as artifacts on the magnetic anomaly profile or map and be misinterpreted as target zones. Gradiometer surveys do not require a base station.

Variations in the earth’s magnetic field caused by magnetic storms are erratic, and surveying should be suspended during such events.

A.5 METAL DETECTORS

MDs use EM induction to locate buried metallic debris. Unlike a MAG, which can only detect ferrous metal, an MD can detect both ferrous metals such as iron and steel and nonferrous metals such as aluminum, copper, and brass. MDs are commonly used by utility and survey crews to locate buried pipes, cables, and property stakes. Systems are also available for detecting buried drums or other metal objects, as well as for delineating the boundaries of trenches and pits containing metallic drums or trash.

A.5.1 Instrumentation

MDs are portable systems that may use either a separate transmitter and receiving coil, or may use the same coil as a transmitter and receiver. In some instruments, two coils are contained in one sensor package, and in others (primarily those used by utility companies), the transmitter and receiving coils are boom mounted and separated by about 4 ft. One newer system uses two coils in a vertical arrangement separated by a height of approximately 2 ft.

The presence of metal is indicated by audible tones, analog readouts, or is logged to a digital data device for later display and analysis. Systems using audible tones or analog readouts are used by utility companies to locate underground pipes or cables. In some cases, these systems can be used in a reconnaissance mode to ascertain whether more detailed search effort is required. Instruments that digitally log the data are more suitable to environmental site investigations because the recorded data can be displayed and interpreted in either profile form or as contoured anomaly maps.

A.5.2 Applicable Systems

Commercially available metal detection systems are designed for pipe and cable locator surveys conducted by utility companies. Paint marks or flagging is used with these systems wherever the operator encounters detectable metals.

Geonics, Inc., makes a dedicated MD (EM-61) that can determine the depth to target and, according to the manufacturer, can detect a steel drum to a depth of 10 ft. The EM-61 uses two square coils in either a trailer or harness mount, with the electronics carried in a backpack.

FEM systems also have metal detection capabilities. Geonics EM-31 and EM-38 systems can be used to locate burial sites containing metal, with the EM-38 being suitable for locating individual objects buried at a shallow depth (1 to 2 ft). GSSI distributes the multifrequency GEM system, which is suitable for locating discreet metal targets.

A.5.3 Principle of Operation

MDs operate on the induction principle, similar to the FEM method, but they differ from FEM systems by not providing an electrical conductivity measurement. The transmitter coil induces eddy currents within nearby metal objects, and the receiver detects the secondary magnetic field induced by these eddy currents. In general, the larger the surface area, the greater the secondary magnetic response and the greater the depth of burial that can be detected.

The EM-61 system takes advantage of the fact that the secondary EM fields induced in metallic targets are of longer duration than those arising from natural, moderately conductive earth. In this case, the measurement period is delayed until after the earth response has dissipated (Geonics 1993). The GEM system uses a variable frequency approach, which allows tuning the instrumentation to specific target sizes, composition, and burial depth.

Most MDs can be operated by a single individual. Some can be mounted to a vehicle for coverage of large areas, and others, such as the EM-61, can either be trailer or harness mounted.

MDs are continuously sensing instruments. Hand-held devices can be used with a side-to-side sweeping motion while moving forward or can be held steady while walking the traverse. Systems that incorporate a data logging device are normally used to acquire data along profiles.

For all practical purposes, the area of detection of an MD is approximately equal to its coil size or coil spacing. Therefore, an MD scans an area directly beneath the sensor, with little lateral influences. Because of their small lateral response, MDs provide a good means of locating a target. Some can accommodate large coil sizes to provide greater width of coverage on each pass. Larger coil sizes also increase the depth of investigation up to a point, but at the expense of not detecting smaller objects at shallow depths.

Reconnaissance MD data can be obtained at speeds up to about 5 mph by using a vehicle. Generally, when detailed data is required, the survey will be run at much slower speeds of 1 to 2 mph. Micro-search work for very small targets will require much slower speeds (0.25 to 1 mph).

A.5.4 Units of Measurement

Units of measurement for many MDs consist of variable pitched tones (where higher pitches indicate increased metal content), and relative scales (larger numbers indicate greater metal content). The EM-61 outputs its measurements in millivolts. The GEM systems express the metal content in ppm, which represents the ratio of the secondary magnetic field to the primary field.

A.5.5 Response

MDs have a relatively short detection range because a detector's response is proportional to the cross section of the target and inversely proportional to the sixth power of the distance to the target. The larger the surface area, the deeper the target can be buried and still be detectable. Small metal objects such as quart-sized containers can be detected at a distance of approximately 2–3 ft. Some MDs will detect larger objects, like 55-gal drums, at depths of 3 to 10 ft, and massive piles of 55-gal drums may be detected at depths of up to about 15 ft. MDs respond to metal objects only if the objects are directly beneath the coils or sensor. MD responses for typically encountered buried objects are depicted in Figure A.11.

The approximate detection ranges of MDs for various target sizes and two different coil diameters, 1.0 and 3.0 ft, are presented in Figure A.12. The detection range increases as the size of the target increases. Each of the specific targets shown in Figure A.12 can be detected at greater depths with the larger-diameter search coil. The smaller metal detection coil can detect small coin-sized targets, but the larger coil can not. Therefore, the coil size must be selected to provide the necessary detection capability for the smallest target of interest.

A.5.6 Applications

A.5.6.1 Locating and Defining Boundaries of Buried Disposal Sites

An MD can be used to locate and define the boundaries of a burial site if the site contains a sufficient quantity of buried metal. The response may be erratic, depending on the amount of metal and its orientation and depth of burial.

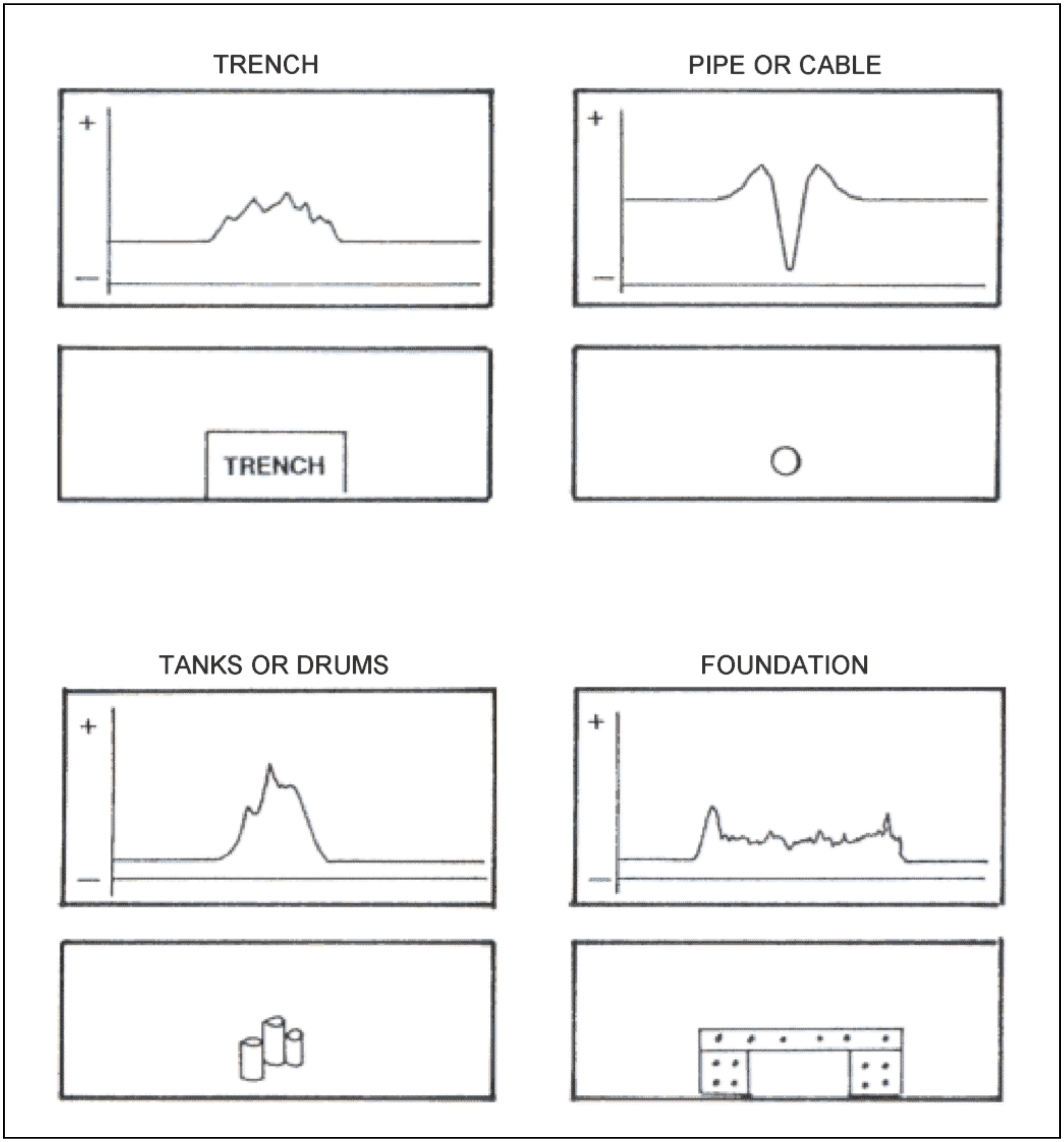


FIGURE A.11 Generalized Response of Metal Detectors to Various Objects

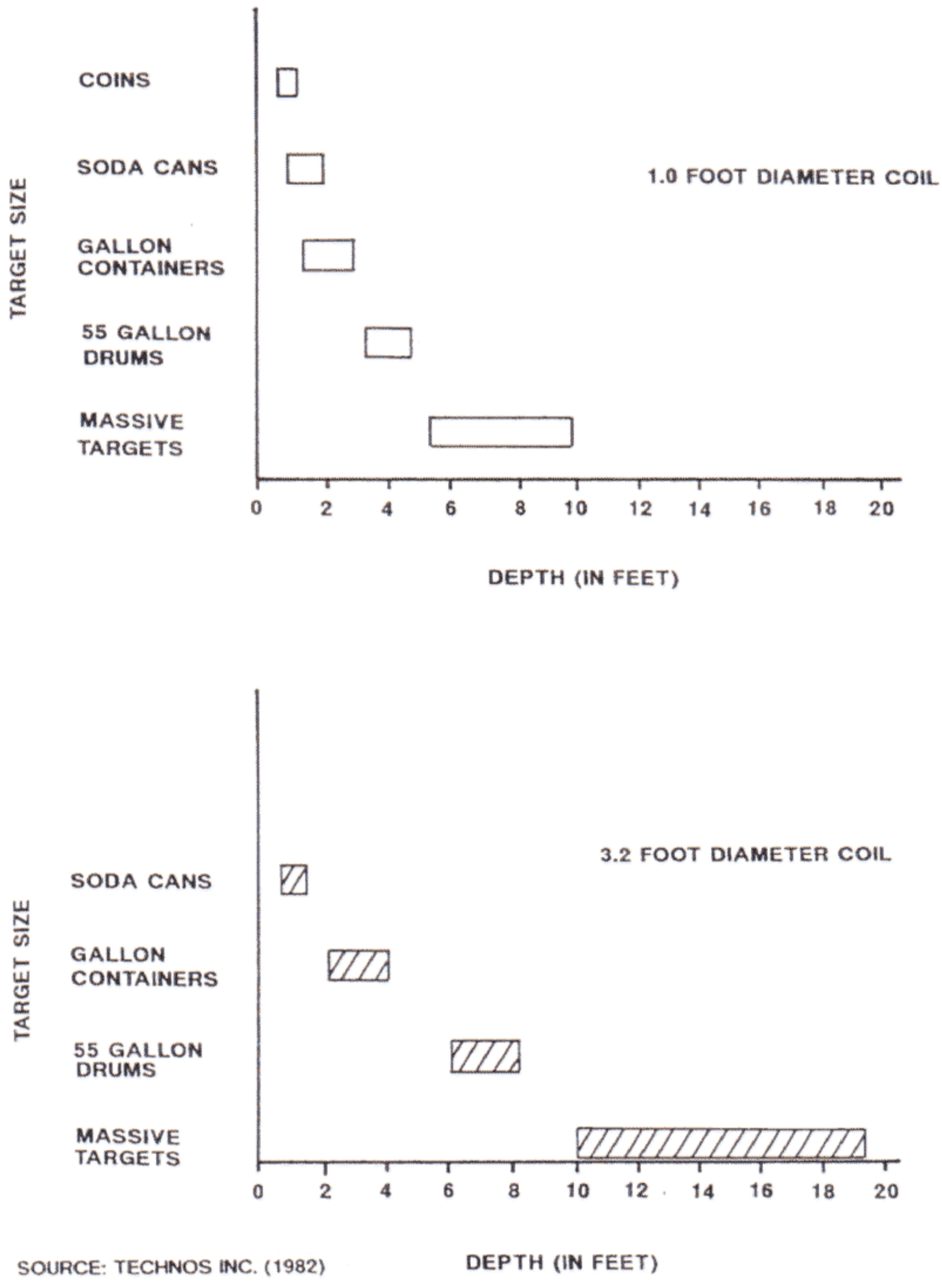


FIGURE A.12 Metal Detectors Investigative Decline for Different Target Sizes and Coil Diameters

A.5.6.2 Locating Drums, Tanks, Pipes, Cables, and Foundations

Metal pipes, cables, drums, tanks, or reinforcement bars in foundations are usually readily detected. These features cause a noticeable change in MD response. Localized anomalies suggest the presence of drums and tanks, whereas anomalies that form linear trends can indicate the presence of pipes and cables.

A.5.6.3 Locating UXO

In the case of buried UXO items, particularly those that are relatively small (such as hand grenades and small shells), a micro-search should be carried out. The MD must be run along a closely spaced survey line grid spaced no more than 1 to 2 ft apart, depending on target size and metal detector coil size. Also, the MD must be moved very slowly along the survey line (0.25 to 1 mph). An MD can locate UXO made of ferrous or nonferrous metal. It is one of the most sensitive methods that can be used for small, shallow targets such as UXO. Since buried UXO items can be relatively deep (up to 16.5 ft in clayey soils for a 155 mm shell; Henegar 1976), deeper targets will be more difficult — often impossible — to detect with a metal detector.

A.5.7 Limitations and Environmental Interference

MDs can be affected by nearby metallic pipes, fences, cars, and buildings. Some are affected by changes in soil conditions, particularly those that do not have the ability to null-out the influences of magnetic minerals, clays, and salt water. MDs also have a relatively shallow depth range.

A.6 GENERAL CONSIDERATIONS FOR CONDUCTING GEOPHYSICAL SURVEYS

A.6.1 Selection of Methods

The methods discussed in this appendix are generally simple to deploy and offer a wide range of options and equipment for a successful geophysical program at preconstruction environmental site investigations. The choice of the method or methods used is both site and target dependent. For example, an EM-31 instrument would not prove an ideal choice for locating small targets, unless there is strong evidence that the targets would be found in large clusters. Alternately, a GPR survey that was successful at one site might prove useless at another site underlain by soil that is more clay rich. Table A.1 summarizes the applications of specific methods and Table A.2 lists the key features of individual techniques.

In many cases, two or more complementary geophysical techniques should be considered in order to guarantee a measure of success. For example, use of both a MAG and an MD at a site will allow discrimination of areas that contain only iron debris from those that have aluminum, copper, or brass.

GPR equipment is the most difficult to use, and the results are the most difficult to interpret. The greatest drawback of GPR is its limited depth of penetration in certain soil and site conditions. However, GPR is the one method that provides a picturelike cross section from which a depth can be estimated. Also, GPR offers the highest resolution potential of all the methods.

FEM equipment is relatively easy to use, it is not critically limited by soil conditions, and the data are relatively straightforward to interpret. However, the data can be adversely affected by interference from metal-containing cultural features above or below the surface.

MAGs are relatively easy to use and, in most cases, not critically limited by soil conditions. The data are relatively easy to interpret but can be affected by interference from cultural features (above or below the surface) that contain ferrous metal.

MDs are relatively easy to use, although some are limited by soil conditions. The data are relatively easy to interpret but can be affected by interference from nearby cultural features (above or below the surface) that contain metal.

A.6.2 Approach to Field Search Operations

Geophysical search surveys can be carried out at three levels of detail. Each level is intimately tied to the target size and needs of the construction project:

- *Reconnaissance search* with widely spaced survey lines (10 to 50 ft apart) and rapid traverse speeds. This type of survey is intended to locate larger features, such as old landfills, dumps, and burial sites, and not intended to provide 100% coverage of a site. Individual, small targets will not be detected unless they fall on or very close to a survey line.

- *Detailed search* uses closely spaced survey lines (3 to 10 ft apart) and slower traverse speeds (about 1 to 2 mph). A detailed survey is usually designed to provide close to 100% site coverage, or even overlapping site coverage for a minimum expected target size.

- *Micro-search* surveys use very closely spaced survey lines (typically a few feet or less) and traverse speeds of 0.25 to 0.50 mph. A micro-search is designed to provide 100% coverage, with redundant measurements, so that even the smallest of targets can be readily detected.

In addition to the level-of-detail requirements, there are two basic approaches to search work for identifying target areas. In the first approach, the search crew carries out the survey from beginning to end over the entire search grid area, and after the search is completed, a map of anomalies over the site is generated. The map provides documentation and a degree of quality assurance over the field work. Once an anomaly map is produced, the search team may be redirected to go back to each anomaly and accurately locate it. This task is accomplished by rerunning the lines on which anomalies were detected, but at a slower speed and with a smaller station interval. Additional closely spaced survey lines may also be needed to further define the boundaries of each anomaly.

In the second approach, the search team proceeds along a survey line, and when an anomaly is encountered, the team stops to accurately locate the anomaly and characterize it. The anomaly may be dug up at that time. This method does not necessarily provide an anomaly map of the site. There are also greater possibilities of missing a small area and for documentation errors to creep into the program. The search team may not resume the survey at the last measurement station, or they could easily resume the survey on a nearby survey line and not complete the line on which an anomaly was found.

A.6.3 Detection Probability

A target may not be detected by a geophysical method if there is insufficient contrast in the parameter being measured, if the target is sufficiently small, or if it is buried too deep. Detection probability is also related to the size of the target in relation to line spacing of the survey grid. If the target is larger than the line spacing, the probability of detection is very high. If the dimensions of the target are less than the line spacing, then there is a very good probability that the target will be missed.

If previous data or experience is not available for planning a geophysical survey, rules of thumb can be used as a guide. However, in practice, tests should be run with specific targets and the instrumentation to be used selected to ensure a reasonable detection probability if data or experience is unavailable. If there is no detection distance data for the type of targets expected to be encountered, then the search team should obtain similar targets (e.g., dummy UXO) or simulate target size, mass, and cross-sectional area (as appropriate, depending on the geophysical techniques being used) and carry out simple field tests to develop an estimate of detection limits. Tests can be run with EM, MAG, and MD in air rather than to burying targets in the ground. This procedure will provide a best-case response. GPR tests must be run in soil typical of the site.

Most areas to be surveyed are not clean and undisturbed but instead contain a variety of targets and high levels of background interference. Therefore, one may not obtain clear and obvious target signatures. This factor must be considered when planning the survey and considering detection levels. For example, in a "clean" area, a target may easily be identified by a magnetic anomaly of 10 gammas/ft. On the other hand, with site interference, a 100 gammas/ft response may be required to detect the same target.

Instruments should be checked for correct operation at the beginning of each day or at the beginning of each survey. Manufacturers' procedures should be followed and the operations check noted in a field log.

A.6.4 Survey Design

The purpose of the geophysical survey is to provide support information in order to allow an area proposed for construction to be cleared. The layout of the survey grid must be tailored to both the construction project needs and to the requirements of the geophysical instrument. Special attention must be given to excavation areas, such as utility trenches. For example, if the construction needs are to excavate to a depth of 10 ft but the geophysical method is only sampling to a depth of 5 ft, then the site will have to be surveyed and excavated to 5 ft, then resurveyed again before proceeding with a second excavation to 10 ft.

A survey grid should be laid out such that the survey lines are straight and parallel. The line spacing must be established on the basis of the expected target size(s), the level of coverage desired, and the program objectives in terms of probability of detection. Assuming that 100% site coverage is desired, the spacing between survey lines must be close enough that if a target were to lie halfway between two survey lines (a worst-case condition), it would be detected by traverses on both of the adjacent survey lines. It is generally better to err on the side of caution and select smaller line spacings. In some cases, the geophysical survey lines are run at right angles along the grid. This is especially important for FEM and GPR surveys designed to detect underground pipes and utilities. With regard to these two methods, the best target response occurs when the survey is run at a right angle to the pipe orientation.

Surveyor's pin flags are commonly used to mark the grid. Plastic flags are available that allow their use when MAGs or MDs are employed. The grid or profile labeling scheme should be sufficiently obvious to the survey team so there is no confusion in running the survey lines. In some cases where lines are closely spaced (5 to 20 ft), it is often possible to not mark every other survey line because a skilled survey team can easily, and without loss of accuracy, locate themselves between two lines.

Grids deployed for geophysical surveys are usually temporary (life span from several weeks to less than a year). For environmental site investigations lasting longer periods, a more permanent grid system should be used. Wooden stakes or surveyor's stakes should be driven into the corners of the grid, and, if possible, measurements to nearby structures, such as fences or buildings, should be recorded. Both of these steps should allow the geophysics grid to be reconstructed if needed.

The accuracy of the survey grid layout and its documentation should be related to the need to reoccupy a given location on the basis of a report and site map. In some cases, where the anomalies are being inspected as the survey proceeds, an accurate location grid and site map may not be necessary. In this case, the grid is necessary only to ensure that the search team adequately covers the site.

A.6.5 Limitations due to Depth of Survey

Because the depth to which a given target can be detected by any one of the methods is limited, a surface survey with geophysical methods does not ensure that all hazards will be detected. They may be present but beyond the range of detection. Deeper surveys can be accomplished only by an alternating sequence of search and strip operations (removal of soils to a maximum safe depth). The same problem occurs when carrying out a drill site clearance (a survey of a possible drill site so that drilling can be safely carried out without encountering hazards). The depth of a surface survey is quite limited and should be recognized as such. Drilling beyond the stated depth may encounter hazards.

A.6.6 Detonation Potential from Geophysical Methods

Ground penetrating radar, electromagnetic, and metal detectors are considered active geophysical methods because they radiate electromagnetic energy into the ground. This radiated energy may be sufficient to trigger certain types of fuse systems. Unfortunately, there is no publicly available literature on this topic because the military regards it as classified information. Coordination with the Explosives Ordnance Detachment (EOD) unit servicing each military site is strongly recommended when working in sites with a UXO potential. It is particularly important to provide the EOD personnel with energy specifications of the instruments used (e.g., wattage and signal frequency).

A.7 COST AND LEVEL OF EFFORT ESTIMATION

Generally a two-man team will be required to conduct a geophysical search. The level of effort and cost of search surveys will vary considerably, depending on the following:

- Size of the site,
- Amount of site coverage,
- Objective of the survey,
- Whether multiple geophysical methods are used,
- Site accessibility, and
- Extent and detail involved with the survey grid.

Given an open, accessible site of an acre (about 200 × 200 ft) and the objective of locating burial trenches with an EM-31, a two-man search team could lay out the survey grid with lines 10 ft apart (21 lines with markers every 20 ft) and survey the 1-acre site in one 8-hour day (about 1 line mile of data). Most of the time will be spent installing the survey grid; some time will be required for equipment set up, data management, and quality control of the data. Actual survey time will be relatively small, about an hour or two.

If the objective of the survey over a 200 ft × 200 ft site is to look for a single buried drum with a MAG, a line spacing of about 5 ft should be used (41 lines with markers every 20 ft). This spacing will increase the survey to about 1.7 line miles of data and require about 1.5 days, much of which would be spent laying out the survey grid.

If the objective is to look for UXO (i.e., a single 155-mm shell in the upper few feet) with a MAG, line spacing should be decreased to about 2.5 ft (about 3.3 line miles of data). About 2 days of effort would be required, much of which would be spent laying out the survey grid (81 lines with markers every 10 ft). In this case, survey lines would be marked off on every other line (every 5 ft), and every other line would be run between the marked survey lines.

Use of a reputable geophysical survey firm is important. Personnel should also have knowledge of health and safety requirements for hazardous waste sites, if appropriate.

A.8 REFERENCES

Breiner, S., 1973, *Applications Manual for Portable Magnetometers,* Geometrics, Sunnyvale, Calif.

Daniels, J.J., 1990, *Fundamentals of Ground Penetrating Radar,* SoftEarth Associates Inc., Westerville, Ohio.

Dobrin, M.B., and Savit C.H., 1988, *Introduction to Geophysical Prospecting,* McGraw-Hill, Chapter 15.

Geonics Limited, 1980, *Electromagnetic Terrain Conductivity Measurements at Low Induction Numbers,* Technical Note TN-6, Mississauga, Ontario, Canada.

Geonics Limited, 1991, *EM-31 Operating Manual,* Mississauga, Ontario, Canada.

Geonics Limited, 1993, *Buried-Metal Detection with the EM-61*, Mississauga, Ontario, Canada.

Henegar, H.H., 1976, *Detection of Unexploded Ordnance,* Technical Report 76-1, U.S. Department of Defense Explosives Safety Board, U.S. Army Mobility Equipment, Research and Development Command, Washington, D.C.

Horton, K.A., et al., 1982, *An Evaluation of Ground Penetrating Radar for Assessment of Low Level Nuclear Waste Disposal Sites,* NRC FIN B6349, Division of Health, Siting and Waste Management, Office of Nuclear Regulatory Research, U.S. Nuclear Regulatory Commission, Washington, D.C.

McNeill, J.D., 1980, *Electrical Conductivity of Soils and Rocks,* Technical Note TN-5, Geonics Limited, Mississauga, Ontario, Canada.

Peterson, J.C., et al., 1994, *Sensor Technology Assessment for Ordnance and Explosive Waste Detection and Location,* Jet Propulsion Laboratory, Pasadena, Calif.

APPENDIX B:

SOIL GAS SAMPLING TECHNOLOGIES

APPENDIX B:

SOIL GAS SAMPLING TECHNOLOGIES

B.1 INTRODUCTION

Soil gas sampling technologies (SGSTs) are typically employed in the early phases of site characterization sampling. Contaminants released to the environment could exist in the subsurface in several phases, including a nonaqueous liquid phase, dissolved phase, sorbed phase (adsorbed to soil), and vapor phase. In some cases, pollutants that can exist in a vapor phase can be detected with SGST. Thus, soil gas can be studied to locate contamination sources in the subsurface.

Because soil gas consists of only a fraction of the subsurface matrix (soil, groundwater, capillary water, etc.), soil gas data are generally used only as a screening technique to help the investigator choose the optimal soil or groundwater sampling location. The primary advantages of SGST over conventional sampling approaches are that it:

- Costs less,
- Produces less investigation-derived waste, and
- Allows for a relatively quick turnaround time between sample collection and the receipt of results.

The primary disadvantages of SGST are as follows:

- The techniques cannot be used to sample and analyze constituents of concern that do not have a vapor phase (that portion of the subsurface matrix that is sampled by SGST).
- Typically, analytical results from SGST cannot be readily used as input for risk assessments.

B.2 BACKGROUND

As is the case for many techniques in the hazardous waste characterization field, SGST was first used as a surface geochemical technique in oil and gas exploration. SGST can be divided into two broad categories, active and passive. Active techniques require the installation of soil gas extraction points, the removal of soil gas through the extraction points by an extraction device such as a vacuum pump, and analyses of the collected soil gas sample by gas chromatography (GC) or GC plus mass spectrometry (MS).

In general, active soil gas sampling techniques are best suited for the rapid exploration of volatile organics originating from highly concentrated "sources" in relatively permeable soils. In contrast, passive soil gas techniques rely on the diffusion of soil gas (from the subsurface or in the subsurface) and the adsorption of the soil gases onto the sorbent. A number of passive soil gas monitoring techniques are currently available. For the purposes of illustration, three monitoring techniques are discussed here: the Petrex, Emflux®, and Gore-Sorber® systems.

B.3 ACTIVE SOIL GAS MONITORING

Generally, active soil gas sampling involves driving a hollow steel sampling probe to a depth of 20 feet or less. In some cases, the soil gas probe may be installed by using a hand auger, powered auger, or any direct push technology (DPT) previously described in Chapter 3. In areas suspected of containing unexploded ordnance (UXO), before the probes are placed, the position of the probes should be determined to be clear of subsurface UXO. The above-ground portion of the probe is attached to a vacuum pump. The probe is purged of several probe volumes of air to ensure that soil gas is contained within the probe, then a sampling device is used to withdraw a soil gas sample through an in-line sample port. Alternately, if desired, soil gas can be collected in a Tedlar sample bag and transported to an analytical instrument, where a sample is withdrawn from the bag by a syringe. The sample can then be injected immediately into the analytical equipment of choice (Figure B.1).

The analyses of the collected soil gas sample can be conducted either simultaneously (in situ) during extraction, or the sample can be collected in a sample container (bag, syringe, etc.) and analyzed either in a GC/MS located on site or at an off-site fixed laboratory.

B.4 PASSIVE SOIL GAS METHODS

Discussed below are three passive soil gas monitoring techniques: Petrex, Emflux, and Gore-Sorber.

B.4.1 Petrex

The Petrex system relies on the adsorption of vapor-phase constituents on ferromagnetic elements partially coated with activated charcoal and the subsequent analyses of thermally desorbed vapor-phase constituents by MS. The ferromagnetic/carbon elements are emplaced inside a culture tube within collectors (one in each collector) and deployed in the exploration area at a constant depth for a given survey. The collectors are retrieved when a "time calibration collector" reveals that the loading of gases on the charcoal absorbent has been sufficient. A culture tube is then removed from the sample point, capped, and sealed. The sample holding time is about four months. Minute quantities of the vapor-phase constituents of concern are thermally desorbed from

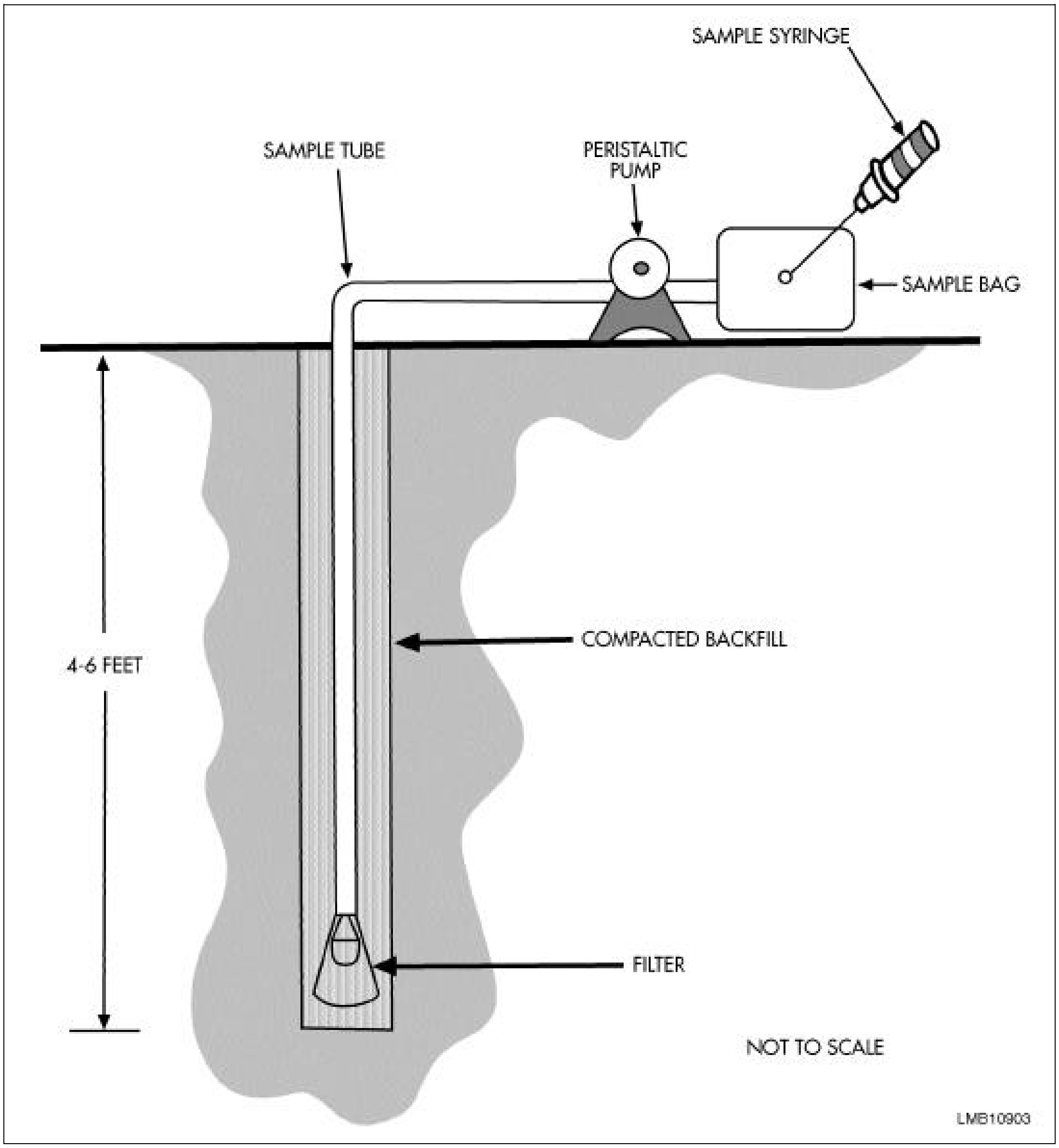


FIGURE B.1 Active Soil Gas Monitoring

the carbon (using a Curie-pint pyrolysis/thermal desorption inlet), separated by ion mass, and counted, and a mass spectrum of masses is obtained.

The Petrex system uses a charcoal element as the sorbent. Activated charcoal (prepared in a proprietary process) is bonded on a ferromagnetic wire. The coated wire is placed inside a collector tube.

B.4.2 Emflux® Soil Gas Investigation System

The Emflux system relies on Quadrel's proprietary computer model (which is based on the gravitational phenomenon known as "earth tides") to predict periods of maximum soil gas emission. Knowing when these favorable periods occur aids investigators in locating and mapping subsurface chemical contamination.

Standard Emflux field kits for shallow subsurface sampling (collectors are placed about 4 in. below ground surface) are 3 in. high by 9 in. wide by 9 in. long. Field kits for surface-based sampling are 9 in. high by 9 in. wide by 19 in. long. Figure B.2 provides line drawings of key components. Each Emflux sample cartridge contains 100 mg of selected adsorbent(s) and, after 3 to 7 days of deployment, is analyzed at an off-site fixed laboratory. The Emflux system has proven to be capable of accurately identifying a broad spectrum of volatile and semivolatile organic compounds, including halogenated compounds, petroleum hydrocarbons (aromatics, aliphatics, etc.), polynuclear aromatic hydrocarbons, and methane, to concentrations at and below parts-per-billion levels. Field procedures for Emflux are provided in Figure B.3.

B.4.3 Gore-Sorber® System

The Gore-Sorber module is shown in Figure B.4. The Gore-Sorber system relies on the adsorption of contaminants on sorbents placed within sheaths of expanded polytetrafluorethylene (PTFE). These sheaths are prepared like long lengths of cord within which the sorbents are sheathed. The cord serves as a means for inserting and retrieving the PFTE to and from the subsurface. Once the PFTE is removed, it is typically analyzed at an off-site fixed laboratory.

PTFE membranes exclude liquid water but do not restrict vapor transfer, thus allowing any contaminants with a vapor phase to freely penetrate them and collect on the adsorbent material. In addition, because the sorbent media can be protected from contact with ground and soil pore water, this technique can be used in saturated, low-permeability, and poorly drained soils.

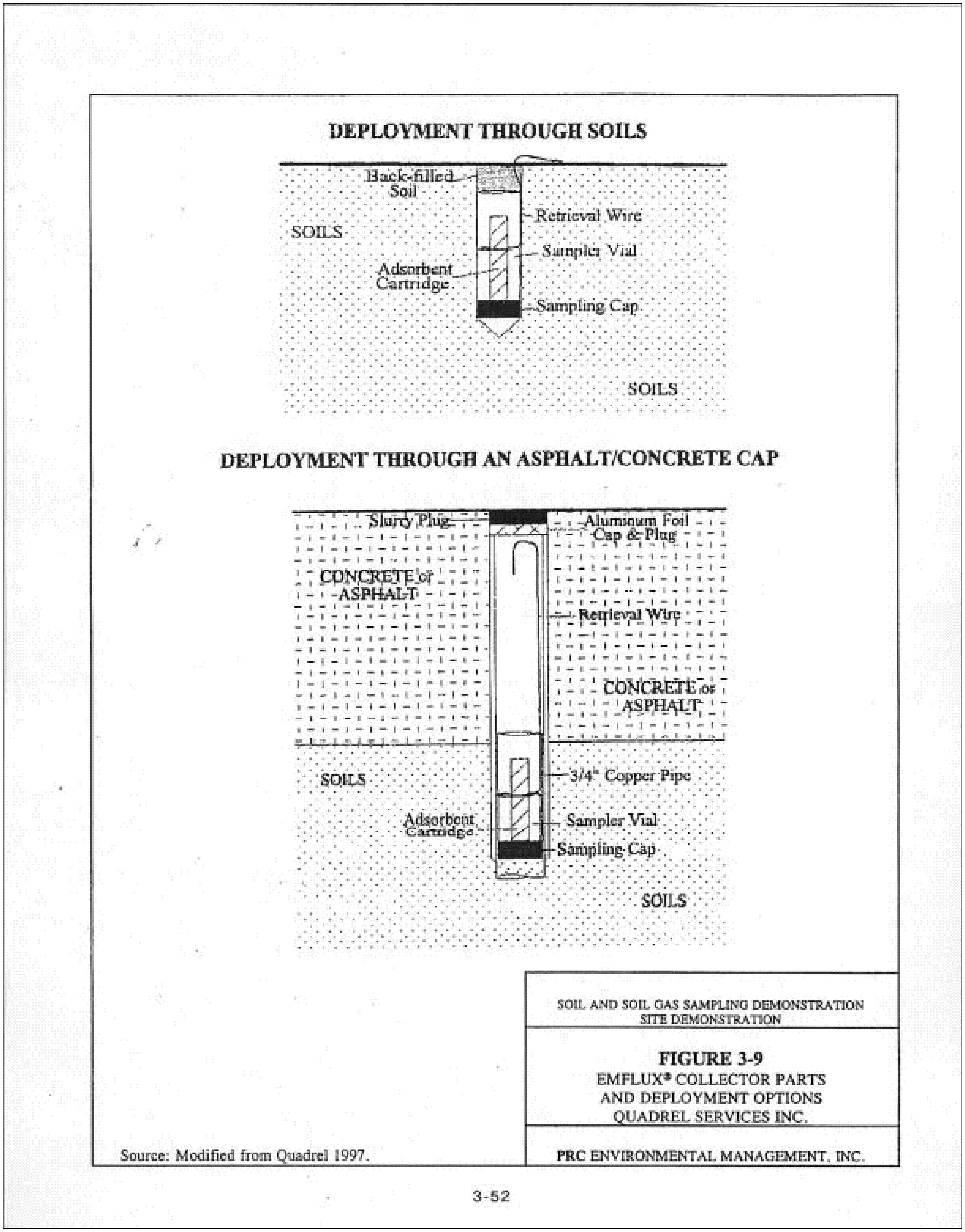


FIGURE B.2 Emflux Collector Parts and Deployment Options (Source: EPA 1997)

Deployment/Retrieval of Emflux® Collectors

The following field procedures are routinely used during Emflux® soil-gas surveys. Modifications can be and are incorporated from time to time in response to individual project requirements. In all instances, Quadrel adheres to EPA-approved QA/QC practices.

1. Field personnel carry Emflux® components and support equipment to the site and deploy the Emflux® collectors in a prearranged survey pattern. Although Emflux® collectors require only one person for emplacement and retrieval, the specific number of field personnel required depends on the scope and schedule of the project. Each collector emplacement generally takes less than 2 minutes.

2. For those sample locations covered with debris or vegetation, a field technician clears vegetation and debris exposing the ground surface. Using a hammer and a 3/4-inch-diameter pointed metal stake, the technician creates a hole approximately 3 inches deep. For those locations covered with asphalt or concrete cap, the field technician drills a 1-inch-diameter hole through the cap to the soils beneath. (If necessary, the collector can be sleeved with a 3/4-inch inside diameter (i.d.) copper pipe for either capped or uncapped locations).

3. The technician then removes the solid plastic cap from an Emflux® collector (a glass vial containing an adsorbent cartridge with a length of wire attached to the vial for retrieval) and replaces it with a sampling cap (a plastic cap with a hole covered by screen meshing). The technician inserts the collector, with the sampling cap end facing down, into the hole (The collector is then covered with either local soils for uncapped locations, aluminum foil and a concrete patch.) The collector's location, time and date of emplacement, and other relevant information are recorded on the Field Deployment Form.

4. As a QC check during emplacement and retrieval, the technician takes periodic ambient-air control samples and records the date, time, and location of each. (One or more trip blanks are also included as part of the QC procedures.)

5. Once all Emflux® collectors have been deployed, field personnel schedule collector recovery (approximately 72 hours after emplacement) and depart, taking all no-longer-needed equipment and materials with them.

6. Field personnel retrieve the collectors at the end of the 72-hour exposure period. At each location, a field technician withdraws the collector from its hole and wipes the outside of the vial clean using gauze cloth; following removal of the sampling cap, the threads of the vial are also cleaned. A solid plastic cap is screwed onto the vial and the sample location number is written on the label. The technician then records sample point location, date, time, etc., on the Field Deployment Form.

7. Sampling holes are refilled with soil, sand, or other suitable material. If collectors have been installed through asphalt or concrete, the hole is filled to grade with a plug of cold patch or cement.

8. Following retrieval, field personnel ship or carry the Emflux® collectors to analytical laboratories under contract to Quadrel. The remaining equipment is returned to Quadrel's preparation facility.

FIGURE B.3 Field Procedures for Emflux (Source: EPA 1997)

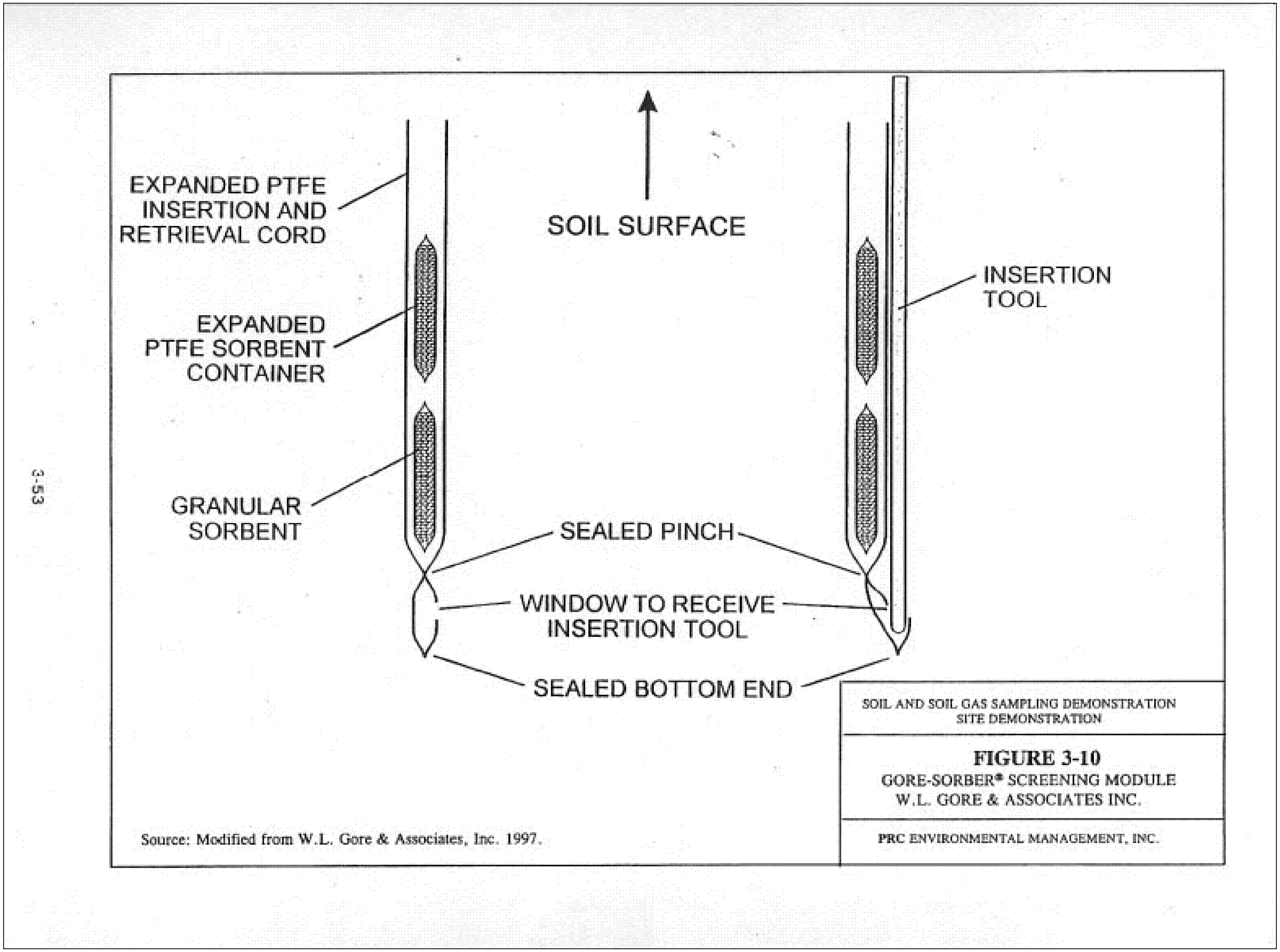


FIGURE B.4 Gore-Sorber Screening Module (Source: EPA 1997)

Gore-Sorber can be used to evaluate a number of contaminants including volatile and semivolatile organic compounds, explosives, chemical agents/breakdown products, pesticides/ herbicides, and PCB congeners. Figure B.5 describes the deployment of the Gore-Sorber.

B.5 REFERENCES

EPA, 1997, *Superfund Innovative Technology Evaluation Program Final Demonstration Plan for the Evaluation of Soil Sampling and Soil Gas Sampling Technologies*, prepared by PRC Environmental Management, Inc., Lenexa, Kans., for U.S. Environmental Protection Agency, National Exposure Research Laboratory, Las Vegas, Nev., Aug.

Gore-Sorber® Deployment/Retrieval

A typical Gore-Sorber® consists of several separate passive sorbent collection devices (sorbers). A typical sorber is 15 to 25 mm long, with a 3 mm I.D., and contains 40 mg of a suitable granular adsorbent material depending on the specific compounds to be detected. Typically, polymeric and carbonaceous resins are used for their affinity for a broad range of VOCs and SVOCs. The sorbers are sheathed in the bottom of a 4-foot length of vapor-permeable insertion and retrieval cord. This construction is termed a Gore-Sorber® module. Both the retrieval cord and sorbent container are constructed solely of inert, hydrophobic, microporous Gore-Tex® expanded polytetrafluoroethylene (ePTFE, similar to Teflon® brand PTFE). Additionally, the module construction facilitates easy installation and retrieval at a desirable installation depth of 2 to 3 feet using simple hand tools.

Installation of the modules is performed by the customer. Although Gore-Sorber® modules can be installed to any depth, a slam bar or electric rotary hammer-drill is typically used to auger a ½ inch-to ¾-inch-diameter pilot hole for the deployment of the modules to an average depth of 2 to 3 feet below grade.

After the pilot hole is completed, modules are inserted into the completed boreholes using the stainless-steel insertion rod supplied by W.L. Gore & Associates. The top of each cord is typically fastened to a cork, which is tamped flush with the ground surface to assist in retrieval of the module, and to seal the annulus of the boring.

Module retrieval requires that field personnel locate the module, remove the cork, grasp the retrieval cord and manually pull the module from each location. Corks are separated from the module and discarded. The exposed modules are resealed in their respective designated shipping vials and placed immediatelyon ice in the supplied coolers. In addition, trip blanks and water temperature control blanks (provided by W.L. Gore & Associates) are also returned. Coolers are returned along with the chain-of-custody form to W.L. Gore & Associates laboratory in Elkton, Maryland, via overnight carrier.

FIGURE B.5 Field Procedures for Gore-Sorber (Source: EPA 1997)

APPENDIX C:

RISK ASSESSMENT METHODS USED TO DEFINE ANALYTICAL SENSITIVITY OBJECTIVES AND INTERPRET ANALYTICAL RESULTS*

* Section 2.3 of a document prepared by Argonne National Laboratory for the U.S. Army, Aberdeen Proving Ground, Maryland.

Soil Contaminant Levels and Associated Risks to Construction Workers at the Construction Site for Work Request CEQ37CE, Edgewood Area, Aberdeen Proving Ground, Maryland

by

L.L. Reed, S.W. Myers,* D.H. Rosenblatt, and L.T. Shepard

Center for Environmental Restoration Systems
Argonne National Laboratory
9700 South Cass Avenue
Argonne, Illinois 60439

June 30, 1997

Work sponsored by United States Army Corps of Engineers, Baltimore District. Report submitted to U.S. Army Directorate of Public Works, Aberdeen Proving Ground, Maryland.

* Myers is affiliated with Hydro-Terra, Inc., Columbia, Maryland.

Contents

2.3 Risk Assessment Methods Used to Define Analytical Sensitivity Objectives and Interpret Analytical Results

2.3.1 Overview

The purpose of this section is to establish criteria for interpreting the data provided in Section F.3. The following pages will present estimates of the soil contaminant concentrations at which workers would not be adversely affected and discuss potential hazards to nearby populations. If the analytical results indicated borderline safety or endangerment on the basis of soil contaminant criteria derived in this section, additional data analysis and risk assessment would be performed. Upgrading of personnel protective clothing and equipment might provide sufficient protection to allow construction to proceed. The criteria established will also indicate when the analytical methods used are sufficiently sensitive — or even unnecessarily sensitive.

2.3.2 Worker Exposure Factors

2.3.2.1 Inhalation of Construction Site Dust

The objectives of the discussion that follows are to (1) define, for a situation worse than is likely to be encountered, levels of significance for toxic dust-borne air contaminants at which even the most toxic compounds in the target substance lists presented in Tables 2 and 3 (separately or in combination) will not exceed occupational safety and health standards for dust inhalation, and (2) show whether the analytical sensitivities of the testing methods used in the current work are adequate to detect the target compounds at the defined levels.

EPA has issued guidance for emission factors to be applied to dust emitted during construction site preparation (Grelinger et al. 1988). Although not site-specific, the estimate of 1.2 tons/acre·month (for particles measuring less than 30 μ in diameter) has the predictive advantage of not requiring an estimate of the level of vehicular traffic the project will involve. For this project, the real concern is that total suspended particulates (TSP) might be inhaled or partially swallowed, and all of the toxic material borne by the particulates could be absorbed. For this reason, a factor of three has been suggested to convert from PM_{30} (particulate matter of 30-μ diameter or less) to TSP (Shipman 1991).

The maximal case, intended to represent the largest probable building site, would involve a plot of land in an area near Baltimore, Maryland, measuring 500 ft × 500 ft (250,000 ft^2 or

23,225 m^2 or 5.74 acres). We have assumed that land clearance will require 5 work days (40 hours or 0.25 month) for site preparation and foundation work, after which the dust loss should be markedly lower. The total emissions would be: 3 × 1.2 tons/acre·month × 5.74 acres × 0.25 month × 2,000 lb/ton × 454 g/lb × 1,000 mg/g = 4.7×10^9 mg of dust. In the calculations that follow, a "box" model is used.

With a wind speed of 4.2 m/s (13.8 ft/s) for the Baltimore area (Cowherd et al. 1984), and the wind blowing across the 500-ft width of the property, about 500/13.8 = 36.2 s would be required to replace all air over the property; thus, there would be 144,000 s/36.2 s per change = 3,978 air changes over the 5 work days. If we assume that the dust rises 2 meters to fill the "box," it occupies 2 × 23,225 = 46,450 m^3 of air above the property. The average concentration of site-generated dust is therefore estimated as $4.7 \times 10^9/(3{,}978 \times 46{,}450) = 25.4$ mg/m^3, or 25.4×10^{-6} kg/m^3.

Averaged over the 22 work days of the month (rather than 5 days), the exposure is 5.77×10^{-6} kg/m^3 (average monthly on-site dust level). The most stringent occupational safety and health standards (U.S. Department of Labor 1990) for the compounds in the target compound list are for arsenic and silver (0.01 mg/m^3). The ratio of this value to 5.77×10^{-6} is equal to 1,733 mg/kg; this is the soil concentration below which exposure by particulate inhalation should have no adverse effects. To allow a margin of safety, however, dust inhalation will be considered significant if soil concentrations above 170 mg/kg are reported (analytical methods are all far more sensitive than this level). This low criterion (compared to 1,733 mg/kg) allows for the possible co-occurrence of several contaminants as well as exposure by more than one pathway.

As a cloud of dust is blown away from the construction site, it disperses both laterally and vertically, and heavier particles settle out. In time, much of the dust is intercepted or washed out by rain, carrying the least volatile compounds with it. In most cases, passersby or occupants of nearby buildings are not in the path of the dust very long and do not breathe the dust as rapidly as construction workers. Thus, the general population should be exposed to considerably less dust than workers at the site.

2.3.2.2 Inhalation of Vapor Emissions — General Case

Similar to those in the preceding section, the objectives of the discussion that follows are to (1) define, for a situation worse than is likely to be encountered, a level of significance for toxic vapor-phase volatile organic air contaminants at which even the most toxic volatile organic compounds in the target compound list presented in Table 2 (separately or in combination) will not exceed occupational safety and health standards for vapor inhalation, and (2) show that the analytical sensitivities of the testing method used in the current work are adequate to detect the target compounds at the defined level.

We have assumed that land clearing removes the top 1-ft layer of soil. If a toxic volatile compound was originally distributed evenly in the soil, then over a period of time, the portion of the compound in the surface layer will have been depleted more than the portion in the deeper layers. The balancing assumptions will be made that the removed surface soil layer does not contribute significantly to air emissions,* and that the subsurface soil layer is evenly contaminated (at the highest detected concentration, c_o, expressed in units of $\mu g/cm^3$) to a semi-infinite depth at the moment the surface layer is stripped off. Theory predicts that a gradient of emissions from the surface will soon be established, so that the emission rate decreases with time. The total quantity of a compound emitted per unit area of the newly exposed surface in time (t) is expressed as $Q_t = 2c_o\ (Dt/')^{1/2}$, where D is the calculated effective diffusion coefficient through the soil (Lyman et al. 1990). Calculation of D (Lyman et al. 1990) requires values for the vapor-phase diffusion coefficient (D_v, cm^2/s), the air-filled soil porosity (s), the total porosity of the soil (s_t), the soil bulk density (ρ_b, g/cm^3), and the expression for change of vapor density with concentration (dp/dc), for which the ratio of the dimensionless Henry's Law constant to the soil-water distribution coefficient ($K_H/K_d = K_H/K_{oc}f_{oc}$) is substituted. Here, K_{oc} is the ratio of the amount of a chemical adsorbed on the soil per unit weight of organic carbon (oc) to the concentration in soil water; f_{oc} is the fraction of organic carbon in the soil. The modified equation is:

$$D = D_v\, s^{10/3}\, K_H/(f_{oc}\, K_{oc}\, \rho_b\, s_t^2)\ cm^2/s \qquad (1)$$

Values of D_v, K_{oc} and K_H are compound-specific, and may be found in various sources (EPA 1988) or estimated (Lyman et al. 1990). The following default values may be used for the other input values (compare EPA 1988):

$f_{oc} = 0.02$
$s = 0.35$
$s_t = 0.50$
$\rho_b = 1.32\ g/cm^3$

With use of the default values, the soil diffusion constant equation is reduced to $D = 4.58\ D_v\, K_H/K_{oc}$ and the emission equation becomes:

$$\begin{aligned} Q_t &= 4.28\ c_o\, \{D_v\, K_H\, t/('K_{oc})\}^{1/2}\ \mu g/cm^2 \qquad (2) \\ &= 2.41\ c_o\, \{D_v\, K_H\, t/('K_{oc})\}^{1/2}\ \mu g/cm^2 \end{aligned}$$

Q_t is multiplied by the area (in square centimeters) to obtain E_v, the quantity of pollutant emitted from the beginning of the process. Because the exposure is actually intermittent, one

* Consider the generalized worst-case contaminant (i.e., a compound with the volatility of methylene chloride). Assume that the first 1 ft of soil was piled up at the edge of the property, and that it contained the same concentration (c_o) as the deeper soil. Even if all of the compound were emitted during the exposure period of one month, it would amount to only one quarter of the emissions estimated by the model described herein. In view of the uncertainties involved, this difference is too small to be of concern.

could calculate and average individual segments of exposure. However, with only a small sacrifice in accuracy, we can estimate the total emissions for the month and multiply the resulting Q_t by the ratio of hours worked to total hours in the calculation to obtain an adjusted Q_t value (Q_t*), from which exposure can be calculated.

For the present worst-case example, a disturbed area of 500 ft × 500 ft (considerably larger than the current site dimensions) will again be considered. This once more gives an area of 250,000 ft^2, 23,225 m^2, or 2.32×10^8 cm^2. If it is assumed that one month (22 8-hour work days equivalent to 176 hours, out of 30 days equivalent to 720 hours) is required for the construction project, then $Q_t^* = 176/720\ Q_t$ or $0.244\ Q_t$. The value of t (seconds) is 2.59×10^6. Thus, the total of the vapor emissions during working hours is expressed as:

$$E_v = \{0.244 \times 2.41\ (2.32 \times 10^8)\ (2.59 \times 10^6)^{1/2}\}\ c_o\ (D_v\ K_H/K_{oc})^{1/2} \qquad (3)$$
$$= 2.19 \times 10^{11}\ c_o\ (D_v\ K_H/K_{oc})^{1/2}\ \mu g \text{ in the 176 work hours}$$

With a 36.2-second air replacement time (i.e., 500 ft/13.8 ft/s), there will be 17,500 exchanges in 176 hours in the 46,450 m^3 "box" described in Section F.2.3.2.1. Thus, the air concentration of contaminant as vapor emissions is calculated by means of the following equation.

$$c_a = \{2.19 \times 10^{11}/(46{,}450 \times 17{,}500)\}\ c_o\ (D_v\ K_H/K_{oc})^{1/2} \qquad (4)$$
$$= 270\ c_o\ (D_v\ K_H/K_{oc})^{1/2}\ \mu g/m^3$$
$$(\text{or } 2.7 \times 10^{-4} c_o\ (D_v\ K_H/K_{oc})^{1/2}\ \mu g/m^3)$$

Hence,

$$c_a/c_o = 2.7 \times 10^{-4}\ (D_v\ K_H/K_{oc})^{1/2}\ \text{[dimensionless]} \qquad (5)$$

As a generalized worst-case example, c_a/c_o for the most volatile of the organic compounds on the target compound list (Table 2) will be combined with the lowest 8-hour time-weighted average occupational safety and health standard (OSHS) from among these volatile target compounds.

Input Data for the Most Volatile Compound — Methylene Chloride

D_v = 0.10525 cm^2/s (linear interpolation to 25°C of data from EPA 1988)

K_H = 0.10506 at 25°C (multiplying 0.00257 atm m^3/mol from Oak Ridge National Laboratory [ORNL 1989] by the conversion factor 40.88 mol/m^3 atm)

K_{oc} = 8.8 (ORNL 1989)

$(D_v K_H/K_{oc})^{1/2} = (0.10525 \times 0.10506/8.8)^{1/2} = 0.03544$

OSHS for the Most Toxic Volatile Compound — 1,2-Dichloroethane

OSHS = 4 mg/m^3 (U.S. Department of Labor 1990)

The worst-case general vapor inhalation screening criterion, c_B, is calculated as follows:

$$\begin{aligned} c_B &= \text{OSHS}/(c_a/c_o) \times 0.001\ \text{m}^3/\text{L} \times (1/1.32)\ \text{L/kg} \qquad (6) \\ &= [4/\{2.7 \times 10^{-4} \times (D_v K_H/K_{oc})1/2\}] \times 0.0007576 \\ &= [4/\{2.7 \times 10^{-4} \times 0.03544\}] \times 0.0007576 \\ &= 317\ \text{mg/kg} \end{aligned}$$

To allow a margin of safety, however, vapor inhalation of volatile organic compounds will be considered significant if soil concentrations above 60 mg/kg are reported (analytical methods are all far more sensitive than this level). This low screening criterion value (compared with 317 mg/kg) allows for the possible co-occurrence of several volatile contaminants.

2.3.2.3 Direct Soil Ingestion

The rate of soil ingestion does not depend on the size or nature of the site. Examination of the results of a recent study (Calabrese et al. 1990) suggests that adults may ingest about 50 mg of soil per day. As a worst case, we have assumed consumption of 100 mg/day of soil. If the 22 exposure days are averaged over the 30-day total period, the exposure will be 22/30 of that value, or 73.33 mg/day of soil. A soil concentration of 1 mg/kg of a toxic chemical will result in a dose of 7.333×10^{-5} mg or, for a 70-kg individual, $7.333 \times 10^{-5}/70 = 1.05 \times 10^{-6}$ mg/kg·day (which can be added to the dermal exposure, as shown below).

2.3.2.4 Dermal Absorption

The rate of dermal absorption does not depend on the size or nature of the site. EPA's cited values for adherence of soil to human skin range from 1.45 to 2.77 mg/cm^2 (EPA 1988). For our study, a judgment-based value of 2.0 mg/cm^2 is used. Based on the assumption that the construction workers will be required to wear shirts and long trousers, if not protective clothing, the head and upper extremities, with areas of 1,180 cm^2 and 3,190 cm^2 (total 4,370 cm^2), could be coated with soil. Thus, the possibility exists for a total soil loading on the skin of $2 \times 4{,}370 =$ 8,740 mg. At a toxicant concentration of 1 mg/kg, this amount of soil would contain 0.00874 mg of the compound. If the 22 exposure days are averaged over the 30-day total period, the exposure will be 22/30 of that value, or 0.00641 mg/day. We can assume that a worker would permit the soil to remain on his body no more than 12 hours before washing. In this period, about 1% of a compound with a high affinity for soil organic matter (i.e., high K_{oc}) and low volatility, such as benzo[a]pyrene (Yang et al. 1989), would be absorbed into the body from a thin layer of soil. Because no information has been found regarding the dermal penetration of more volatile compounds in soil, a dermal penetration value of 3% for 12 hours has been arbitrarily adopted here for all such compounds. In 12 hours, then, soil containing a somewhat volatile toxicant at a concentration of 1 mg/kg might release as much as $0.03 \times 0.00641/70 = 2.75 \times 10^{-6}$ mg/kg/day to a 70-kg person. For the least volatile compounds (pyrene, pesticides and PCBs) a dermal penetration value of 1% is used, so that soil containing 1 mg/kg of the toxicant would release 0.92×10^{-6} mg/kg/day to a 70 kg person. It will be assumed that the systemic dose received by this route is toxicologically equivalent to an oral dose. Thus, the two can be combined, with 1 mg/kg in the soil equivalent to 5×10^{-6} mg/kg/day over the exposure period.

2.3.2.5 Calculation of Combined Ingestion/Percutaneous Absorption Criteria

Reference doses (RfDs) for most non-carcinogens were taken from Table A of the Health Effects Summary Tables (EPA 1991, 1992). Slope factors for most of the carcinogens, found in Table B of that reference, were divided into the risk value (10^{-4}) to obtain functional risk-specific dose values (RSDs). Use of a 10^{-4} risk value in the calculation reflects what would be a relatively high risk from the carcinogen if an individual were continuously exposed to such a level; however, because exposure to the chemicals in question would be extremely brief, a much lower lifetime risk is actually expected. An exception was made for benzene — a lower risk value (10^{-5}) was used for this compound because it is more frequently encountered in the environment. EPA has indicated that, for known or suspected carcinogens, acceptable exposure levels for the general public at National Priorities List sites should generally correspond to excess 95% upper bound lifetime cancer risks to an individual between 10^{-4} and 10^{-6} (EPA 1990b). Because occupational limits are less stringent than those for the general public, the criteria chosen here should be sufficiently conservative.

As explained above, the dose calculated for ingestion of soil containing 1 mg/kg of a toxic chemical is estimated as 1.05×10^{-6} mg/kg·day; the dose of the more volatile chemicals absorbed through the skin from soil containing a toxic chemical at 1 mg/kg is 2.75×10^{-6} mg/kg·day. Thus, the total ingested and absorbed percutaneously is 3.8 × 10-6 mg/kg/day. However, because the less volatile pesticides, polychlorinated biphenyls (PCBs), and polynuclear aromatic hydrocarbons (PAHs) (represented here only by pyrene), transfer from soil to skin at a much lower rate — about one-third of that adopted for more volatile compounds (see Section F.2.3.2.4) — the toxic chemical dose calculated for absorption through the skin for these classes of compounds from 1 mg/kg in soil is 0.92×10^{-6}, for a total ingestion plus percutaneous absorption value of 1.97×10^{-6} mg/kg·day. Inorganics (metals) are not absorbed through the skin from soil; only the ingestion level applies to them.

Once the dose rate resulting from exposure to 1 mg/kg of contaminant in soil and the RfD or RSD have been determined, they are combined to produce the chemical-specific and site-specific ingestion/percutaneous absorption criterion value, C_{ipa}, which is calculated as follows:

$$C_{pa}\ (mg/kg) = [1\ mg/kg \times oral\ RfD\ (mg/kg{\cdot}day)] / [dose\ rate\ from\ 1\ mg/kg\ in\ soil\ (mg/kg{\cdot}day)] \quad (7)$$

The RSD instead of the RfD is used for carcinogens.

Table 4 lists the estimated combined ingestion and percutaneous absorption-driven soil concentration criteria for soil contaminants. Comparison of the results presented in Section F.2.3.2.1 with those in Table 4 indicates that inhalation of construction site dust is a relatively unimportant pathway. However, because some volatile noncarcinogenic compounds may contribute significantly to the overall toxic effects of site contaminants, we recommend that the vapor inhalation pathway be included in the detailed evaluation of positive analytical results. The criteria presented for individual compounds represent the *minimum* requirements for analytical sensitivity — if possible, the analyses should be considerably more sensitive to account for the simultaneous effects of two or more contaminants. Naturally occurring contaminants (e.g., metals) that fall within the worldwide or (better) the Eastern U.S. normal concentration range (especially if below the worldwide mean or median) can be excluded from further consideration. Numerous mitigating circumstances or protective actions might be used to allow construction activities to proceed.

It should be noted that the soil criteria for aldrin and dieldrin are about three times lower than the current detection limit (10 μg/g). This does not necessarily indicate that the analytical method is insufficient to ensure worker safety; the RSD was based on assumptions meant to be protective to the most sensitive sub-populations of the general public over a lifetime of exposure. An acceptable exposure value derived from the OSHA Final Rule Limit (U.S. Department of Labor 1990) of 0.025 mg/m^3 for dieldrin would be about 0.0071 mg/kg·day [(0.025 mg/m^3) × (20 m^3/day breathing rate)/(70 kg body weight)]. The RSD value in Table 4 is 6.25×10^{-6} mg/kg·day. The very low soil values for aldrin and dieldrin, as well as PCBs, that are listed in Table 4 result from the extremely conservative approach used to calculate their RSDs.

2.3.2.6 Soil Contaminant Criteria

The following discussion addresses how the analytical results presented in Section F.3 were evaluated. Soil contaminant criteria were developed by using several risk assessment methods. The values derived from each method were compared and, for organic compounds, the most conservative value was selected as the soil contaminant criterion. Metals were treated as explained below. The selected criterion for each substance on the target compound list is given in Table 5. These values were used to assess the analytical results presented in Section F.3.

The soil contaminant criteria for the volatile compounds were selected from the following two values: (1) the ingestion/percutaneous absorption criterion given in Table 4, and (2) the general vapor inhalation criterion. The lower of the two values was selected as the most conservative soil contaminant criterion.

The soil contaminant criteria for the semivolatile, pesticide, and PCB compounds were selected from the following two values: (1) the general dust inhalation criterion, and (2) the ingestion/percutaneous absorption criterion given in Table 4. The lower of the two values was selected as the most conservative soil contaminant criterion.

TABLE 4 Soil Criteria for Site Pollutants Based Solely on Ingestion/Percutaneous Absorption

Compound	Subchronic Oral RfD (mg/kg·day)	Oral Slope Factor $(mg/kg \cdot day)^{-1}$	RSD (mg/kg·day)	Soil Criterion (mg/kg)
Volatiles				
Benzene	--	0.029	3.45×10^{-4}	91
Carbon tetrachloride	(0.003)[a]	0.13	7.69×10^{-4}	202
Chlorobenzene[b]	0.2	--	--	52,600
Chloroform	0.01	0.006	0.0167[c]	2,630
1,2-Dichloroethane	--	0.091	0.00110	289
1,1-Dichloroethene	(0.009)[a]	0.60	1.67×10^{-4}	44
Ethylbenzene[b]	1.0	--	--	263,000
Methylene chloride	(0.06)[a]	0.0075	0.0133	3,500
1,1,2,2-Tetrachloroethane	--	0.20	0.00050	131
Tetrachloroethene	(0.1)[a]	0.051	0.00196	516
Toluene[b]	2.0	--	--	526,000
1,1,1-Trichloroethane[b]	0.9	--	--	237,000
Xylene, total	4.0	--	--	1,000,000
Acid, Base/Neutrals				
Acenaphthene	0.6	--	--	158,000
Anthracene	3.0	--	--	789,000
bis(2-Chloroethyl) ether	--	1.1	9.09×10^{-5}	24
1,4-Dichlorobenzene[d]	0.2	--	--	52,600
Dimethyl phthalate	10.0			1,000,000
Di-n-butyl phthalate	1.0	--	--	263,000
2,4-Dinitrotoluene	--	0.68	1.47×10^{-4}	39
Fluoranthene	0.4	--	--	105,000
Hexachlorobenzene	(0.0008)[a]	1.6	6.25×10^{-5}	16
Hexachlorobutadiene	(0.002)[a]	0.078	0.00128	337
Hexachloroethane	(0.01)[a]	0.014	0.0071	1,870
Naphthalene	0.04	--	--	10,500
Nitrobenzene	0.005	--	--	1,320
Phenol	0.6	--	--	158,000
Pyrene[e,f]	(0.3)[a]	0.261	3.83×10^{-4}	194
2,4,6-Trichloroaniline[g]	--	0.034	0.00294	77
1,2,4-Trichlorobenzene	0.0131	--	--	3,450
2,4,6-Trichlorophenol	--	0.011	0.00909	2,392
Pesticides				
Aldrin[f]	--	17	5.88×10^{-6}	2.9
4,4'-DDT[f]	--	0.34	2.94×10^{-4}	149
Dieldrin[f]	--	16	6.25×10^{-6}	3.2
Endrin[f]	0.0005	--	--	254
Heptachlor[f]	--	4.5	2.22×10^{-5}	11.3

TABLE 4 (Cont.)

Compound	Subchronic Oral RfD (mg/kg·day)	Oral Slope Factor $(mg/kg·day)^{-1}$	RSD (mg/kg·day)	Soil Criterion (mg/kg)
Other Organics				
PCBs[f,h]	--	7.7	1.30×10^{-5}	6.6
Inorganics[i]				
Arsenic[j]	(0.1)[a]	--	5.71×10^{-5}	54
Barium	0.05	--	--	47,600
Cadmium[k]	0.001	--	--	952
Chromium(VI)	0.02	--	--	19,000
Copper[l]	0.037	--	--	35,200
Lead[m]	--	--	--	500
Mercury	0.0003	--	--	286
Nickel	0.02	--	--	19,000
Selenium (as selenious acid)	0.003	--	--	2,860
Silver	0.003	--	--	2,860
Vanadium	0.007	--	--	6,670
Zinc	0.02	--	--	19,000

a Value not used because it does not take carcinogenic potential into account.

b Volatile non-carcinogen, requires consideration of vapor pathways.

c Subchronic oral RfD used because it is lower than the RSD.

d An inhalation RfD of 0.7 mg/m^3 for 1,4-dichlorobenzene was converted to the usual units through multiplication by ($20\ m^3$/day ÷ 70 kg) to give 0.2 mg/kg·day; it was assumed that this would also be the oral RfD.

e The slope factor for pyrene was estimated according to ICF-Clement Associates 1988.

f As noted in the text, the exposure dosage corresponding to 1 mg/kg of a contaminant in soil for the less volatile compounds by the ingestion/percutaneous absorption route is considered to be 1.97×10^{-6} mg/kg·day.

g 2,4,6-Trichloroaniline at the Edgewood Area of APG is an artifact resulting from the decomposition of N,N'-bis(2,4,6-trichlorophenyl)urea. This compound should be deleted from the list of target compounds.

h The criterion presented here for PCBs is more stringent than the criterion developed by EPA in classifying contaminated soil as a hazardous waste.

i Inorganics are not absorbed percutaneously; the exposure dosage corresponding to 1 mg/kg in soil is thus only that for ingestion (1.05×10^{-6} mg/kg).

TABLE 4 (Cont.)

---

[j] EPA's Risk Assessment Forum has proposed a unit cancer risk of 5×10^{-5} $(\mu g/L)^{-1}$ for arsenic in drinking water. Thus, at a carcinogenic risk of 10^{-4}, the concentration would be 2.0 µg/L. Exposure at 2L/day would be 4 µg/day or 0.0571 µg/kg·day for a 70-kg person. The acceptable soil concentration would be $(5.71 \times 10^{-5})/(1.05 \times 10^{-6}) = 54$ mg/kg.

[k] An IRIS oral reference dose of 0.001 mg/kg·day (food) for cadmium is cited in ORNL 1990.

[l] The value for copper was based on a drinking water RfD of 1.3 mg/L. From this, an RfD in more common units was calculated as (1.3 mg/L × 2 L/day)/ 70 kg = 0.037 mg/kg·day.

[m] EPA has provided no reference doses or slope factors for lead, which is now considered a carcinogen. Lead concentrations are quite high (>1,000 mg/kg) near most roads and in many urban areas. A concentration of 500 mg/kg in soils is widely considered acceptable, especially because cleanup to levels lower than this would be very difficult (EPA 1989).

TABLE 5 Soil Contamination Criteria

Contaminant	Soil Contaminant Criterion (mg/kg)	Contaminant	Soil Contaminan Criterion (mg/kg)
Volatiles		*Acid, Base/Neutrals (Cont.)*	
Benzene	60	Pyrene	170
Carbon tetrachloride	60	2,4,6-Trichloroaniline	170
Chlorobenzene	60	1,2,4-Trichlorobenzene	170
Chloroform	60	2,4,6-Trichlorophenol	170
1,2-Dichloroethane	60		
1,1-Dichloroethene	44	*Pesticides*	
Ethylbenzene	60	Aldrin	2.9
Methylene chloride	60	4,4'-DDT	149
1,1,2,2-Tetrachloroethane	60	Dieldrin	3.2
Tetrachloroethene	60	Endrin	170
1,1,1-Trichloroethane	60	Heptachlor	11.3
Toluene	60		
Xylene, total	60	*Other Organics*	
		PCBs	6.6
Acid, Base/Neutrals			
Acenaphthene	170		
Anthracene	170	*Inorganics*	
Bis(2-chloroethyl) ether	24	Arsenic	73
1,4-Dichlorobenzene	170	Barium	1,500
Dimethyl phthalate	170	Cadmium	95
Di-n-butyl phthalate	170	Chromium(VI)	1,000
2,4-Dinitrotoluene	39	Copper	700
Fluoranthene	170	Lead	500
Hexachlorobenzene	16	Mercury	29
Hexachlorobutadiene	170	Nickel	700
Hexachloroethane	170	Selenium (as selenious acid)	170
Naphthalene	170	Silver	170
Nitrobenzene	170	Vanadium	300
Phenol	170	Zinc	2,000

The soil contaminant criteria for the metals were selected from the following three values: (1) the general dust inhalation criterion, (2) 10% of the ingestion/percutaneous absorption criteria given in Table 4, and (3) the maximum from the range of naturally occurring metals concentrations in the soils of the eastern United States (from Table 10). The maximum of the background range was generally selected as the soil contaminant criterion unless the risk-based criterion was greater. In that case, the lower of the two values (1 or 2) was selected as the most conservative soil contaminant criterion. The criterion selection process for lead was an exception because there are currently no inhalation or ingestion RfDs for lead. An interim soil cleanup level of 500 to 1,000 mg/kg for lead in soil has been established by EPA (EPA 1989). Therefore, 500 mg/kg was selected as the conservative soil contaminant criterion for lead.

5 References

Bodek, I., et al., 1988, *Environmental Inorganic Chemistry: Properties, Processes, and Estimation Methods,* Pergamon Press, N.Y.

Calabrese, E.J., et al., 1990, "Preliminary Adult Soil Ingestion Estimates: Results of a Pilot Study," *Regul. Toxicol. Pharmacol.* 12:88-95.

Cowherd, Jr., C., et al., 1984, *Rapid Assessment of Exposure to Particulate Emissions from Surface Contamination Sites*, prepared by Midwest Research Institute, Kansas City, Missouri., for the Office of Health and Environmental Assessment, U.S. Environmental Protection Agency, Washington, D.C., under Contract No. 68-03-3116.

EPA, 1988, *Superfund Exposure Assessment Manual*, EPA/540/1-88/001, Office of Remedial Response, U.S. Environmental Protection Agency, Washington, D.C.

EPA, 1989, *Interim Guidance on Establishing Soil Lead Cleanup Levels at Superfund Sites,* OSWER 3554-02, Office of Solid Waste and Emergency Response, Washington, D.C.

EPA, 1990a, "Thermal Chromatography/Mass Spectrometry for Screening Semivolatile Organic Compounds," in *Test Methods for Evaluating Solid Waste* (SW-846), U.S. Environmental Protection Agency.

EPA, 1990b, "400 CFR, Part 300: National Oil and Hazardous Substances Pollution Contingency Plan," *Federal Register*, 55(35):6154-6176, Feb. 21.

EPA, 1991, *Health Effects Assessment Summary Tables (Annual)*, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C., OERR 9200.6-303 (91-1).

EPA, 1992, *Health Effects Assessment Summary Tables (Annual)*, Office of Emergency and Remedial Response, U.S. Environmental Protection Agency, Washington, D.C., OERR 9200.6-303 (92-1).

Grelinger, M.A., et al., 1988, *Gap Filling PM_{10} Emission Factors for Selected Open Dust Sources,* prepared by Midwest Research Institute, Kansas City, Mo., for the Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, N.C. under Contract 68-02-3891, EPA-450/4-88-003 (PB88-196225).

ICF Clement Associates, 1988, *Comparative Potency Approach for Estimating the Cancer Risk Associated with Exposure to Mixtures of Polycyclic Aromatic Hydrocarbons*, Interim Final Report, prepared for EPA under Contract No. 67-08-4403, Fairfax, Virginia.

Lyman, W.J., et al., 1990, *Handbook of Chemical Property Estimation Methods: Environmental Behavior of Organic Compounds*, American Chemical Society, Washington, D.C.

Nemeth, G., 1989, *RCRA Facility Assessment Report - Edgewood Area - Aberdeen Proving Ground, Maryland*, prepared by Waste Disposal Engineering Division, U.S. Army Environmental Hygiene Agency, Aberdeen Proving Ground, Md.

Oak Ridge National Laboratory: see ORNL.

ORNL, 1989, *The Installation Restoration Program Toxicology Guide, Volume 2, Biomedical and Environmental Information Analysis,* prepared by the Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, for the Aerospace Medical Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, under Department of Energy Interagency Agreement No. 1891-A076-A1.

ORNL, 1990, *The Installation Restoration Program Toxicology Guide, Volume 5, Biomedical and Environmental Information Analysis,* prepared by the Health and Safety Research Division, Oak Ridge National Laboratory, Oak Ridge, Tennessee, for the Aerospace Medical Division, Air Force Systems Command, Wright-Patterson Air Force Base, Ohio, under Department of Energy Interagency Agreement No. 1891-A076-A1, November.

Shacklette, H.T. and J.G. Boerngen, 1984, *Element Concentrations in Soils and Other Surficial Materials of the Conterminous United States*, U.S. Geological Survey Professional Paper 1270, U.S. Government Printing Office.

Shipman, Dennis, 1991, Private Communication, SO_2/Particulate Matter Programs Branch, Air Quality Management Division, Office of Air Quality Planning and Standards, U.S. Environmental Protection Agency, Research Triangle Park, N.C.

U.S. Department of Labor, 1990, 29 CFR, Ch. 17, Part 1910, *Occupational Safety and Health Standards, Subpart Z, Toxic and Hazardous Substances*, Washington, D.C.

U.S. Environmental Protection Agency: see EPA.

Watson, W., et al., 1989, "On-Site X-Ray Fluorescence Spectrometry Mapping of Metal Contaminants in Soils at Superfund Sites," *American Laboratory*, v. 21, 5 pp.

Yang, J.J., et al., 1989, "Percutaneous Absorption of Benzo(a)pyrene from Soils with and without Petroleum Crude Contamination," in *Petroleum Contaminated Soils*, Vol. 2 (E.J. Calabrese and P.T. Kostecki, editors), Lewis Publishers, Inc., Chelsea, Mich.

APPENDIX D:

GENERIC STATEMENT OF WORK FOR UXO AVOIDANCE*

* From Ordnance and Explosives Center of Expertise (OE-CX), Interim Guidance (Draft ETL 385-1-2), August 1996.

APPENDIX D:

GENERIC STATEMENT OF WORK (FOR UXO AVOIDANCE)

Instructions: Bracketed words, phrases or sentences are options for the preparer to select from. Options not selected or applicable shall be removed from the text prior to inclusion of the Section into the RFP. In addition, all notes and instructions to preparer shall be removed from the text prior to inclusion of this Appendix into the RFP.

NOTE TO PREPARER: The point of contact to report UXO or RCWM is dependent on the site specific conditions and arrangements. Work on an active installation will normally require reporting UXO to the Range Control Officer, Facility Engineer or Post Headquarters. Work on Formerly Used Defense Sites (FUDS) will require prior coordination to determine the point of contact. POC on a FUDS will usually be the local or state law enforcement agency. If the FUDS is a non-DOD Government installation, the installation manager can call the local EOD Unit. Once the local POC has been contacted, U.S. Army Engineering and Support Center, Huntsville must be contacted also.

A-1. General. The Contractor shall provide a two person Unexploded Ordnance (UXO) team to provide on-site UXO support during all sampling activities. This includes soil sampling and the drilling of monitoring wells. The UXO team will not destroy any UXO encountered. The UXO team will report all UXO to [Range Control Officer] [local CE representative] [other appropriate office], designated as the point of contact, and the Contracting Officer who will in turn notify the Huntsville Division, Corps of Engineers. [The local POC will contact the local law enforcement agency and request that they contact the local EOD unit for disposition of the ordnance.]

A-2. Definitions.

a. Ordnance and Explosive (OE). Bombs and warheads, guided and ballistic missiles, artillery, rocket and mortar ammunition, small arms ammunition, anti-personnel and anti-tank mines, demolition charges, pyrotechnics, grenades, containerized and uncontainerized explosives and propellants, military chemical agents and all similar and related items or components, explosive in nature or otherwise designed to cause damage to personnel or material. Soils with explosive constituents are considered to be OE if the concentration is sufficient to be reactive and present an imminent safety hazard.

b. Unexploded Ordnance (UXO). An item of explosive ordnance that has failed to function as designed or has been abandoned, discarded or improperly disposed of and is still capable of functioning and causing damage to personnel or material.

c. Inert Ordnance. An item that has functioned as designed, leaving an inert carrier. An item manufactured to serve a specific training purpose. Fragments from UXO.

d. Explosive Ordnance Disposal (EOD) Personnel. Active duty military EOD personnel.

e. UXO Personnel. Former EOD personnel employed by a contractor.

f. Recovered Chemical Warfare Materiel (RCWM). RCWM is defined as chemical agent material and/or associated equipment and surrounding contaminated media discovered either by chance or during deliberate real estate recovery/restoration operations that was previously disposed of as waste. RCWM is classified as hazardous waste by the Army and not within the scope of the Army Chemical Surety Program.

g. Chemical Event. Discovery of an actual or suspected chemical agent or container that may require emergency transportation or disposal.

A-3. UXO Team Composition and Qualifications. UXO Teams shall consist of two members with the following qualifications:

a. UXO Team Leader. This is the individual who has the direct responsibility and is the technical lead for all UXO operations on the site. This individual shall have documented experience in supervising range clearance operations and supervising personnel. This individual shall be a graduate of the U.S. Naval Explosive Ordnance School at Indian Head, Maryland and have at least 10 years of combined military active duty EOD and contractor UXO experience. Three years active duty military EOD experience is nonwaiverable for this position.

b. UXO Team Member. Be a graduate of the U.S. Naval Explosive Ordnance School at Indian Head, Maryland. Have at least 3 years of active duty EOD experience. May be a UXO assistant with five years combined active duty military EOD and contractor UXO experience.

A-4. Responsibilities and Authority. The UXO Team will provide the explosive ordnance recognition, location and safety function for the prime contractor. The UXO team leader has the final authority for on site personnel regarding all matters concerning UXO.

A-5. Work and Safety Plans. The UXO team will assist in the development of the Contractor's site safety and health plan and the work plan. The UXO team leader will conduct UXO safety briefings for all site personnel and visitors.

A-6. Access Routes to Sampling Locations.

a. Prior to sampling or well drilling crews going on site, the UXO team shall conduct a reconnaissance of the sampling area. The reconnaissance shall include locating a clear path for the sampling crews, vehicles and equipment to approach the site. The approach path, at a minimum will be twice the width of the widest vehicle. The Contractor will clearly mark all boundaries of the cleared approach path to prevent personnel from straying into uncleared areas. No personnel shall be allowed outside the cleared paths.

b. If UXO is encountered on the surface, divert the approach path around the UXO, clearly mark the area and report the UXO.

c. A magnetometer shall be used to insure there is no subsurface UXO within the approach path. If a magnetic anomaly is encountered, assume it to be a UXO and divert the path around the anomaly. Only UXO personnel shall handle UXO and operate the magnetometer.

A-7. Soil Sampling and Well Drilling Sites.

a. The UXO team shall locate magnetic anomaly free areas for soil samples and well drilling. If a preselected area indicates magnetic anomalies, a new sampling/drilling site will be chosen.

b. The Contractor will clearly mark the boundaries of the cleared soil sampling or well site. Personnel will not go outside the cleared area. As a minimum, the cleared area will be a square, with a side dimension equal to twice the length of the largest vehicle or piece of equipment to be brought on site.

c. Prior to drilling equipment being moved to the proposed well location, the UXO team shall locate a magnetic anomaly free site. This shall be accomplished using a magnetometer with downhole monitoring capabilities. The UXO team shall start the borehole with a hand held or portable auger. At not more than a two foot depth, the auger will be withdrawn and the magnetometer will be lowered into the borehole. This procedure will be used to insure that smaller items of UXO, undetectable from the surface can be detected. If no magnetic anomalies are found, the procedure will be repeated at two foot intervals to the maximum depth of the auger, but not less than 6 feet. If the proposed well site is still free of magnetic anomalies, the drilling equipment may be brought on site and utilized. Borehole monitoring with the magnetometer shall continue at two foot intervals, until the site geologist determines that virgin soil is reached.

A-8. Recovered Chemical Warfare Materials (RCWM).

a. If suspected RCWM is located at any time, all work will cease immediately. Site workers will withdraw along cleared paths from the area containing the RCWM. The Contractor will clearly mark the area containing the RCWM, and report the chemical event as specified in Paragraph A-1. The contractor shall standby in an upwind location until relieved by a government representative. The report of discovery of suspected RCWM will be made within one hour of the discovery. The POC will make the final determination as to the actual presence of RCWM.

b. If the POC confirms the presence of RCWM, the Government person in charge will report the chemical event to the appropriate agencies.

c. When contacting the POC about suspect RCWM, the Contractor will provide the information listed in Figure D.1. Contact with the POC will not be delayed due to lack of information. The suspected RCWM report will follow the format in Figure D.1.

Figure A-1. Sample Suspected RCWM Data Report	
ii. Date and local time of event	
ii. Location	
iii. Quantity and type of munition(s) or container(s) and chemical agents involved.	
iv. Description of what has happened.	
v. Description of property damage.	
vi. Personnel casualties and/or injuries	
vii. Whether medical services or facilities were required.	
viii. Assistance required.	
ix. Any other pertinent information.	

APPENDIX E:

LITERATURE REVIEW

APPENDIX E:

LITERATURE REVIEW

As part of the task for updating this *Procedures Manual for the Environmental Survey and Clearance of a Construction Site,* we conducted a literature review. We used World Wide Web-based information technologies and searched the collection of the U.S. Army Environmental Center's Technical Information Center (TIC).

We searched the following Internet locations for topics such as unexploded ordnance (UXO), construction site clearance, and site assessment:

U.S. Navy home page	http://www.navy.mil
U.S. Air Force home page	http://www.af.mil
U.S. Marine Corps home page	http://www.hqmc.mil

However, the sites did not contain or refer to any helpful information on construction site evaluation and clearance.

In contrast, the U.S. Army home page (http://www.army.mil); the Web site of the U.S. Army Engineering and Support Center, Ordnance and Explosives Center of Expertise (OE-CX), Huntsville, Alabama; the DENIX Web site; and the Defense Technical Information Service Web site did contain and refer to information sources that we looked at while preparing the manual.

CHAPTER 1

For Chapter 1, a number of Army regulations and an Army guidance manual were useful in establishing the general requirements for a construction site survey. The most recent version of Army Regulation 200-1, "Environmental Protection and Enhancement" (effective date March 1997), was used as a starting point for the literature review. This regulation discusses construction site selection surveys (in Chapter 15), other environmental programs, and requirements. Chapter 15 also discusses construction site surveys in the context of property transactions (acquisitions, sales, or lease). Army Regulation 415-15, "Army Military Construction Program Development and Execution," requires the establishment of screening procedures for preconstruction investigation and clearance. Construction site environmental surveys are also discussed in the *U.S. Army Environmental Restoration Programs Guidance Manual* (April 1998), with regard to how construction projects relate to the Installation Restoration Program.

In addition, the TIC collection yielded three documents that provided information about current construction site clearance practices used by the U.S. Army. Activities described in

Environmental Baseline Study and Construction Site Environmental Survey and Clearance, Waikakalaua Family Housing Project Site, District of Wahiawa, Oahu, Hawaii, prepared by Woodward-Clyde Consultants, Honolulu, Hawaii, for the U.S. Army Engineer Division, Fort Shafter, Hawaii (April 1990) followed the recommendations in the draft *Construction Site Clearance Manual (TM 5-8XX-X),* by the U.S. Department of the Army. The Waikakalaua Family Housing Project involved the performance of an environmental geophysical survey and a soil gas survey, the collection of environmental media samples for analyses, a quality control/quality assurance (QA/QC) review of the data, and a risk assessment.

We also found two construction site clearance documents prepared by the U.S. Army Center for Health Promotion and Preventive Medicine (CHPPM) in the TIC library:

- Hazardous and Medical Waste Study No. 37-26-3684-95, *Quick Response Construction Site Clearance, Fort Campbell, Kentucky* (April 25–28, 1995).

- Hazardous Waste Study No. 37-26-3711-95, *Construction Site Clearance, Army Travel Camp, Meade Field, Fort Sam Houston, Texas* (May 1–5, 1995).

The two CHPPM documents described a different approach than that discussed in the previous three documents. CHPPM did not use either geophysical or soil gas sampling as part of the construction site clearance process. Rather, it relied solely on the collection and analyses of soil samples and the comparison of analytical results to either risk-based screening levels or to values obtained from a site-specific risk assessment.

CHAPTER 2

We derived the content of Chapter 2 from a number of sources. The *Federal Register* (60 FR 56468, 56467 [1995]) provided useful information about U.S. Department of Defense (DOD) statutes, directives, and regulations requiring DOD to address risks to human health and the environment from military munitions. A U.S. Environmental Protection Agency (EPA) document, *Guidance for Performing Preliminary Assessment under CERCLA, 9345.0-01A* (1991), was useful in helping us craft the method for reviewing archival information and visually inspecting prospective construction sites. In addition, because of the similarities between a Superfund preliminary assessment/site inspection and a Resource Conservation and Recovery Act (RCRA) facility assessment, the EPA document, *RCRA Facility Assessment Guidance,* OSWER Directive No. 9502.00-05 (October 1986), also proved useful in developing preconstruction assessment procedures.

CHAPTER 3

The technical approach discussed in Chapter 3 has its origin in a standard guide developed by the American Society of Testing and Materials (ASTM). The *Standard Guide for Risk-Based Corrective Action [RBCA] Applied at Petroleum Release Sites* (S 1739-95) recognizes that release sites vary significantly in terms of complexity, physical and chemical characteristics, and risks posed to human health and the environment. To account for this diversity, the RBCA approach uses a tiered method to tailor investigation activities to site-specific conditions. For example, the RBCA approach provides for using "look-up" tables in lieu of performing burdensome site-specific risk assessments to appraise risks. The concept of the look-up table was incorporated into this document, allowing the evaluator to compare analytical results with concentrations in generic risk-based concentration tables to evaluate whether a given site represents a threat to construction workers.

The technical approach in Chapter 3 is also based on the data quality objective (DQO) process discussed in the *U.S. Army Environmental Restoration Programs Guidance Manual* (April 1998) and the EPA's *Guidance for the Data Quality Objectives Process,* EPA QA/G-4, EPA/600/R-96/055 (September 1994). The EPA document was particularly useful in providing a generic framework for the development of sampling and analysis plans. We gathered information for data collection and sample analysis methods from two Internet sites: Federal Remediation Technologies Roundtable, Field Sampling and Analysis Technologies Matrix home page, at http://www.FRTR.gov/site, and the EPA's Environmental Monitoring Methods Index, at http://www.epa.gov/epahome/index.

We took the requirements for a sampling and analysis health and safety plan directly from 29 CFR 1910.120, "Hazardous Waste Operations and Emergency Response Standard."

CHAPTER 5

We primarily used Army-related documents as sources of information on UXO and chemical warfare agent (CWA) avoidance, clearance, and detection. *Report of the Defense Science Board Task Force on Unexploded Ordnance (UXO) Clearance, Active Range UXO Clearance, and Explosive Ordnance Disposal (EOD) Programs,* from the Office of the Under Secretary of Defense for Acquisition and Technology (April 1998), proved to be a useful primer on UXO detection, avoidance, and remediation. One Internet site, managed by the U.S. Army Engineering and Support Center, Ordnance and Explosive Center of Expertise, Huntsville, Alabama, at http://www.hnd.usace.army.mil/oew/, contains a wealth of information on UXO and explosives. We referred to four documents listed on this Web site during the preparation of this manual:

- *Procedures for Conducting Preliminary Assessments at Potential Ordnance Response Sites,* Interim Guidance, Draft ETL 1110-1-165, U.S. Army

Engineering and Support Center, Ordnance and Explosives Center of Expertise (OE-CX), Huntsville, Alabama (April 1995).

- *Quality Management Plan for Ordnance and Explosive Projects (OE),* Draft, U.S. Army Corps of Engineers, Engineering and Support Center, Ordnance and Explosives Center of Expertise (OE-CX), Huntsville, Alabama (February 24, 1995).

- *Ordnance and Explosives Quality Manual (OEQM), Level 1 — Policy,* U.S. Army Corps of Engineers, Engineering and Support Center, Ordnance and Explosives Center of Expertise (OE-CX), Huntsville, Alabama (March 1997).

- *Minimum Investigation Amounts for Ordnance Sites,* A. Dohrman, U.S. Army Corps of Engineers, Engineering and Support Center, Ordnance and Explosives Center of Expertise (OE-CX), Huntsville, Alabama (July 1997).

In addition, the TIC library provided us with a number of useful reports or work plans that discuss standard operating procedures for conducting ordnance surveys:

- *Fort George G. Meade Ordnance Survey (1,400-Acre Parcel),* Final Report, U.S. Army Environmental Center, Aberdeen Proving Ground, Maryland (June 1994).

- *Work Plan for Unexploded Ordnance (UXO) Surface Clearance and Sampling Project, Fort Wingate Depot Activity (FWDA), New Mexico,* prepared by UXB International, Inc., Chantilly, Va., for U.S. Army Corps of Engineers, Huntsville, Alabama (January 1995).

- *Final Removal Report, Volume 1, Ordnance and Explosives (OE) Interim Removal and Sampling Action, Fort Sheridan, Illinois,* prepared by Human Factors Applications, Inc., for U.S. Army Corps of Engineers, Engineering and Support Center, Huntsville, Alabama (March 27, 1997).

Chapter 5 includes a brief discussion of CWAs and other chemical agents and compounds significant to the military. The primary source we relied on for information on these subjects was *Technical Aspects of Military Significant Chemical Agents/Compounds,* Army Field Manual FM 3-9, Marine Corps Warfighting Publication (MCWP) 3-3, Air Force Manual (AFM) 355-7, AFJPAM 32-4008, initial draft, U.S. Department of the Army, the Air Force, and the Marine Corps (1996).

CHAPTER 6

We used Internet sites and conventional library sources to prepare Chapter 6. We referred to a number of QA documents, including these:

- National QA guidance and requirements documents,
- Region 10 QA documents,
- Superfund Contract Laboratory (CLP) Program data validation guidelines, and
- Other Superfund and RCRA documents.

After reviewing these documents, we determined that something less than an exhaustive QA/QC review (vis a vis the Superfund CLP) would be appropriate for a construction site clearance effort. Accordingly, we used the EPA Region 9 document, *RCRA Corrective Action Program, Data Review Guidance Manual* (July 1995; updated June 1996) as a source of information on how to conduct the desk-top data review.

CHAPTER 7

Some of the sources for the chapter on risk assessment procedures have already been mentioned (such as the ASTM RBCA standard and the CHPPM documents). They describe how to conduct risk assessments by comparing analytical results to the values in standard look-up tables. For site-specific risk assessment procedures, we used a report that documents construction site clearance activities at the Edgewood Arsenal in Maryland. Titled *Soil Contaminant Levels and Associated Risks to Construction Workers at the Construction Site for Work Request CEQ 37CE, Edgewood Area, Aberdeen Proving Ground, Maryland,* by L.L. Reed, S.W. Meyers, D.H. Rosenblatt, and L.T. Shepard of Argonne National Laboratory (June 1997), it describes how to conduct sampling and analyses and perform a site-specific risk assessment.

CHAPTER 8

The primary sources for Chapter 8 were the two CHPPM documents cited in the description of the literature review for Chapter 1.