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

This standard is issued under the fixed designation D6169/D6169M; 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 geotechnical and 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.~~

1.2 This guide should be used in conjunction with referenced ASTM ~~guides, practices,~~Guides D420 and D5730~~methods on drilling techniques for geoenvironmental investigations and use of~~ , and individual practices for sampling devices referenced in 2.1~~, and with~~ . Soil and rock samplers are most often used in drilled/pushed boreholes using various drilling methods/technologies in Guide ~~D5730~~D6286~~.~~ and it addresses ability to use these samplers.

1.3 Refer to Practice D6640 and Guide D4547 for handling of samples for environmental investigations. Practices D4220/D4220M and D5079 are used for preserving and transporting soil and rock samples.

1.4 This guide does not address selection of sampling devices for hand-held soil sampling ~~equipment,~~ equipment (Guide D4700) and soil sample collection with solid-stem augering ~~devices,~~ devices (Practice D1452/D1452M), or collection of grab samples or hand-carved block samples (D7015/D7015M) from accessible excavations. Refer to ~~Appendix~~ X1.2 for ~~guidance on these topics. This guide should be used in conjunction with Guide~~ additional guidance on use of soil ~~D4700 when thin-walled, split barrel, ring-lined barrel and piston samplers with solid- and hollow-stem augers are used in the unsaturated zone.~~and rock sampling devices for both environmental and geotechnical applications.

1.5 This guide does not address devices for collecting cores from submerged sediments or other sampling devices for solid wastes. Refer to ~~Guide~~Guides D4823 ~~for guidance~~and D6232 ~~on~~for these ~~topics.~~materials.

1.6 The values stated in either SI units or inch-pound units are to be regarded separately as standard. The values stated in each system ~~are~~may not ~~necessarily~~be exact equivalents; therefore, ~~to ensure conformance with the standard,~~ each system shall be used independently of the ~~other, and~~other. Combining values from the two systems ~~shall not be combined.~~may result in non-conformance with the standard.

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

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***A Summary of Changes section appears at the end of this standard**

~~*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.*~~

1.7 *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 judgment. The word "Standard" in the title of this document means that the document has been approved through the ASTM consensus process.*

1.8 *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, health, and environmental practices and determine the applicability of regulatory limitations prior to use.*

1.9 *This international standard was developed in accordance with internationally recognized principles on standardization established in the Decision on Principles for the Development of International Standards, Guides and Recommendations issued by the World Trade Organization Technical Barriers to Trade (TBT) Committee.*

2. Referenced Documents

2.1 *ASTM Standards:*[2]

D420 Guide for Site Characterization for Engineering Design and Construction Purposes
D653 Terminology Relating to Soil, Rock, and Contained Fluids
~~D1452~~D1452/D1452M Practice for Soil Exploration and Sampling by Auger Borings
~~D1586~~D1586/D1586M Test Method for Standard Penetration Test (SPT) and Split-Barrel Sampling of Soils
~~D1587~~D1587/D1587M Practice for Thin-Walled Tube Sampling of Fine-Grained Soils for Geotechnical Purposes
D2113 Practice for Rock Core Drilling and Sampling of Rock for Site Exploration
~~D3550~~D3550/D3550M 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
D3740 Practice for Minimum Requirements for Agencies Engaged in Testing and/or Inspection of Soil and Rock as Used in Engineering Design and Construction
~~D4220~~D4220/D4220M Practices for Preserving and Transporting Soil Samples
D4452 Practice for X-Ray Radiography of Soil Samples
D4547 Guide for Sampling Waste and Soils for Volatile Organic Compounds
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 (Withdrawn 2017)[3]
D5084 Test Methods for Measurement of Hydraulic Conductivity of Saturated Porous Materials Using a Flexible Wall Permeameter
D5088 Practice for Decontamination of Field Equipment Used at Waste Sites
~~D5434~~D5608 ~~Guide~~Practices for ~~Field Logging of Subsurface Explorations of Soil and Rock~~Decontamination of Sampling and Non Sample Contacting Equipment Used at Low Level Radioactive Waste Sites ~~(Withdrawn 2021)~~
D5730 Guide for Site Characterization for Environmental Purposes With Emphasis on Soil, Rock, the Vadose Zone and Groundwater (Withdrawn 2013)[3]
~~D5781~~D5778 ~~Guide for Use of Dual-Wall Reverse-Circulation Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water Quality Monitoring Devices~~Test Method for Electronic Friction Cone and Piezocone Penetration Testing of Soils
~~D5782~~D6001/D6001M Guide for ~~Use of Direct Air-Rotary Drilling for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices~~Direct-Push Groundwater Sampling for Environmental Site Characterization
~~D5783~~D6151/D6151M ~~Guide for Use of Direct Rotary Drilling with Water-Based Drilling Fluid for Geoenvironmental Exploration and the Installation of Subsurface Water-Quality Monitoring Devices~~Practice for Using Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling
~~D5784~~D6232 Guide for ~~Use~~Selection of ~~Hollow-Stem Augers for Geoenvironmental Exploration and the Installation of Subsurface Water Quality Monitoring Devices~~Sampling Equipment for Waste and Contaminated Media Data Collection Activities
D6282 Guide for Direct Push Soil Sampling for Environmental Site Characterizations
~~D5872~~D6286 Guide for ~~Use of Casing Advancement Drilling Methods for Geoenvironmental Exploration and Installation of Subsurface Water Quality Monitoring Devices~~Selection of Drilling and Direct Push Methods for Geotechnical and

[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.

Environmental Subsurface Site Characterization

~~D5875~~D6519 ~~Guide for Use of Cable-Tool Drilling and Sampling Methods for Geoenvironmental Exploration and Installation of Subsurface Water-Quality Monitoring Devices~~Practice for Sampling of Soil Using the Hydraulically Operated Stationary Piston Sampler

D6640 Practice for Collection and Handling of Soils Obtained in Core Barrel Samplers for Environmental Investigations

~~D5876~~D6914/D6914M ~~Guide for Use of Direct Rotary Wireline Casing Advancement Drilling Methods for Geoenvironmental Exploration and~~ Practice for Sonic Drilling for Site Characterization and the Installation of Subsurface ~~Water-Quality~~ Monitoring Devices

~~D5911~~D7015/D7015M ~~Practice for Minimum Set of Data Elements to Identify a Soil Sampling Site~~Practices for Obtaining Intact Block (Cubical and Cylindrical) Samples of Soils

~~D6151~~D8170 ~~Practice~~Guide for Using ~~Hollow-Stem Augers for Geotechnical Exploration and Soil Sampling~~Disposable Handheld Soil Core Samplers for the Collection and Storage of Soil for Volatile Organic Analysis

3. Terminology

~~3.1 *Definitions*—For definitions of general technical terms used within this guide, refer to Terminology D653.~~

3.1 *Definitions:*

3.1.1 For definitions of general technical terms used within this standard, refer to Terminology D653.

3.1.2 *intact, adj—in soil and rock*, material obtained by a process following the state of practice (or standard of care) intended to preserve in-situ structure, water content, density, and other properties to a level consistent with the intended purpose for testing.

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 intact 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 (3.2.15) will generally provide chemically intact samples. Nonrepresentative samples may also be chemically intact, 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 intact samples as discussed in 6.4 and ~~6.10~~6.4.3. Physically intact samples (3.2.13) will generally provide chemically intact 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 D1587/D1587M, Hvorslev (**1**~~)~~),[4] and Paikowsky et al. (**2**) for appropriate formulas for calculating ~~wall~~clearance 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 *direct push ~~sampling system—~~(DP) method, v—*~~for the purposes of this guide,~~a subsurface ~~sampling system using samplers generally 50 mm [2 in.] 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~~investigation method by which drive rod, casing tube, sampling, and logging devices are pushed, driven, or vibrated into soils or unconsolidated formations to be sampled or logged without rotary drilling and removal of cuttings (D6001/D6001M, D6286~~truck, van, all-terrain vehicle (ATV), trailer, skid, or drill rig.~~).

3.2.5.1 *Discussion*—

For the purposes of this guide, a subsurface investigation method that uses hand-held percussion driving devices, or hydraulic percussion, quasi static push, or vibratory drive systems that are mounted to a truck, van, all-terrain vehicle, trailer, skid, or drill rig.

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

3.2.6 *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 50 mm [2 in.] using rotary, drive, push, or vibratory advancement methods.

~~3.2.7 *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.~~

3.2.7 ~~*group*~~*Group A*—samples for which only general visual identification or profile logging is necessary (see ~~Practices~~Practice ~~D4220~~D4220/D4220M).

3.2.8 ~~*group*~~*Group B*—samples for which only water ~~content and classification tests, optimum dry density or 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~~content, classification tests, compaction, and/or bulk samples for laboratory prepared test specimens is required (see Practice ~~D4220~~D4220/D4220M).

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

3.2.9 ~~*group*~~*Group C*—intact, natural formed or field fabricated, samples for density determination; or for swell pressure, percent swell, consolidation, ~~permeability testing~~hydraulic conductivity, and shear testing with or without stress-strain and volume change measurements, to include dynamic and cyclic testing (see ~~Practices~~Practice ~~D4220~~D4220/D4220M).

3.2.9.1 *Discussion*—

Group C samples are physically intact samples used primarily for geotechnical engineering properties tests. Some of these tests, such as bulk density and permeability are useful for environmental investigations. Additional physical and hydrologic properties that require Group C type samples are identified in Table 1.

3.2.10 ~~*group*~~*Group D*—samples that are fragile or highly sensitive for which tests in Group C are required (see Practices ~~D4220~~D4220/D4220M).

~~3.2.12 *intact 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 intact sample* and *physically intact sample*.)~~

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

3.2.12 *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)**.

3.2.13 *physically intact 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.

3.2.13.1 *Discussion*—

Group C and D core samples are physically intact. Generally, collection of intact samples may 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.

3.2.14 *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.)

3.2.15 *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~~non-sensitive chemical constituents, and lithologic logging. (See discussion in 6.3.) **Adapted from U.S. Geological Survey, 1980 (3)**

3.2.15.1 *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 necessarly

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

Tests to be Performed	Physically Intact	Chemically Intact	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]~~			
Non-sensitive 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~~	~~. . .~~
Volatile and Semi-volatile Organics	. . .	X	. . .
Nitrogen- and Sulfur-Containing Species	. . .	X	. . .
Redox-Sensitive Species (As, Cr, Fe, Mn, Se)	. . .	X	. . .
Other Sensitive Inorganics (Hg, cyanides)	. . .	X	. . .
Per-Polyfluoroalkyl Substances (PFAS, PFOS,PFOA)	. . .	. . . X	. . .

[A] Physically intact 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,~~compatibility, sample collection, handling and transport required to obtain chemically intact samples.

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.

3.2.16 *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.)

3.2.17 *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.

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

3.2.18.1 *Discussion*—
Generally, samplers with a wall area ratio greater than ~~15 %~~ 15 percent (see ~~Table 2~~6.2.2 for additional specifications). Typical thick wall samplers are found in Test Method ~~D1586~~D1586/D1586M and Practice ~~D3550~~D3550/D3550M. (See 7.3.)

3.2.19 *thin-wall sampler*—a sampler that meets the specifications in Practice ~~D1587~~D1587/D1587M. (See 7.4.)

TABLE 2 General Sampler Specifications Defining Intact Samples ~~For~~for Group C and D Samples[A]

Sampler Characteristics	Intact (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 (4)~~
Clearance ratio (inside)			Shuter and Teasdale (**5**)
~~Nonplastic soils~~	~~0.5 to 1 %~~	~~NA~~	~~and Practice D1587.~~
Nonplastic soils	0.5 to 1 %	NA	and Practice D1587/D1587M.
Intermediate plasticity	1 to 2 %	NA	See also Table 7.
~~Plastic soils (clays)~~	~~2 to 3 %~~	~~NA~~	
Plastic soils (clays)	0 to 3 %	NA	
~~Length~~			~~Practice D1587~~
Length			Practice D1587/D1587M
Sands	< 10 diameters	> 10 diameters	
Clays	< 15 diameters	> 15 diameters	
~~Diameter~~			~~Shuter and Teasdale (4)~~
Diameter			Shuter and Teasdale (**5**)
~~Compressible soils~~	~~> 76.2 mm [3 in.]~~	~~< 76.2 mm [3 in.]~~	
Compressible soils	> 75 mm [3 in.]	< 75 mm [3 in.]	
~~Less compressible soils~~	~~> 50.8 mm[D] [2 in.]~~	~~< 50.8 mm[D] [2 in.]~~	
Less compressible soils	> 50 mm[D] [2 in.]	< 50 mm[D] [2 in.]	

[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 intact samples of all soil materials. For denser soils, Pitcher (see ~~7.7.2~~7.6.1) or Denison samplers (see ~~7.7.3~~7.6.2) may be required.
[C] Samples collected with thick-wall samplers may qualify as ~~intact~~representative samples for the purpose of description of in situ morphologic properties ~~provided that visual indicators discussed~~and for the purpose of ~~6.2 indicate minimal disturbance (see~~chemical characterization. Thick-walled samplers equipped ~~Table 3), and for the purpose of chemical characterization.~~with thin sharp cutting shoes extensions can be designed to acquire intact samples (6.2).
[D] ~~50.8~~ 50 mm [2-in.] samples for Group C samples for engineering tests are not recommended.

3.2.20 *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.

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

3.2.21.1 *Discussion*—
Refer to D1587/D1587M, Hvorslev (**1**) and Paikowsky et al. (**2**) for appropriate formulas for calculating wall area ratio.

3.2.22 *wireline core sampling*—a sampling process in which rotating or pushed core samplers are raised and lowered inside 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~~ investigation for geotechnical and environmental purposes. ~~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~~professional experience 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~~Guide D6286 on drilling methods and sampling equipment, and diamond drilling Guide D2113. Drilling and ~~D6151 and drilling method-specific guides (see Guides~~sampler specific practices and guides listed throughout ~~D5781,~~this ~~D5782,~~guide ~~D5783,~~are ~~D5784,~~used ~~D5872, D5875 and D5876)~~ as part of developing a detailed site investigation and sampling ~~plan (see 5.1.5 of Guide~~plan. The sampling plan should start with development of a ~~D5730) for sites that require mobilization of a drill rig for~~site conceptual model and phased investigations to locate sampling sites (D420, D6286~~subsurface investigations.~~). The selection of ~~drilling methods~~sampling equipment 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~~sampling equipment may influence choice of sampling devices.

4.3 This guide Samples should be usedhandled in conjunctionaccordance with Guide D5434 for field logging of soil and rock samples, Practice D5911D4220/D4220M for data elements to identify a soil sampling site, and where appropriate, Practice D4220, for preserving and transporting soil samples, Practice D5079 for preserving and transporting rock core samples, samples for geotechnical purposes. For environmental work sample handling procedures should be in accordance with Practice D6640 for collection and handling of soils obtained in core barrel samplers for environmental investigations, Practice D3694 for preparation of sample containers and for preservation of organic constituents, and Practice D5088 for decontamination of field equipment used at waste sites.

NOTE 1—The quality of the result produced by this standard is dependent on the competence of the personnel performing it, and the suitability of the equipment and facilities used. Agencies that meet the criteria of Practice D3740 are generally considered capable of competent and objective testing/sampling/inspection/etc. Users of this standard are cautioned that compliance with Practice D3740 does not in itself assure reliable results. Reliable results depend on many factors; Practice D3740 provides a means of evaluating some of those factors.

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, purposes: testing of engineering and hydraulic properties on intact samples, measurement of in situ chemical and biological characteristics, and identification and classification 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 ofproperties and are only useful to get basic information on geologic and hydrogeologic properties of the subsurface.

5.2 *Laboratory Testing for Engineering and Hydraulic Properties Intact Samples*—In Situ Physical and Hydraulic Properties-Laboratory —Laboratory measurements of physical properties, such as bulk density, porosity, shear strength, consolidation of clays, hydraulic conductivity, and thin-section analysis of sediments, and hydraulic properties, such as specific yield and hydraulic conductivity sediments require intact cores that retain the in situ properties of the sample. Bulk density and porosity are the parameters requiring intact samples that are most significant in environmental investigations because of their significance in vadose zone and groundwater modeling.Intact samples should best preserve bulk density and porosity, which is important for both geotechnical and environmental purposes. Hydraulic properties of permeable materials are generally best measured using in situ aquifer tests (see Table A1.1 of Guide D5730, for list of ASTM standards on aquifer tests), but collection of intact samples for laboratory permeameter tests may provide useful information on vertical changes in hydraulic properties. properties depending on the preservation and transport of the intact sample prior to testing. Impermeable materials, such as clays, are generally best measured in the laboratory using intact 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 affect the field permeability of a material. Section 6.1 discusses criteria for evaluating degree of sample disturbance. Table 1 lists parameters that require intact samples.

5.3 *Chemical and Biological Characteristics for Groundwater Quality Evaluations*—Chemical and Biological Characteristic-sSamples —Samples for measurement of stable chemical constituents generally do not require physically intact samples, but do require representative samples. discrete representative samples that are not subjected to cross contamination. Samples for measurement of sensitive chemical constituents, such as volatile organic compounds, require physically intact samples thatcompounds require special handling procedures (D6640 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 borehole groundwater or 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 such as dual tube direct push or sonic drilling 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 6.106.4.3). Intact 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 Classification, Lithology, and Hydrogeologic Properties*—Geologic and Hydrogeologic PropertiesSamples

~~—Samples~~ for geologic properties, such as lithology, stratigraphy, and structure should generally be ~~representative, but~~ representative. There are many drilling methods that can continuously sample formations with disturbed but representative samples and these are preferred for the best information on the subsurface materials. With some drilling methods that do not produce cores, 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). ~~Intact samples are required for adequate characterization of fractures in dense unconsolidated material and rock.~~ The quality of definition of ~~hydrogeologic~~geologic units will be a function of the quality of lithologic, stratigraphic, and structural interpretations from sampling and 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—*~~Sample Physical Disturbance~~The ~~—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 intact 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~~measured by laboratory tests. Geotechnical engineers need intact samples on large projects where the compressibility and shear strength must be determined in laboratory tests. Geotechnical engineers often use thick wall drive samplers for additional penetration resistance data and to obtain representative samples on most all projects. Environmental engineers dealing with subsurface contamination are primarily concerned with hydraulic properties that are best measured by field tests (see 5.2). ~~However, the~~ The degree of disturbance also affects the quality of borehole log descriptions and subsequent ~~interpretations.~~ interpretations derived from laboratory and/or field testing. Disturbed soil cores allow logging of primarily textural and density/consistency changes. Intact soil cores allow description of soil morphologic features that are valuable for developing interpretations concerning the potential for contaminant movement in the subsurface (**~~5~~4**). Collection of oriented intact rock cores allow assessment of fracture location and orientation in the subsurface (see 7.9.4).

6.2.1 *Discussion of Physically Intact—*~~Definition of Physically Intact~~There is no such~~—The use of the term "intact" to describe a soil or rock sample always has to be qualified~~ thing as an "undisturbed sample 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. ~~Samples collected~~ Committee D18 has adopted the term *intact sample* (3.1.2~~using a thin-wall sampler provide the least disturbed core samples in soft soils, yet~~) to designate that the sample is taken with traditional/industry standard samplers using a good, accepted practice for standard of care. Intact samplers are usually thin wall tubes or large diameter soil core samplers. Practice ~~D1587~~D1587/D1587M ~~uses the term "relatively intact"~~ on the thin wall tube has an extensive discussion of evaluation of the sample quality. By evaluation recompression behavior in laboratory consolidation tests of clays, sample quality can be evaluated, and quality classifications have been proposed (D1587/D1587M~~to characterize samples taken with a thin-wall tube sample.~~ , Appendix). Geotechnical engineers recognize that in clean, drained, sands it is difficult to obtain a suitable and Intact sample by insertion of thin wall tube alone, which leads to reliance on penetration resistance data such as D1586/D1586M or other insitu tests such as the cone penetrometer (D5778). In the past, the only intact sampling of clean sands was possible by expensive insitu freezing followed by soil coring but there are new polymer gel injection samplers (see 7.5.1 and 7.9.2.1) that are being used. The factors that affect physical sample disturbance are numerous and complex enough that professional judgment is still required to determine whether a sample is physically ~~intact. Framing that determination in the context of the objective of the sample (see~~ intact for the intended proposed use of the sample.~~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 2—Reference (**3**) defines intact 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. (**6**) 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. (**7**) define intact samples as "very high quality samples taken under strictly controlled conditions in order to minimize structural disturbance of the sample". The definition of intact 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 *Effects of Sampling Device on Degree of Physical Disturbance—*~~Affect of Sampling Device on Degree of Physical Disturbance~~The ~~—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. Thin wall push samplers and piston samplers with thin-walled tubes are used for intact sampling. Thick wall push or drive samplers cannot provide intact samples unless the used specialized thin wall cutting shoe designs (7.4.2.4). Larger Diameter samplers provide better intact samples as discussed in the thin wall standard Practice D1587/D1587M~~The~~ where 125 mm [5-in.] samplers are preferred to the smaller minimum diameter of 75 mm [3 in.] sample tubes. In the thin wall standard 125 mm [5-in.] samplers can obtain longer samples. The sample diameter rule applies to other samplers with diameters of 100 to 150 mm [4 to 6 in.] are preferred. 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 as the Denison sampler (see 7.6.2), or vibratory/sonic sampling methods (see 7.2.4 and 7.3.3) may be required to collect intact samples in firm to stiff cohesive soils and dense sands. In extreme cases, such as critical liquefaction studies in clean sands, intact cores can be obtained by freezing or injection of stabilizers using rotary soil core barrels (7.9.2). 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 (**~~4~~5**) and most of the geotechnical references **(6 and 7)** identified in the appendix provide further discussion of considerations and techniques for collecting intact cores.

6.2.3 *Criteria for Evaluating Degree of Physical Disturbance in Push and Drive Samples—*~~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 intact for Group C and D samples as defined in Practice ~~D4220~~D4220/D4220M. Although the definition of these groups has a primarily geotechnical focus, intact samples for hydrogeologic analysis and testing have the same requirements (Refer to Shuter and Teasdale (**~~4~~5**) for a detailed discussion of requirements for intact soil samples for hydrogeologic analysis and testing). ~~Group~~Groups 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 Intact Soil Samples—Environmental Investigations—*~~When to Collect Physically Intact Soil Samples~~Intact ~~—Intact~~ 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 intact samples should be based on a judgment that the added information obtained from intact 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 intact samples ~~(Group~~(Groups 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).

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

Indicator	Intact/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) ~~impact (driven samples only)~~	Absent	Weakly to strongly evident
~~Practice D1586 blow count (*N*)[C]~~	~~*N* <20~~	~~*N* >20~~
Practice D1586/D1586M blow count (*N*)	*N* <30	*N* >30
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 ~~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~~
Drilling fluid	Not used, or not visible	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 50.8-mm [2-in.] thin-wall sampler will often collapse in soils with *N* values of 30 or greater (**8**).~~

6.3 *Sample Representativeness—*~~Sample Representativeness~~Group B~~—Soil samples~~ soil samples as defined in Practice D4220/D4220M are physically representative of the sampled interval and are primarily used for soil/rock classification and subsurface logging for lithology evaluation. 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.~~Geotechnical engineers often use incremental thick wall drive samplers (D1586/D1586M, D3550/D3550M~~For example, Group B soil samples as defined in Practice~~) with added benefit of using penetration resistance data to ~~D4220 are physically representative, but may not be chemically representative if the sampling technique, sampling device~~ estimate engineering properties. In environmental work, continuous representative sampling using direct push methods (7.3.2), sonic core (7.3.3~~or containers result in~~), or hollow-stem augers (7.6.3 ~~chemical alteration of the sample. Disturbed samples collected using thin-wall and thick-wall samplers usually give representative samples for physical analysis. However, when~~) are used since drilling/sampling methods are preferred since no fluids are used in the drilling process. When drilling methods involve drilling fluids, sample moisture content and chemistry may be altered. Drill cuttings or auger-flight samples are inadequate for most investigations (8.3). 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—*~~Sample Chemical Integrity~~Soil ~~—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 intact or relatively intact samples using stainless steel or brass liners or clear plastic (typically ~~Lexan~~PVC)~~)~~ liners that are immediately sealed for transport or special coring, paring, or ~~subcoring~~sub-coring 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 is that the sampling device and sample handling procedures minimize contact of the sample with the atmosphere and losses or transformation during sample handling, transport, and analysis. Lewis et al. (9) and Turriff and Klopp (10) describe special sampling devices, preservation and handling procedures for minimizing loss of volatile constituents from soil samples. Chapelle (11) and Leach et al. (12) describe procedures and equipment for collecting soil samples that preserve anaerobic, reducing conditions. Some sampler materials or linter materials may be incompatible or possibly interfere with analysis of some chemical parameters. For example, stainless steel samplers or liners generally should not be used when chromium is one of the primary analytes of interest. Also, many plastic liners may absorb some of the volatile organic compounds commonly tested for during environmental investigations, resulting in biased data. Selecting the appropriate sample and liner materials before beginning field work is recommended to prevent down time and possibly the need to resample. Also, failure to follow proper equipment decontamination procedures, such as described in Practice D5088, may result in cross contamination of soil samples.~~

6.4.1 Sampling equipment must be cleaned a decontaminated prior to and in between sampling events. Consult practices D5088 and D5608 for methods to decontaminate sampling equipment and perform in accordance with the site sampling plan. New samplers should be cleaned prior to use to remove any manufacturing chemicals left on the equipment. Sampling equipment may require decontamination when moved between sampling sites and when leaving the project. In hole drill rods, augers, and casings should be decontaminated when removed from the sampling site.

6.4.2 Storage of samples in liners are not recommended and most soil cores require immediate sub-sampling. Procedures for soil core handling for chemical testing are given standard D6640. Sampling for Volatile Organic Compounds (VOC) is addressed in Guide D4547 and often the core may be rapidly sub-sampled on site using other methods such as Guide D8170 or other similar small hand core samplers. Samples for other chemical characterization generally require sub-sampling into glass or plastic jars or vials and preserved with refrigeration. Verify containers and preservation requirements meet the data quality objectives as specified by the lead regulatory agency, in the project work plan, and with the selected analytical laboratory.

6.4.3 *Prevention of Cross Contamination*—Open thin-wall and thick-wall samplers may cause cross-contamination of soil samples by including material from a higher interval. Casing advancement methods (including continuous sampling with a hollow-stem auger, double-tube direct push, or vibratory/sonic drilling), or stable boreholes where the drilling method has a larger diameter than the sampler help minimize cross-contamination of sample from above the water table. Temporary seals for the barrel shoe that are pushed aside when the sampler enters the soil interval being sampled will prevent contact of the inside of the sampler with contaminated soil, soil gas or groundwater as it advances through an open borehole. Piston samplers results in less cross-contamination than open thin-wall and thick-wall samples both above and below a water table. Piston samplers used below the water table in contaminated aquifers should have good seals (O-rings or leather packing) to prevent water from entering the sampler before it is in position. A common problem with soil sampling is groundwater cross contamination below the water table. Most drilling and direct push methods using open boreholes and casing will have standing groundwater below the water table in the borehole that has the potential to cross contaminate subsequent deeper sampling. In cases where there is standing water in the borehole, the sampling procedure should be changed to using sealed sampler like the single tube direct push sampler (D6282) or a sealed piston sampler if cores are adversely affected.

6.4.4 Lewis et al. (**8**) and Turriff and Klopp (**9**) describe special sampling devices, preservation and handling procedures for minimizing loss of volatile constituents from soil samples. Chapelle (**10**) and Leach et al. (**11**) describe procedures and equipment for collecting soil samples that preserve anaerobic, reducing conditions. Some sampler materials or liner materials may be incompatible or possibly interfere with analysis of some chemical parameters. For example, stainless steel samplers or liners generally should not be used when chromium is one of the primary analytes of interest. Selecting the appropriate sample and liner materials before beginning field work.

6.5 *Nature of Geologic Materials*—~~Nature of Geologic Materials~~The ~~—The~~ type of geologic material to be sampled is a primary consideration in selection of sampling devices, and the ease or difficulty in obtaining an intact sample. Table 4 provides some general ratings on suitability of core sampling devices for different geologic materials. In geotechnical investigations soils are often classified as cohesive (clays) and cohesionless (silt, sand, and gravel), with the basic types differentiated based on density or consistency (**~~13~~12**).Table 5 provides criteria used to define density/consistency classes based on *N* values for standard penetration test (see Practice ~~D1586~~D1586/D1586M) and unconfined compressive strength. Saturation increases the difficulty in sampling of all unconsolidated materials, but especially sands. Cohesionless well graded sands and sensitive, soft, low plasticity clays and silts pose the greatest difficulties for collection of intact samples. Where only representative samples are required, retainers (7.9.1) may improve sample recovery, especially in cohesionless soils. If other methods fail in clean sand, ~~vibratory/sonic or freezing followed by~~ freezing or polymer gel injection piston (7.5~~rotary coring may be required~~) and rotary samplers can be used to obtain intact samples of cohesionless sediments (see 7.9.3). In very dense unconsolidated materials (stiff to hard clays, glacial tills), specially designed rotary core samplers such as the Denison and Pitcher sampler, or a large-diameter rotary core may be required (see 7.6).

6.6 *Sampling Equipment Characteristics*—~~Drill Rig Characteristics~~All ~~—All~~ drill rigs and direct push equipment do not have the same ~~capabilities.~~ capabilities (D6286). Site geologic conditions and sampling needs should be well enough defined beforehand that a rig capable of deploying the full range of appropriate sampling and backup tools are selected. Procedures for collecting core samples using some drilling methods such as cable tool and solid stem auger are relatively cumbersome compared to ~~hollow-stem~~

TABLE 4 Suitability of Core Sampling Devices for Different Geologic Materials[A]

NOTE 1—Key: Ratings: E = excellent; G = good; F = fair; P = poor; NA = not applicable. Other: FD = face discharge; RBD = recessed bottom discharge.

Sampler Type	Soil/Unconsolidated Material[B]						Rock[C]	
	Fine-Grained		Coarse, Cohesive		Cohesionless[D]			
	Soft-Stiff	Stiff-Hard	Sand	Gravel	Loose	Dense	Soft	Hard
Drive/Push Samplers								
Thick-Wall	E-G	G-P	E-G	F-P	F-P	G-P	NA	NA
Thin-Wall	E	F-P	G-F	NA	F-P	P	NA	NA
Piston[E]	E	F-P	G-F	NA	E-P	P	NA	NA
Direct Push	F-G	G-F	F-P	NA	F-P	F-G	NA	NA
Sonic Core	G-P	G-E	F-E	G-E	G-F	F-E	G-E	F-G
Rotating Soil Core Samplers								
Hollow-Stem Auger	G-F	E-G	E-G	F-P	F-P	G-P	NA	NA
Pitcher	G-F	E-G	E-G	G-P	G-P	E-P	NA	NA
Denison[F]	G-F	E-G	E-G	G-P	F-P	G-P	NA	NA
Rotating Rock Core Samplers[G]								
Single Tube, FD	NA	NA	NA	NA	NA	NA	F-P	E-P
Double Tube RBD	P	P	NA	F-P[H]	NA	G-P	E	E
Triple Tube	P	P	NA	P	NA	G-P	E	E

[A] Ratings are for general guidance only. Performance of specific sampling devices can vary depending on the type of drill rig, diameter of the sampler and nature of the geologic material.
[B] Refer to Table 5 to density/consistency terminology.
[C] Soft rock includes shales, siltstone, and weakly cemented sandstone. Hard rock includes limestone, dolomite, and most igneous and metamorphic rocks.
[D] Loose cohesionless soils are difficult to recover with most drive/push sampling devices unless retainers are used, especially when saturated. Materials in this category include saturated sensitive clays, silts and sands, sensitive organic silts, soft clays, unsaturated loose sands and silty sands. Very dense soil material is also difficult to penetrate with most drive/push sampling devices. Examples of dense materials would include compact tills and weakly cemented soil/rock.
[E] Numerous types of piston samplers have been developed, but only a few are commercially available; many are effective in sampling saturated, cohesive soils, but have varying effectiveness for sampling cohesionless soils.
[F] Denison sampler ratings are for soil sampling configuration with inner barrel advanced ahead of outer rotating core barrel. In the rock coring configuration ratings are same as for double tube RBD sampler.
[G] Numerous types of single- and double-tube rotating core samplers are available, with specific designs and cutting heads selected based on rock hardness and degree of jointing and fracturing.
[H] Only if gravels are very dense or cemented.

TABLE 5 Soil Terminology Related to Sample Device Selection[A]

Basic Soil Types	Density or Consistency	Range of Standard Penetration Resistance[B]	Range of Unconfined Compressive Strength[C]
Cohesionless	Very loose	Less than 4	Not applicable
	Loose	4 to 10	Not applicable
	Medium dense	10 to 30	Not Applicable
	Dense	30 to 50	Not applicable
	Very dense	Greater than 50	Not Applicable
Cohesive	Very soft	Less than 2	Less than 0.25 kg/cm^2
	Soft	2 to 4	0.25 to 0.5
	Medium stiff	4 to 8	0.5 to 1.0
	Stiff	8 to 15	1.0 to 2.0
	Very stiff	15 to 30	2.0 to 4.0
	Hard	Greater than 30	Greater than 4.0

[A] Source: Adapted from USACE (~~13~~12).
[B] *N* value (numbers of blows to advance standard split barrel 0.3 m [1 ft] using Practice ~~D1586~~D1586/D1586M.
[C] Kg/cm^2 ~~=~~≈ tons/ft^2. Unconfined compressive strength (q_u) may also be approximated using a pocket penetrometer or Torvane shear apparatus.

~~augers~~sonic, direct push, hollow-stem augers, and rotary drilling methods. ~~Hollow-stem augers and~~ Open hole sonic, dual tube direct push, hollow-stem augers, and other rotary drilling methods (with and without casing advancement) are generally flexible in the types of sampling devices that can be ~~used.~~ used as the open hole allows for insertion of different samplers. Where deep holes are to be sampled, wireline sampling capabilities should be considered (see ~~7.2.2~~7.2.5).~~ Most drill rigs with rotary advancement capabilities allow use of rotating core samplers. Triple Tube Core Barrels are similar to a double tube core barrel, but have an additional inner liner consisting of either a clear plastic tube or a thin metal split tube, in which the core is retained. This core barrel best preserves fractured and poor quality rock cores.~~

NOTE 2—Refer to Shuter and Teasdale (~~4~~5) for a description of coring procedures using cable tool and solid stem augers.

6.7 *Sample Continuity*—~~Sample Continuity~~Continuous ~~—Continuous~~ coring provides the highest quality samples for lithologic logging of ~~boreholes, but generally takes more time and consequently is more expensive than intermittent sampling. Hollow stem auger continuous coring systems~~ boreholes. Rapid continuous soil coring is commonly performed with hollow stem augers (see 7.6.3~~)~~)), direct push dual tube (D6282), vibratory/sonic ~~coring,~~drilling and ~~conventional and~~sampling (D6914/D6914M ~~wireline~~). Wireline rock coring systems are ~~commonly~~ used ways for collecting continuous ~~cores. The most appropriate time for collection of continuous cores is often during early stages of environmental investigations, but continuous coring may also be useful when defining the extent and pathways of a contaminant plume.~~ rock cores more rapidly than incremental sampling with conventional core barrels. Intact soil sampling and penetration resistance drive sampling are done incrementally in discrete, targeted zones. Both discrete and continuous sampling may be appropriate in the same borehole. For example, when investigating a ~~contaminant plume downgradient of the source area,~~ deep layer or zone of concern, discrete sampling may be adequate above the ~~zone of contamination, while continuous coring may be desirable through the contaminated~~ zone. If the same cores are used for both logging and testing, the full core should be described first.~~ Most drilling methods provide the option of taking continuous or intermittent core samples. For investigations in relatively shallow unconsolidated material direct push systems allow continuous coring. Conventional single-tube rotary diamond drilling (see Practices D2113, and D6151) and vibratory/sonic coring provide continuous cores in bedrock materials. If continuous cores are desired when using a hollow-stem auger, a continuous barrel sampler that advances with the auger as described in Guide D4700 and Practice D6151 will generally be most efficient. This system essentially functions as a double-tube rotating core sampler with the auger representing the outer tube and is able to collect high quality cores even though the sampler construction does not meet the requirements of a thin-wall sampler. Continuous cores can also be obtained using appropriate rotating core samplers with a rotary drill rig.~~

6.7.1 *Effects of Sampling Intervals*—Unless continuous samples are taken, a thin critical weak layer, confining layer, or other geologic feature may be missed. Geotechnical engineers using thick wall drive samplers, such as the SPT (D1586/D1586M) for blow counts, require some spacing for the next penetration test. The traditional practice of performing SPT at 5 ft intervals or change of materials based on cuttings (8.3) may miss a critical geologic feature. Fig. 1 shows the probability of finding a critical low permeability confining layer of given thickness versus sampling interval. SPTs can be taken at shorter intervals of 2.5 ft spacings allowing 1 ft cleanouts between tests. For environmental sampling it is best to use continuous sampling methods for the best logging which requires detailed evaluation of complex hydro-stratigraphic facies (**13**).

6.8 *Sampler Materials*—~~Sampler Materials~~Soil ~~—Stainless steel is generally the preferred material for sampler construction when sampling for inorganic and organic chemical contaminants, unless liners are used. Other metals may be acceptable for chemical~~

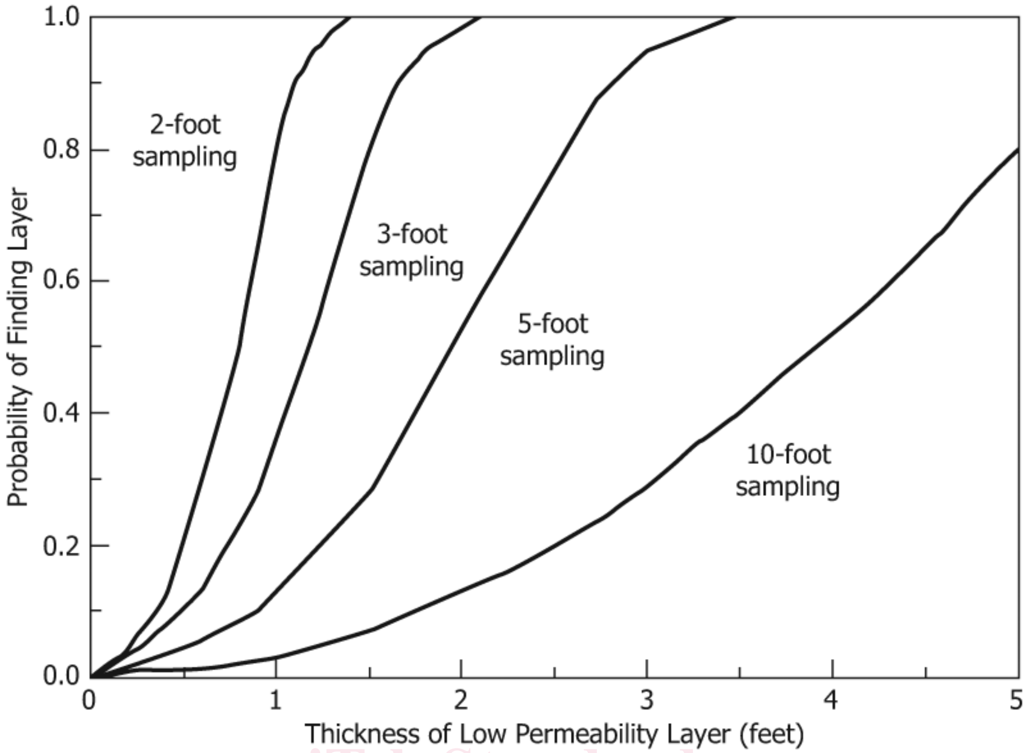

FIG. 1 Sampling at intervals can save money, but the practice creates a risk of missing important geologic units. Continuous sampling is advisable in complex geologic environments (14).

sampling provided that there is no likelihood of chemical interaction between the soil material and the metal that would affect analytes of interest. Use of liners of the appropriate material minimize contact of soil samples with the sampling device (seeand rock samplers are made from steel to withstand driving, push, and rotational forces. Thick wall drive shoes are often hardened by carburization to withstand rugged driving conditions. Rotary core bits use carbide, diamonds, or polycrystalline inserts 6.9.3).for cutting.

6.9 *Liners—*Liners—Liners facilitate sample handling and storage. Key considerations in the selection of liners include type (split or solid) and liner materials. Liners should be cleaned and decontaminated prior to use (6.4.1).

6.9.1 Split liners are recommended for use when logging and sampling for nonsensitive chemical constituents is being done representative sampling logging and sub-sampling in the field. Split liners allow for easy handling and inspection of samples. Most samplers with exception of the thin-wall tube can be designed to accommodate split liners. Direct push samplers using solid plastic liners have special liner splitting tools that rapidly open solid tubes for logging. Split liners are recommended for environmental sampling using Practice D6640 to access the soil sample in the field for chemical sub-sampling activities.

6.9.2 Solid liners are often used when samples must be preserved for later laboratory analysis or stored for later logging. When samples are being preserved for physical testing they should be sealed and stored using methods in Practice D4220D4220/D4220M for shipment to the laboratory. When samples are being collected for environmental chemical analysis they should be preserved, stored, and transported using the procedures appropriate for the analytes of concern. This can be accomplished by following Practice D3694 for preparation of sample containers and for preservation of organic constituents or other appropriate procedures specified by the client or regulatory authority. Examples of samplers with solid liners include ring-lined sampler (see 7.5.17.3.1), pitcher (see 7.6.1), Denison (see 7.6.2), and rock core barrels (see 7.7). A thin-wall tube functions as a liner if the ends are to be sealed for shipment. Sealing of liners should normally be performed by trimming away loose soil and inserting moisture proof plugs or by cutting the liner flush to the soil and capping the ends with moisture-proof material. Liners should be strong enough to support the core during shipment. Liners should be round and matched to the tolerances of the sampler. The best tolerance is achieved when the core fits in the liner without an air gap, but also without excessive core friction. If the core is over cut by a clearance ratio that is too large, oxidation and biological growths may occur with sustained storage.storage even if the ends are sealed since an air gap exists between the core and solid liner inside. It is especially important to use correct clearance ratios for coring, so the soil core fits snugly in the liner with no air gap.