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Division of Drinking and Ground Waters

Technical Guidance Manual for Ground Water Investigations

Chapter 15

Use of Direct Push Technologies for Soil and Ground Water Sampling

Geoprobe® Systems

February 2005

Governor : Ted Strickland
Director : Chris Korleski

TECHNICAL GUIDANCE
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GROUND WATER INVESTIGATIONS

CHAPTER 15

USE OF DIRECT PUSH TECHNOLOGIES FOR SOIL AND GROUND WATER SAMPLING

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PREFACE

This document is part of a series of chapters incorporated in Ohio EPA's *Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring* (TGM), which was originally published in 1995. DDAGW now maintains this technical guidance as a series of chapters rather than as an individual manual. These chapters can be obtained at http://www.epa.state.oh.us/ddagw/tgmweb.aspx.

The TGM identifies technical considerations for performing hydrogeologic investigations and ground water monitoring at potential or known ground water pollution sources. The purpose of the guidance is to enhance consistency within the Agency and inform the regulated community of the Agency's technical recommendations and the basis for them. In Ohio, the authority over pollution sources is shared among various Ohio EPA divisions, including the Emergency and Remedial Response (DERR), Hazardous Waste Management (DHWM), Solid and Infectious Waste (DSIWM), and Surface Water (DSW), as well as other state and local agencies. DDAGW provides technical support to these divisions.

Ohio EPA utilizes *guidance* to aid regulators and the regulated community in meeting laws, rules, regulations, and policy. Guidance outlines recommended practices and explains their rationale. The Agency may not require an entity to follow methods recommended by this or any other guidance document. It may, however, require an entity to demonstrate that an alternate method produces data and information that meet the pertinent requirements. The procedures used usually should be tailored to the specific needs and circumstances of the individual site, project, and applicable regulatory program, and should not comprise a rigid step-by-step approach that is utilized in all situations.

ACKNOWLEDGMENTS

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Primary author: **Sydney Poole,** DDAGW-CO, who had primary responsibility for researching and writing the document.

Additional writing and editing was provided by the members of the Ohio EPA Direct Push Technologies Workgroup. Personnel who contributed to the DPT Workgroup include: **Eric Schultz**, DHWM-CO; **Joe Jellick**, DEFA,-CO (formerly of DERR, CO); **Karl Reinbold**, DERR-CO; **Matt Justice**; DERR-SWDO (formerly of DDAGW, SWDO); and **Erik Hagen**, DHWM-CO.

Editor: **Jeff Patzke**, DDAGW-CO, who served as editor and project coordinator of the Technical Guidance Manual.

The Ohio EPA would also like to thank the numerous people who provided input on the document during its developmental stages. The comments and recommendations of DDAGW-District Offices, and other Ohio EPA Divisions, State and Federal Agencies, private consultants, and regulated community were greatly appreciated.

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USE OF DIRECT PUSH TECHNOLOGIES FOR SOIL AND GROUND WATER SAMPLING

Direct push technology (DPT) devices are investigation tools that drive or push small-diameter rods and tools (typically not exceeding four inches in diameter) into the subsurface by hydraulic or percussive methods. Direct push can be used for a number of applications. Specialized direct push probes may be used to collect *in-situ* geophysical, geochemical, and geotechnical measurements. Applications include soil sampling, ground water sampling, geophysical sensing, geochemical sensing, and soil gas sampling. The purpose of this guidance document is to discuss the applications of direct push to soil and ground water sampling.

DPT tools such as the cone penetrometer have been used for assessing site geology for many years. With the invention of the Hydropunch$^{(TM)}$ in 1988, (Edge and Cordry, 1989) an alternative to monitoring wells for collecting ground water samples was developed. DPT technology became more popular in the 1990's in response to a growing need to assess sites more quickly and cheaply. A growing number of inquiries from the public about DPT during this time prompted Ohio EPA to form a Direct Push Technologies Workgroup in June of 1998 to evaluate DPT as they relate to site characterization.

Depending on site conditions, DPT methods may offer an attractive alternative to traditional sampling methods such as hollow stem augering with split spoon sampling. Advantages include the smaller size of the DPT rigs, which allows for sampling in spaces that would be impossible for larger, conventional hollow stem auger (HSA) rigs; and quicker penetration, allowing for more efficient and economical site characterization. DPT also produces fewer cuttings, and the smaller diameter holes require fewer materials for well installation or probehole sealing. An additional benefit is that a minimal amount of waste material is produced when compared to traditional drilling methods. The speed and mobility advantages of DPT soil sampling may allow a more complete and accurate investigation of site geology. Similarly, when investigating ground water, the speed of investigation and a lack of a need for well materials may allow for a more thorough characterization of the hydrogeology of the site. Purge water disposal volumes are smaller, since the volume of water extracted during well development and purging is much less than it would be for a conventionally installed well due to the smaller radius of disturbed aquifer around the well.

DPT is applicable in unconsolidated sediments. It is most applicable for shallow depths (less than 100 feet), but may be able to go deeper depending on site conditions. Because of the lighter weight and therefore limited downward force, penetration may be difficult in sediments containing a high percentage of gravels and cobbles or in dense, highly compacted sediments (such as overconsolidated till). Alternative drilling methods may be advisable in situations of unfavorable conditions.

This paper addresses the use of DPT in the applications of both stratigraphic investigations and chemical analysis. The primary sources of information for this document include: ASTM Method D6282-98; EPA (1997); ASTM Method D6001-98(2002); ASTM Method D6724-04; ASTM Method D6725-01; and the draft EPA guidance *Groundwater Sampling* *and Monitoring with Direct Push Technologies (draft)*. The knowledge and experience of the DPT Workgroup members are also reflected.

EQUIPMENT FOR ADVANCING DPT RODS

DPT devices may be driven by manual, mechanical, or hydraulic methods, and may be truck-mounted or stand-alone. A DPT tool string includes the sample collection tool and extension rods for advancement and retrieval of the sample tool. There are two types of rod systems: 1) single tube and 2) two tube. Both allow for soil, soil gas, and ground water sampling. Single and two tube systems have overlapping applications and can be used in many of the same environments. However, there are strengths and limitations associated with each that should be considered.

SINGLE TUBE (SINGLE ROD)

Single tube rod systems are the most commonly used. They use a single string of rods to connect the probe or sampling tool to the rig. The rod diameters are smaller than the sampler, typically around one inch, but may range from 0.5 to 2.125 inches. Once a sample has been collected, the entire string must usually be removed from the probe hole. If subsequent sample collection at greater depths is required, the process must be repeated by re-entering with an empty sampler. Figure 15.1 shows a visual representation of this process.

TWO TUBE (CASED, DUAL TUBE)

Two tube rod systems advance two sections: an outer tube, or casing, and a separate inner rod with the sampler attached (Figure 15.2). The outer tube is used for stabilization. The inner tube is used for sampler recovery and insertion. Because two tubes are advanced, outer tube diameters are relatively large, typically 2.4 inches; however, they can range between 1.25 and 4.2 inches. The outer casing and inner extension rod with sampler are advanced simultaneously for the length capacity of the sampler. The sampler is removed from the probehole and a new sample barrel or plug bit is inserted for each increment of depth. Because the hole is cased, continuous sampling is simplified and expedited.

Withdrawing the tool string from the probehole is accomplished by applying a retractive force on the tool string assembly. The drill string can either be withdrawn by direct mechanical pull through use of a hydraulic system, or by line-pull using mechanical or hydraulic powered winches or cathead and rope windlass type devices. The drill string can also be retracted by back-pounding using weights. However, back-pounding can cause disturbances to the sample and should be avoided.

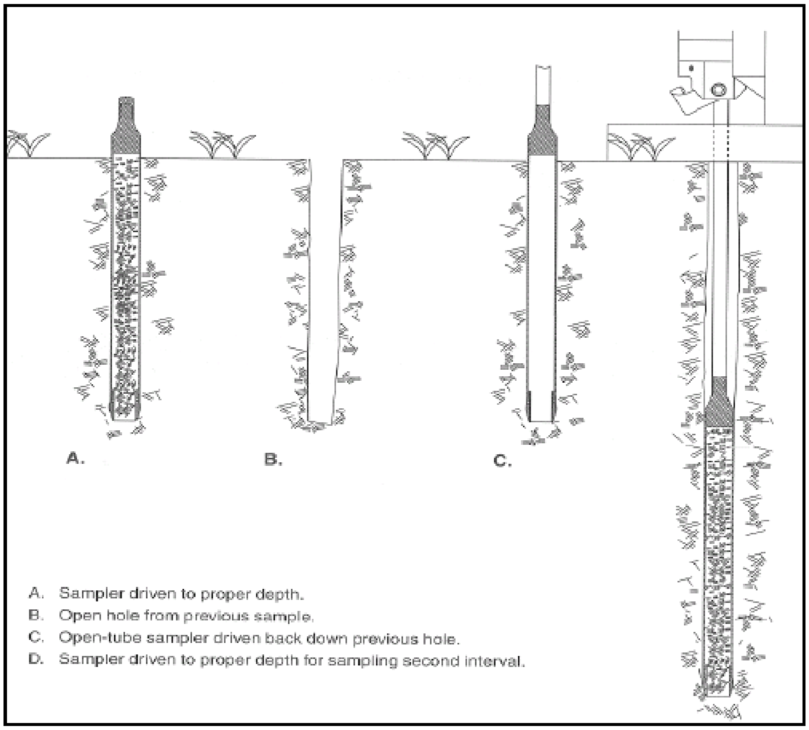

Figure 1: Figure of a typical open ended sampling device used for continuous coring (from Geoprobe® Systems, 1997)

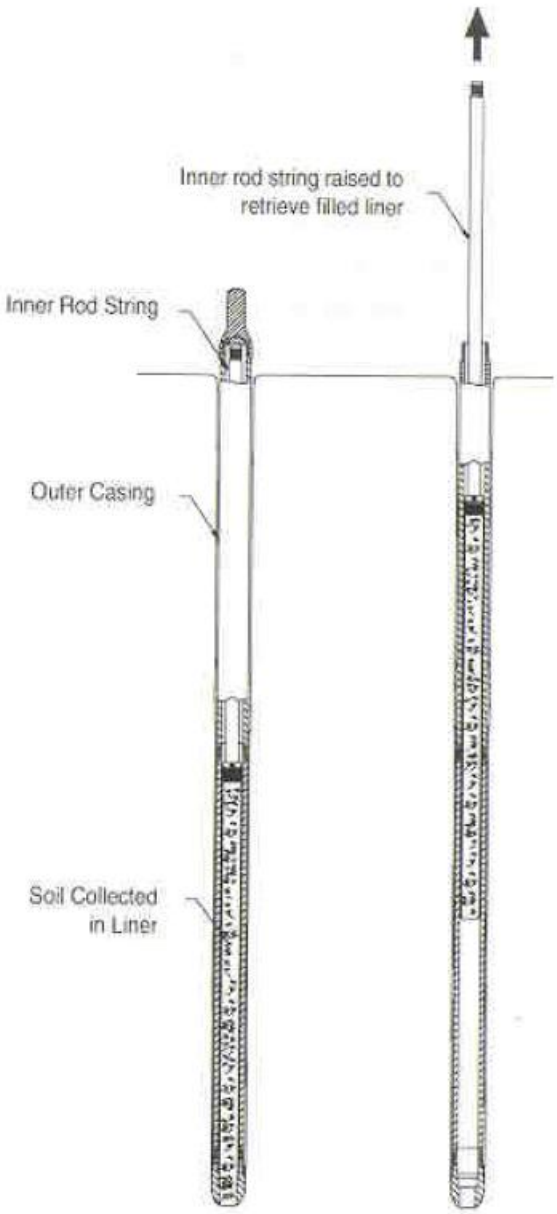

Figure 15.2 A two tube rod system. The outer and inner tube assembly are driven to depth as one unit. Once proper interval is reached, the inner tube and sample are withdrawn (from Geoprobe® Systems, 1997).

SOIL SAMPLING

There are two types of DPT soil samplers: 1) open barrel and 2) closed barrel. Open barrel samplers remain open as they are pushed to the target depth. Closed barrel samplers remain closed until reaching the target depth. The primary sources of information on soil sampling used in this document may be found in ASTM Method D6282-98 and EPA (1997).

OPEN BARREL SAMPLERS

These samplers have an open end allowing material to enter at any time or depth (Figure 15.1). They may also be referred to as unprotected or unsealed samplers. The three most commonly used open barrel samplers are: 1) open solid barrel; 2) split barrel (or split spoon); and 3) thin-walled. Available sampler lengths range from one to five feet. Split barrel and thin-walled samplers are also commonly used with hollow stem augers. They are discussed at greater length in "Drilling and Subsurface Sampling", Chapter 6 of the *Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring* (Ohio EPA, 1995).

Open Solid Barrel Samplers

Open solid barrel samplers consist of a head assembly, a barrel, and a drive shoe. The sampler is attached to the DPT rods at the head assembly. A check valve, which allows air or water to escape as the barrel fills with soil, is located within the head assembly. The check valve improves the amount of soil recovered in each sample by allowing air to escape. With the use of liners, samples can be easily removed for volatile organic compound (VOC) analysis or for observation of soil structure.

Split Barrel Samplers (Split Spoon Samplers)

Split barrel samplers, also often used with hollow stem augers, are similar to open solid barrel samplers except that the barrels are split longitudinally so that the sampler can be easily opened. The primary advantage of split barrel samplers is that they allow direct observation of soil cores without the use of liners and without physically extruding the soil core. As a result, split-barrel samplers are often used for geologic logging. Split barrel samplers, however, may cause more soil compaction than open solid barrel samplers because the tool wall thickness is often greater. Although liners are not compatible with all split barrel samplers, they may be used to reduce the need for decontamination. Additional information on the use of split spoon samplers with hollow stem augers may be found in "Drilling and Subsurface Sampling", Chapter 6 of the *Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring* (Ohio EPA, 1995).

Thin-Walled Tube Samplers (Shelby Tubes)

Thin-walled tube samplers, similar to larger diameter samplers known as Shelby tubes, are used with both DPT and hollow stem augers for collecting undisturbed samples. The sampling tube is typically attached to the sampler head using recessed cap screws or rubber expanding bushings. The sampler walls, made of thin steel with a sharpened cutting edge, minimize soil compaction compared to other types of samplers. Relatively undisturbed samples are required for certain geotechnical analyses such as permeability and triaxial shear tests. More information on the use of thin wall samplers may be found in "Drilling and Subsurface Sampling", Chapter 6 of the *Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring* (Ohio EPA, 1995).

CLOSED BARREL SAMPLERS (PISTON SAMPLERS)

Piston samplers are the only type of closed barrel soil sampler currently available (Figure 15.3). They are similar to open solid barrel samplers, except that the opening is sealed with a rigid, pointed piston that displaces soil as it is advanced. When the sampler has been pushed to the desired depth, the piston is unlocked by releasing a retaining device, and subsequent pushing or driving forces soil into the sampler. The assembly can then be removed and soil extracted. Piston samplers are typically air and water tight; however, if o-ring seals are not maintained, leakage may occur. Piston samplers also have the advantage of increasing the recovery of unconsolidated sediments as a result of the relative vacuum that is created by the movement of the piston.

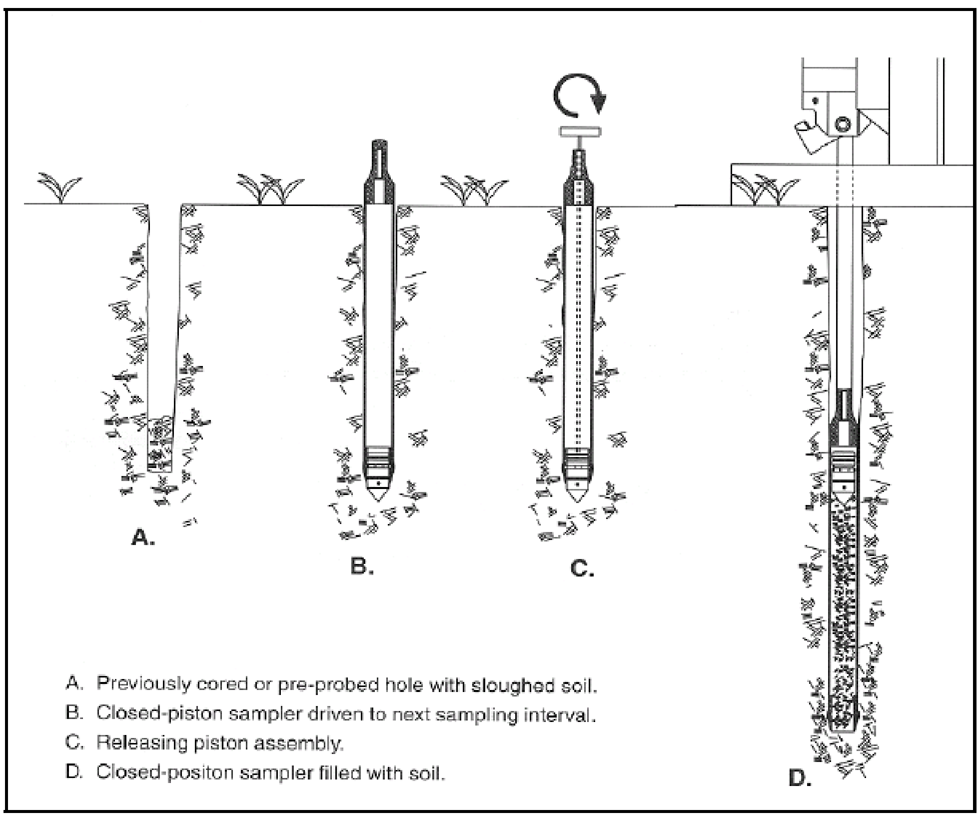

Figure 3: Figure of a typical closed barrel sampling device used for discrete depth sampling (from Geoprobe® Systems, 1997).

SOIL SAMPLING METHOD EVALUATION

DPT offers many advantages for soil sampling, including fast site assessment, rig mobility, and greater efficiency than conventional drilling methods. Use of available sampler lengths of up to five feet can allow for more continuous sampling intervals than are possible with conventional split-spoon samplers. In general, DPT is applicable in unconsolidated sediments that are conducive to withdrawing sufficient soil volume for analysis. A discussion of what should be considered when determining whether to use a single tube or two tube sampler follows. Where sample quality or quantity may not meet sampling objectives, alternatives such as switching to a different sampling method (e.g., hollow stem auger), or a different sampling tool (e.g., a wider diameter sampler) should be employed.

Single Tube Sampling Considerations

Because only one string of rods is used, single tube systems are not as heavy as two tube systems and enable quicker rod connection. Because of the lightweight rod string, situations in which a single sample is desired or with shallow sampling depths can be sampled quickly and easily with few complications.

However, the lack of hole casing can cause some complications when continuous sampling to greater than ten feet is desired. Sampling with single tube rods can be slower because the probe hole may collapse or slough without the stabilization of an outer casing rod. A second drawback of single tube systems is the potential for formation or saturated zone cross contamination during continuous sampling. Because the probe hole is uncased during rod retraction and reinsertion, the open probe hole can serve as a conduit for potentially contaminated soils or ground water from overlying zones that may slough or migrate to otherwise uncontaminated lower zones. Cross contamination is of particular concern if NAPLs (non-aqueous phase liquids) are present that could migrate down the probe hole. Also, when multiple samples are taken, repeated entry can deform or skew the alignment of the probehole. This can create problems when sealing the probehole if a skewed hole prevents complete insertion of a tremie pipe or permits bridging of bentonite pellets or granules.

With no outer casing in place to guard the sampler during rod reinsertion, sample biasing may be exacerbated by probehole collapse, probe hole sloughing, or probe hole smearing. Thus, the sampler may collect soil samples from varying zones as it is advanced to the target depth. If the displaced material is contaminated or contains analytes at levels higher than the target depth, the target sample may be biased high. Conversely, if the collapsed material is cleaner or contains analytes at concentrations lower than the target depth, the target sample may be biased low. In either case, the sample collected is not representative of the target depth.

Depending on site conditions, the collection of undisturbed samples using thin-walled samplers with DPT may or may not be feasible. Typically, DPT rigs are mounted on lighter trucks than HSA rigs, and do not have hydraulic systems that are capable of generating as much downward force as HSA rigs. Consequently, HSA rigs are better equipped to push thin-walled sample tubes over a wider range of soil condition than DPT rigs.

Two Tube Sampling Considerations

The use of the outer casing in a two-tube system has several advantages. Two tube systems are faster than single rod systems for continuous sampling at deeper sampling depths (i.e., depths below ten feet). Because only the inner sample barrel is removed, and not the entire rod string, reaching the target depth is not complicated by probe hole sloughing and collapse. In addition, the outer casing maintains the probe hole's alignment during multiple insertions of the sampling rod. This helps assure a proper grout seal. Because the outer casing is never removed during sampling, the probe hole remains sealed, reducing the potential for sloughing of contaminated soil or migration of contaminated fluids down the hole. The outer casing also protects non-sealed samplers from sample biasing caused by smearing. In addition, the outer casing enables the use of non-sealed samplers for vertical contaminant profiling above the saturated zone.

Use of the outer casing in a two-tube system also has disadvantages. It is heavier, requiring twice as much rod and a heavier rig, thus making it more cumbersome and more expensive to use. The two tube system is also more susceptible to soil friction because of its larger diameter, slowing boring and sampling. An oversized drive shoe is sometimes used to reduce friction and buckling but may increase the risk of contamination migration down the probehole. Even using heavier driving equipment, penetration depths are often not as great as those possible with single rod systems due to the increased friction.

Soil Sampling Recommendations

DPT is appropriate for soil sampling when:

- Its use and methodologies are consistent with the data quality objectives of the sampling program.
- Unconsolidated sediments are to be sampled.
- Materials to be sampled contain a low percentage of gravel and cobbles and are not dense or highly compacted.
- Materials to be sampled are less than 100 feet in depth. DPT may be able to probe deeper in some circumstances.

If using DPT:

- Two tube sampling should be used whenever possible. This is especially important if NAPLs are present, or if there is a potential for sloughing to a lower zone. If a single tube is used for vertical profilers, it is imperative that sealed samplers are used.

- Closed barrel samplers should be used for most applications. The only situation where non-sealed samplers would be acceptable is with single sample collection events above the saturated zone.

- If recovery of samples or cave-in of the probehole is problematic, the data quality objectives should be supplemented or different sampling techniques employed.

- Probeholes should be sealed using retraction grouting with a tremie tube and a liquid slurry material. However, surface pouring may be appropriate for shallow probeholes (less than 10 feet deep) in cohesive formations.

GROUND WATER SAMPLING

There are two common types of ground water sampling equipment used in DPT methods: tools for obtaining one-time grab samples, and wells installed using DPT for short-term or long-term sampling. Most sampling devices used with DPT tools are composed of stainless steel or other inert metals. Well screen materials may be composed of stainless steel, polyvinyl chloride, polyethylene, or polytetrafluoroethylene. The primary sources of information on ground water sampling used in this document are ASTM Method D6001-98(2002), ASTM Method D6724-04, ASTM Method D6725-01 and the draft EPA guidance *Groundwater Sampling and Monitoring with Direct Push Technologies (draft).*

GROUND WATER GRAB SAMPLERS

DPT ground water sampling tools are of three basic types: exposed screen samplers, closed screen samplers, and ground water profilers.

Exposed Screen Samplers

Exposed screen samplers, sometimes referred to as mill-slotted well point samplers, consist of a well screen that allows the influx of ground water and a riser pipe that allows the extraction of a sample. In practice, exposed screen samplers are driven to the approximate sample depth below the ground surface. A ground water sample is taken by extracting water with either a bailer or tubing/pump combination. This necessitates purging and development prior to sampling. A typical exposed screen sampling assembly is shown in Figure 15.4.

Because the exposed screen can be pushed to different depths, exposed point samplers have an advantage in taking multi-level water samples without having to remove the tool string. This can be a significant time saving, especially where three-dimensional plume mapping is a data quality objective.

Exposed screen samplers may have significant disadvantages. Clogging of the well screen can occur when probing through silty or clay-rich soils as well as with ground water high in suspended solids. For this reason, they are commonly used in geologic formations composed of sands and gravels. If soil is contaminated above the saturated zone of interest, draw-down by the tool string and/or sloughing of contaminated soil produce false-positive results. In addition, contaminated ground water trapped in the well point bore can also be drawn from one zone to another, potentially biasing sampling results at the point of interest. The initial ground water withdrawn from the sampler can be turbid because of the disturbance of the formation while using DPT tools. In addition, because of the small screen diameter, development of the formation can be difficult.

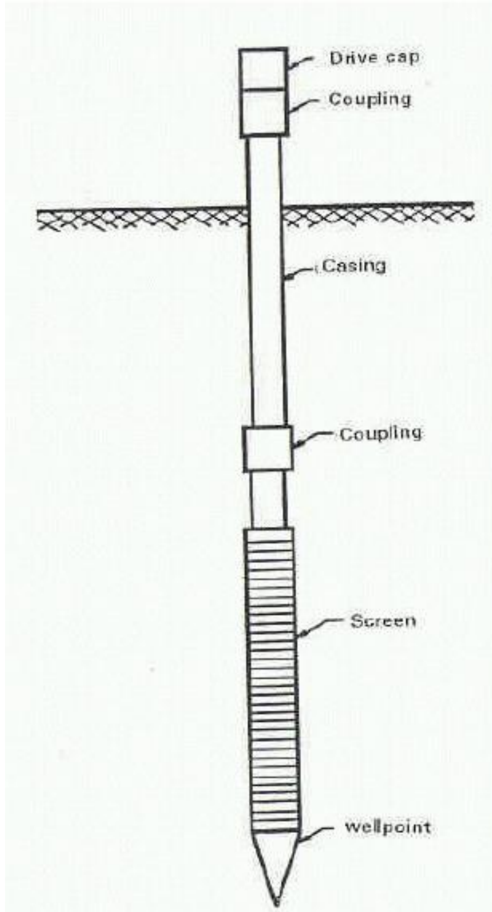

Figure 15.4 Diagram of a typical exposed screen sampler (Source: Aller et al., 1991)

Closed Screen Samplers

Closed screen samplers (Figure 15.5) are protected, sealed sampling devices consisting of a well screen housed within a protective sheath to which are attached an expendable drive point, drive rod(s), and drive head. The assembly is initially driven with the outer casing in place. Rubber O-rings keep the device water tight, eliminating the threat of formation fluids entering the screen before deployment and assuring sample integrity. Once the desired depth is reached, the outer casing is retracted to expose the screen to formation water. After a sample is obtained, the expendable drive point is left in place and the sampling assembly is removed. Screen length can vary from one to five feet.

Since the screen is only exposed after the tool has been placed at the target depth, susceptibility of the screen to clogging is reduced. The O-ring seals make the sampler water tight and reduce the likelihood of cross-contamination. In addition, closed screen samplers can be configured to leave the screen and riser in place as a temporary monitoring device.

Turbid samples may be caused both by the disturbance of the formation while driving DPT tools, and by the high initial entrance velocity of water into the sampler before the water level inside the sampler reaches equilibrium with the formation water. As with exposed screen samplers, development of the formation can be difficult due to the small screen diameter. A problem can also occur if the screen remains within the outer casing when it is retracted, and therefore fails to be exposed to the formation and ground water.

Ground Water Profilers

In situations where discrete vertical profiling is desired, a ground water profiler may be used. The profiler is used to detect vertical variations in contaminant concentrations at a single location. Like an exposed screen sampler, a ground water profiler has sampling portholes or a screen through which samples are taken. The profiler is pushed to the desired sampling depth, and a probe rod is used to knock out the expendable drive point. A sample is taken with a peristaltic or other small diameter pump through a tube positioned within the screened area. Once the sample is taken, the sampler may be advanced to the next sampling depth. To prevent plugging of the screen or sampling portholes, the pumping direction of the pump may be reversed and a small amount of water injected into the screen to maintain a positive pressure on the screen and prevent clogging of the sampling ports. Only clean, potable water of known chemical quality transported from off-site should be used. The pump flow is again reversed once the next sampling depth is reached, and another ground water sample is taken from that depth. Once all samples are taken, the probehole may be sealed by pumping grout through the profiler. Figure 15.6 shows a typical ground water profiler assembly.

Quick, easy vertical contaminant profiling is available with a ground water profiler. Similar to exposed screen samplers, ground water profilers can take multi-level water samples without having to remove the tool string, thus providing a quick and efficient way of obtaining three-dimensional plume mapping. Ground water profilers have an advantage over exposed screen samplers, however, in that pumping water into the sampler can reduce or eliminate soil clogging of the screen.

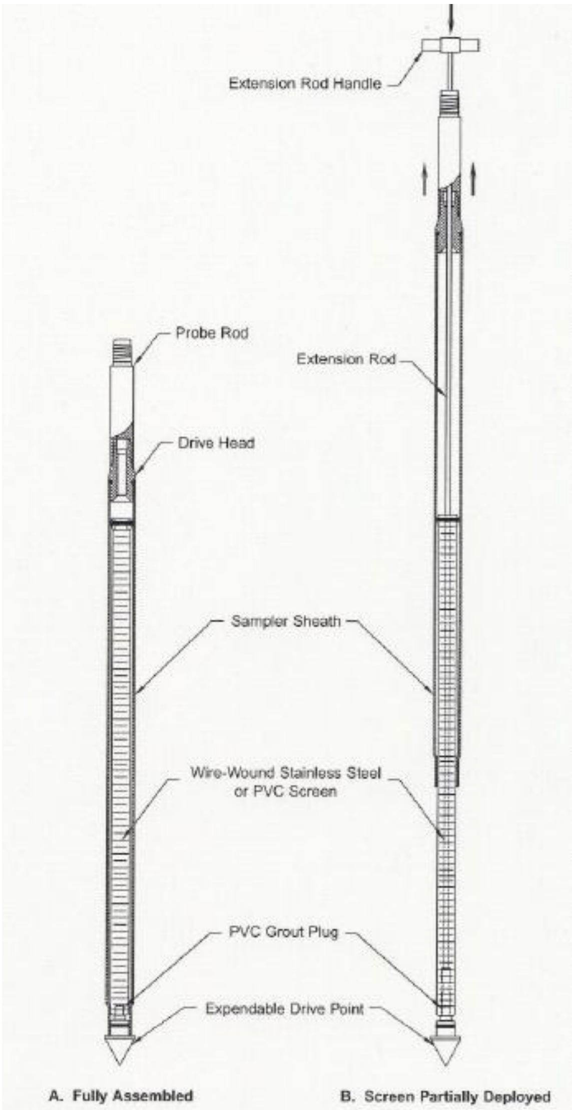

Figure 15.5 Typical closed screen sampler assembly (from Geoprobe® Systems 2001.

Whenever multiple depths are sampled, there is a possibility of drawing contamination to deeper depths that could potentially bias results. While pumping water into the screen during driving may decrease the chances of this happening, the practice can create some problems of its own. Even though the water is pumped into the sampler under low pressure, some water may be introduced into the formation. Alternatively, when the next sample is withdrawn, the clean water may mix with the formation water and cause samples to be biased low. Care should be taken to note the volume of water pumped into the sampler to ensure that the same volume of water is withdrawn. In addition, because of the small diameter and because multiple samples are obtained from one pushing event, it is unlikely that the formation can be sufficiently developed prior to obtaining the sample.

DPT INSTALLED WELLS

DPT used for advancing probe rods can be adapted to install wells for long- and short-term monitoring of ground water. The preferred and most common approach is to push the probe rods or the drive casing to the desired depth with a sacrificial tip. The screen and well casing are usually inserted into the rods or drive casing to the total depth. This protects the screen from becoming plugged with soil and being exposed to any overlying zones of contamination. ASTM (2002) provides additional guidance on DPT well installation.

Conventionally Screened and Packed Wells

The inside diameter of probe rods or temporary drive casings used for DPT well installations range from 1 ½ to 3 ½ inches. Wells can be installed using conventional well casings and screens with inside diameters up to 2 inches, provided the well can be properly packed and sealed. If the screen is installed in non-cohesive formation material, it may collapse around the screen as the rods or outer casing are removed, eliminating the need for placement of the filter pack. If the formation is stable or cohesive soil, filter pack material may be placed around the screen by pouring it into the annular space between the rod or casing string as the sections are pulled from the hole. The well is sealed by pouring granular bentonite into the annular space or pumping a bentonite slurry through tubing that has been run to the top of the filter pack. The well is grouted from the bottom up by pumping a cement-bentonite slurry through the tubing as the outer string and tubing are removed from the hole.

Pre-Packed Screen Wells

Wells can also be installed using pre-packed well screens, which help to eliminate problems with small diameter wells in the placement of filter pack around the screen (Figure 15.7). A pre-packed screen is an assembly consisting of an inner slotted screen surrounded by a wire mesh sleeve that acts as a support for filter media. The pre-packed screen assemblies can either be shipped with filter media already packed within the mesh sleeve or can be shipped without filter media and packed with filter sand in the field. Refer to ASTM D5092-02 for appropriate sizing of filter pack material. The wells are sealed and grouted using same procedure described for conventionally completed DPT wells. ASTM D6725 (2002) provides additional guidance on the use of pre-packed wells.

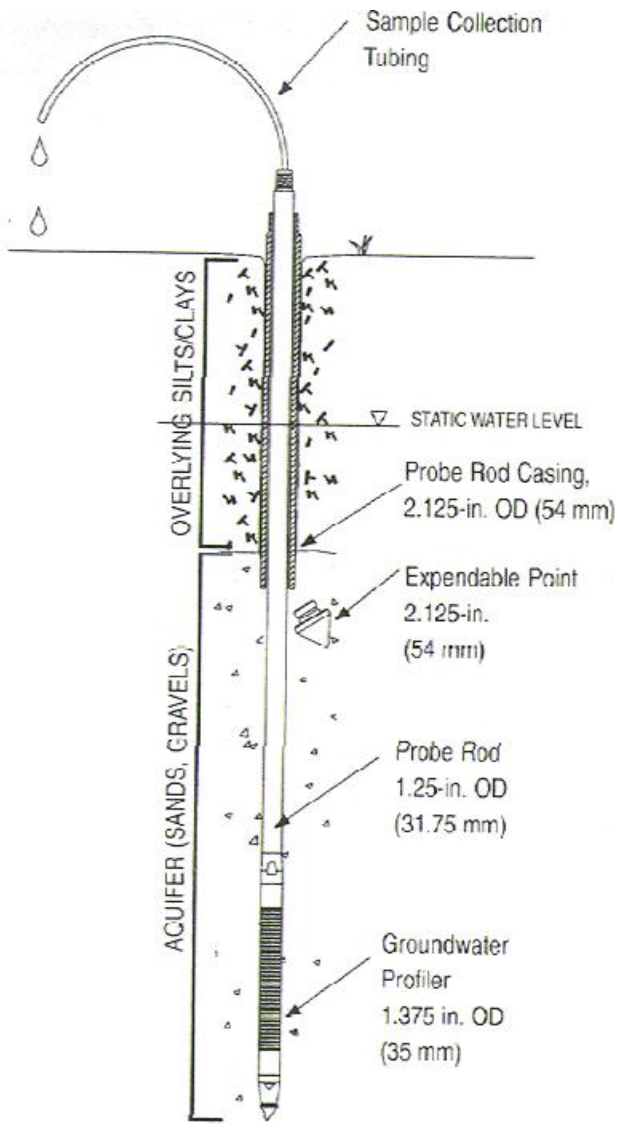

Figure 15.6 Typical ground water profiler assembly from Geoprobe® Systems, 2002).

Development of DPT Wells

Due to the effects of DPT installation on the soils around the well, development of each well is usually needed to ensure sample representativeness. Development of DPT wells helps repair damage done to the formation during the driving of DPT tools, and increases the hydraulic communication between the well and the formation. More information regarding monitoring well development may be found in Chapter 8 of the *Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring* (Ohio EPA, 1995). Due to the small casing diameters, the equipment available to develop small diameter wells is limited to small capacity bailers, inertial pumps, and small diameter bladder pumps. Field parameters, including turbidity and draw down, should be monitored during development to determine when the formation and ground water have stabilized. ASTM D 6725-01 (*Standard Practice for Direct Push Installation of Prepacked Screen Monitoring Wells in Unconsolidated Aquifers*) suggests the use of an inertial lift (or check valve) pump to both surge and purge the formation as an effective method for developing small diameter wells. The downward stroke of the inertial lift pump provides a surging of the water column and loosens the fines in the formation. The following upward stroke of the pump simultaneously removes the loosened fines, preventing them from clogging the screen. However, in finer grained formations, over surging should be avoided to prevent clogging the screen with fines (ASTM D 6725-01). It may be necessary to perform additional purging with a non-surging pumping device to attain lowered turbidity levels for wells installed in fine-grained formations (ASTM D 6724-04).

Probehole and Monitoring Well Sealing

Because any open hole can act as a conduit for contaminants to the subsurface, all probeholes should be appropriately sealed and abandoned. Due to the small diameter of DPT probeholes, sealing the probeholes offers a few special challenges. It is important to select appropriate sealing methods based on the site-specific conditions, such as position relative to the water table, presence or absence of NAPL, or risk of sloughing. An inadequately sealed probehole or monitoring well can create a preferential pathway for the infiltration of contaminants to previously uncontaminated zones. The procedures for borehole sealing in Chapters 9 of the *Technical Guidance Manual for Hydrogeologic Investigations and Ground Water Monitoring* (Ohio EPA, 1995) should be followed for all probehole sealing. Additional information about the methods discussed below may be obtained from U.S. EPA (1997).

Grouting machines are available for use with small diameter wells that allow the operator to properly seal monitoring well installations and seal soil and ground water sample holes. The use of grouting machines reduces problems of grout bridging and incomplete seals associated with adding grouting materials from the ground surface.

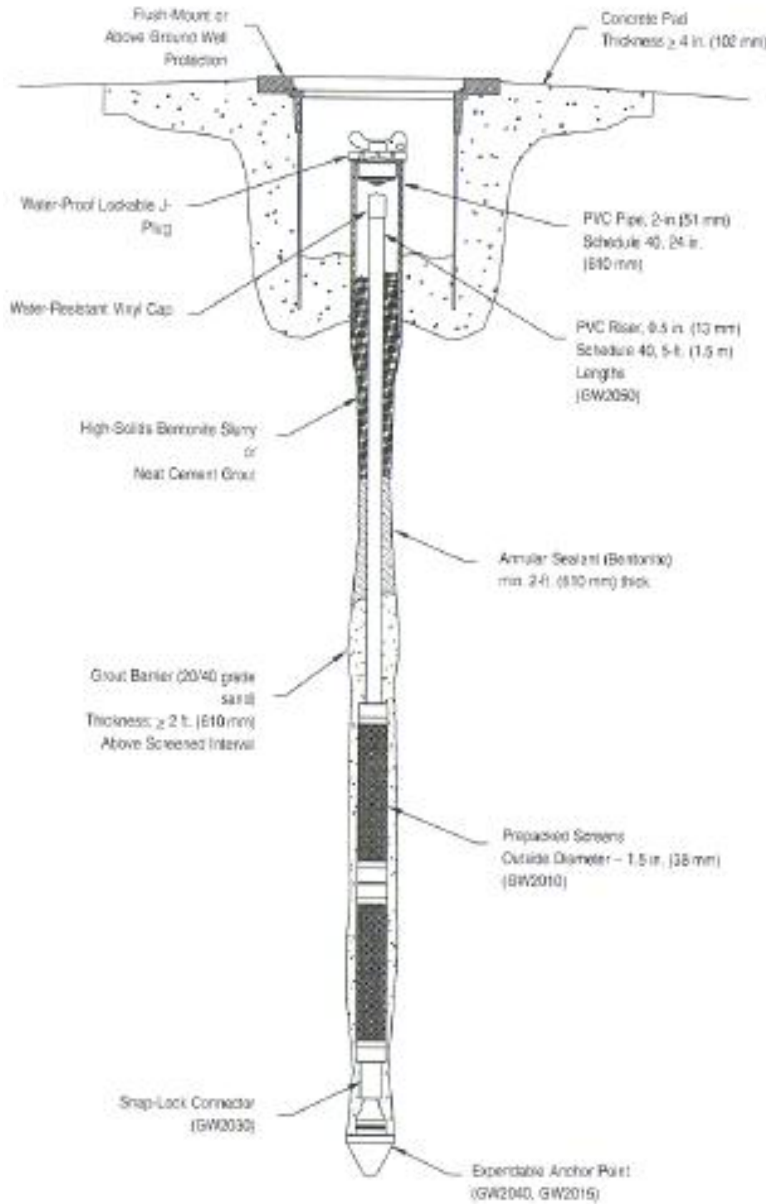

Figure 15.7: Typical pre-packed screen well assembly from Geoprobe® Systems, 2002)

GROUND WATER SAMPLING METHOD EVALUATION

The various types of ground water samplers and wells that are used with DPT are evaluated in the following sections.

Grab Samplers

With respect to site screening investigations in which ground water samples are not being collected for compliance purposes, grab samplers (closed screen, open screen, and ground water profilers) may delineate site-wide hydrogeology more quickly and efficiently than monitoring wells. Because they are easy to use and do not require well materials, grab samplers typically have a significant advantage over traditional monitoring wells as site screening tools. In addition, they often facilitate hydrogeological evaluation and plume mapping, and can be very helpful in optimizing the location and construction of permanent monitoring wells.

Conversely, with respect to obtaining representative ground water samples that generate accurate and verifiable data, the use of grab samplers does present a few challenges. Correct placement of the screened interval is particularly important given the short screen and discrete sampling interval, so that contaminant layers are not missed. The short time frame of many DPT investigations is often insufficient for adequate well development and equilibration with the surrounding formation water. Because there is no filter pack installed around a DPT sampling tool, fines may clog the well screen when sampling in fine-grained formations, preventing ground water from reaching the sampler. Also, the lack of a bentonite seal may allow VOCs to off gas into the atmosphere from the ground water zone if the vadose zone/surficial materials are relatively cohesive and the annular space has not collapsed. Clogging of the screen could cause samples to be biased lower than actual contaminant concentrations. Problems with turbidity may arise due to the inability to adequately develop the sampler. Finally, when sampling objectives include trend analysis and monitoring of remediation efforts as goals, the one-time sampling inherent in samples taken with DPT tools is often not appropriate for these monitoring requirements.

When a closed screen sampling tool is opened for sampling, the entrance velocity of water into the screen can be high due to the hydraulic head of the formation water. This initial high entrance velocity can induce degassing of the sample as well as turbidity. Because of these concerns, significant purging of the sampler and the sampling zone should be performed before sampling to reduce bias. As a general rule, multi-level sampling can be accomplished only with repeated advances of a sealed-screen sampler, especially when using a single-tube rod system. Since the probehole must stay open between advances of the sampler, cross-contamination may be a problem between sampling events. Sealed-screen samplers used within a cased/two-tube rod system can eliminate the problems with cross-contamination when multi-level sampling. However, even when using tools that reduce the potential for cross-contamination, all sampling equipment should be decontaminated between sampling intervals.

Ground water profilers solve the problem of screen clogging by pumping water into the screen during advancement. This makes ground water profilers an ideal choice when screening of vertical contaminant profiles is desired. Additionally, they may be used to pinpoint a location of highest vertical contamination for more precise placement of well screens. However, the addition of water into the subsurface may lead to sample biasing. Care should be taken to ensure that natural formation water is collected when sampling.

Wells

DPT installed wells allow for long-term monitoring of ground water trends, while grab samplers do not. Since they can be installed with filter pack, they allow for more thorough well development and lower sample turbidity than grab samplers. Wells installed using DPT also offer several advantages over wells installed with conventional methods. The speed and mobility of DPT sampling allow a more complete and accurate investigation than would be available with conventional wells. Commercially available screen lengths as short as one foot allow DPT wells to be installed in a vertically precise manner, i.e., avoiding excessive or inadequate screen lengths. Drilling cuttings and purge water volumes are less as a result of the smaller well diameters. Several studies have recently been completed comparing DPT installed wells with conventionally installed wells (U.S. EPA, Technology Innovation Office, Hanscom AFB Comparison Study), (Kram, Lorezana, Michaelsen, Lory, 2001). The studies found no significant difference in the quality of samples taken from DPT wells as compared to conventionally installed wells.

The limitations of DPT installed wells are a consequence of the small diameter of such wells. The inside diameter (ID) of probe rods or temporary drive casing used for DPT wells range from 1½ to 3½ inches. The smaller diameter well diameters limit the choices of purging and sampling equipment. Several types are currently available, including check-valve (inertial lift) pumps, peristaltic pumps, small diameter bladder pumps, and small-diameter electric submersible pumps. New small diameter pumps are continually being developed. In addition, due to the smaller well diameter, a smaller radius of the formation is impacted during well development, potentially resulting in a less well developed well than a larger diameter well. As with all DPT applications, installation of wells with DPT is limited to unconsolidated sediments, and may be limited by depth or the presence of gravels or cobbles. These limitations should be considered in site sampling and analysis plans.

Wells installed with pre-packed well screens allow for more control over placement of the filter pack. Because of the smaller diameter of the probehole with DPT, the annulus around the riser and screen is smaller than with conventional drilling (HSA) methods. This smaller annulus (less than two inches) makes it more difficult to ensure that filter material is placed evenly around the screen when using gravity placement of the filter material. Because of this limitation, bridging of the filter sand can result. Bridging can create voids in the filter pack, leading to turbid samples. In addition, the presence of voids can potentially allow the bentonite seal to be drawn into the screened zone, contaminating the well. Because the filter media is placed around the screen at the surface, pre-packed screens allow more control over the filter pack grain size and eliminate bridging of the filter media. Use of pre-packed screens may make it possible to use finer grain filter pack sand than is used for conventional well filter pack, providing less turbid samples.

APPLICATIONS OF DPT FOR GROUND WATER SAMPLING

Considerations for Use as a Screening Tool

Screening can be defined as a reconnaissance investigation used to identify site-specific matrix types and hydrogeology, determine the presence and the extent of contamination, and select sampling locations for permanent well installation. Screening samples are not intended to meet the same data quality objectives as compliance samples. Because reconnaissance is the purpose for selecting screening samples, data quality objectives may be less stringent than those utilized for other investigations but still satisfy the purpose of defining the extent of contamination and selecting sampling locations for more compliance sampling. Depending on the time frame of the project, screening samples can be either evaluated in the field using a field instrument (e.g., flame ionization device, photoionization device, or portable gas chromatograph), or sent to a laboratory for analysis.

DPT has many advantages that make it ideal for use as a ground water screening tool. Screening applications that DPT would work well for include: detecting the presence of ground water contaminants; assessing the relative concentrations of contaminants; investigating pathway completeness; conducting three-dimensional plume definition; and guiding the installation of monitoring points.

Any type of DPT sampler or well can be used for screening applications, depending on the goals and data objectives that are desired. The limitations of each type should be kept in mind when planning the sampling exercise. The project goals and site conditions will dictate which type is used. Vertical depth sampling is best done using a sealed grab sampler with a two-tube rod system to prevent cross-contamination. A ground water profiler may also be used. If only a single sample is needed, either a closed or open screen sampler is appropriate. The user should be aware of the potential for clogging of the screen when using an open screen sampler. When no analysis of concentration trends over time is needed, grab samplers can be used. If an analysis of COC concentrations over time is desired for site screening, temporary or permanent wells can be installed. All probeholes should be properly sealed when sampling is complete. The preferred method of sealing is using retraction grouting with a tremie tube and a liquid slurry material. However, surface pouring may be appropriate for shallow probeholes (less than 10 feet deep) in cohesive formations.

Considerations for Collection of Compliance Samples

Compliance samples are collected to meet regulatory requirements, which often include standards such as “protective of human health and the environment.” Such standards generally assume quality assurance/quality control (QA/QC) objectives that ensure laboratory results with a high degree of accuracy and precision. Sample collection and analytical techniques used should be recognized as those that produce valid, repeatable, representative data by U.S. EPA, Ohio EPA, and environmental professionals. Definitive samples and their associated laboratory results should meet all required QA/QC criteria, including those for use in risk assessments, and should be scientifically valid, legally defensible, repeatable, and representative of subsurface conditions (Puls and Barcelona, 1996). An example is ground water sampling for hazardous and municipal solid waste landfills as required by the Ohio Administrative Code (OAC) chapters 3745-54-90 through 3745-55-01 and OAC 3745-27-10, respectively.

DPT technology can be used to collect compliance ground water samples if the data quality objectives are met. Since reproducibility is necessary to the proper collection of compliance samples, grab samples representative of a one-time sampling event cannot be reproduced over time and are thus not appropriate for use in compliance sampling. The sample point should be a permanent or temporary well. Samples from properly constructed DPT wells should be equivalent in accuracy to conventional ground water samples. To achieve this equivalency, the well should be properly constructed, sealed, developed, purged, and sampled. Ohio EPA believes that the only way to achieve this level of data quality using DPT is with DPT wells installed using pre-packed well screens. Because the filter media is placed around the screen at the surface, pre-packed screens allow more control over the filter pack grain size and eliminate bridging of the filter media.

Another consideration of using DPT wells as an alternative to conventional monitoring wells for collecting compliance ground water samples is that the yield of DPT wells will be lower due to their smaller diameter (typically 0.5 to <2 inches; conventional well diameters are generally >2 inches). Depending on the sampling technique, more time may be required to extract a relatively large-volume ground water sample from a DPT well than an equivalently-screened conventional monitoring well.

DPT installed wells are not recommended in situations when a well must be installed to monitor a zone of unknown ground water quality that underlies a contaminated zone. A "telescoping" well should be installed to prevent cross-contamination, and the upper water-bearing zone should be drilled, cased, and grouted separately. DPT cannot be used to install a "telescoping" well because the well annulus is too small to allow for sufficient grout sealing (US EPA, 2004).

SPECIALIZED MEASUREMENT AND LOGGING TOOLS

Specialized direct push probes may be used to collect *in-situ* geotechnical, geophysical, and analytical measurements or soil gas samples. A number of tools are available, and more are being developed. The following is a discussion of some of the tools used in conjunction with site characterization and contaminant detection. The tools and technologies noted in this section are used for screening investigations. Because reconnaissance is the purpose for screening applications, data quality objectives may be less stringent than those utilized for other investigations but still satisfy the purpose of defining the extent of contamination and selecting sampling locations for more compliance sampling. To properly interpret the information collected with these instruments, soil and ground water data (e.g., soil type, presence of NAPL, laboratory analysis, etc.) are generally needed for comparison to the instrument response. Data from the analysis of previously collected soil and ground water samples may be used. If such data is not available, a limited number of soil borings will likely be needed to provide soil and ground water data.

Additional information about the technologies discussed in this section, including illustrations, is presented in U.S. EPA (1997), *Direct Push Technologies,* in *Expedited Site Assessment Tools for Underground Storage Tank Sites*; draft EPA guidance *Groundwater Sampling and Monitoring with Direct Push Technologies*; and the Field Analytic Technologies Encyclopedia (FATE). FATE is an online encyclopedia providing information about technologies for field sampling, sensing, and analysis of contaminated media. The web site is provided by the U.S. EPA Office of Superfund Remediation and Technology Innovation (OSRTI) and may be accessed at http://fate.clu-in.org.

GEOTECHNICAL

Cone penetrometer technology (CPT) may be used to quickly and efficiently evaluate soil stratigraphy. CPT characterizes the subsurface lithology by testing the response of the soil to the force of a penetrating cone. Sensors mounted in the tip of the rod send electronic signals to a computer at the ground surface, where the information is processed. CPT cones are pushed rather than vibrated into the subsurface. They may be used either with a CPT rig or in conjunction with a DPT platform that has pushing capabilities.

The most commonly used type of CPT cone is called a three-channel cone. It contains sensors that measure soil resistence on both the end of the cone and the friction sleeve, which is a cylindrical sleeve on the side of the penetrometer tip. The tip resistance to sleeve resistance ratio, called the friction ratio, can be used to estimate the soil type. The resistance data are recorded in real time at the surface to show relative density with depth. A continuous vertical profile of stratigraphy can be inferred from these data through comparison with existing drilling and soil sampling information. ASTM reports that CPT typically reaches depths of 66-130 feet, but can reach as deep as 230 feet when heavier equipment is used. However, the maximum depth of investigation is always dependent on site conditions and the specific drilling, sampling and logging equipment being used.

GEOPHYSICAL

Geophysical logging probes can be used with DPT rods to evaluate subsurface conditions. A limited amount of drilling and soil sampling information in the immediate vicinity of the geophysical logging locations are needed to correlate geophysical responses with known site stratigraphy and subsurface conditions. Two examples of standard geophysical logging tools that may be used with CPT and DPT probes include:

Electrical conductivity (or resistivity) probes are used to evaluated stratigraphy, located ground water zones, and identify the presence of contaminant plumes. Clay layers are more conductive than sand due to the greater number of positively charged ions on the surfaces of clay minerals. Conductivity fluctuations are also affected by soil moisture content and the ionic strength of ground water.

Nuclear logging tools are used to evaluate stratigraphy, ground water conditions, and subsurface contaminant distribution. Two types of nuclear logging tools include: (1) those that measure the natural radioactivity of a formation, and (2) those that emit radiation and measure the corresponding response of the formation. The first type of tool measures gamma radiation emissions from naturally occurring uranium, thorium, and radioactive potassium present within clay minerals, and are useful in distinguishing clay-rich strata from sand-rich strata. The second type of tool exposes the boring walls to a relatively strong radiation source (gamma rays or neutrons), and measures the formation response which depends on its density (or porosity), water content, and the presence or absence of hydrocarbons.

HYDROGEOLOGICAL

A piezocone is similar to a three-channel CPT cone with the addition of a pressure transducer mounted in the cone. Measurements of pore water pressure using a piezocone can determine the depth of the saturated zone and the relative permeability of the saturated sediments. A piezocone can also be used to perform dissipation tests by pausing the downward advancement of the probe to measure the change in pore water pressure over time while the cone is held stationary. Dissipation tests are useful for determining hydraulic conductivity.

ANALYTICAL

A number of chemical sensors can be used in combination with DPT to provide screening level analysis of contaminants at depth.

Induced fluorescence systems use ultraviolet light to induce fluorescence of polynuclear hydrocarbons (PAHs). With ***laser-induced fluorescence (LIF)***, UV light is emitted from a nitrogen laser through a sapphire window into the soil. The UV light induces fluorescence of PAHs. The fluorescence signal is then transmitted to the surface via a fiber-optic cable. The ***fuel fluorescence detector (FFD)***, works in a manner similar to LIF except that a mercury lamp is used as the light source. FFD can be configured to target detection of a number of different hydrocarbon contaminants.

A ***membrane interface probe (MIP)***, also called a semipermeable membrane sensor, heats the soil to promote volatile constituents to diffuse across a thin permeable membrane on the probe's side. Once inside the probe, an inert carrier gas carries the chemicals to the surface where they can be analyzed. The presence or absence of VOCs and their relative distribution can be estimated.

The U.S. Army's ***Site Characterization Analysis Penetrometer System (SCAPS) Hydrosparge*** is similar to the MIP except that the SCAPS Hydrosparge actively purges hydrocarbons from the sample rather than allowing them to diffuse into the sampler. The SCAPS Hydrosparge uses an inert gas to purge VOCs from ground water. The carrier gas then carries the VOCs to the surface for real time analysis. As with data from the MIP, the Hydrosparge detects the presence or absense and relative distribution of VOCs (California EPA, 2000).

The ***thermal desorption VOC sampler*** works similarly to the MIP and Hydrospage samplers. The TDS system employs a special DPT probe that collects a soil sample into a chamber at depth where it is then heated, causing VOCs in the sample to desorb from the soil. A pneumatic system then employs a carrier gas that transports the VOCs to the surface for qualitative analysis.

XRF, or x-ray fluorescence, emits x-rays onto subsurface soils to induce fluorescence of the elements in the subsurface. The elements present in a sample are excited by the x-rays and emit fluorescent x-ray with a characteristic energy signature. The x-rays are then detected in the probe tip.

Explosive Sensor (ES), uses electrochemical sensors to respond to the presence of compounds characteristic of explosives (RDX, TNT, HMX) and their breakdown products. The tool is used along with geophysical sensors to determine soil lithology.

SOIL GAS SAMPLING

Soil gas sampling is used to indicate areas of contamination in the subsurface. Due to the complex partitioning behavior of volatile organic compounds from liquid phases to the soil atmosphere, and transportation of soil gas through the vadose zone (Ullom, 1995), results from soil gas sampling can provide an indication of soil or ground water contamination. However, because soil gas analytical results provide a qualitative indication of contamination, they are best suited for site screening purposes. Conventional activities such as ground water sampling of monitoring wells and performance of soil borings always will be necessary to confirm and/or monitor subsurface contamination. Depending on the type of sampler employed, soil gas samples are retrieved either directly through the probe rods or through tubing (polyethylene or Teflon®) inserted into the probe rods.

Soil Gas Samplers

Expendable tip samplers have an expendable tip that separates from the DPT rods once the desired sampling depth is reached and the rods are withdrawn a few inches to expose the soil. To sample deeper, the probe must be withdrawn and another expendable tip attached, which can make this a time-consuming sampling method if multiple depth sampling is desired.

Retractable tip samplers can be attached to the end of the probe rods by a steel connecting tube that is screened or slotted to allow for gas to enter the probe rods. To sample, the rods are withdrawn a few inches, exposing the connecting tube. When sampling multiple depths in a single probehole, the probe rod should be withdrawn and the tip secured to assure a proper seating of the tip.

Exposed screen samplers have a slotted or screened terminal end fitted onto the probe rods, similar to exposed screen samplers used for ground water sampling. Exposed screen soil gas samplers allow rapid sampling of multiple depths in the same probehole. A disadvantage to these samplers is that cross-contamination of the sample slot or screen can occur if the probe is pushed through contaminants as the probe is pushed to the sampling depth.

Cased system samplers collect soil gas using a cased or two-tube DPT rod string. This method causes less compaction of soils than other methods and allows multiple level sampling. It can, however, be slower to sample using cased systems than non-cased rods.

Retrieving Soil Gas Samples

No matter which sampler system is chosen, the samples can be retrieved by one of two methods. The soil gas may be drawn directly through the probe rods, or soil gas can be sampled through a sampling tube inside the probe rods. Sampling through the probe rods is a fairly simple method of sampling. A disadvantage of this method is the large volume of air within the probe rods that must be purged prior to collecting a sample. Sampling through the probe rods also increases the chances of sampling of atmospheric gases instead of the intended sample interval. In addition, because the connections between the rods may not be air tight, soil gas may be drawn from subsurface intervals other than the targeted zone.

Withdrawing the samples through tubing can overcome these problems. Using polyethylene or Teflon® tubing for sampling reduces the purge volumes required and eliminates the possibility of drawing air from the joints between rod sections. Sampling through tubing does, however, complicate the sampling equipment needed and adds an additional expense.

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