



Designation: D 5730 – 02

Standard Guide for Site Characterization for Environmental Purposes With Emphasis on Soil, Rock, the Vadose Zone and Ground Water¹

This standard is issued under the fixed designation D 5730; the number immediately following the designation indicates the year of original adoption or, in the case of revision, the year of last revision. A number in parentheses indicates the year of last reapproval. A superscript epsilon (ε) indicates an editorial change since the last revision or reapproval.

INTRODUCTION

This guide covers the selection of the various ASTM Standards that are available for the investigation of soil, rock, the vadose zone, ground water, and other media where the investigations have an environmental purpose.² It is intended to improve consistency of practice and to encourage rational planning of a site characterization program by providing a checklist to assist in the design of an environmental reconnaissance/investigation plan. The subsurface conditions at a particular site are usually the result of a combination of natural geologic, topographic, hydrologic, and climatic factors, and of historical modifications both natural and manmade. An adequate and internally consistent site characterization program will allow evaluation of the results of these influences. Site characterization for engineering, design, and construction purposes are addressed in a separate guide, Guide D 420.

The understanding of environmental processes occurring in soil and rock systems depends on adequate characterization of physical, chemical, and biological properties of soil and rock. Processes of interest may include, but are not limited to, surface and subsurface hydrology, contaminant mobilization, distribution, fate and transport; chemical and biological degradation of wastes; and geomorphological/ecological processes. Although this guide focusses primarily on characterization of soil and rock, it is understood that climatic and biotic factors may also be important in understanding environmental processes in soil and rock systems.

1. Scope

1.1 This guide covers a general approach to planning field investigations that is useful for any type of environmental investigation with a primary focus on the subsurface and major factors affecting the surface and subsurface environment. Generally, such investigations should identify and locate, both horizontally and vertically, significant soil and rock masses and

ground water conditions present within a given site area and establish the characteristics of the subsurface materials by sampling or in situ testing, or both. The extent of characterization and specific methods used will be determined by the environmental objectives and data quality requirements of the investigation. This guide focuses on field methods for determining site characteristics and collection of samples for further physical and chemical characterization. This guide does not address special considerations required for characterization of karst and fractured rock terrane. In such hydrogeologic settings refer to Quinlan and Guide D 5717, (1).

1.2 This guide refers to ASTM standard methods by which soil, rock, vadose zone, and ground water conditions may be determined. Laboratory testing of soil, rock, and ground-water samples is specified by other ASTM standards which are not specifically discussed in this guide. Laboratory methods for measurement of physical properties relevant to environmental investigations are included in Appendix X1.

1.3 The values stated in SI units are to be regarded as the standard.

¹ This guide is under the jurisdiction of ASTM Committee D18 on Soil and Rock and is the direct responsibility of Subcommittee D18.01 on Surface and Subsurface Characterization.

Current edition approved July 10, 2002. Published October 2002. Originally published as D 5730 – 95. Last previous edition D 5730 – 98.

² This guide is under the jurisdiction of Subcommittee D18.01 (Surface and Subsurface Characterization) of the Committee on Soil and Rock, and as such has a primary focus on subsurface characterization, including soil, rock, and fluids contained therein (including liquid and gaseous components), and subsurface biota. Surface hydrology, meteorology, air quality, geomorphic processes, biota, and waste materials (when present at a site) are to a greater or lesser extent linked to environmental processes in soil and rock systems. Consequently other ASTM methods of particular relevance to environmental site investigations are identified in this guide, but are addressed in less detail.

1.4 *This standard does not purport to address all of the safety concerns, if any, associated with its use. It is the responsibility of the user of this standard to establish appropriate safety and health practices and determine the applicability of regulatory limitations prior to use.*

1.5 *This guide offers an organized collection of information or a series of options and does not recommend a specific course of action. This document cannot replace education or experience and should be used in conjunction with professional judgment. Not all aspects of this guide may be applicable in all circumstances. This ASTM standard is not intended to represent or replace the standard of care by which the adequacy of a given professional service must be judged, nor should this document be applied without consideration of a project's many unique aspects. The word "Standard" in the title of this document means only that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 The pertinent ASTM guides for selection of field investigation methods are listed at appropriate points in the sections that follow, and a comprehensive list of guides, standards, methods, practices, and terminology is contained in Appendix X1. Table X1.1 and Table X1.2 provide an index of field and laboratory standards listed in Appendix X1.

2.2 ASTM Standards:

- C 998 Practice for Sampling Surface Soil for Radionuclides³
- D 420 Guide to Site Characterization for Engineering, Design, and Construction Purposes⁴
- D 422 Test Method for Particle-Size Analysis of Soils⁴
- D 653 Terminology Relating to Soil, Rock, and Contained Fluids⁴
- D 1140 Test Method for Amount of Material in Soils Finer than the No. 200 (75- μ m) Sieve⁴
- D 1452 Practice for Soil Investigation and Sampling by Auger Borings⁴
- D 1586 Test Method for Penetration Test and Split-Barrel Sampling of Soils⁴
- D 1587 Practice for Thin-Walled Tube Geotechnical Sampling of Soils⁴
- D 2113 Practice for Diamond Core Drilling for Site Investigation⁴
- D 2434 Test Method for Permeability of Granular Soils (Constant Head)⁴
- D 2487 Classification of Soils for Engineering Purposes (Unified Soil Classification System)⁴
- D 2488 Practice for Description and Identification of Soils (Visual-Manual Procedure)⁴
- D 2922 Test Methods for Density of Soil and Soil-Aggregate In Place by Nuclear Methods (Shallow Depth)⁴
- D 3404 Guide for Measuring Matric Potential in the Vadose Zone Using Tensiometers⁴
- D 3441 Test Method for Deep, Quasi-Static, Cone and Friction-Cone Penetration Tests of Soil⁴

- D 3550 Practice for Ring-Lined Barrel Sampling of Soils⁴
- D 3584 Practice for Indexing Papers and Reports on Soil and Rock for Engineering Purposes⁴
- D 4043 Guide for Selection of Aquifer-Test Method in Determining of Hydraulic Properties by Well Techniques⁴
- D 4044 Test Method (Field Procedure) for Instantaneous Change in Head (Slug Tests) for Determining Hydraulic Properties of Aquifers⁴
- D 4050 Test Method (Field Procedure) for Withdrawal and Injection Well Tests for Determining Hydraulic Properties of Aquifer Systems⁴
- D 4104 Test Method (Analytical Procedure) for Determining Transmissivity of Nonleaky Confined Aquifers by Overdamped Well Response to Instantaneous Change in Head (Slug Test)⁴
- D 4105 Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Modified Theis Nonequilibrium Method⁴
- D 4106 Test Method (Analytical Procedure) for Determining Transmissivity and Storage Coefficient of Nonleaky Confined Aquifers by the Theis Nonequilibrium Method⁴
- D 4127 Terminology Used with Ion-Selective Electrodes⁵
- D 4210 Practice for Interlaboratory Quality Control Procedures and a Discussion on Reporting Low Level Data⁵
- D 4220 Practice for Preserving and Transporting Soil Samples⁴
- D 4448 Guide for Sampling Groundwater Monitoring Wells⁶
- D 4547 Practice for Sampling Waste and Soils for Volatile Organics⁶
- D 4630 Test Method for Determining Transmissivity and Storativity of Low Permeability Rocks by In Situ Measurements Using the Constant Head Injection Test⁴
- D 4631 Test Method for Determining Transmissivity and Storativity of Low Permeability Rocks by In Situ Measurements Using the Pressure Pulse Technique⁴
- D 4687 Guide for General Planning of Waste Sampling⁶
- D 4696 Guide for Pore-Liquid Sampling from the Vadose Zone⁴
- D 4700 Guide for Soil Sampling from the Vadose Zone⁴
- D 4750 Test Method for Determining Subsurface Liquid Levels in a Borehole or Monitoring Well (Observation Well)⁴
- D 5079 Practices for Preserving and Transporting Rock Core Samples⁷
- D 5084 Test Method of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter⁷
- D 5092 Practice for Design and Installation of Ground Water Monitoring Wells in Aquifers⁷
- D 5093 Test Method for Field Measurement of Infiltration Rate Using a Double-Ring Infiltrometer With a Sealed-Inner Ring⁷

³ Annual Book of ASTM Standards, Vol 12.01.

⁴ Annual Book of ASTM Standards, Vol 04.08.

⁵ Annual Book of ASTM Standards, Vol 11.01.

⁶ Annual Book of ASTM Standards, Vol 11.04.

⁷ Annual Book of ASTM Standards, Vol 04.09.



- D 5195 Test Method for Density of Soil and Rock In-Place at Depths Below the Surface by Nuclear Methods⁷
- D 5254 Practice for Minimum Set of Data Elements to Identify a Ground-Water Site⁷
- D 5269 Test Method for Determining Transmissivity of Nonleaky Confined Aquifers by the Theis Recovery Method⁷
- D 5270 Test Method for Determining Transmissivity and Storage Coefficient of Bounded, Nonleaky, Confined Aquifers⁷
- D 5314 Guide for Soil Gas Monitoring in the Vadose Zone⁷
- D 5408 Guide for Set of Data Elements to Describe a Ground-Water Site; Part 1—Additional Identification Descriptors⁷
- D 5409 Guide for Set of Data Elements to Describe a Ground-Water Site; Part 2—Physical Descriptors⁷
- D 5410 Guide for Set of Data Elements to Describe a Ground-Water Site; Part 3—Usage Descriptors⁷
- D 5447 Guide for Application of a Ground-Water Flow Model to a Site-Specific Problem⁷
- D 5451 Practice for Sampling Using a Trier Sampler⁶
- D 5717 Guide for the Design of Ground-Water Monitoring Systems In Karst and Fractured-Rock Aquifers⁴
- E 177 Practice for Use of the Terms Precision and Bias in ASTM Test Methods⁸
- E 380 Practice for Use of the International System of Units (SI) (The Modernized Metric System)⁸
- E 1527 Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process⁶
- G 57 Test Method for Field Measurement of Soil Resistivity Using the Wenner Four-Electrode Method⁹

NOTE 1—*Non-ASTM References*: Appendix X2 identifies major non-ASTM references that focus on field methods for environmental site characterization. Other guidance documents covering procedures for environmental investigations with specific objectives or in particular geographic settings may be available from federal, state, and other agencies or organizations. The appropriate agency or organization should be contacted to determine the availability and most current edition of such documents.

3. Terminology

3.1 Definitions: ¹⁰

- 3.1.1 *site*, *n*—a place or location designated for a specific use, function, or study.
- 3.1.2 *site*, *v*—to determine a place or location for a specific use, function, or study.
- 3.1.3 *characterization*, *n*—the delineation or representation of the essential features or qualities existing at a site.
- 3.1.4 *characterize*, *v*—the process of delineation or representation of the essential features or qualities existing at a site.

3.1.5 *conceptual site model*, *n*—for the purposes of this guide, a testable interpretation or working description of the relevant physical, chemical, and biological characteristics of a site.¹¹

3.1.6 *environment*, *n*—the aggregate of conditions, influences, and circumstances that affect the existence or development of properties intrinsic to a site.

3.1.7 *environmental*, *adj*—having to do with the environment.

3.1.8 *environmental site characterization*, *n*—the delineation or representation of the essential features or qualities, including the conditions, influences, and circumstances, existing at a place or location designated for a specific use, function, or study.¹²

3.1.9 *environmental audit*, *n*—the investigation process to determine if the operations of an existing facility are in compliance with applicable environmental laws and regulations.

3.1.10 *environmental site assessment (ESA)*, *n*—the process by which a person or entity seeks to determine if a particular parcel of real property (including improvements) is subject to recognized environmental conditions.¹³

3.2 In addition to Terminology D 653, Appendix X3 identifies major references from a range of disciplines that can be used as sources for definitions of terms that are related to environmental site characterization.

4. Significance and Use

4.1 This guide provides a general approach to environmental site characterization. Environmental site characterization provides information for a wide variety of uses including:

4.1.1 Determination of ambient background or baseline conditions, including, but not limited to, geochemistry, hydrogeology, microbiology, mineralogy, and water quality.

4.1.2 Assessment of site suitability for a future use or a use which may be compromised by site characteristics, such as flooding, seismic activity, and landslides (mass wasting).

4.1.3 Protection of site quality from the detrimental effects of human activities and natural processes, or minimization of

¹¹ The meaning of conceptual site model may have more restricted or specific meanings depending on the objective or use of the model. For example, ground water flow modeling focuses on the physical characteristics as they relate to subsurface flow (see Guide D 5447), and a conceptual site model for the purpose of risk assessment will focus on contaminant sources, pathways, and receptors to exposure.

¹² Environmental audits and environmental site assessments as defined below are examples of environmental site characterization with specific objectives.

¹³ This definition is taken from Practice E 1527. Other definitions of environmental site assessment may apply in other contexts. For example, EPA's Site Assessment Branch, Hazardous Site Evaluation Division in the Office of Emergency and Remedial Response defines site assessment as the decision process for identifying the most seriously contaminated uncontrolled hazardous waste sites that will receive funding for long-term remediation. Practice E 1527 defines *recognized environmental conditions* as "the presence or likely presence of any hazardous substances or petroleum products on a property under conditions that indicate an existing release, a past release, or a material threat of a release of any hazardous substances or petroleum products into structures on the property or into the ground, ground water, or surface water of the property." In other environmental site investigations, nonhazardous substances (because of their physical condition, smell, or other aesthetic properties) or substances that have hazardous characteristics but do not meet a regulatory definition of hazardous may be the focus of the investigation.

⁸ *Annual Book of ASTM Standards*, Vol 14.02.

⁹ *Annual Book of ASTM Standards*, Vol 03.02.

¹⁰ The first seven definitions are ordered logically to illustrate construction of the definition for *environmental site characterization* rather than in alphabetical order.



adverse environmental impacts. Specific examples of uses of environmental site characterization for these purposes include: (1) delineation of ground-water or wellhead protection areas, (2) assessing the suitability of sites for disposal of industrial and residential liquid and solid wastes, (3) assessing soil suitability for land treatment of wastes, and (4) evaluating soil suitability for agricultural practices in order to minimize soil erosion and contamination from agricultural chemicals.

4.1.4 Assessment of the type, distribution, and extent of surface and subsurface contamination to determine compliance; risk to human health and the environment; and responsibility for remediation. Such assessments include: (1) sites involved in real estate transactions, (2) controlled and uncontrolled hazardous waste sites, (3) controlled and uncontrolled municipal solid waste, wastewater, and other nonhazardous waste disposal sites.

4.1.5 Assessment of surface and subsurface environmental processes that affect the fate, mobilization, and rate of transport of natural and anthropogenic chemicals in the subsurface.

4.1.6 Assessment of the type, distribution, and extent of natural and anthropogenic radioactive elements in the subsurface.

4.1.7 Assessment of the degree of risk that adverse subsurface site conditions not related to 4.1.4 and 4.1.5 pose to human health and safety or the natural ecosystem.

4.1.8 Selection and design of remediation systems for cleanup of subsurface contamination and of other reclamation or rehabilitation practices on disturbed land.

4.2 This guide is meant to be a flexible description of investigation requirements; methods defined by other ASTM Standards (Appendix X1) or non-ASTM techniques (Appendix X2) may be appropriate in some circumstances. The methods and amount of effort required for environmental site characterization will vary with site conditions and objectives of the investigation. This standard does not set mandatory guidelines and does not constitute a list of necessary steps or procedures for all investigations. In karst and fractured rock hydrogeologic settings, this guide should be used in conjunction with Guide D 5717.

5. Steps in Planning and Conducting Environmental Site Characterization

5.1 The following minimum elements, not necessarily in sequential order, are required for most environmental site investigations to determine project and site strategy:

5.1.1 Definition of objectives, site boundaries,¹⁴ and other information necessary for efficient project planning.¹⁵

5.1.2 Collection of available existing data and information about the site, pertinent to the objectives of the investigation.¹⁶

5.1.3 Development of one or more conceptual site models of the site from existing information. The objectives of the investigation will affect the type and complexity of site conceptualization.

5.1.4 Performance of a reconnaissance site investigation, that may include nondestructive geophysical methods, and relatively simple field sampling and characterization methods,¹⁷ to refine the conceptual model of the site.

5.1.5 Development of a detailed site investigation and sampling plan, that identifies methods to be used to collect and analyze required additional data, protocols for sampling and field measurements, and procedures to ensure quality assurance and quality control of site characterization data. Criteria

¹⁴ The boundaries of a site are defined using one or more of the following considerations: (1) land ownership, (2) current and past land use, (3) natural site characteristics (topography, soils, geology, hydrology, biota). Where site boundaries are initially defined by ownership, natural site characteristics should be evaluated to determine whether the scope of at least parts of the investigation should include areas that are offsite. For example, investigations of ground water contamination should include identification of any potential sources of contamination that are upgradient from a site.

¹⁵ This should include, but not necessarily be limited to: (1) definition of the technical and scientific approach to be used, (2) organization of a data management system, including both paper and electronic records, (3) identification of types of personnel and technical expertise, appropriate ASTM and other methods and field equipment required to meet the defined objective, (4) defining how spatial data will be recorded (see Section 7.1.3), (5) identification of applicable primary and secondary regulatory programs, and any required coordination with government agencies and other organizations, (6) development of health and safety plans, where appropriate, (7) identification of scheduling and budgetary constraints, (8) definition of data quality requirements for each stage of the investigation, (9) identification of deliverables at intermediate stages of the investigation and upon completion, (10) selection of performance measures to determine whether the objective has been achieved, and (11) definition of project decision statements.

¹⁶ A site visit prior to extensive collection of existing data should be made unless the limited scope of a project does not allow multiple visits. The advantage of such a visit is that it may prevent preconceived ideas derived from inaccurate existing information from influencing initial conceptual site model development.

¹⁷ When contaminated sites are being investigated, field chemical analytical methods can be valuable for identifying areas where more detailed investigations may be required, and for designing cost-effective detailed sampling and monitoring plans. Surface geophysical methods may be especially valuable for guiding placement of exploratory drillholes and placement of vadose zone and ground water monitoring installations. Any such field methods should be documented for quality assurance and quality control.



defining the quality of data that are collected is a requirement for most environmental site investigations.¹⁸

5.1.6 Collection of field samples and measurements in accordance with the site investigation and sampling plan.¹⁹

5.1.7 Analysis of field and laboratory data to further refine the conceptual model of the site and preparation of a report that fulfills the objectives of the investigation.

5.2 Environmental site characterization is an iterative process of continually refining a conceptual site model of a site as new information becomes available. The objective of the investigation and availability of funds to carry out the investigation will affect the final number of iterations that are possible. For example, a Phase I Environmental Site Assessment (Guide E 1527) for a real estate property transaction may require only a single site visit to evaluate whether any activities may have resulted in contamination of the site. Complex sites, however, may require multiple site visits to collect data in order to develop a satisfactory conceptual model of the site, especially if a human health and environmental risk assessment is required. The number of site visits may be reduced by on-site analysis of results and real-time adjustments to the site investigation plan (see Section 7).

5.2.1 Planning for environmental site investigations should recognize that regional and local differences in climate, biota, soils, geology, and hydrology will influence the selection of appropriate methods and procedures.

5.2.2 Urban settings create special challenges for planning environmental site investigations. Difficulties include busy streets, access to public and private property, especially occupied buildings and fenced areas, and determining predisturbance background environmental conditions. Consult with local agencies and private property owners for relevant information. Select methods and schedule activities accordingly.

6. Collection of Existing Data and Site Reconnaissance

6.1 Collect and review available technical data from the literature and historical records, and conduct interviews before

any field program is started. These include, but are not limited to, topographic maps, aerial photography, satellite imagery, geologic maps, statewide or county soil surveys, and mineral resource surveys covering the proposed project area. Reports of subsurface investigations of nearby or adjacent projects should be studied. If feasible, all existing data should be critically evaluated and independently confirmed.

6.1.1 The Natural Resource Conservation Service (formerly U.S. Soil Conservation Service) and the Agricultural Stabilization and Conservation Service (ASCS) are the primary sources of aerial photographs at the county level. The U.S. Geological Survey is the primary source for satellite imagery, and agencies other than SCS (USGS EROS Data Center).²⁰ Aerial photographs also may be available from the following federal agencies where lands under their jurisdiction are involved: Bureau of Land Management, Bureau of Reclamation, U.S. Army Corps of Engineers, U.S. Environmental Protection Agency Photo-Interpretation Center (EPIC), U.S. Forest Service, and U.S. Fish and Wildlife Service. State natural resource agencies and local/regional planning agencies also may be good sources of aerial photographs.²¹ Guide D 5518 provides additional information of how to obtain air photos.

6.1.2 The United States Geological Survey and the geological surveys of the various states are the principal sources of geologic maps, reports on mineral resources, ground water, and surface water.²³ Guidebooks prepared by professional associations, technical journals, and published conference and symposium proceedings may also be important sources of information.

6.1.3 United States Department of Agriculture Soil Conservation Service soil surveys, where available and of recent date, should enable the investigator to estimate the range in soil profile characteristics to depths of 1.5 or 2 m (5 or 6 ft) for each soil mapped.²⁴

6.1.4 Preliminary information on sites where commercial and industrial activity has occurred should include site history, such as type of activity, location of existing surface and subsurface building, and chemicals, manufactured, used, or stored at the site.²⁵

¹⁸ The level of data accuracy and precision needed to meet the intended use for the data must be determined and this constitutes the “data quality requirements” referred to in this guide. The term data quality requirements is similar to the term data quality objectives (DQOs) used to describe the quality determination process in the U.S. EPA RCRA/Superfund program, but does not necessarily include statistically based confidence levels for assessing false negative or false positive designations. For chemical characterization, data quality requirements may vary depending on the phase of the investigation. For example, relatively inexpensive field instrumentation such as colorimetric test kits, or portable gas chromatographs can be used to analyze a relatively large number of samples initially to identify areas with different levels of contamination. Data requirements at this level would specify that instrumentation used be capable only of detecting the presence of a contaminant at or above the regulatory level of concern. These results in turn would guide sampling of a moderate number of samples for more accurate field analytical methods or a mobile laboratory. Finally, a relatively small number of samples might be selected for analysis that would meet the rigorous data quality requirements of EPA’s contract laboratory program (CLP). This phased approach has the potential for significant cost and time savings as compared to the use of CLP laboratories for the analysis of all samples.

¹⁹ Prior to commencement of any intrusive exploration the site should be checked for underground utilities or other buried materials. Should evidence of potentially hazardous or otherwise contaminated materials or conditions be encountered in the course of the investigation, work should be interrupted until the circumstances have been evaluated and revised instructions issued before resumption.

²⁰ USGS EROS Data Center, Sioux Falls, SD 57198.

²¹ The following references on air-photo interpretation may be of value: Avery (2),²² Ciciarelli (3), Denny et al (4), Drury (5), Dury (6), Johnson and Gnaedinger (7), Lattman and Ray (8), Lueder (9), Miller and Miller (10), Ray (11), SCS (12), Strandberg (13), Wright (14).

²² The boldface numbers in parentheses refer to a list of references at the end of the text.

²³ Sun and Weeks (15) provide a comprehensive bibliography of the U.S. Geological Survey’s regional aquifer systems analysis program. Data from the RASA program are being synthesized and published in the Ground Water Atlas of the United States (16).

²⁴ Each soil type has a distinctive soil profile due to age, parent material, relief, climatic condition, and biological activity. Consideration of these factors can assist in evaluating the potential for movement of contaminants in the vadose zone and ground water based on differing soil characteristics. Boulding (17) and Cameron (18) provide guidance on interpretation of soil properties in relation to potential for contaminant transport. Changes in soil properties in adjacent areas often indicate changes in parent material or relief.

²⁵ Practice E 1527 and Practice E 1528 provide guidance on the types of information that should be collected and sources from which such information can be obtained.





6.2 Study the soil and rock in the vicinity of the proposed project in areas where descriptive data are limited by insufficient or inadequate geologic or soil maps. Take advantage of all exposures of the rock and soil to obtain the best understanding of them. Obtain information on both vertical and horizontal properties of the materials and their distribution. Make appropriate notes and, where appropriate, illustrate by sketches. The notes should include data outlined in 9.3.²⁶

6.3 Prepare and compile preliminary maps of the project area using aerial photography and topographic maps that show ground conditions. The scale of the map should be appropriate for the area being investigated. Aerial photographs and topographic maps at scales of 1:15 000 to 1:24 000 are available for most parts of the United States and are usually adequate as a basis for a preliminary map of sites covering tens to hundreds of acres. The distribution of the predominant soil and rock deposits likely to be observed during the investigation may be shown using data obtained from geologic maps, landform analysis, and limited ground reconnaissance. Experienced photointerpreters can deduce much subsurface data from a study of black-and-white, color, and color-infrared photographs because similar soil or rock conditions, tend to have similar patterns of appearance in regions of similar climate or vegetation.²⁷

6.4 Perform site reconnaissance. This provides an opportunity to check the accuracy of information compiled from existing sources, and to make site observations to assist in refining the conceptual model of the site. Site reconnaissance should be planned to identify the site characteristics needing further investigation.²⁸

7. Detailed Site Investigation

7.1 Review objectives of the investigation and develop a detailed site investigation plan. The detailed site investigation plan should clearly identify the types of data that are required to meet the objectives of the investigation.²⁹ A complete

environmental site investigation will usually encompass the following activities:³⁰

7.1.1 Review available information, both regional and local, on the geologic history (including seismic activity and other potential geologic hazards), rock, soil, ground water, surface water, and other significant environmental and anthropogenic features (for example, buried utilities) occurring at the proposed location and in the immediate vicinity of the site.

7.1.2 Interpret aerial photography and other remote sensing data.

7.1.3 Select appropriate methods for locational data collection coincident with field observations and sampling.³¹ Failure to accurately locate elevation and x-y coordinates of observation points and samples can severely compromise the accuracy of interpretations developed from the data. Where geographic information systems (GIS) are to be used for data management, analysis and visualization, locational accuracy should at a minimum satisfy the resolution of the system to be used.

7.1.4 Perform field reconnaissance for identification of surficial geologic and hydrologic conditions, mapping of stratigraphic or lithologic exposures and outcrops, mapping of vegetation and other significant ecological conditions, and examination of anthropogenic features at the site.

7.1.5 Perform on-site investigation of the surface and subsurface materials by geophysical surveys, borings, or test pits.

7.1.6 Obtain representative samples for chemical, biological, and physical analysis of soil, rock, and ground water. When required for the objectives of the investigation, these should be supplemented by samples suitable for the determination of in situ physical and chemical properties, such as hydraulic conductivity and flow-through sorption tests (see 11.2). Measurement of in situ properties requires collection of undisturbed samples (see definitions in Terminology D 653). Where present, wastes and sediments from surface water bodies should also be sampled.

7.1.7 Perform field identification of soil, sediments, and rock with particular references to physical and chemical properties, such as, but not limited to, color, odor, texture (grain-size distribution), mineralogy, zone of increased or reduced porosity and permeability, depth of occurrence, and the types and locations of structural discontinuities.

²⁶ The following major references may be useful for field geologic and hydrogeologic investigations: Bishop (19), Brassington (20), Bureau of Reclamation (21, 22), Compton (23, 24), Dutro, et al (25), Erdélyi and Gálfi (26), Fetter (27), Lahee (28), LeRoy, et al (29), Low (30), Rahn (31), Tearpocke and Bischke (32). Guides for field description of rocks include: Fry (33), Thorpe and Brown (34), and Tucker (35).

²⁷ This preliminary map may be expanded into a detailed site map by locating all test holes, pits, and sampling stations and by revising boundaries as determined from the detailed subsurface survey. Geographic information systems (GIS) should be considered for visualization, map preparation, data manipulation, and analysis.

²⁸ Exploratory sampling of soil solids, soil gas, or ground water using temporary in situ samplers may provide useful information for design of the sampling plan in the detailed site investigation plan. Surface geophysical methods may also be useful at this stage of the investigation.

²⁹ Considerations for identifying data requirements include: (1) data required to comply with applicable federal, state, or local regulatory programs, (2) data required as inputs to computer models expected to be used, (3) data required for selection and design of implementation measures (that is, protective measures at controlled waste disposal sites, remediation options at contaminated sites).

³⁰ Examples of investigations that may not require all of the activities in this section include environmental site assessments for real estate property transactions that do not identify recognized environmental conditions using Practice E 1527 Phase 1 Assessment Process or Practice E 1528 Transaction Screen Process, and Environmental Audits to assess presence or degree of lead or asbestos contamination in a building.

³¹ The U.S. EPA (36) requires latitude/longitude determination for all agency-sponsored data collection and activities that define or describe environmental characteristics about a site. The U.S. EPA (37) provides guidance to selecting latitude/longitude determination methods. Global positioning systems (GPS) are used for locating field observation points when accuracy on the order of tens of meters is sufficient, which is sufficient for many GIS applications (U.S. EPA, (38)). Other coordinate systems (such as x-y coordinates referenced to a known datum, State Plane, UTM) can also be used if more convenient in the field, and converted to latitude and longitude, if required.



7.1.8 Identify and measure the potentiometric surface(s) of the aquifer or aquifers. Methods for determining ground-water levels are covered in Test Method D 4750. The variability of these positions in both short (minutes to days) and long (months to years) time frames should be considered.³²

7.1.9 Assess vertical and horizontal variations in the pedologic, geologic, and hydrologic characteristics of the subsurface, including the vadose zone, aquifers, and confining units. When the flow direction and velocity of ground water are concerns, special emphasis should be placed on evaluating the degree of aquifer anisotropy, presence of highly permeable unconsolidated materials such as sands and gravels, extent and orientation of soil joint and rock fracture development, and extent of conduit development in karst limestone. Where unconsolidated materials consist of thick loess, alluvial, lacustrine materials, or glacial till, the spacing and depth of vertical soil jointing should be evaluated as potential zones of preferential contaminant movement (42). Guide D 5717 identifies methods for characterization of karst and fractured rock aquifers.

7.1.10 Assess temporal changes in subsurface hydrologic conditions, including changes in ground-water levels using piezometers or monitoring wells, changes in soil moisture conditions using tensiometers (see Guide D 3404), neutron soil moisture probes (see Test Method D 5093) or other methods, and measurement or estimation of soil moisture flux. Changes in soil solute quality using suction lysimeters and other methods (see Guide D 4687).

7.1.11 Identify type and extent of contaminants, if present, and identify and assess the geochemical characteristics of subsurface solids and ground water that may affect the fate and transport of contaminants. Temporal changes in soil pore liquids and ground-water quality should be characterized by periodic sampling from monitoring wells installed in accordance with standard procedures (see Guide D 4696—pore liquids, and Practice D 5092—ground-water monitoring wells). Important geochemical characteristics include organic matter content, clay mineralogy, pH, Eh, specific conductance, and temperature.³³

8. Use of Field Methods in Environmental Site Characterization

NOTE 2—All field procedures should be documented by identifying time, date, location, and personnel involved. Practice D 5254 identifies additional basic information required for documentation. Guide D 5408, Guide D 5409, and Guide D 5410 can serve as checklists to ensure that important additional information is not omitted. Paragraph 7.1.3 contains additional discussion of locational data considerations.

³² Other methods in addition to direct water level measurements may be useful for characterizing depth to water table. For example, description of the color, depth, and patterns of mottling of soil horizons may be indicative of long-term seasonal high ground water positions. Boulding (39) and Vepraskas (40) describe methods recently adopted by the Soil Survey Staff (41) for description and interpretation of morphologic features indicative of soil wetness. At contaminated sites, color variations can also be chemically induced or the result of staining.

³³ Microorganisms in soil and ground water may play a significant role in the transport and fate of inorganic constituents (such as nitrate, sulfate, and redox sensitive species, such as iron, manganese, arsenic, chromium, and selenium) and organic chemicals. Table X1.2 identifies ASTM methods for characterization of microorganisms and biodegradation potential.

8.1 Equipment and procedures used in site characterization for environmental purposes can be classified in the following general categories:

8.1.1 Indirect observation of surface and subsurface conditions using remote sensing techniques and geophysical surveys (see Section 9),

8.1.2 Direct observation of subsurface conditions and field description using visual-manual procedures (see Section 10),

8.1.3 Sampling for further physical, chemical, and biological testing and analysis (see Section 11), and

8.1.4 In situ testing of soil, rock, vadose zone, and aquifer characteristics (see Section 12).

8.2 Many test methods and procedures are potentially applicable to environmental site investigations.³⁴ Factors to consider when selecting equipment and procedures for a site investigation include:

8.2.1 *Objectives and Data Quality Requirements of the Investigation*—For example, a Phase I Environmental Site Assessment may require only simple, hand-held equipment. On the other hand, site investigations for suitability for long-term storage of high-level radioactive wastes involve complex and sophisticated instrumentation and testing.

8.2.2 *Characteristics of the Site*—Soils and geology of the site and properties of known or suspected contaminants will influence the type of drilling methods used and selection of sampling equipment. Different aquifer test procedures and analytical methods are required based on aquifer characteristics such as degree of confinement, presence of nearby hydrologic boundaries, and how much of an aquifer is intersected by the central test well.

8.2.3 *Characteristics of the Equipment or Method*—When several alternatives are available to achieve a given objective a number of factors should be considered in selecting equipment and methods. Equipment available from commercial sources is generally preferable to homemade equipment because specifications can be readily documented and replacement parts can usually be obtained quickly and be used without affecting the comparability of results with the broken equipment. Equipment with the greatest durability and reliability is preferable. Standard ASTM test methods or standard operating procedures and protocols established by government agencies should be used whenever applicable. The timeliness of results is another important consideration when selecting equipment or methods. Methods that provide real-time data that fulfill data quality requirements are preferable to methods that require use of offsite laboratories. Special circumstances may require use of uncommon or nonstandard equipment, methods, or procedures. The use of such equipment and procedures should be justified in the detailed site investigation plan.

8.2.4 *Cost of the Equipment or Method*—All factors affecting cost should be considered before selecting equipment or methods. For example, the higher initial cost of using dedicated samplers for ground-water monitoring wells may be more cost-effective in the long run as a result of reduced sample collection costs.

³⁴ A recent EPA report, (43) provides information on more than 200 methods.



8.3 Equipment and standard operating procedures (SOPs) should be identified in the detailed site investigation plan. Equipment design and specifications should be documented and standard operating procedures defined. Any departures from equipment and procedures defined in the site investigation plan should be documented and justified.

9. Field Methods: Remote Sensing and Geophysical Surveys

9.1 Remote sensing techniques may assist in mapping the geological formations and for evaluating variations in soil and rock properties. Satellite and airborne mapping methods, such as multispectral imagery obtained from the LANDSAT platform and SLAR (side-looking airborne radar imagery), may be used to find and map the areal extent of subsurface materials and geologic structure. Interpretation of aircraft photographs and satellite imagery may locate and identify significant geologic features that may be indicative of faults and fractures. Interpretation of aerial photography taken at different times can identify changes in land use and identify areas that have been disturbed by human activity. Some ground control is generally required to verify information derived from remote sensing data.

9.2 Surface geophysical investigations can be a useful guide in the placement of boring, test hole, vadose zone, and monitoring well locations. Surface geophysical methods are essential at most contaminated sites to avoid hazardous drilling locations. Surface geophysical methods, together with push technologies (see 10.1.5), are especially valuable for ensuring that permanent monitoring well locations intercept contaminant plumes and that background reference wells reflect uncontaminated conditions. Interpretation of surface geophysical surveys should be verified by borings or test excavations, or confirmed by different types of geophysical measurements. Surface and borehole geophysical measurements provide a useful supplement to borehole and outcrop data and assist in interpolation between holes. Seismic, ground penetrating radar, electrical resistivity and electromagnetic methods can be particularly valuable when distinct differences in the physical or electrochemical properties of contiguous subsurface materials are indicated.³⁵

9.3 Major applications of surface geophysical methods for environmental site characterization include:³⁶

9.3.1 Ground penetrating radar may be useful in defining soil and rock layers, water table, and man-made structures in the depth range from $\frac{1}{3}$ to 10 m (1 to 30 ft).

9.3.2 Electromagnetic induction, electrical resistivity, and induced polarization (or complex resistivity) techniques can be

used to map variations in water content, clay horizons, stratification, depth to aquifer/bedrock, and conductive contaminant plumes.³⁷

9.3.3 The shallow seismic refraction method can be used to map soil horizons, stratigraphic depth profiles, and water tables. It can be especially useful in determining depth of unconsolidated material where bedrock is at a depth of 30 m or less.

9.3.4 The seismic reflection method may be useful in delineating geological units at depths below 15 to 30 m (50 to 100 ft). It is not constrained by layers of low seismic velocity and is especially useful in areas of rapid stratigraphic change.

9.3.5 Magnetic surveys may be useful for detecting the presence of subsurface ferrous materials within 1 to 3 m of the ground surface.

9.4 Borehole geophysical methods can be used to obtain information on lithology, stratigraphy and formation properties, aquifer properties, ground-water flow and direction, borehole fluid characteristics, contaminant characterization, and borehole/casing characterization. Major categories of borehole logging methods include: (1) electrical and electromagnetic, (2) nuclear, (3) acoustic and sonic, and (4) miscellaneous methods, such as caliper, temperature, and borehole flowmeters. Considerations in the selection of borehole logging methods include, but are not limited to, (1) diameter of the borehole, (2) presence or absence and type of casing, (3) presence or absence and type of borehole fluid; and (4) characteristics of the subsurface formations.³⁸

9.5 All geophysical methods require site conditions that provide contrasts in the subsurface property being measured by the method, and, depending on the method, may be subject to interferences at a site, such as metal fences, powerlines, FM radio transmission, or ground vibrations. The depth of penetration and interference effects are highly site specific. Depth penetration and resolution vary with local conditions. Data collection and interpretation for geophysical surveys require skilled personnel familiar with the principles and limitations of the method being used.

10. Field Methods: Direct Observation of Subsurface Conditions³⁹

10.1 The type of equipment required for an intrusive subsurface investigation depends upon various factors including, but not limited to, the type of subsurface material, the depth of exploration, the nature of the terrain, the intended use of the data, and prevention of cross-contamination of aquifers.⁴⁰

³⁵ Major references that address use of surface geophysical methods for environmental site characterization include: Benson et al (44), Boulding (45), Haeni (46), Ward (47,48), and Zohdy et al (49).

³⁶ Depth ranges indicated here and for other geophysical methods are typical ranges for instruments available at the time this guide was written and intended to give a general idea of the capabilities of different methods. Actual depth penetration at a particular site is dependent on site conditions, instrumentation used for field measurements, and methods used to analyze the signal data. Depth of penetration can also increase with improved instrumentation and signal analysis methods.

³⁷ Test Method G 57 is intended for use in the control of corrosion in buried structures. Use of the electrical resistivity method in environmental investigations involves field procedures and data interpretation that differ substantially from the procedures outlined in this guide.

³⁸ Major references that address use of borehole geophysical methods for environmental site characterization include: Boulding (45), Keys (50), Keys and MacCary (51), and Respod (52).

³⁹ Major references on borehole drilling methods for direct observation of the subsurface and for installation of ground-water monitoring wells include: Aller et al (53), Eggington et al (54), Clark (55), Driscoll (56), Harlan et al (57), Lehr et al (58), Roscoe Moss Company (59), Ruda and Bosscher (60), and Shuter and Teasdale (61).

⁴⁰ Plans for a program of intrusive subsurface investigation should check whether there are requirements for licensing of installers and permits for installation and proper closure of bore holes and wells at the completion of the investigation.



Identify the location of buried utility lines, pipes, and any other subsurface anthropogenic features using maps or geophysical methods (9.2) prior to drilling.

10.1.1 Hand augers, hole diggers, shovels, and push tube samplers are suitable for exploration of surficial soils to depths of 1 to 5 m (3 to 15 ft).

10.1.2 Earth excavation equipment, such as backhoes, draglines, and drilled pier augers (screw or bucket) can allow in situ examination of soil deposits and sampling of materials containing cobbles and boulders.

10.1.3 In soil and unconsolidated material hollow-stem augers are commonly used for collection of geoenvironmental samples and installation of monitoring wells. Hollow-stem augers commonly reach depths of up to 45 m (about 150 ft) and large auger rigs can reach depths of up to 100 m (about 330 ft) under favorable conditions.⁴¹ Greater depths are possible in unconsolidated material if casing advancement methods are used. Sections 11.2.2 and 11.2.3 identify ASTM methods for collection of unconsolidated material samples.

10.1.4 For bedrock and for deep unconsolidated material, well drilling equipment such as rotary and cable tool systems is usually required. Normally samples are collected in the form of sand sized cuttings captured from the return flow, which generally are not adequate for environmental site characterization but other methods of determining stratigraphy, such as borehole geophysical logging methods are available (see Section 9.4). Diamond rotary coring (see Practice D 2113) is the preferred method of obtaining samples for physical property testing and geologic characterization of rocks. Diamond drills are effective to depths of up to 600 m or more, even in extremely strong igneous and metamorphic rocks. As depths in unconsolidated material increase, sampling devices attached to drill rods become increasingly cumbersome due to the time required to lower and retrieve the sampler. Wireline soil sampling, in which the sampler is lowered, driven, and retrieved on a wireline through the drill pipe, allows retrieval of samples at frequent intervals and provides for prompt visual identification of soil texture and subsurface features (Section 10.3). More commonly wireline systems are used for rock coring. Various factors affect the depth at which wireline sample becomes more cost effective than drill-rod attached sampling devices, including the length of the core barrel, the height of the mast on the rig being used, the number of hoist lines available for handling sampling tools and the hardness of the rock. The breakeven point for the two methods typically ranges between 15 m (50 ft) and 45 m (150 ft). As hole depths increase, cost savings using wireline sampling methods increase. Reduced physical labor for drill crews using wireline methods help to reduce worker fatigue, improving efficiency and safety.

10.1.5 Cone penetration technologies (CPT) and other drive/push technologies (DPT) are being used increasingly for environmental field investigations to depths of 100 to 300 ft (30.5 to 100 m) depending on geology and push capacity of the

system. The CPT methods can be used for lithologic characterization, measurement of hydraulic conductivity of soils, sampling of solids, soil gases and ground water, and in situ chemical detection (see 11.3). Accurate lithologic characterization using CPT requires correlation of measured resistance with one or more direct subsurface observations for each site. Advantages of CPT and DPT at contaminated sites include: no cuttings, increased worker safety, and improved siting of permanent monitoring wells.

10.2 A stratigraphic profile in complex geology is often developed by correlation of lithologic character established by a significant number of borings, by continuous geophysical profiling techniques, and surface mapping. This phase of the investigation may be implemented by plotting logs of soil and rock exposures in walls of excavations or cut areas and by plotting logs of the test borings. Then one may interpolate between, and extrapolate a reasonable distance beyond, these logs. The spacing of these investigations depends on the geologic complexity of the project area and on the importance of soil and rock continuity to the project design. Exploration should be deep enough to identify all strata that might be significant in assessing environmental conditions at the site.

10.3 Field description of test pits and excavations and boring logs are an essential element of environmental site investigations. Test pits allow observation of pedogenic soil features that are larger than the diameter of borings and allow the most accurate description of subsurface features in the soil zone that may influence movement of contaminants in the vadose zone. Paragraph 6.4.3 in Guide D 5409 identifies key features that should be included in field description of samples and unconsolidated material. Additional description of samples of soil and rock may be added after samples have been transported from the field. Subsurface observation records should be kept in a systematic manner for each project. Such records should include, when applicable:

10.3.1 *Description of Each Site or Area Investigated*—Each test hole, boring, test pit, or geophysical test site should be referenced to an established coordinate system, datum, or permanent monument (see 7.1.3):

10.3.2 Subsurface investigation logs of each test hole, boring, test pit, or cut surface exposure should show the field description and location of each material, and any water encountered, either by symbol or verbal description. Guide D 5434 provides guidance for field logging of subsurface explorations for soil and rock. Reference to a Munsell Soil or Rock Color Chart designation is a substantial aid to the description of soil and rock materials.⁴¹ Various soil classification systems are available for description of soil and other unconsolidated materials in the field. The selection of the classification system depends on the purpose and data needs of the investigation and the end users of the information. The ASTM (Classification D 2487 and Practice D 2488) version of the Unified Soil Classification System (USCS) is used by most governmental agencies and geotechnical engineering firms for the description of soil for engineering purposes both in the United States and in many other countries. The USDA system

⁴¹ Fluid rotary drilling can extend to greater depths in unconsolidated materials, but is generally not recommended for environmental investigations because drilling fluids can alter subsurface chemistry.



system (41,63,64),⁴² developed by the Soil Conservation Service for agricultural aspects of near surface soils, is especially useful for environmental investigations because it can provide hydrologic information for soils. Using the modified Wentworth grain size scale (AGI Date Sheet 29.1; (65), which is widely used by geologists, in combination with the USDA textural system will provide useful additional data on soil particle-size distribution because the Wentworth system has more subdivisions in the silt and gravel particle-size classes. Field classification of samples and exposures should be confirmed with laboratory tests (Classification D 2487, Test Method D 422, and Test Method D 1140) if the information is critical to the investigation program.⁴³ Laboratory test results should clearly identify the textural system being used, because different systems may have slightly different grain-size cutoffs. Use of sieves that include all divisions of the USCS, USDA and modified Wentworth scales will provide the greatest amount of useful information for the coarse fraction, and measurement of all relevant cutoffs for the fine fraction in the three systems will ensure that environmental and engineering interpretations using all three systems will be possible.

10.3.3 Location and description of seepage and water-bearing zones, zones of low permeability, and records of potentiometric elevations found in each test hole, boring, piezometer, or test pit,

10.3.4 Grain size distribution of unconsolidated materials in the interval to be screened when installation of a ground-water monitoring well is planned,

10.3.5 The results and locations of in situ test results (see Section 12),

10.3.6 Percentage of core recovery and rock quality designation (RQD) in core drilling. Deere and Deere (69) provides guidance on RQD, and

10.3.7 Graphical presentation of field and laboratory data, such as graphic borehole logs, cross sections, potentiometric maps, and contaminant concentration isopleths, facilitates interpretation and understanding of subsurface conditions.

11. Field Methods: Sampling

11.1 The location, type of samples collected, and sampling equipment should be in accordance with the sampling plan

⁴² Color photographs of rock cores, soil samples, and exposed strata may be of considerable value. Each photograph should include an identifying number or symbol, a date, and a reference scale. Soil Conservation Service (62) provides standardized procedures for photographic documentation of rock cores.

⁴³ Both USCS and USDA classification systems can be used to estimate some hydrologic properties of soils impacting the fate and transport of contaminants. The plasticity index of the USCS is directly related to colloidal content in the soil and resulting sorptive capacity. The USCS system is more applicable to very coarse-grained alluvial deposits containing appreciable gravels. Saturated hydraulic conductivity can often be estimated within two or three orders of magnitude based on both USCS and USDA classification, and estimates can sometimes be narrowed within one order of magnitude for clean sands or in fine-grained soils where descriptions of morphology (structure, macroporosity, fissures, laminations, etc.) of undisturbed cores or exposures are possible. Numerous additional hydrologic parameters have been correlated to the USDA classification system for near-surface soils and could be useful for fine-grained unconsolidated material at greater depths. These parameters include: capillary fringe (39), specific yield (66), field moisture capacity (67), and available water capacity (68). Estimation of hydrologic parameters may be useful during the initial site characterization phases, but should not replace necessary definitive field and laboratory measurements which may be required for final site evaluations.

developed in the detailed site investigation plan. A statistically valid method should be used to select sampling locations if required by the data-collection objectives. Sample equipment and procedures should be appropriate for the medium being sampled (soil, rock, soil gas, soil-pore liquids, ground water, solid/liquid waste) and be designed to minimize the introduction of error into physical and chemical test results. Barth et al (70) and Mason (71) provide guidance on development of soil sampling plans. Gilbert (72) provides a good general reference on statistical aspects of sampling and monitoring for environmental purposes. Geostatistical methods are especially useful for developing a sampling strategy and analysis of results when parameters are spatially correlated.⁴⁴

11.2 *Solids Sampling*⁴⁵—The type of solids sample will depend on the purpose of the sample.

11.2.1 Disturbed or grab samples using augers (see Practice D 1452) and trier samplers (see Practice D 5451) are used primarily for chemical analyses, but are also suitable for texture analysis.

11.2.2 Split barrel samplers (see Test Method D 1586) provide samples that allow description of lithology and other subsurface features, and laboratory measurements of soil parameters unaffected by sample disturbance (for example, water content, gradation or particle size, organic content, and nonsensitive and chemical constituents) but are not suitable for laboratory measurement of soil properties.

11.2.3 Thin-wall tube (see Practice D 1587) and ring-lined barrel samplers (see Practice D 3550) collect undisturbed samples of unconsolidated material that are suitable for laboratory testing of hydrologic properties, and diamond core drilling (see Practice D 2113) provides similar samples for consolidated rock. Undisturbed core samples can provide important information on structure, sedimentary features, secondary porosity, and color patterns that cannot be obtained from disturbed samples.

11.2.4 Guide D 4700 provides guidance on soil sampling in the vadose zone. Special considerations in sampling of soil for radionuclides and volatile organics are addressed in Practice C 998 and Practice D 4547, respectively. Practice D 4220 covers procedures for preservation and transportation of soil samples and Practices D 5079 does the same for rock core samples.

11.3 Other Sampling:

11.3.1 Characterization of the vadose zone may require sampling of soil gases and soil pore liquids. Guide D 5314

⁴⁴ Most soil physical and chemical properties are spatially correlated, and the location of contaminants in soil and ground water are also usually spatially correlated. Clark (73) is a good introductory text on geostatistics and Isaaks and Srivastava (74) provide advanced treatment of this subject. The ASCE Task Committee on Geostatistical Techniques in Geohydrology (75) contains a good review of basic concepts and applications. Several public domain geostatistical software packages are available from U.S. EPA (76,77,78). Geostatistical methods may not be appropriate where soil contamination exists as localized hotspots. Zirschky and Gilbert (79) provide guidance on statistical sampling designs for detecting hot spots at hazardous-waste sites.

⁴⁵ The investigation may require the collection of sufficiently large soil, rock, waste, and ground water samples of such quality as to allow adequate testing to determine the soil or rock classification or mineralogic type, or both, and chemical constituents of potential interest or concern.