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Standard Guide for Selection of Soil and Rock Sampling Devices Used With Drill Rigs for Environmental Investigations[1]

This standard is issued under the fixed designation D6169; 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.

1. Scope

1.1 This guide covers guidance for the selection of soil and rock sampling devices used with drill rigs for the purpose of characterizing in situ physical and hydraulic properties, chemical characteristics, subsurface lithology, stratigraphy and structure, and hydrogeologic units in environmental investigations.

1.2 This guide does not specifically address selection of soil sampling devices for use with direct-push sampling systems, but the information in this guide on thick-wall and thin-wall samplers is generally applicable to direct-push soil sampling.

1.3 This guide should be used in conjunction with referenced ASTM guides, practices, and methods on drilling techniques for geoenvironmental investigations and use of sampling devices referenced in 2.1, and with Guide D5730.

1.4 This guide does not address selection of sampling devices for hand-held soil sampling equipment, and soil sample collection with solid-stem augering devices, or collection of grab samples or hand-carved block samples from accessible excavations. Refer to Appendix X1.2 for guidance on these topics. This guide should be used in conjunction with Guide D4700 when thin-walled, split barrel, ring-lined barrel and piston samplers with solid- and hollow-stem augers are used in the unsaturated zone.

1.5 This guide does not address devices for collecting cores from submerged sediments or sampling devices for solid wastes. Refer to Guide D4823 for guidance on these topics.

1.6 The values stated in SI units are to be regarded as the standard. However, dimensions of materials used in the drilling industry are given in English units by convention, therefore, English units are used where necessary in this guide.

1.7 *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.*

1.8 *This guide offers an organized collection of information or series of options and does not recommend a specific course of action. This document cannot replace education and experience and should be used in conjunction with professional judgement. The word "Standard" in the title of this document means that the document has been approved through the ASTM consensus process.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D657 Specification for Isopropyl Acetate (Withdrawn 1977)[3]
D1452 Practice for Soil Exploration and Sampling by Auger Borings
D1586 Test Method for Penetration Test (SPT) and Split-Barrel Sampling of Soils
D1587 Practice for Thin-Walled Tube Sampling of Soils for Geotechnical Purposes
D2113 Practice for Rock Core Drilling and Sampling of Rock for Site Investigation
D3550 Practice for Thick Wall, Ring-Lined, Split Barrel, Drive Sampling of Soils
D3694 Practices for Preparation of Sample Containers and for Preservation of Organic Constituents
D4220 Practices for Preserving and Transporting Soil Samples
D4452 Practice for X-Ray Radiography of Soil Samples
D4700 Guide for Soil Sampling from the Vadose Zone
D4823 Guide for Core Sampling Submerged, Unconsolidated Sediments
D5079 Practices for Preserving and Transporting Rock Core Samples
D5084 Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter

[1] This guide is under the jurisdiction of ASTM Committee D18 onSoil and Rock and is the direct responsibility of SubcommitteeD18.21 on Groundwater and Vadose Zone Investigations

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[2] For referenced ASTM standards, visit the ASTM website, www.astm.org, or contact ASTM Customer Service at service@astm.org. For *Annual Book of ASTM Standards* volume information, refer to the standard's Document Summary page on the ASTM website.

[3] The last approved version of this historical standard is referenced on www.astm.org.

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D5088 Practice for Decontamination of Field Equipment Used at Waste Sites
D5434 Guide for Field Logging of Subsurface Explorations of Soil and Rock
D5730 Guide for Site Characterization for Environmental Purposes With Emphasis on Soil, Rock, the Vadose Zone and Ground Water
D5781 Guide for Use of Dual-Wall Reverse-Circulation Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
D5782 Guide for Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
D5783 Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
D5784 Guide for Use of Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices
D5872 Guide for Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
D5875 Guide for Use of Cable-Tool Drilling and Sampling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
D5876 Guide for Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices
D5911 Practice for Minimum Set of Data Elements to Identify a Soil Sampling Site
D6151 Practice for Using Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling

3. Terminology

3.1 *Definitions*—Terminology used within this guide is in accordance with Terminology D653 except as noted below.

3.2 *Definitions of Terms Specific to This Standard:*

3.2.1 *borehole grab sampler*—a sampling device with a cutting head that advances by rotation and collects a sample by scraping side or bottom rather than coring. See Section 8.1

3.2.2 *chemically undisturbed core sample*—a soil or rock core sample in which the sampling device, collection and handling procedures result in preservation of the chemical properties to a degree that satisfies the purpose for which the sample was taken.

3.2.2.1 *Discussion*—For nonsensitive chemical constituents, representative samples will generally provide chemically undisturbed samples. Nonrepresentative samples may also be chemically undisturbed, but are generally not suitable for analysis because of their uncertain integrity, location or origin. For sensitive chemical constituents, special sample collection and handling procedures are generally required to obtain chemically undisturbed samples as discussed in 6.4 and 6.10. Physically undisturbed samples will generally provide chemically undisturbed samples provided that sampling technique, and materials for sampling devices and containers are selected to avoid chemical alteration.

3.2.3 *clearance ratio (inside)*—the difference between inside diameter of the sampling tube and inside diameter of cutting edge or shoe divided by the inside diameter of the cutting shoe or edge.

3.2.3.1 *Discussion*—refer to Hvorslev (**1**)[4] and Paikowsky et al. (**2**) for appropriate formulas for calculating wall area ratio.

3.2.4 *core—for the purposes of this guide*, a cylindrical sample of soil or rock obtained by means of a thick-wall, thin-wall, or rotating core sampler.

3.2.5 *cuttings—for the purposes of this guide*, soil material or small-sized rock fragments brought to the surface in the air or fluid stream of a rotary drill rig, bailing from a cable tool rig, sticking to drill bits or auger flights, or as return from auger flights. See 8.3.

3.2.6 *direct push sampling system—for the purposes of this guide*, a subsurface sampling system using samplers generally 2 in. (50 mm) in diameter or less that use hand-held percussion driving devices, or mobile hydraulic, vibratory or percussion drive systems that are mounted to a small truck, van, all-terrain vehicle (ATV), trailer, skid, or drill rig.

3.2.7 *drill rig—for the purposes of this guide*, a land-based wheeled, ATV, or skid-mounted assembly or offshore or barge mounted assembly capable of drilling boreholes and collecting soil or rock samples with a diameter generally greater than 2 in. (50 mm) using rotary, drive, push, or vibratory advancement methods.

3.2.8 *drill-rod core sampling*—a sampling process in which a fixed drill rod assembly advances a thick-wall or thin-wall sampler or a rotating drill rod assembly advances a rotating core samplers.

3.2.9 *group A*—samples for which only general visual identification is necessary (see Practices D4220).

3.2.10 *group B*—samples for which only water content and classification tests, proctor and relative density, or profile logging is required and bulk samples that will be remolded or compacted into specimens for swell pressure, percent swell, consolidation, permeability, shear testing, CBR, stabilimeter, etc. (see Practices D4220).

3.2.10.1 *Discussion*—Group B samples are disturbed, remolded samples used primarily for engineering properties tests.

3.2.11 *group C*—intact, natural formed or field fabricated, samples for density determination; or for swell pressure, percent swell, consolidation, permeability testing and shear testing with or without stress-strain and volume change measurements, to include dynamic and cyclic testing (see Practices D4220).

3.2.11.1 *Discussion*—Group C samples are undisturbed samples used primarily for engineering properties tests. Some of these tests, such as bulk density and permeability are useful

[4] The boldface numbers given in parentheses refer to a list of references at the end of the text.

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for environmental investigations. Additional physical and hydrologic properties that require Group C type samples are identified in Table 1.

3.2.12 *group D*—samples that are fragile or highly sensitive for which tests in Group C are required (see Practices D4220).

3.2.13 *liner*—cylindrical tubes or rings made of metal or plastic placed inside a core sampling device to facilitate sample retrieval and handling.

3.2.14 *nonrepresentative sample*—a soil sample that consists of drill cuttings of uncertain integrity, location or origin, or other incomplete or contaminated portions of subsurface materials; generally not suitable for testing or analysis (**3**).

3.2.15 *physically undisturbed core sample*—a soil or rock core sample in which the sampling device, collection and handling procedures result in preservation of the in situ physical and hydraulic properties (such as, structure, density, and moisture content) to a degree that satisfies the purpose for which the sample was taken.

3.2.15.1 *Discussion*—Group C and D core samples are physically undisturbed. Generally collection of undisturbed samples require use of thin-wall or double-tube rotating core sampling devices, but as discussed in 6.2, thick-wall samplers may be satisfactory for some objectives.

TABLE 1 General Sample-Type Requirements for Measurement of Physical and Chemical Properties

Tests to be Performed	Physically Undisturbed	Chemically Undisturbed	Representative
Physical/Hydrologic Properties			
Hydraulic Conductivity	X	. . .	. . .
Specific Yield	X	. . .	. . .
Pressure Head (Matric Potential)	X	. . .	. . .
Moisture Characteristic Functions[A]	X	. . .	X
Water Content	. . .	. . .	X
Particle Size Distribution	. . .	. . .	X
Bulk Density/Porosity	X	. . .	. . .
Strength Properties	X	. . .	. . .
Compressibility	X	. . .	. . .
Mineralogy			
Gross Mineralogy	. . .	. . .	X
Soil Thin Section Micromorphology	X	. . .	. . .
Surface Properties			
Ion Exchange Capacity	. . .	X	. . .
Sorption (Batch Tests)	. . .	X	. . .
Sorption (Flow-Through Tests)	X	. . .	. . .
Sorption Site Density	. . .	X	. . .
Surface Area	. . .	. . .	X
Nonsensitive Chemical Constituents[B]			
Most Total Elemental Concentrations	. . .	. . .	X
Carbonate	. . .	. . .	X
Soil Organic Carbon	. . .	. . .	X
Sensitive Chemical Constituents[C]			
Microbiology	. . .	X	. . .
Volatile and Semivolatile Organics	. . .	X	. . .
Nitrogen- and Sulfur-Containing Species	. . .	X	. . .
Redox-Sensitive Species (As, Cr, Fe, Mn, Se)	. . .	X	. . .
Other Sensitive Inorganics (Hg, cyanides)	. . .	X	. . .

[A] Physically undisturbed sample preferred, but repacked representative sample may be adequate.

[B] Chemical constituents that are sufficiently stable that no special attention need to be given to sample device/container compatibility, or sample handling, transport, and storage if analyzed within a few months.

[C] Special consideration of sample device/container compabitility, sample collection, handling and transport required to obtain chemically undisturbed samples.

3.2.16 *piston core sampler*—a thin-wall or, less commonly, thick-wall sampling device in which the inner piston is held in a fixed position and the cutting head and outer barrel is advanced mechanically or hydraulically into the soil. See 7.5.

3.2.17 *representative soil sample*—a soil sample from a known subsurface interval in which some structural features do not survive but other properties, such as moisture content, grain size and gradation and chemical characteristics of the sample interval are preserved; suitable for mechanical and chemical analysis for nonsensitive chemical constituents, and lithologic logging. (Adapted from U.S. Geological Survey, 1980). See discussion in 6.3.

3.2.17.1 *Discussion*—This definition follows general usage in the geologic profession, and differs from the definition of representative sample in the statistical sense. The sample is only representative of the subsurface material encountered by the sampler and is not necessarily representative of the formation being sampled. Sample representativeness in the latter sense needs to be addressed in the sample design that defines the specific location of sampling.

3.2.18 *rotating core sampler*—a rotating cylindrical sampler with a coring bit that cuts away soil or rock material from around the core. See 7.6.

3.2.19 *sensitive chemical constituents*—chemical species or compounds for which the composition or concentration in soil may change rapidly in soil in response to disturbance, or interaction with sample container materials, due to processes such as volatilization, degassing, microbial action or abiotic oxidation-reduction reactions.

3.2.20 *thick-wall sampler*—a core sampler that does not satisfy the requirements for collection of undisturbed Group C and D samples.

3.2.20.1 *Discussion*—Generally, samplers with a wall area ratio greater than 15 % (see Table 2 for additional specifications. Typical thick wall samplers are found in Test Method D1586 and Practice D3550. See 7.3.

3.2.21 *thin-wall sampler*—a sampler that meets the specifications in Practice D1587. See 7.4.

3.2.22 *undisturbed sample*—a soil sample that has been obtained by methods in which every precaution has been taken to minimize disturbance to the sample (see Terminology D653). See also definitions for chemically undisturbed sample and physically undisturbed sample.

3.2.23 *vibratory core sampling*—a sample process in which a thick-wall or thin-wall sampler is advanced using high frequency vibrations rather than hydraulic or percussion forces.

3.2.24 *wall area ratio*—The ratio of gross wall area due to thickness divided by the inside opening of the sampler.

3.2.24.1 *Discussion*—Refer to Hvorslev (**1**) and Paikowsky et al. (**2**) for appropriate formulas for calculating wall area ratio.

3.2.25 *wireline core sampling*—a sampling process in which rotating or pushed core samplers are raised and lowered inside

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TABLE 2 General Sampler Specifications Defining Undisturbed Samples For Group C and D Samples[A]

Sampler Characteristics	Undisturbed (Thin-Wall sampler)[B]	Disturbed[C] (Thick-Wall sampler)	Source
Wall thickness/OD ratio	< 2.5 %	> 2.5 %	Hvorslev (1)
Wall area ratio	< 15 %	> 15 %	Hvorslev (1) and Paikowsky et al. (2)
Clearance ratio (inside)			Shuter and Teasdale (7) and Practice D 1587D1587. See also Table 7.
Nonplastic soils	0.5 to 1 %	NA	
Intermediate plasticity	1 to 2 %	NA	
Plastic soils (clays)	2 to 3 %	NA	
Length			Practice D1587
Sands	< 10 diameters	> 10 diameters	
Clays	< 15 diameters	> 15 diameters	
Diameter			Shuter and Teasdale (7)
Compressible soils	> 3 in. (76.2 mm)	< 3 in. (76.2 mm)	
Less compressible soils	> 2 in.[D] (50.8 mm)	< 2 in.[D] (50.8 mm)	

[A] Group C samples include samples for the following geotechnical tests: density, percent swell, consolidation, permeability testing and shear testing with or without stress-strain and volume change measurements. Group D samples are fragile or highly sensitive for which test in Group C are required. Group C samples collected for environmental testing purposes would include laboratory measurement of hydraulic conductivity, and flow-through core tests for sorption and leachability.

[B] Thin-wall samplers cannot get undisturbed samples of all soil materials. For denser soils, Pitcher (see 7.7.2) or Denison samplers (see 7.7.3) may be required.

[C] Samples collected with thick-wall samplers may qualify as undisturbed samples for the purpose of description of in situ morphologic properties provided that visual indicators discussed 6.1.2 indicate minimal disturbance (see Table 3), and for the purpose of chemical characterization.

[D] 2-in. (50.8 mm) samples for Group C samples for engineering tests are not recommended.

drill rods with a wireline and attached for coring or pushing with an overshot latching mechanism.

4. Significance and Use

4.1 Direct observation of the subsurface by the collection of soil and rock samples is an essential part of site characterization for environmental purposes (see 7.1.7 of Guide D5730). This guide provides information on the major types of soil and rock sampling devices used on drill rigs to assist in selection of devices that are suitable for known site geologic conditions, and provide samples that meet project objectives. This guide should not be used as a substitute for consulting with someone experienced in sampling soil or rock in similar formations before determining the best method and type of sampling.

4.2 This guide should be used in conjunction with Guides D2113 and D6151 and drilling method-specific guides (see Guides D5781, D5782, D5783, D5784, D5872, D5875 and D5876) as part of developing a detailed site investigation and sampling plan (see 5.1.5 of Guide D5730) for sites that require mobilization of a drill rig for subsurface investigations. The selection of drilling methods and sampling devices goes hand-in-hand. In some cases soil sample requirements may influence choice of drilling method, or conversely, types of available drill rigs may influence choice of sampling devices.

4.3 This guide should be used in conjunction with Guide D5434 for field logging of soil and rock samples, Practice D5911 for data elements to identify a soil sampling site, and where appropriate, Practice D4220, for preserving and transporting soil samples, Practice D5070 for preserving and transporting rock core samples, Practice D3694 for preparation of sample containers and for preservation of organic constituents, and Practice 5088D5088 for decontamination of field equipment used at nonradioactive waste sites.

5. Objectives of Sampling Soil and Rock

5.1 Samples of soil and rock can be collected for three major purposes in environmental investigations: measurement of in situ physical and hydraulic properties, measurement of in situ chemical and biological characteristics, and identification of geologic and hydrogeologic characteristics of the subsurface. Table 1 identifies general sample-type requirements for measurement of physical, hydrologic and chemical properties of the subsurface. Most coring devices (see Section 7) provide good to excellent samples for all three purposes. Borehole grab samplers and drill cuttings (see Section 8) are unsuitable for measurement of in situ physical and hydrologic properties. Depending on the specific drilling method, borehole grab samples or cuttings may provide adequate information of geologic and hydrogeologic properties of the subsurface.

5.2 *In Situ Physical and Hydraulic Properties*—Laboratory measurements of physical properties, such as bulk density, porosity, consolidation of clays, and thin-section analysis of sediments, and hydraulic properties, such as specific yield and hydraulic conductivity require undisturbed cores that retain the in situ properties of the sample. Bulk density and porosity are the parameters requiring undisturbed samples that are most significant in environmental investigations because of their significance in vadose zone and groundwater modeling. Hydraulic properties of permeable materials are generally best measured using aquifer tests (see Table A1.1 of Guide D5730, for list of ASTM standards on aquifer tests), but collection of undisturbed samples for laboratory permeameter tests may provide useful information on vertical changes in hydraulic properties. Impermeable materials, such as clays, are generally best measured in the laboratory using undisturbed cores (see Test Method D5084). However, it should be recognized that laboratory measurements generally do not consider preferential flow or secondary porosity effects which can significantly

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affect the field permeability of a material. Section 6.1 discusses criteria for evaluating degree of sample disturbance. Table 1 lists parameters that require undisturbed samples.

5.3 *Chemical and Biological Characteristics*—Samples for measurement of stable chemical constituents generally do not require physically undisturbed samples, but do require representative samples. Samples for measurement of sensitive chemical constituents, such as volatile organic compounds, require physically undisturbed samples that minimize sample degassing from compression or expansion. Whenever chemical analysis of samples is an objective of the investigation, sampling devices that result in chemical alteration should be avoided. Chemical alteration is most problematic with devices in which drilling fluids come in direct contact with the sample and when sensitive constituents such as volatile organic chemicals and redox sensitive elements (iron, manganese, arsenic, chromium, selenium), or microorganisms below the water table are to be sampled. In contaminated soil and groundwater, casing advancement methods should be used to prevent cross-contamination of samples. Sampling for such constituents requires use of samplers and sampling procedures that avoid or minimize contact with drilling fluids, the atmosphere, other contaminated soil or groundwater, and sample containers made of nonreactive materials (see 6.4 and 6.10). Undisturbed samples are preferred when column leaching or sorption tests are to be performed in the laboratory, although representative disturbed samples can be used in unstructured soil materials if the bulk density is known. Table 1 identifies types of samples required for specific chemical and biological properties.

5.4 *Geologic and Hydrogeologic Properties*—Samples for geologic properties, such as lithology, stratigraphy, and structure should generally be representative, but nonrepresentative samples combined with observations of drilling advancement rates may provide some information on changes in lithology if it is not feasible to collect representative samples (see 8.3). Undisturbed samples are required for adequate characterization of fractures in dense unconsolidated material and rock. The quality of definition of hydrogeologic units will be a function of the quality of lithologic, stratigraphic, and structural interpretations supplemented by water level data and aquifer tests.

6. Specific Criteria for Selection of Sampling Devices

6.1 When the specific objectives of sample collection have been defined (see 4.2), the applicable criteria described below should be identified and the sampling device or devices that will best fulfill the sampling objectives selected for use. When a sampling device has been selected, at least two should be procured, along with appropriate spare parts. Two samplers may be used in alternation if this enhances efficiency of field operations and sample collection, or the second sampler serves as a backup in the event the first one becomes damaged.

6.2 *Sample Physical Disturbance*—The degree of physical disturbance of a soil or rock sample is primarily a concern when in situ physical and hydraulic properties are to be measured. Historically, geotechnical investigators have placed more emphasis on collection of physically undisturbed soil samples than environmental investigators because measurement of many engineering properties requires such samples, whereas alternative methods to permeameter tests (that is, single and multi-well aquifer tests) are available for measuring hydraulic parameters (see 5.2). However, the degree of disturbance also affects the quality of borehole log descriptions and subsequent interpretations. Disturbed soil cores allow logging of primarily textural and density/consistency changes. Undisturbed soil cores allow description of soil morphologic features that are valuable for developing interpretations concerning the potential for contaminant movement in the subsurface (**4**). Collection of oriented undisturbed rock cores allow assessment of fracture location and orientation in the subsurface (see 7.9.4).

6.2.1 *Definition of Physically Undisturbed*—The use of the term "undisturbed" to describe a soil or rock sample always has to be qualified because the sampling process inevitably results in some degree of disturbance as a result of factors such as stress relief or dilation or compression from insertion. The definition of an undisturbed soil sample in Test Method D657 (see 3.2.14) does not provide explicit criteria for determining whether a sample is undisturbed. Samples collected using a thin-wall sampler provide the least disturbed core samples in soft soils, yet Practice D1587 uses the term "relatively undisturbed" to characterize samples taken with a thin-wall tube sample. The factors that affect physical sample disturbance are numerous and complex enough that professional judgement is still required to determine whether a sample is physically undisturbed. Framing that determination in the context of the objective of the sample (see 3.2.15) makes it easier to make a positive or negative determination using the criteria discussed below, provided that the sampling objectives have been clearly defined prior to collection.

NOTE 1—Reference (**3**) defines undisturbed sample as follows: essentially an in-place specimen in which features such as structure, density, and moisture content are preserved; suitable for most engineering testing and analysis. Rehm et al. (**5**) give a similar definition as samples in which "the physical and chemical properties of the sample have been altered little from the original in situ condition during the collection process." Davis et al. (**6**) define undisturbed samples as "very high quality samples taken under strictly controlled conditions in order to minimize structural disturbance of the sample". The definition of undisturbed sample in this guide (see 3.2.15) adds precision to the above definitions by relating the term to the objective for which the sample is collected.

6.2.2 *Affect of Sampling Device on Degree of Physical Disturbance*—The following three general characteristics of samplers affect the degree of physical disturbance of the sample: increasing wall thickness increases disturbance, increasing tube diameter decreases disturbance, and increasing tube length increases disturbance. The same sampler may cause different degrees of disturbance, depending on the material being sampled, with highly plastic and compressible soils and well sorted noncohesive sands being most susceptible to disturbance. Driving the same sampler can disturb a sample more than pushing the sampler. Thin-wall samplers (see 7.4) generally provide the highest quality cores in terms of minimizing sample disturbance in fine-grained cohesive materials. Piston samplers (see 7.5) may be required for collecting cores in cohesionless materials, with thin-wall types creating less disturbance than thick-wall types). Rotary core samplers, such

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as the Denison sampler (see 7.6.2), or vibratory/sonic sampling methods (see 7.2.4) may be required to collect undisturbed samples in firm to stiff cohesive soils and dense sands. Depending on the sampler and soil material, thick-wall samplers may also be satisfactory for measurement of in situ physical and hydraulic properties (see 6.2.3). Shuter and Teasdale (**7**) and most of the geotechnical references identified in the appendix provide further discussion of considerations and techniques for collecting undisturbed cores.

6.2.3 *Criteria for Evaluating Degree of Physical Disturbance in Push and Drive Samples*—Table 2 identifies the main sampler characteristics that determine whether a sample is physically undisturbed for Group C and D samples as defined in Practice D4220. Although the definition of these groups has a primarily geotechnical focus, undisturbed samples for hydrogeologic analysis and testing have the same requirements (Refer to Shuter and Teasdale (**7**) for a detailed discussion of requirements for undisturbed soil samples for hydrogeologic analysis and testing). Group C and D samples will also provide high quality samples for visual logging of soil morphologic and sedimentary features that are sensitive to disturbance by thick-wall samplers. Table 3 gives a number of indicators that can be used to evaluate the degree of disturbance in core collected using a thick-wall sampler. X-ray radiography (see Practice D4452) may also be useful for evaluating the quality of Group C and D cores.

6.2.4 *When to Collect Physically Undisturbed Soil Samples*—Undisturbed physical soil samples in cohesionless soils (sands and gravels) are generally more costly in time and money than disturbed samples, and in environmental investigations the decision to obtain undisturbed samples should be based on a judgement that the added information obtained from undisturbed cores outweighs the added costs. Drill cuttings or auger-flight samples are inadequate for most environmental investigations, so the question will generally be framed in terms of whether disturbed core thick-wall samples or thin-wall/rotating core sampling devices should be used. Examples of when high-quality undisturbed samples (Group C and D) in environmental investigations might be appropriate for environmental investigations include: determination of laboratory hydraulic conductivity and porosity for calibration of geophysical logs in an area, thin section examination of sediments for mineralogy and microstructural features, engineering properties for fill/cut slope stability, slurry walls and backfill design for design of waste disposal facilities and remediation of contaminated soil and groundwater, collection of spatially oriented cores to establish strike and dip of formation layering and evaluate potential contaminant pathways in joint and fracture systems (see 7.9.4).

6.3 *Sample Representativeness*—Soil samples from a known subsurface interval that do not preserve in situ structural properties, but for which other physical properties such as water content and particle size distribution or chemistry, or combination thereof, are unaltered, are representative samples. Requirements for obtaining physically and chemically representative samples may differ. For example, Group B soil samples as defined in Practice D4220 are physically representative, but may not be chemically representative if the sampling technique, sampling device or containers result in chemical alteration of the sample. Disturbed samples collected using thin-wall and thick-wall samplers usually give representative samples for physical analysis. However, when drilling methods involve drilling fluids, sample moisture content and chemistry may be altered. Borehole grab samples and drill cuttings may be representative if the sample collection method allows precise determination of the sample interval, measures are taken to prevent mixing of material from other intervals, and the drilling method does not alter sample characteristics (see 8.4).

6.4 *Sample Chemical Integrity*—Soil samples collected for chemical analysis usually do not need to preserve in situ structural characteristics of the sample but must be representative of the sampled interval. Relatively stable chemical properties, such as mineralogy, organic matter content (excluding recent organic residue) and many inorganic constituents can be collected using any device that gives a representative sample. Sensitive chemical constituents, such as redox-sensitive metals, volatile organic chemicals, and other organic chemicals that are subject to biodegradation may require collection of undisturbed or relatively undisturbed samples using stainless steel or brass liners that are immediately sealed for transport or special coring, paring, or subcoring devices that allow rapid placement or transfer of samples into containers for onsite analysis or preservation and transport to a laboratory. Key considerations in sampling sensitive chemical constituents

TABLE 3 Indicators of Degree of Core Disturbance in Driven Samples[A]

Indicator	Undisturbed/Less Disturbed	More Disturbed/Disturbed
Advancement Method	Pushed	Driven
Core Recovery	Core length = sample interval	Core length < or > sample interval
Soil morphology/sedimentary structures[A]	No or little observable deformation	Moderate to extensively deformed
Core length (indicator of expansion or compaction)[B]	Length of core equal to sampled interval	Length of core > or < sampled interval
Partings at intervals equal to the distance of each drive impact (driven samples only)	Absent	Weakly to strongly evident
Practice D1586 blow count (N)[C]	N <20	N >20
Core shoe (soil with course fragments)	No visible damage to cutting shoe	Cutting shoe nicked or bent
Gravel fragments or large roots in core	No evidence of grooving along core	Core has been grooved by rock or root fragments inside the core
Borehole condition	Cased or stable borehole with no caving	Unstable, uncased borehole
Drilling fluid	Not used	Drilling fluid coats core top, bottom and sidewalls

[A] Based on visual observation of split cores or x-ray radiography using Test Method D4452.
[B] Also indicator for pushed thin-wall samples.
[C] A standard 2 in. (50.8 mm) thin-wall sampler will often collapse in soils with N values of 30 or greater (**23**).

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