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AN OVERVIEW OF
DIRECT PUSH TECHNOLOGY

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SECTION 1

INTRODUCTION

A thorough site investigation is one of the first steps in the assessment and eventual remediation of a contaminated site. The traditional site investigation usually involves mobilizing a drilling rig and using off site laboratories to assess samples. A new approach to site assessment is now becoming commonplace, and is providing an alternative to the traditional approach. This new approach combines "direct push sampling" with a mobile laboratory to provide a less expensive, more rapid site assessment.

The original direct push sampler is the cone penetrometer which has been used in geotechnical engineering for many years. Cone penetration systems are commonly mounted on vehicles designed to bring 10 to 30 tons to bear on the tool string. These vehicles are usually large trucks that are very conspicuous and not designed for rough sites. For these reasons, they may have limited utility for some site investigations. Recently, both hand held and vehicle mounted variations of this sampling tool have been designed specifically for site investigations. This equipment is considerably smaller and more portable than cone penetrometers or traditional drilling rigs, allowing greater

access to confined or rough areas. In contrast to cone penetrometers that rely on static force alone, these tools typically use a percussion hammer in addition to static force to "push" the tool string into the subsurface without drilling. The tool string consists of small diameter steel probing rods (1 to 1.4 inch O.D.) and may include a variety of soil, soil vapor, and groundwater samplers. Collectively, this specialized equipment and its associated in-situ samplers fall into the emerging field known as "Direct Push Technology" (DPT).

As with any subsurface exploration technique, these new tools may not be the most appropriate method for exploring every contaminated site. The method selected for a given site depends on subsurface geology and the depth to groundwater. Tuttle and Chapman (1992) indicate that DPT equipment is generally used in the same types of unconsolidated sediments as hollow stem augers. Where these conditions exist, DPT equipment is providing faster, less expensive site investigations than more traditional equipment. In addition, these tools have begun to demonstrate their flexibility for not only in-situ sampling, but the measurement of remediation design parameters and the installation of monitoring probes.

Tillman (1993a) lists the following advantages of DPT equipment:

- Streamlines site investigations
- Reduces the quantity of permanent wells
- Provides multi-media sampling (soil, groundwater, and soil vapor)
- Allows multiple depth sampling at the same location
- Eliminates contaminated soil disposal problems
- Provides both chemical and physical data
- Allows on site sample analysis

Other advantages include ease of mobilization, minimal site disruption, and speed of sample collection (Christy and Spradlin, 1992) which combine to give this method lower overall costs than more traditional approaches. Since the vehicle mounted probing systems are usually deployed in panel vans or pickup trucks, they can enter, sample and leave a site fairly inconspicuously.

Tillman (1993a) indicates DPT equipment can take samples from 20 to 40 borings each day at depths from 10 to 20 feet. When used in tandem with a mobile laboratory, this technology has demonstrated its ability to conduct a very rapid initial site assessment. Tillman and Leonard (1993) cite a case history where DPT was used to collect 34 soil vapor samples on the first day. This data was analyzed, and 17 selective water samples were obtained in an attempt to

define the edge of the contaminant plume. Soil samples were collected at five foot intervals at the areas of highest concentrations which helped define the extent of vertical contamination. By the third day, enough information had been collected to define the limit of groundwater contamination, and characterize the extent of soil contamination. Remedial plans were developed using this data for both the soil and the groundwater.

Although DPT equipment has numerous advantages, it also has some limitations. Probing is not possible in cemented soils or bedrock. Soil deposits containing large cobbles usually prevent effective probing. Even in the most ideal conditions, the equipment has a limited depth which is always less than traditional drilling equipment. Finally, like other types of new technology, DPT equipment is not yet accepted by many regulatory agencies, especially as a substitute for conventional groundwater monitoring wells.

Although this equipment is rapidly gaining recognition it is faced with other obstacles. It is an evolving technology, and new platforms and tools are being introduced rapidly. Many engineers may be leery of its newness and opt for a more proven (and more expensive) system. Finally, success in the field depends on a skilled crew equipped with a full suite of sampling tools.

This report will cover the various types of direct push platforms currently available. It will cover the types of soil, soil vapor, and groundwater samplers used with the direct push platforms, and how they are used for site assessment, monitoring, and collecting important remedial parameters. It will also cover the ways direct push sampling is being combined with field laboratories to create a self contained site assessment system. Finally, the report will highlight several case histories that demonstrate the use of this equipment. While this report is not a definitive guide to Direct Push Technology, it should provide an overview of this new and innovative site assessment tool.

SECTION 2

DIRECT PUSH PLATFORMS

2.1. Hand Held Probing Equipment

Hand held probing equipment is the simplest and least expensive direct push platform, but these samplers have more limitations than vehicle mounted probes. Given these limitations, they still have extreme flexibility and can collect soil, soil vapor, and groundwater samples. They can literally be walked into sites that are inaccessible to equipment. They also provide engineers, scientists, and other remediation professionals the ability to obtain their own samples during the earliest stages of site investigation.

The main disadvantage of hand held equipment is it's limited penetration. Depths of 10 to 15 feet are not uncommon, however sampling in the 5 range is more realistic. Hand held equipment tends to be slower and more labor intensive than the vehicle mounted systems. Finally, sample size tends to be limited and the laboratory performing the analysis should be consulted prior to selecting this method.

2.1.1. Manual Drivers

The manual driver is the simplest and most "brute force" DPT sampling tool. This tool is available with handles or with a sliding drop weight (Figure 2.1). Both types are

used primarily for soil sampling, but kits are available that will allow soil vapor and groundwater sampling as well. Manual drivers are only useful in uniform unconsolidated sediments. They are generally unable to pass through cobbles. Geoprobe Systems (1994) and Clements Associates Inc. (1994) report their manual drivers can drive probes to 15 - 18 feet in favorable conditions but they are most appropriate in shallow situations. They have been used to drive probes through clays and gravelly soils, compacted fills, and frozen soils. Both types require the use of a probe jack to extract the probe rods.

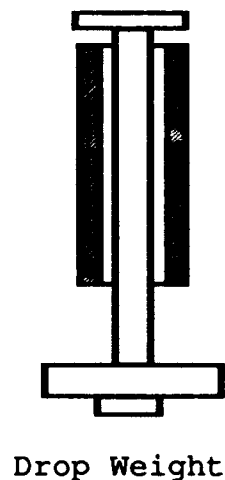
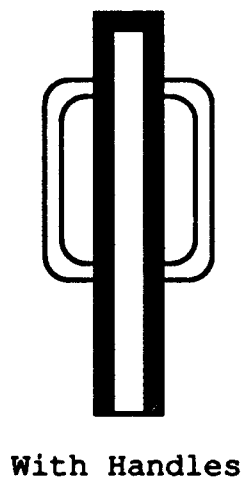


Fig. 2.1

Manual Drivers

The handled style is heavier, weighing over 30 pounds. The weighted body of the driver is slipped over the probe rod and then repeatedly raised and dropped, driving the probe into the soil. The slide hammer style weighs about half as much and operates like the drop hammers commonly used in laboratory compaction tests.

The primary advantage of manual drivers is their ability to sample in areas with no power supply and restricted space. For example, these tools could be used to drive a probe between two closely spaced structures with minimal site disruption. They can also be brought on site and "set up" more rapidly than conventional drilling or DPT equipment. Their simple design makes these tools the most reliable and least expensive direct push platforms.

2.1.2. Hand Held Percussion Drills

Another variation of hand held DPT platforms is the percussion drill. These drills are either powered electrically or with a small gasoline engine (Figure 2.2). The models with gasoline engines have the advantage of being truly "self - contained" and can be carried onto very challenging sites. These drills were developed as construction tools and are available from several power tool manufacturers.

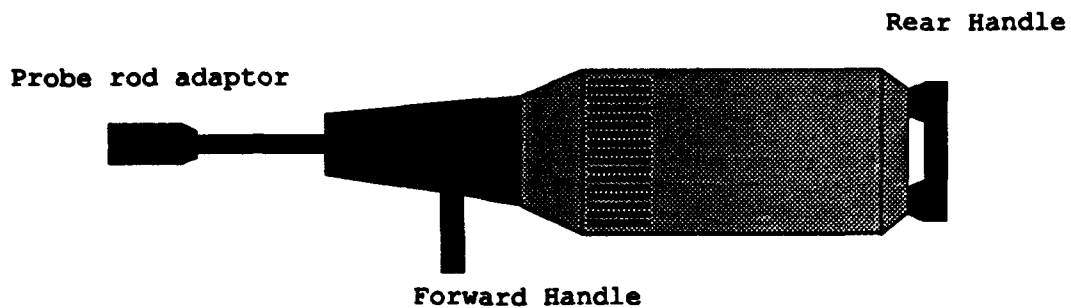


Fig 2.2 Hand Held Percussion Drill

Special adapters that are compatible with the different proprietary probe rods are chucked into the drill. These adapters have an open receptacle that is then slipped over the probe rod. Geoprobe Systems (1994) reports these drills can quickly drive their largest diameter (1.4 inch O.D.) probes to depths exceeding 10 feet. These tools can also be equipped with carbide bits that allow them to drill through various pavements. Like the manual drivers, a probe jack must be used to extract the probe rods. These drills are more expensive than the manual drivers but are still relatively inexpensive compared to the larger vehicle mounted probes.

2.1.3. Probe Jacks

Probe jacks are used to remove rods that have been driven by one of the hand held tools. These jacks are generally lever action and use a cam device to grasp the probe rods. At least one model is available that uses a

foot pedal instead of a handle. This model can also be used to jack probe rods into the ground.

2.2. Vehicle Mounted Probes

Sampling at greater depths requires more muscle than the hand held tools can provide. Vehicle mounted probes can provide the extra power. Static forces are applied using a hydraulic cylinder and the vehicle itself as a reaction weight. The hydraulic system is usually powered by a hydraulic pump on the vehicle's engine. Powered percussion hammers are used in conjunction with the static force to place the probe rods (Figure 2.3). These probes are capable of reaching greater depths and powering through stiff layers and pavements.

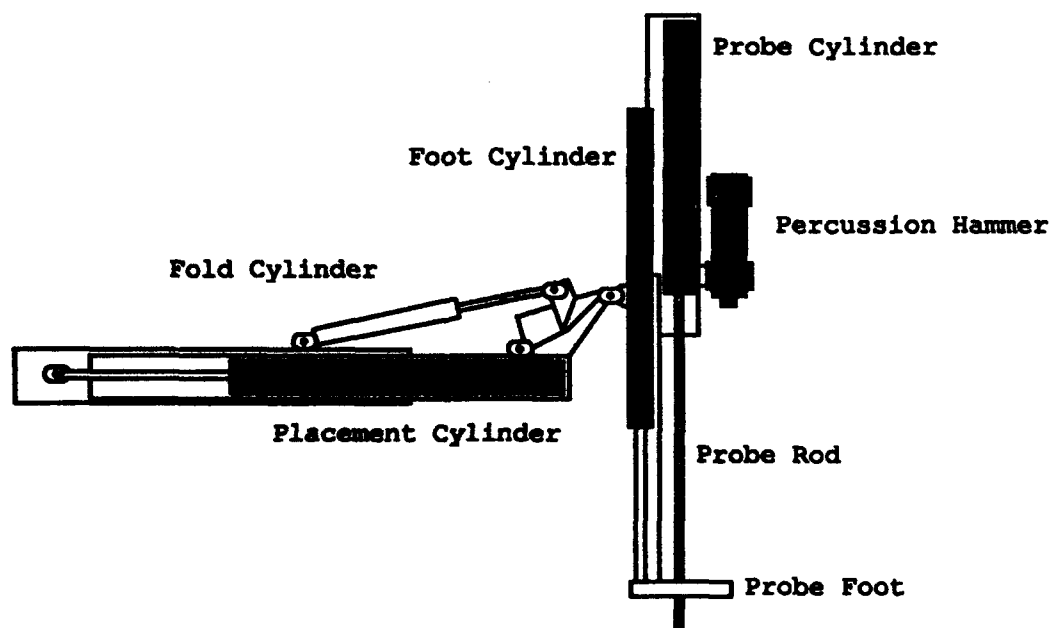


Fig 2.3 Typical Hydraulic Probe

Christy and Spradlin (1992) indicate typical vehicle mounted probing equipment uses static forces of 3 to 5 kips combined with percussion hammers having continuous outputs of 8 horsepower. These energies have been used for multimedia sampling at depths exceeding 70 feet. Tillman (1993a) indicates smaller systems with 1 to 2 kip reaction weights are also common. These probes are more commonly used to reach 10 to 20 foot depths. Setup time for both types is short, and the probes can be advanced and retrieved quickly. The reduced equipment size (compared to a drilling rig) and rapid mobilization helps minimize site disruption.

Typically, a hydraulic probing device is mounted in the back of a pick-up, cargo van, or a larger truck style chassis (Figure 2.4). The carrier vehicle can also serve as a mobile lab, or a secure area to store the equipment. In addition, it provides the reaction weight, which alone can be enough to advance probes strings 20 feet. The device is deployed by extending the placement cylinder until the unit clears the vehicle. Next, the fold cylinder is activated and the unit is tilted upright. The foot cylinder is used to place the probe foot firmly on the ground, then the probe cylinder is used in conjunction with the percussion hammer to drive the tool string into the ground. The entire unit can be folded down for transport. In addition, the placement cylinder pivots at the vehicle end on some models

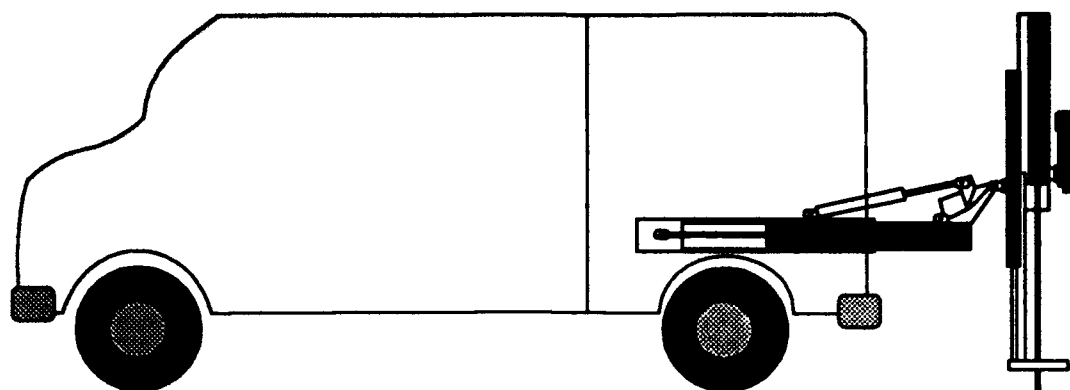


Fig 2.4 Typical Vehicle Mounted Probe

so the probe can be swung from side to side taking several closely spaced samples at one location.

Vehicle mounted DPT equipment is capable of rapidly pushing the tool string into the subsurface. Figure 2.5 shows typical penetration rate data from Christy and Spradlin (1992). This data was measured while driving a 1 inch O.D. tool string with a percussion driver into alluvial soils. No specific information was provided on the soil type or depth to groundwater. Total depth was achieved in 15 minutes. According to this paper, it normally takes 10 to 20 minutes to place and remove a probe to a depth of 20 feet.

The ability to rapidly reach depth, collect a sample and move to the next location provides several advantages to DPT equipment. First, the rapid sampling speed reduces the costs of an overall investigation program. The lowered cost per sample can allow the collection of more samples for the same budget. The larger number of samples increases the

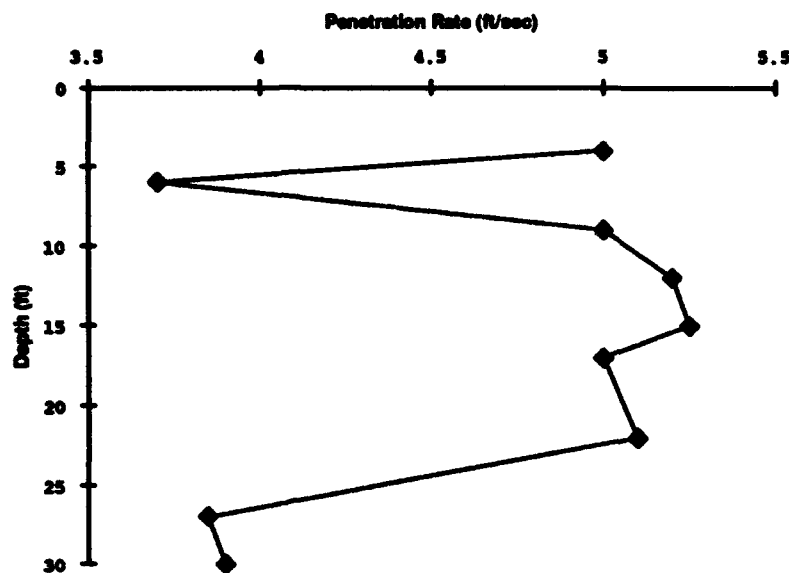


Fig. 2.5 Typical Penetration Rate

probability the contaminated area will be well defined and is useful in developing a remediation program. McCrory and Wallace (1992) indicate the following sampling frequency is typical for probing equipment.

SAMPLING FREQUENCY FOR DPT EQUIPMENT		
<u>Equipment</u>	<u>Depth (feet)</u>	<u>Samples / Day</u>
Hand Held Device	3 to 5	30 to 60
Vehicle Mounted Probe	6 to 10	25 to 35
Vehicle Mounted Probe	11 to 15	15 to 24
Vehicle Mounted Probe	16 to 20	10 to 15
Vehicle Mounted Probe	21 to 25	5 to 10
Vehicle Mounted Probe	greater than 25	1 to 8

The purchase price of this equipment is significantly greater than the hand held equipment. Numerous consulting firms specializing in DPT are now on the market, and their equipment or services can be negotiated on an as needed basis which eliminates the need to purchase the equipment outright. In addition, the costs (and the hourly rates) for this type of equipment are significantly less than traditional drilling rigs. When the job site is accessible to a vehicle, this equipment can provide high quality multimedia samples very rapidly.

Another advantage of DPT equipment is a smaller crew size. Traditional drilling requires a skilled drill crew, personnel for equipment decontamination (if necessary), and a geologist or engineer for sample collection. DPT crews are typically smaller because the equipment is easier to operate, and the crew is more technically oriented. This also helps minimize site disruption.

2.3. Trailer Mounted Probes

Trailer mounted probes are a common variation of the vehicle mounted probes. This style of equipment typically has two augers which are drilled into the ground to provide the reaction force. Portable generators either mounted to the trailer or brought in separately make these rigs truly self-contained. The distinct advantage of this arrangement is the ability to get it into very rough sites. These rigs

have been pulled onto sites by tracked vehicles and even flown in by helicopter.

2.4. Probing Equipment and Accessories

In addition to the hand held or vehicle mounted probe system, a variety of equipment and accessories are necessary for all probing operations. These accessories are used to assemble the tool string that the probe system will push into the ground. Each probe manufacturer has a proprietary accessory line, and use of incompatible parts could damage the tool string.

2.4.1. General Accessories

The most basic probing accessory is the probe rods. These rods are small diameter, flush threaded pipes that attach to various sampling tools. They are designed to withstand the rigors of percussion probing without bending. Many probe rods (and other accessories) are coated with a special finish to minimize damage and corrosion. The rod threads are typically heat treated to inhibit fatigue fracturing.

The topmost section of the probe rod is protected by drive or pull caps. These female threaded top caps protect the rod threads and are designed to be struck or grasped by the hydraulic probe. Occasionally the pull cap threads fail during extraction. When this occurs, a specially designed

rod extractor is twisted into the damaged rod and a new pull cap is installed. This allows the damaged section to be removed.

Another critical accessory is the probe tip (Figure 2.6). Probe tips have a long shank with an annular o-ring that slides into a holder threaded to the bottom of the probe rod. The o-ring creates a seal that prevents liquefied soils from entering the probe rod. Expendable points are not mechanically attached to the probe rod and are left in the ground during sampling operations. Retractable points are attached to the probe rod with a special keeper that allows them to be removed after a sample is collected. Both types of points are removed for sampling by retracting the tool string, or lowering a rod down the center of the probe string to push them out. The use of both types of tips during sampling operations is discussed

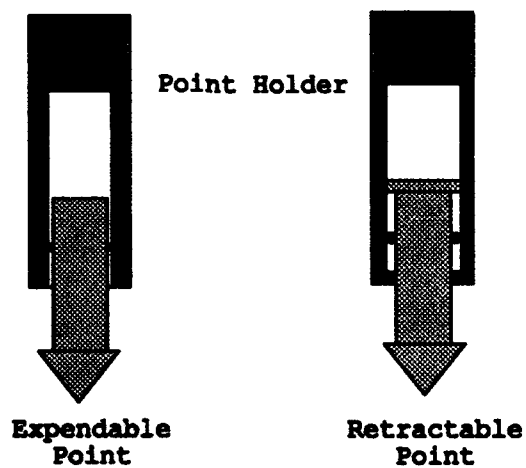


Fig. 2.6 Probe Tips

in detail in the next section. Solid drive points are also available for pre-probing a hole prior to sampling.

Specialized accessories are available for probing through surface pavements. Hardened drill steels with carbide tipped bits are used to probe through as much as 30 inches of pavement. These drills are advanced hydraulically and with percussion in the same manner as a standard probe rod. The drill steels are equipped with ports that can be attached to an air compressor. The use of compressed air to blow pavement cuttings from the borehole greatly increases the penetration rates and working depths.

2.4.2. *Percussion Hammers*

Percussion hammers are used with vehicle mounted DPT equipment to push tool strings through hard packed soil, gravelly zones, fill materials, and surface frost. The probe is generally allowed to advance on static weight alone until refusal, then percussion is applied. Christy and Spradlin (1992) indicate the average percussion hammer in use today applies an impulse force of 600 to 1200 pounds to the top of the tool string at a frequency of 30 Hz. Advancing probes beyond 25 feet without percussion is uncommon.

SECTION 3

SITE ASSESSMENTS WITH DIRECT PUSH EQUIPMENT

Most site assessments have three goals: determining (1) the extent of contamination, (2) whether remediation will be necessary, and (3) the best remediation strategy. DPT systems are designed to collect the data required to meet these goals. Specialized sampling tools for soil, soil vapor and groundwater have been introduced by the probe manufacturers and other environmental firms.

3.1. Vapor Sampling

The most common use of DPT in the environmental field is soil vapor sampling. Samples are collected and used to define subsurface VOC contamination. Christy and Spradlin (1992) estimate soil vapor sampling accounts for 50% of the current environmental work using probing equipment. If a field gas chromatograph is used to analyze the samples, the survey is rapid and easy to perform and does not yet require any regulatory agency protocols. Tillman and Leonard (1993) indicate it is not uncommon to collect 30 soil vapor samples in one day using DPT samplers, and samples are successfully recovered about 95% of the time. These factors combine to make this one of the most economical methods for determining the source and extent of VOC contamination.

Shallow sampling (3 to 5 feet) of soil vapor is typically done with hand held probing equipment. A hole is advanced to depth with one of the hand held tools. Next the probe rod is extracted leaving an open boring. A smaller stainless steel rod is lowered down the boring and sealed with an inert sealant (e.g., bentonite). Samples are extracted using a manual syringe pump attached to the stainless steel rod.

Deeper soil vapor sampling is usually done with a vehicle mounted probe. A specialized vapor sampler is threaded onto the end of the probe rod and then pushed to the desired depth. Several different vapor sampling probe configurations are currently in use in the United States (Figure 3.1).

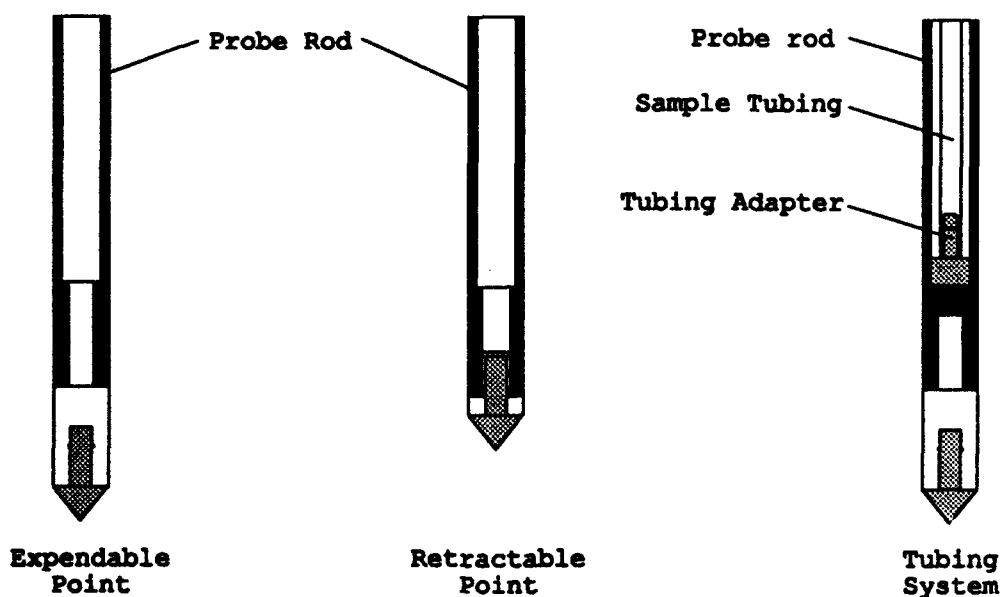


Fig. 3.1 Soil Vapor Samplers

The expendable point configuration is the most common. The probe rod is pushed to the required and then pulled up slightly, disengaging the expendable point. Soil vapors are drawn up through the probe rod with a vacuum. Since the tip is left in the boring, only one depth can be sampled with this system. The retractable point style operates on the same principal except the tip is attached to the probe rod and can be retrieved, decontaminated and used to screen additional depths in the same boring.

The third system uses either a retractable or an expendable point. After the probe has been driven to depth and retracted to open the tip, tubing with a special threaded tubing adapter is lowered downhole. At the surface, the investigator rotates the tubing with a slight downward pressure to engage the threads, connecting the tubing to the end of the probe rod. Teflon, stainless steel, and polyethelene tubing are available. The primary advantage of this system is a reduced purge volume. Christy and Spradlin (1992) indicate this system has a 2.5 to 15.1 ml/ft purge volume compared to 33 ml/ft for the other probe types.

The vacuum pressure equipment is located inside the probe vehicle. Christy and Spradlin (1992) indicate a vacuum pressure of 21 inches of Hg is common. They also indicate the sampling equipment can be equipped to detect

leaks in the sampling train. When a sample cannot be extracted due to low air permeability, a soil sample is usually collected for headspace analysis.

3.2. Soil Sampling

Soil sampling with DPT equipment is becoming increasingly common. Soil samplers are useful because they can be utilized to define the site's lithology and provide information on contamination. Tillman and Leonard (1993) indicate the success rate for soil sampling is also high (about 90% recovery rate). Most soils can be sampled unless they are too saturated. When highly saturated, they may drain out of the tube making sampling impossible. Discrete or continuous samples can be obtained.

3.2.1. Discrete Samplers

Discrete soil samples are collected with the hand held and vehicle mounted systems using a specialized piston sampler mounted on the end of the probing rod (Figure 3.2). The sampler's body is a tube (typically 10 to 24 inches in length) containing one or more liners (end to end). The liners (Teflon, stainless steel, or clear plastic) are used to contain the core after it is removed from the sampler. A special retractable tip surrounded by a cutting shoe is mounted to the end of the sampler. The entire unit is

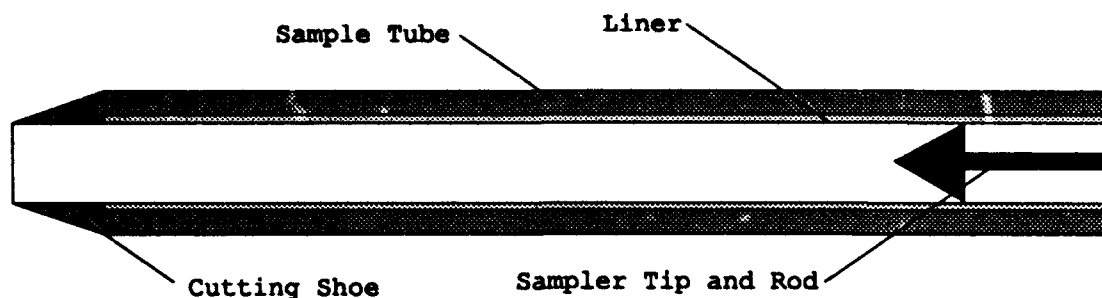


Fig. 3.2 Discrete Soil Sampler

pushed to the desired depth, the tip is retracted and the sampler advanced until it fills.

The entire sampler is then brought to the surface where the individual liners are removed and sealed, or the soil is extruded from them into storage vials. Christy and Spradlin (1992) indicate these samplers have been routinely used at depths exceeding 30 feet.

3.2.2. Continuous Samplers

A new, larger diameter sampler is currently available that will allow continuous coring from the surface to the desired depth (Geoprobe, 1994). This sampler collects 45 inch long, 1 1/2 inch diameter soil samples in Teflon, clear plastic or stainless steel liners. The sampler is constructed the same as the discrete sampler except the sampler is advanced until full then removed. An extension rod is added and a clean sampler is pushed to the bottom of the previous boring, and advanced until full. The process is repeated until a complete core to the desired depth has

been extracted. This system requires a more powerful vehicle mounted hydraulic probe than the discrete sampler.

3.3. Water Sampling

Driven well points have been used for many years for groundwater extraction. DPT groundwater extraction is accomplished in much the same fashion with smaller diameter tools. These tools can collect groundwater samples at depths exceeding 30 feet. Tillman and Leonard (1993) indicate the recovery rate for water sampling is about 85%. Since DPT groundwater techniques are typically less expensive, faster, and more flexible than traditional techniques they are extremely useful for assessing subsurface contamination before more expensive monitoring wells are established.

One of the most common and simplest water sampling techniques involves pushing a probe rod with an expendable point below the groundwater table. The probe string is retracted enough to disengage the tip, allowing the rod to fill with water. Small diameter tubing with a check valve at one end, is lowered downhole, then oscillated to produce a momentum pumping action. The sample is collected as the tube fills. Christy and Spradlin (1992) indicate several feet of tubing can be filled with this crude method.

3.3.1. *Mini-bailers*

A more sophisticated water sampling technique can now be performed with a variety of mini-bailers currently on the market. This method begins when a probe rod with an expendable or retractable point is driven below the groundwater table, retracted and allowed to fill with water. The mini-bailer is lowered down the center of the probe rod and water samples are collected, preserved and analyzed in the same manner as those collected with a "normal" bailer in a traditional well. The disadvantage of this method is the limited sample volume due to the bailer's small inside diameter. Nonetheless, this is an adequate water collection method for site screening purposes.

3.3.2. *Water Sampling Probes*

Water sampling probes are the most highly specialized direct push sampler. The simplest water sampling probe is the mill slotted sampler (Figure 3.3). This sampler is attached directly to the end of the probe rod and allows groundwater to enter the tool string in the same manner as the mill slotted well screen allows flow into a well casing.

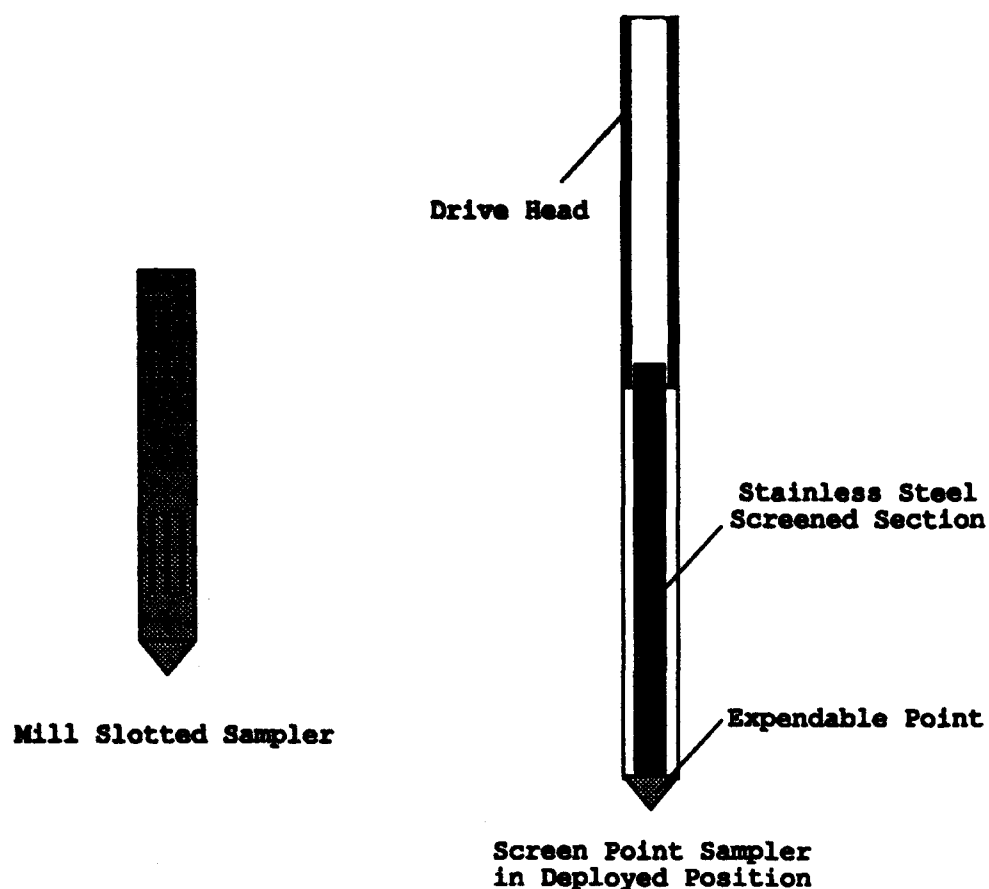


Fig. 3.3 Mill Slotted and Screen Point Samplers

Parks and Hess (1992) indicate samples are extracted from these probes with mini-bailers (for VOC analysis) or a length of polyethylene tubing equipped with a foot valve (for other purposes). The main disadvantage of this sampler is its exposed slots that may become clogged with fine soil during probing.

A more elaborate variation on this design is the screen point sampler (Figure 3.3). While this sampler is being driven to the desired depth, it is enclosed within a special

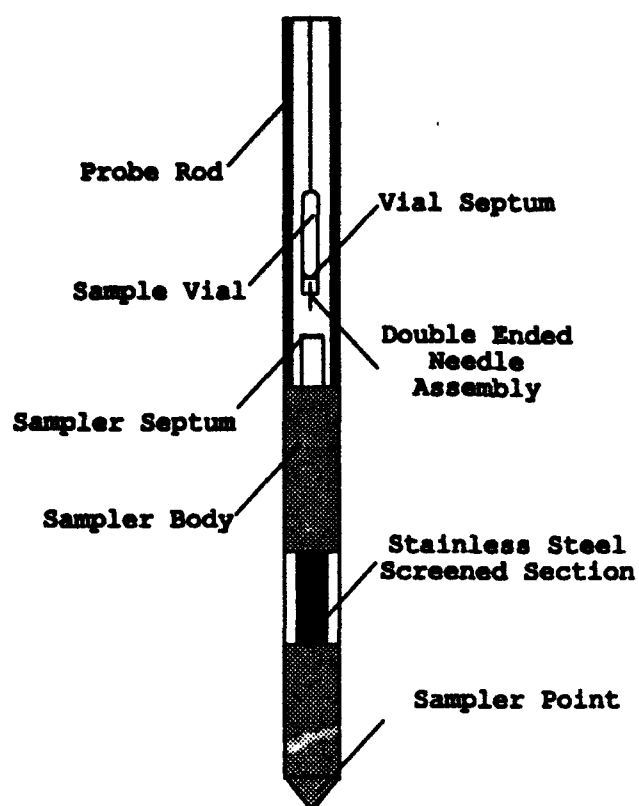


Fig. 3.4 The Enviroprobe Groundwater Sampler

drive head with an expendable point. When the desired depth is reached, the probe rod is pulled up about two feet, dislodging the expendable point and creating a void for the sampler. The stainless steel screened section is then pushed out of the probe with an extension rod. Although the water samples are collected in the same manner as the mill slotted point, this sampler will not clog while driving.

The Enviroprobe, manufactured by Envitech, Inc., is an even more elaborate groundwater sampler (Figure 3.4). Zemo et. al. (1992) indicate this probe is first pushed to the target zone, then pulled up to open the screened section in

the same manner as the screen point sampler. The top of the probe is sealed with a septum. An evacuated sample vial (sealed with a septum) equipped with a spring loaded double ended needle is lowered down the center of the tool string. Both septa are pierced as the vial impales itself and draws in a water sample. The vial is then raised to the surface where the sample is evacuated without ever being exposed to the atmosphere. Since the probe remains in the same location, additional samples can be collected by lowering new vials down the tool string.

Another more elaborate sampler is the Hydropunch,

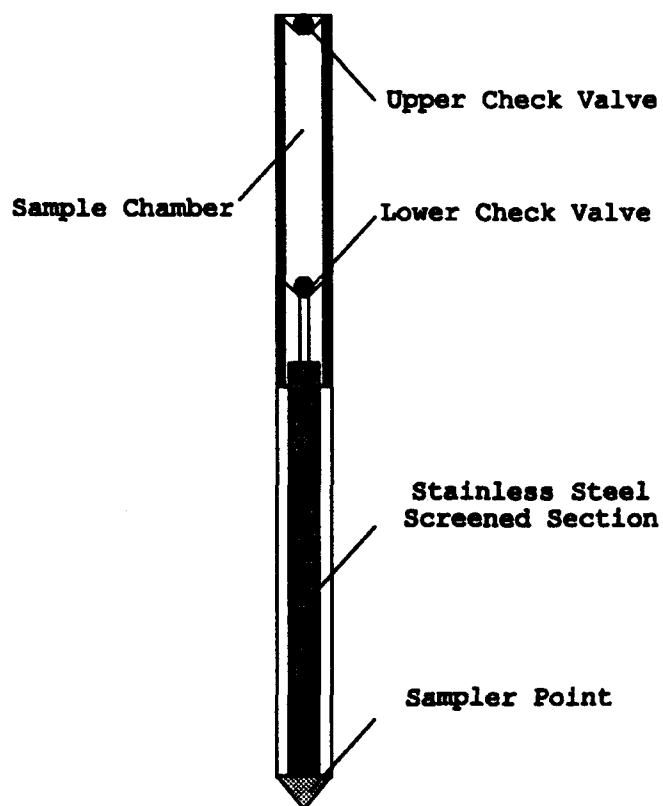


Fig. 3.5 The Hydropunch Groundwater Sampler

manufactured by QED Environmental Systems (Figure 3.5). Zemo et. al. (1992) indicate this sampler is also pushed to the required depth, then pulled back to open the screened section. Groundwater enters the sampler under hydrostatic pressure through a check valve into a sample chamber. Flow continues up the riser pipe past a second check valve until hydrostatic equilibrium is reached. The entire sampler is extracted and the sample evacuated at the surface.

The most elaborate groundwater sampling tool is the Hydrocone, by In-Site Technology (Figure 3.6). The Hydrocone is constructed of stainless steel and Teflon to

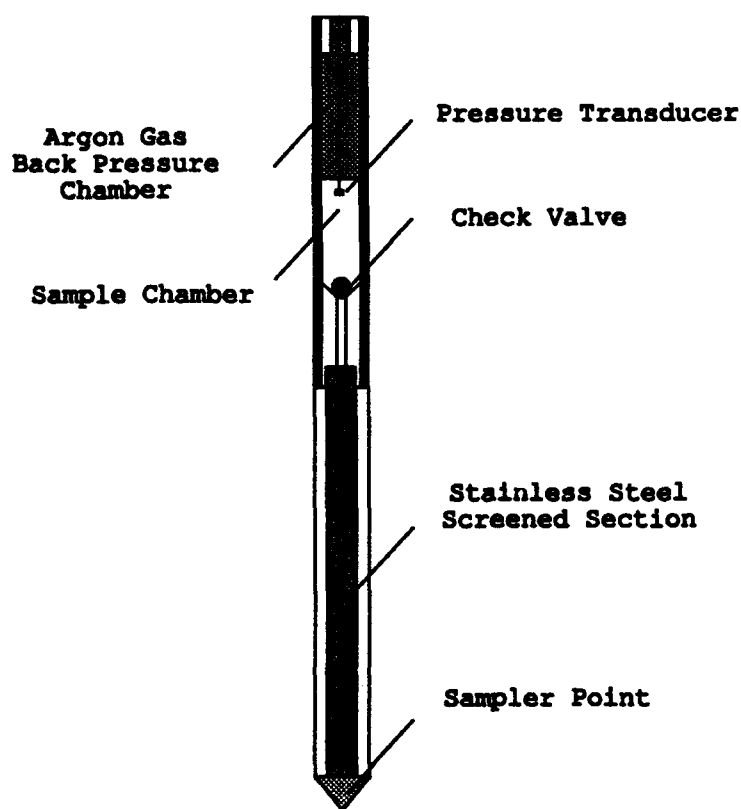


Fig. 3.6 The Hydrocone Groundwater Sampler

ensure quality samples. Scott and Carter (1992) indicate this tool should be thoroughly decontaminated at the surface before being pushed to the desired depth. While in transit, the screened section is contained within the body of the sampler, like the screen point sampler described previously. Once the desired depth is reached, the probe rod is pulled up, opening the screened section. If the fill rate is too rapid, argon gas back pressure is applied to regulate the fill rate. This helps prevent volatilization and controls the amount of fines entering the sampler. A pressure transducer in the fill chamber is monitored at the surface. Once the transducer indicates an adequate volume has been collected, argon gas back pressure is used to pressurize the sample to greater than hydrostatic pressure before it is brought to the surface. The sample is removed from the sampler through a special valve that minimizes aeration and volatilization.

Scott and Carter indicate the Hydrocone has the following advantages:

- Unlike monitoring wells whose screened sections typically provide samples from a long stratigraphic section, the Hydrocone can obtain discrete samples
- The Hydrocone is more cost effective for delineating plumes than the phased monitoring well approach
- No drill cuttings or purge water is generated

- Samples can be analyzed immediately in an on-site lab
- Sample collection can be performed rapidly with minimal disturbance

Additionally, this is the only sampler that is instrumented so the operator knows a sample has been collected before bringing it to the surface.

3.4. Measuring Important Remediation Parameters

In addition to collecting multi-media samples for site assessment, DPT can be used to measure physical parameters important to the design in site remediation plans. One of the most important remediation parameters is air permeability. Air permeability is traditionally obtained by attaching a blower to an existing well and measuring the vacuum effects on other wells in the area. This approach has disadvantages because traditional wells must be in place and screened correctly.

Direct push tools can be used to place the extraction "well" and the monitoring "wells" for a more streamlined and cost effective initial test. These "wells" would consist of the probe string and the preferred soil vapor sampler. Since probe wells are easily placed (in the proper conditions), many sampling points can be developed to generate a site permeability map. The speed and lower costs of these tests is an attractive advantage. Tillman and

Leonard (1993) indicate the costs of these DPT wells is on the order of hundreds of dollars compared to thousands of dollars for more traditional wells. DPT vapor samplers have also been used in small scale sparging tests.

Probing equipment can also be used to develop a mini "well field" of groundwater sampling points. Groundwater probes can be placed rapidly and are inexpensive compared to traditional wells. Once in place, the mini well fields can be used for monitoring purposes or data collection. Tillman and Leonard (1993) indicate these mini-wells can collect data that compares favorably with more traditional water wells. The lower cost of DPT monitoring allows more stations to be installed for tracking contaminants.

SECTION 4

THE MOBILE LABORATORY

The traditional approach to site investigations involves mobilizing a drill rig and shipping the samples it obtains to an off site laboratory. Many times it can take weeks or even months for lab results to come back. This turn around time can delay important decisions. In addition, the cost of this traditional approach often prohibits the collection of enough samples to adequately characterize the contamination.

The advent of laboratory grade field soil vapor and groundwater testing equipment has provided new opportunities for field testing. Recently, firms have begun to combine this new equipment with DPT samplers to provide a complete site investigation system (Figure 5.1). The small size of the typical hydraulic probe allows small labs within the same vehicle. When additional room is required, larger labs are typically established in trailers that can be towed to the site by the probe platform vehicle.

Portable generators provide power and compact air conditioners establish a controlled environment. The labs also contain personal computers, a bench for sample preparation, and a full array of safety equipment.

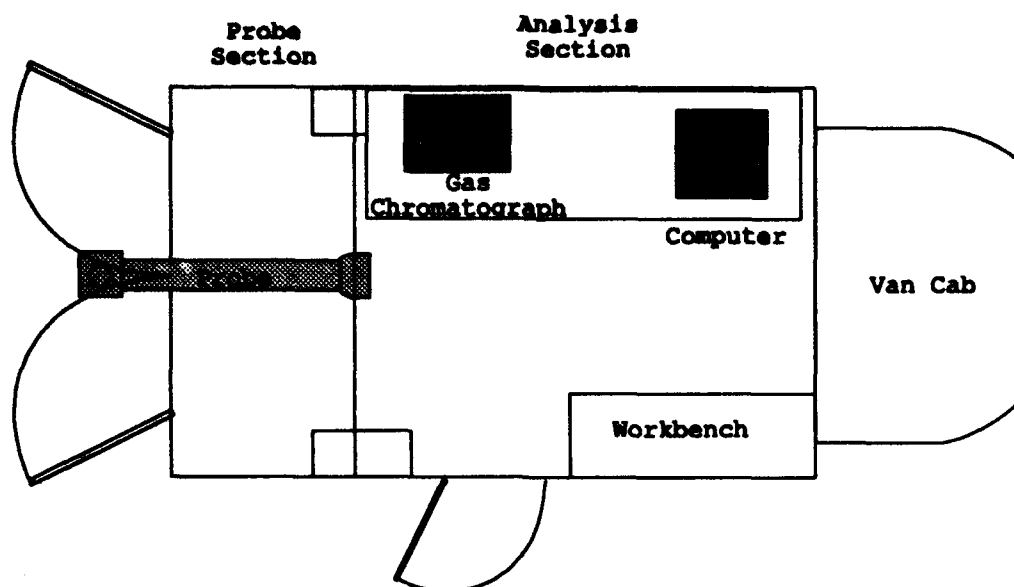


Fig. 4.1 Floor Plan of Mobile Laboratory/Probe

Tuttle and Chapman (1992) indicate mobile labs are typically equipped with the following analytical equipment:

- Laboratory grade gas chromatograph
- PC based chromatographic data system
- Flame ionization (FIDs), Electron capture (ECD), and photo ionization (PID) detectors
- Explosion proof refrigerators
- High temperature drying ovens for sample preparation and equipment decontamination
- Electronic balances

These laboratories are designed to locate volatile and semi-volatile contaminants. They allow rapid, relatively low cost field screening. This expedites the initial survey, lowering its costs, and allows the collection of

more data, which better characterizes site conditions. The initial survey can look for a broad spectrum of contaminants until target contaminants are identified. Then, the remaining site investigation is tailored to find a more specific set of compounds. Soil, soil vapor and groundwater samples can be analyzed, and investigation plans can be easily modified as real time data becomes available. Critical decisions on public health or safety issues can be made in a more timely manner. Finally, cross contamination and errors due to shipment and excessive handling can be avoided.

Samples are analyzed using standard laboratory procedures. Soil vapor samples withdrawn directly from the DPT soil vapor sampler are usually analyzed through direct injection into a GC. The GC can be set up to detect target compounds. Soil and groundwater are commonly analyzed for gasoline and other VOCs using the headspace method (air is extracted from above the sample and injected into a GC). Soil samples are analyzed for PCBs, pesticides and other contaminants using U.S. EPA SW-846 methods. Table 5.1 shows case histories (Tuttle and Chapman, 1992) indicating the speed and flexibility of the DPT/mobile laboratory system.

<u>Site</u>	<u>Sampling depth (ft)</u>	<u># of samples</u>	<u>Time required</u>	<u>Chemicals identified</u>	<u>Cost</u>
Superfund Site	18 - 30	24 w	2 days	TCE and TCA	\$7,500
UST Survey	20 - 25	40 v 15 s 15 w	5 days	BTEX	\$15,000
RCRA Facility	5 - 25	120 s 60 w		chlorinated solvents, and hydrocarbons	\$30,000
Field scale treatability study	3 foot intervals to 24 feet	500 s 50 v	6 weeks	MeCL, DCE, DCA, TCA, TCE	\$90,000

Note:

s =soil
v =vapor
w =water

Table 4.1 DPT/Mobile Laboratory System Case Histories

These case histories as well as hundreds of other site inspections nationwide should help the DPT/mobile laboratory system gain more acceptance. Federal, State, Local and private investigators are beginning to rely on this powerful and flexible investigative system. As this system proves its abilities to conduct rapid, cost effective, high quality site assessments, support for it will almost certainly grow.

SECTION 5

CASE HISTORIES

5.1. Sampling and Analyzing a Hexavalent Chromium Plume

Cherry et. al. (1992) discuss an excellent example of how DPT coupled with a field laboratory has been successfully used in the field. This case history highlights work performed at the Palmetto Wood Preserving Superfund Site in Lexington County, South Carolina. This facility treated wood with preserving solutions (fluoride-chromium-arsenate-phenol, acid-copper-chromate, and chromate-copper-arsenate) from 1963 to 1985. During this 22 year period, spillage of these solutions caused soil, surface and groundwater contamination.

The site was known to be underlain by two aquifers, an unconfined surface aquifer, and a confined deeper aquifer. A previous site investigation performed by EPA contractors, included the installation and sampling of 21 temporary wells and 12 permanent wells. This investigation indicated the contaminant plume was only in the upper aquifer. It appeared to cover approximately four acres, and was flowing to the east-southeast at 3 ft/year. The temporary wells were removed and grouted after the site investigation was completed and the permanent wells were left in place.

The second EPA contract to develop a design for the pump and treat program was awarded to an environmental firm.

This firm went back into the field and re-sampled the remaining wells in an attempt to verify previous results. Since the wells in the center and along the downstream edge of the plume had been removed, 12 new wells were installed. These wells indicated the plume had moved much further east than expected, and contaminants were detected in the lower aquifer.

The design firm was now faced with the dilemma of performing a rapid and accurate site characterization without the costly and time consuming traditional method of drilling and installing additional monitoring wells. The use of DPT was suggested by the project team, and a subcontractor was hired to perform the work.

Using previously developed soil data, a groundwater sampling program was initiated that would utilize DPT and an onsite laboratory. Much of the site was marshland, and the hydraulic probe selected was trailer mounted. The trailer was moved through the site with a large tracked back hoe. The portability of this configuration was a major factor in its ultimate success.

As the sampling progressed, it became apparent that the leading edge of the plume could not be located. The sampling pattern and depths were rapidly modified based on the real time data generated in the field lab. During a two

week period, 26 probings were made to collect groundwater samples at 54 discrete subsurface locations.

The flexibility and ability to collect large amounts of data helped the project team determine the plume had extended more than a half mile beyond their expectations. The contaminated area now included over 20 acres! Contrary to the initial site investigation, most of the plume appeared to be in the lower aquifer. In addition, the new data indicated the plume was moving north-northeast at a much higher rate (300 to 1100 feet per year). Based on this information, an extraction well system was designed that could successfully capture and remove the contaminants.

Each of the DPT sampling points had \$1,200 to install. It was estimated a similar program using traditional monitoring wells would have cost approximately \$12,000 per sampling point. The DPT investigation was completed in 2 weeks. The installation of 26 monitoring wells in the upper and lower aquifers would have taken over 4 months.

DPT had been successfully used in a fraction of the time, for a fraction of the costs, to define a plume that traditional methods had previously incorrectly characterized. If traditional methods had been used, the program would have been several orders of magnitude longer and the costs would have been an order of magnitude higher. The use of DPT and a field laboratory helped obtain a large

amount of real time data in a relatively short period. This data ultimately helped to locate several traditional monitoring wells that are currently being used to measure how the aquifer changes with time. In this instance, DPT was clearly the right tool for the job and proved itself an effective and timely investigation tool.

5.2. Service Station Site Assessment

McCrory and Wallace (1992) provide another example of the successful use of DPT in the field. Their case history involved the use of DPT during several phases of the site investigation at a gas station in Pooler, GA. A faulty pump in one of the station's underground storage tanks resulted in the accidental release of 1,500 gallons of unleaded gasoline. A soil vapor survey was conducted with DPT equipment to determine the extent of contamination in the vadose zone. Using a sampling grid, 30 soil vapor samples were collected in five hours and sent to a lab for analysis. Based on the lab results, a high concentration of BTEX was located in the vicinity of the faulty pump. In addition, the pattern suggested a second release had occurred near the pump island.

Soil samples were collected using DPT equipment to help define the site's lithology. This survey found a clayey sandy silt near the surface and placed the ground water table at five feet. Using this information, five

traditional groundwater monitoring wells were installed. The hydraulic gradient was found to be small (0.1 ft/100 ft) and the direction variable, making predicting the plume migration impossible.

The Pooler water supply well was located only three hundred feet from the gas station. Concern that the water supply might be contaminated made it necessary to precisely locate the plume boundaries. DPT groundwater sampling was selected in the hopes that it could rapidly collect enough detailed information to define the extent of the contamination. A vehicle mounted probe was used to collect 24 groundwater samples in one and a half days. This time included establishing the grid, mobilizing, sampling, and decontaminating the equipment.

This survey indicated that the City water supply was not in danger. The contaminant plume was moving in a vector 90 degrees away from the well for an undefined distance. A second groundwater sampling program (similar to the first) was established to complete the delineation of the plume.

Using the data collected during these site investigations, a remediation plan was developed and approved. During the installation of the soil vapor extraction pipes, the source of the second hot spot (detected in the soil vapor survey) was discovered. Several abandoned tanks and a significant amount of free product

that would have posed a chronic threat were located and removed. This important discovery was made possible by the high density of samples the DPT surveys had provided.

In terms of cost, this case again demonstrated that DPT was a valuable alternative. The average cost per groundwater sample was \$360. The traditional monitoring wells that were installed during the investigation cost \$2,000 and took six hours to drill. Twelve different groundwater samples could be collected with DPT equipment in the same time for the same cost.

McCrory and Wallace (1992) indicated this case history highlighted the following DPT advantages:

- Samples were collected more rapidly
- Unit costs of the samples were lower
- The plume boundaries and hot spots were detected more accurately
- The remedial effort was enhanced by the high quantity and quality data DPT sampling had provided.

5.3. Sampling and Analyzing a Creosote Plume

An interesting description of the marriage of traditional drilling techniques and DPT sampling is presented by Parks et. al. (1992). This case history describes groundwater exploration done at a wood preserving plant in Jackson, TN. The plant's operations had created

enough soil, groundwater and surface water contamination to earn a SuperFund designation.

A sandy unconfined aquifer at the site was underlain by a confining unit at 150 to 200 foot depths. The average depth to the groundwater table was 10 feet. A previous site investigation indicated some of the contamination was heavier than water and had moved below 135 feet.

The EPA asked the USGS to perform a detailed analysis to help define the extent of groundwater contamination. The USGS was interested in the high quality samples DPT could collect, but previous information on soil densities indicated the probing equipment might have limited effective depths. In the field, the DPT equipment was only able to reach 35 feet on its own.

Since deeper samples were required, the USGS decided to mobilize an auger rig. Using a 3 and 3/4 inch I.D. auger, they were ultimately able to advance the boreholes to 85 feet. Periodically, as the drilling advanced, the auger rig would be stopped and moved to the side, leaving the augers in the ground. The DPT rig was then used to probe through the hollow stem into the undisturbed soil below. This technique allowed the collection of high quality, uncontaminated water samples well beyond the DPT rig's limitations.

The mobility of DPT equipment made this type of work possible. Once the auger rig had moved away from the borehole, the DPT rig was able to rapidly move in, set up, sample, and retreat. This flexibility allowed the USGS to take advantage of the high quality samples DPT groundwater sampling could provide without facing depth limitations.

SECTION 6

SUMMARY

Direct Push Technology is rapidly evolving as a valuable site investigation tool. DPT equipment is smaller and more portable than traditional drilling rigs. Probe equipment is less obtrusive than traditional drilling equipment, and capable of sampling in confined or rough areas. The various DPT platforms can be rapidly mobilized, and are generally less expensive than traditional equipment.

A wide range of DPT platforms are currently available. Manual drivers are the simplest DPT systems. Most rely on human power or a small combustion engine and are truly self contained. They can be walked into very rough or confined areas and have been successfully used to collect soil, soil vapor and groundwater samples.

Vehicle mounted samplers provide a more powerful driving system. The probe units can be mounted in light trucks, vans, or even trailers. They can be used to rapidly collect multi-media samples at depths of up to 70 feet. These tools have demonstrated their ability to collect more multi-media samples, for less money than traditional methods.

A variety of DPT multi-media samplers are currently on the market. Soil vapor samplers are the most common and have a high success rate in the right conditions. They are one of the most economical methods for determining the

source and extent of VOC contamination. DPT soil sampling is becoming increasingly more common. These samplers can be used to obtain discrete or continuous specimens with a high degree of success. Finally, a range of high technology groundwater samplers allows the collection of very high quality water samples for a fraction of the cost of monitoring wells.

The use of DPT samplers and a field laboratory can provide a rapid and flexible site assessment. More samples can be collected to better characterize site conditions. As samples are analyzed, assessment plans can be altered to maximize the investigation. Laboratory grade equipment, computers, and the hydraulic probe have been integrated into a complete site assessment system, and field experience has shown just how effective this system can be.

Like most other geotechnical tools, DPT also has limitations. Cemented soils, cobbles, or bedrock usually prevent probing. Even in the most ideal conditions the equipment has depth limitations. Like other types of new technology, DPT has not been fully accepted by regulatory agencies or many engineers who are more comfortable with more proven (and often more expensive) systems. It is unclear how effectively the probe holes can be sealed and how long they remain open after the probe string is removed. Finally, since the technology is fairly new, it is unclear

how long it will last in monitoring applications that require it to remain in place for long periods of time.

Even given these shortcomings, DPT is a valuable site investigation alternative. In the right conditions, DPT equipment has demonstrated its ability to collect quality samples in a timely and cost effective manner. It is a new and rapidly evolving technology with a promising track record that will eventually gain wide acceptance in the field.

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