COMMONWEALTH OF MASSACHUSETTS
EXECUTIVE OFFICE OF ENVIRONMENTAL AFFAIRS
DEPARTMENT OF ENVIRONMENTAL PROTECTION
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COMMONWEALTH OF MASSACHUSETTS

DEPARTMENT OF ENVIRONMENTAL PROTECTION

STANDARD REFERENCES FOR MONITORING WELLS

SMALL DIAMETER DRIVEN WELL SUPPLEMENT

JANUARY 1999

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January 1999

Dear Reader:

Standard References for Monitoring Wells (WSC-310-91) was published in April, 1991 to provide guidance on locating, drilling, installing, sampling and decommissioning monitoring wells. The primary objectives of this volume are to help ensure that monitoring wells are installed properly, and that sampling data obtained from them is valid and can be interpreted consistently.

As anticipated, numerous technological advancements have occurred in the field of groundwater monitoring since the initial publication of Standard References for Monitoring Wells. Specifically, Small Diameter Driven Well (SDDW) technology has evolved to the point where it can be used as a cost effective complement to conventional monitoring wells. In many situations, SDDWs can also be used independently for purposes of site assessment or site remediation.

The Department has noted an increasing demand for this type of technology over the past few years. As a result, we have developed a Supplement to Standard References for Monitoring Wells specifically for Small Diameter Driven Wells. As with Standard References for Monitoring Wells, many people both inside and outside DEP were involved in developing these revisions. Their contributions are greatly appreciated.

This SDDW Supplement represents the DEP's current understanding of this ever-changing technology. It should be noted that we have deliberately chosen not to include certain types of technologies that could foreseeably fall under the heading of "Small Diameter Driven Wells," (e.g. cone penetrometers).

We welcome suggestions for future updates to Standard References for Monitoring Wells and welcome comments on this Supplement on Small Diameter Driven Wells. We hope that you find this Supplement a valuable tool.

Very truly yours,

Deirdre C. Menoyo
Assistant Commissioner
Bureau of Waste Site Cleanup

ACKNOWLEDGMENTS

The Massachusetts Department of Environmental Protection (DEP), Bureau of Waste Site Clean-up (BWSC), Policy and Program Development would like to thank all the individuals who assisted in the development of this supplement to Standard References for Monitoring Wells (Publication No. WSC-310-91). The Small Diameter Driven Well (SDDW) Supplement was reviewed and commented upon by individuals both within DEP and in the private sector.

Experienced field staff from the DEP regional offices were culled together to form a workgroup which provided extensive technical review of this document. The workgroup worked with TRC, DEP's contractor, to prepare this Supplement. The most significant contributors to the technical review process included: Mark Baldi (DEP Central Region), Paul Giddings (DEP Northeast Region), Chris Gill (formerly of DEP Southeast Region), Larry Immerman (DEP Northeast Region), and Paul Spano (DEP Central Region). In addition we would like to thank the following DEP reviewers for their invaluable insights: Cathy Chamberlain (DEP BWSC Western Region), John Fitzgerald (DEP BWSC Northeast Region), Steve Hallem (DEP BRP Boston), Jana Leung (DEP BRP Central Region), and Zack Peters (DEP BWSC Northeast Region). The project was coordinated by Sandra Hurlbut (DEP BWSC Boston).

This document was peer reviewed by several firms that use Small Diameter Driven Well technology. These private sector contributors provided valuable comments and supplied additional reference material that improved the quality of the document: Richard Cadwgan (Checkpoint Environmental, Inc.), Matthew Ednie (Zebra Environmental Corp.), Deborah Farnsworth (MykroWaters, Inc.), Benjamin Gregson (Vanasse, Hangen and Brustlin, Inc.), Wesley McCall (Geoprobe Systems), James O'Brien (O'Brien & O'Brien Associates), and John Swallow (Pine & Swallow Associates, Inc.).

SECTION 1.1 FOREWORD (Revised)

1.1-1 Purpose

This Supplement to Standard References for Monitoring Wells (Supplement) covers the technical aspects of locating, installing, sampling and decommissioning Small Diameter Driven Wells (SDDWs). These revisions have been prepared by the Department of Environmental Protection (DEP) to provide guidance to employees of the Department, consultants, well installers, and members of the regulated community.

The use of SDDWs for site assessment and site remediation activities has significantly increased since the initial publication of Standard References for Monitoring Wells (SRs) in 1991. This Supplement was prepared at the request of DEP staff and other interested parties who routinely use SDDWs. Available research indicates that the use of "direct push" technology for site assessment can provide quality sampling data comparable to conventional well installations, often at a lower cost. In addition, SDDWs can be used for site remediation activities such as air sparging and nutrient injection for bioremediation.

As with any type of well installation there are potential problems resulting from improper installation and/or poor sampling procedures. Results from improperly installed wells are not reliable and should not be used for environmental monitoring purposes. SDDW well installers are encouraged to use this guidance document to circumvent potential installation and sampling problems.

1.1-2 Order of Presentation

This Supplement incorporates both revisions to existing SRs and new sections that are pertinent to SDDW technology. Rather than modifying the entire document, placeholders have been used to link sections in this Supplement to sections in the original SRs. These are ***bold italicized*** for ease of use. In addition, similar subjects in this Supplement are cross-referenced to related sections in SRs. Due to the complexity of the subject matter and the format, it is strongly recommended that this Supplement be used in conjunction with Standard References for Monitoring Wells, January 1991.

This Supplement follows the same basic format as Standard References for Monitoring Wells. For editorial simplicity, the figures follow the text rather than being inserted into the section where they are discussed. References for each revised section of the Supplement are found at the very end of the document. Each new subsection has been assigned its own unique number. Each page contains a header with a reference to "SDDW Supplement," the subsection number, the page number, and date of publication.

It should be noted that this Supplement was not intended to be an exhaustive description of current SDDW technology. Instead, the DEP has opted to portray basic SDDW techniques commonly used in the field. Where possible, the Department has chosen to provide figures of "generic" sampling devices.

SECTION 1.2 TABLE OF CONTENTS (Revised)

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SECTION 3.2 DRILLING TECHNIQUES (Revised)

3.2-1 Purpose

Prior to selecting a well installation technique for a specific project, the objectives of the field investigation program must be established. The program objectives may include any or all of the following:

- Soil or rock evaluation - if undisturbed or representative samples are required, the well installation technique must be able to accommodate the appropriate type of sample collection.
- Characterization of hydrogeologic conditions - the well installation technique should allow for the characterization of each stratigraphic zone, water level measurement, and water sample collection.
- Evaluation of soil or groundwater contamination - the well installation technique must provide the appropriate sample collection methods, must not introduce contaminants or otherwise alter the existing soil or groundwater chemistry, and should not result in subsurface cross-contamination during or after installation.
- Installation of monitoring wells - installation method must permit appropriate well construction and minimize the disturbance to the borehole.

Choice of a specific installation technique for an investigation will impact the schedule, cost, and technical quality of a field investigation. The quality and representativeness of the soil and groundwater samples can be significantly affected by the well installation technique employed. Several items must be taken into consideration to determine the most appropriate well installation method. One of the best resources for selecting an appropriate well installation technique is an experienced contractor. Items that should be considered in the selection process include the following:

- Geologic Conditions:
  - unconsolidated or consolidated
  - type of material, including fill material
  - presence of boulders or cobbles
  - depth to bedrock
- Site Access:
  - property ownership
  - terrain and vegetative cover
  - wetlands and surface water
  - size of working area
  - equipment weight and size
  - need for large equipment
  - road access
  - location of water source if using conventional drilling equipment

- Seasonal Conditions Effecting Access:

  - effect of freezing temperatures, mud, and snow on installation progress
  - need to add antifreeze to pumps when in use under freezing conditions
  - high water conditions

- Existence of Contamination

  - utilize decontamination protocols
  - minimize disturbance and cross contamination
  - minimize impact on site chemistry
  - control drilling discharge, if using conventional installation techniques
  - reduce volume of contaminated spoils, if using conventional installation techniques
  - sampling requirements
  - minimize crew's exposure to potential site hazards
  - follow appropriate health and safety procedures (See Section 2.3 Health and Safety Plans in Standard References for Monitoring Wells, January 1991 for more information)

- Required Hole Size and Plumbness:

  - single-level or multiple-level well installations (See Section 4.0 Piezometers, Observation Wells and Monitoring Wells)
  - small diameter driven wells
  - large diameter wells
  - installation of instruments and down-hole equipment
  - availability of well installation equipment
  - for conventional wells and some SDDWs, adequate annular space for well installation
  - use of packers

- Cost of Installation: There are generally two different cost bases used for well installation contracts. One basis is time and materials required for the installation. The other is cost basis (i.e., unit price per foot of soil or rock of well installed).

Cost, or availability of equipment should not be the determining factor in choosing the proper well installation technique. An evaluation should be made of the impact of the well installation method on the integrity of the subsurface soil and groundwater sample to be obtained in the investigation.

Costs for chemical analyses can be high and money should not be wasted on analysis of unrepresentative samples. Also, analyses and remediation based on faulty data from improperly installed wells could ultimately be quite costly, greatly exceeding the cost of a well-conceived field investigation program.

Several well installation techniques that are commonly employed in environmental investigations are described in Standard References for Monitoring Wells, January 1991. Basic installation techniques and their advantages and disadvantages, are described for the following methods:

- Cable Tool

- Drive and Wash
- Spun Casing
- Solid Stem Augers
- Hollow Stem Augers
- Mud Rotary
- Air Rotary/Air Hammer
- ODEX
- Small Diameter Driven Wells **(this supplement)**

Included in Tables 3.2-1 through 3.2-8 and Appendix A in Standard References for Monitoring Wells, January 1991 is some useful information on conventional monitoring wells including standard casing diameters, casing volumes, drill bits and terminology. Additional information pertinent to Small Diameter Driven Wells is included in this Supplement.

(3.2-2 through 3.2-10: See Standard References for Monitoring Wells, January 1991)

3.2-11 Small Diameter Driven Wells (New Section)

3.2-11.1 General Considerations

Small Diameter Driven Wells (SDDWs) can be used for environmental assessment and for remediation of groundwater and soil. Depending upon site conditions, SDDWs may be used alone or in conjunction with conventional monitoring well installations. SDDWs are typically hollow steel rods advanced using a percussive force (a powered hammer) and driven directly into unconsolidated soil or fill. There are two basic types of SDDWs. One is a single rod system and the other is a dual tube or cased system. The single rod system uses a sequence of rods or steel pipes (gas pipe) to advance the drive point or sampler. Driven wells using a single rod system are generally capable of driving 10 foot to 21 foot long sections of piping. Single rod systems are often used for long term monitoring and are rarely extracted from the ground.

The cased system utilizes two sections, an outer drive rod and an inner sampling tube. Depending upon the sampling objectives, the inner sampling tube can be inserted into the drive rods during driving or inserted through the entire length of the drive rods after the desired sample depth has been reached (see Section 6.1 Sampling Techniques). Drive rods used with the dual tube or cased system are usually made from an expensive hi-grade steel alloy and are retracted after sampling. Drive rod lengths for the dual tube system can be obtained in sizes varying from 1 foot to 4 foot.

The type of advancement SDDWs use is commonly referred to as "direct push." Vibration, created from the hammering, mobilizes soil particles around the casing and creates a "thixotropic" or fluidized zone next to it. The resulting fluidized zone has a low bearing capacity that reduces resistance to penetration and allows the drive rods to be advanced relatively easily. Attached to the leading end of the drive rod is a tapered metal "drive point." This drive point is also referred to as a "tip" when used in soil gas sampling. Drive points are commonly advanced using hydraulic percussion equipment. Other percussion installation methods use electric or pneumatic devices.

SDDWs offer several advantages over conventional monitoring wells. One significant advantage is minimal installation time. The soil's reduced resistance to penetration created by the percussive force allows for rapid advancement of the drive point. Penetration rates vary by vendor and geologic conditions, but typically range between 10 to 50 feet per hour. Penetration depths of over 100 feet may be obtained under ideal conditions.

In addition, SDDW well development is generally not as intensive as conventional well development. Most commercially available SDDWs do not use drilling fluids or produce drill cuttings. As a result, time and money spent on management of drilling waste is negligible. Most SDDWs installed for sampling purposes do not create an annular space that would require the use of a seal or filter pack. These features reduce installation time and allow a greater number of SDDWs to be installed and sampled per day in comparison to conventional monitoring wells. Available information indicates between 6 and 12 wells consisting of total of 200 to 300 feet of pipe can be installed per day. However, installation rates vary depending upon the specific SDDW technique used, staff resources, and geological conditions.

Another advantage of using SDDWs is mobility. Specially outfitted trucks, vans, all terrain vehicles (ATVs) or utility vehicles provide greater mobility than conventional drilling rigs. Such vehicles can access remote locations and their compact size minimizes site disturbance. ATVs or similar utility vehicles are capable of functioning in rough terrain. This style of vehicle is well suited for exploration in soft ground or wetland areas. Hand-held installation techniques, such as vibratory drills or rotary hammer drills, are portable and can be used inside buildings or other confined locations which may be inaccessible to vehicles.

The material used for drive rods is typically carbon steel. Drive rods can also consist of stainless steel, galvanized steel, PVC (rarely) or other suitable and compatible materials. SDDWs have an inside diameter generally ranging between 0.5 and 1.5 inches, although larger inside diameters are currently available. The size of the SDDW is usually determined by its use. For example, smaller inside diameters are often used for soil gas sampling or piezometers. Larger inside diameter SDDWs may be used for soil sampling or groundwater monitoring wells.

Depending upon site assessment goals, SDDWs can be installed for long term monitoring or as temporary sampling points. SDDWs can be used to collect samples from groundwater, soil or soil gas using several types of specialized sampling tools. Groundwater sampling in the single rod system is accomplished using a slotted wellpoint section. Groundwater samples are obtained by lowering a sampling device down the rods and collecting a sample near the slotted wellpoint. The dual tube system may use a screened drive point sampler which is driven to the desired sampling point and then exposed to groundwater by lifting the outer sleeve or jacking the casing back. The dual tube system may also be used to install long term monitoring wells using prepacked well screen. Figures 3.2-15 and 3.2-16 illustrate some types of groundwater sampling devices.

Representative soil samples can be obtained by advancing either an open tube sampler or a closed piston sampler. Soil gas samples can be obtained using specialized probes or slotted pipe and a vacuum pump. Figures 3.2-17 and 3.2-18 depict a closed piston soil sampler and typical soil gas sampling tools.

SDDWs can also be used as air sparging points, vacuum pressure monitoring points, and heat injection monitoring points. When used for air sparging, SDDWs may be equipped with specialized implants or screens used as conduits to pump air into the saturated zone either below or within the contaminated area. The injected air strips the volatile organic compounds (VOCs) from the groundwater allowing them to migrate into the vadose zone where the contaminants are usually drawn into a soil vapor extraction system.

SDDWs can be used to monitor subsurface vacuum or pressure by advancing a predetermined screen interval to the desired depth and placing an air-tight surface seal around the piping. A cap or plug with tubing is then installed into the top of the SDDW to allow pressure monitoring.

When used for heat injection, SDDWs are advanced to the desired depth and completed with an air-tight surface seal. The SDDW is used as a conduit to inject heat into the subsurface. Either steam or hot air can be injected into the subsurface through an injection point. Due to the potential for corrosion, stainless steel construction should be considered for SDDWs used for heat injection and air sparging applications.

There are potential limitations when using SDDWs. SDDW methods can be ineffective or technically infeasible in areas where the overburden consists of very dense till, silt, clay, coarse gravel or boulders. All of these materials may affect sampling ability. Current SDDW technology does not allow confirmation of bedrock by coring. As with any monitoring well installation, SDDW advancement through confined or semi-confined aquifers may create a pathway for contaminant migration. Potential contaminant migration must be addressed using proper installation and decommissioning techniques.

3.2-11.2 Methodology

3.2-11.2.1 Advancement Techniques

As previously described, SDDWs are typically advanced using a percussive force to hammer rods or piping into the ground. This type of advancement is commonly referred to as direct push. The vibration resulting from the hammering mobilizes soil particles creating a fluidized zone around the rods. This fluidized zone has a low bearing capacity. Resistance to penetration is reduced and the well can be advanced relatively easily.

There are 4 basic types of direct push advancement. The most common is a hydraulic vibratory hammer. Others include an electric or pneumatic powered impact driver (hammer) and manually driven "slam bars." With the exception of the manually driven tools, all advancement equipment is generally available as a tower unit or as a hand held hammer drill. However, there are some basic differences in their application. Pneumatic and hydraulic hammers tend to be more powerful than electric hammers. Hand-held hammer drills and manual "slam bars" are more portable than tower units.

Hydraulic installation equipment uses a collapsible tower unit that is mounted on a vehicle. Typically the vehicle is a pick-up truck although vans, ATVs, and utility vehicles are also used. All hydraulic units are powered by either an auxiliary engine or by the vehicle engine. All use a drive-hammer as the percussive force to advance the rods. One vendor has a hydraulic system that uses both the dynamic force of the hammer as well as the static force of the vehicle's weight to advance the rods.

The electric vibratory technique is also used with a vehicle mounted tower. The drive hammer, attached to the top of the collapsible tower, applies percussion and high frequency vibrations to advance the SDDW. The electrical vibratory technique needs an electrical source or generator. Electric hammers are not as powerful as hydraulic and pneumatic techniques.

Pneumatic installation units are also vehicle mounted. This technique is similar to the electric vibratory method except the drive hammer is operated by an air compressor and the drill tower is typically operated with an electric motor. Disadvantages of the pneumatic technique are longer set-up time and the need for additional equipment such as an air compressor and generator.

In some situations, the use of a hand-held rotary hammer drill may be preferred. Rotary hammers are usually electric but hydraulic and pneumatic drills are also available. Hammer drills are much smaller than tower mounted units and are typically used inside buildings or where space is limited. Hand-held hammer drills can also be used in areas not readily accessible by vehicles. Their small size facilitates manual operation but also creates some limitations. Advancement or retrieval of rods at depths greater than a few feet may be difficult.

Similarly, manually driven slam bars provide many of the same conveniences as hand-held hammer drills. They are portable and can be used in tight or confined locations. No power source is needed for their operation. Slam bars also have limitations. Depths greater than a few feet may be difficult to achieve. Likewise, extraction of the rods may be difficult.

One commercially available SDDW application is installed using a direct push method of advancement but the well is completed using conventional monitoring well techniques (see Figure 3.2-16). Individuals employing such installations should refer to Section 3.2-6 in Standard References for Monitoring Wells, January 1991 for guidance on well completion techniques.

3.2-11.3 Advantages and Disadvantages

3.2-11.3.1 Advantages

- Drilling fluids are usually not required.
- No drill cuttings are produced.
- In favorable geologic conditions, advancement rates are typically faster than conventional drilling techniques.
- Representative groundwater samples can be collected at discrete or sequential intervals.
- Hand-held equipment provides accessibility to locations where site conditions limit vehicle and/or equipment size.
- SDDW methods allow for sampling of soil, groundwater, or soil vapor.

3.2-11.3.2 Disadvantages

- Difficult to use in dense geologic conditions or coarse gravel with cobbles and boulders.
- Groundwater sampling may be affected by fouling of screen openings.
- During installation, SDDWs may be deflected by subsurface obstacles and drift from vertical.
- Cannot confirm bedrock refusal by coring.

- Poor recharge of soil vapor or groundwater may result from tight soil formations.
- Potential for cross contamination or introduction of a preferential migration pathway exists if installed improperly.

3.2-11.4 Problems and Possible Solutions

3.2-11.4.1 Subsurface Obstacles

When installing SDDWs in areas with difficult subsurface conditions, obstacles may impede well advancement. For areas where obstructions are encountered, installation should be attempted at a location close to the original sampling point that meets sampling requirements. Alternatively, a larger diameter SDDW and a more powerful hammer may facilitate well installation where subsurface obstacles are found.

3.2-11.4.2 Surface Seals

Surface seals may be needed on SDDWs to reduce the possibility of well contamination. SDDWs can be contaminated by surface water run-off into open drive rods which can effect sample quality. Similarly, ambient air can dilute soil gas samples by "short circuiting," the mixing of air in the contaminated zone with aboveground air. Surface seals may be used to avoid well contamination by surface water run-off and help to minimize the introduction of above ground air into the well during soil gas sampling. To avoid the possible introduction of other volatile contaminants, surface seals should be prepared using bentonite or non-VOC containing materials.

3.2-11.4.3 Chemical Interference in Small Diameter Driven Wells

There is evidence that groundwater quality measurements may be impacted by steel used for well construction. Stainless steel may be a possible source of elevated nickel and/or chromium concentrations when installed in acidic (pH less than 4.0) groundwater. A thorough job of well purging should minimize this effect.

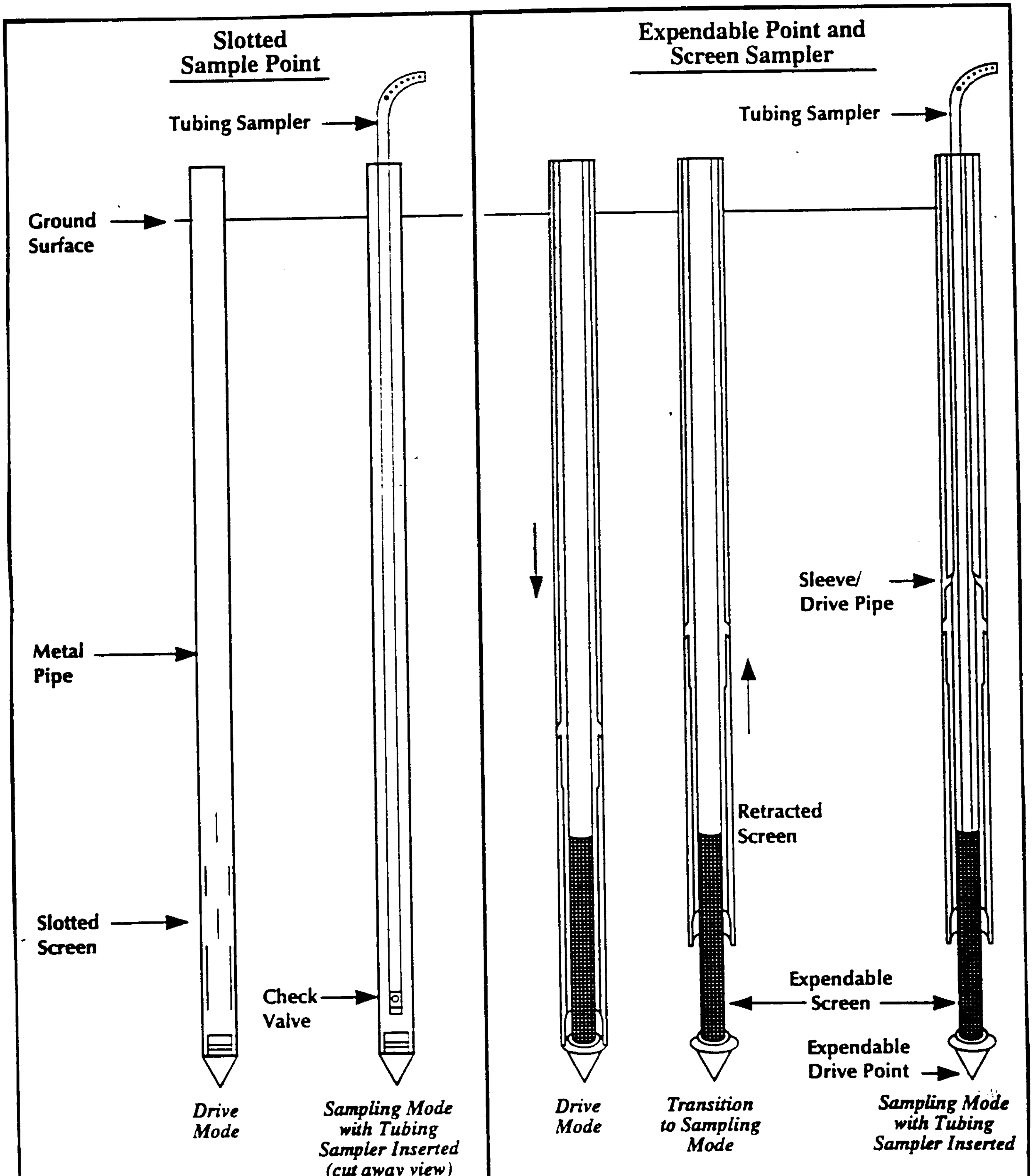
PVC has also been a source of debate for chemical interference. In some cases PVC has been shown to adsorb and desorb low levels of organic compounds. There is also concern that PVC may react with some ketones, aldehydes, and chlorinated solvents which may limit its durability. To minimize possible interference with these chemicals, only PVC that is listed by National Sanitation Foundation (NSF) should be used. NSF-listed PVC is essentially free of readily leachable plasticizers and does not exceed the National Interim Primary Drinking Water Standards in leach tests.

3.2-11.4.4 Failure of Groundwater Sampling Equipment

Inertial check valves may jam when trying to obtain a groundwater sample from an SDDW. This is caused by small particles that are able to pass through the slots of the screen. Failure may be avoided by cleaning the check valve more frequently.

3.2-11.4.5 Vertical Drift

As with conventional drilling techniques, SDDWs may drift from vertical during installation. Vertical drift may occur if the well point encounters a rock that cannot be fractured and compensates by deflecting the SDDW. As the diameter and rigidity of the drive rod decreases, vertical drift is more likely to occur. The use of larger diameter SDDWs and more powerful drive hammers may reduce the occurrence of vertical drift.



Sampler may be driven using various methods. See Section 3.2-11.2.

Ground Water sample may be obtained using various methods. See Section 6.2-3.5. Tubing sampler shown here as example only.

Not to Scale

Source: After Geoprobe Systems (1995)

Figure 3.2-15

Schematic of SDDW Groundwater Samplers.

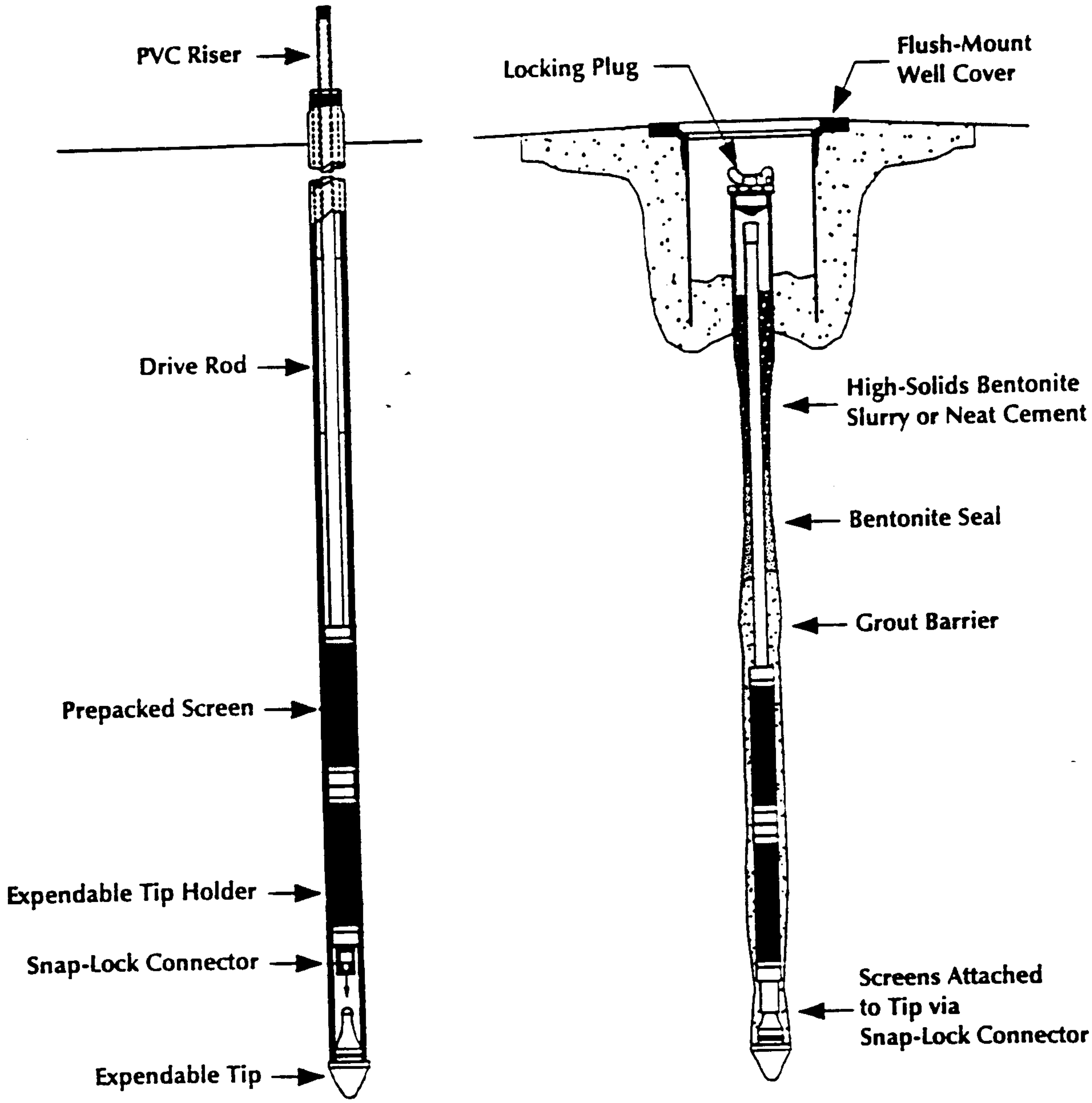
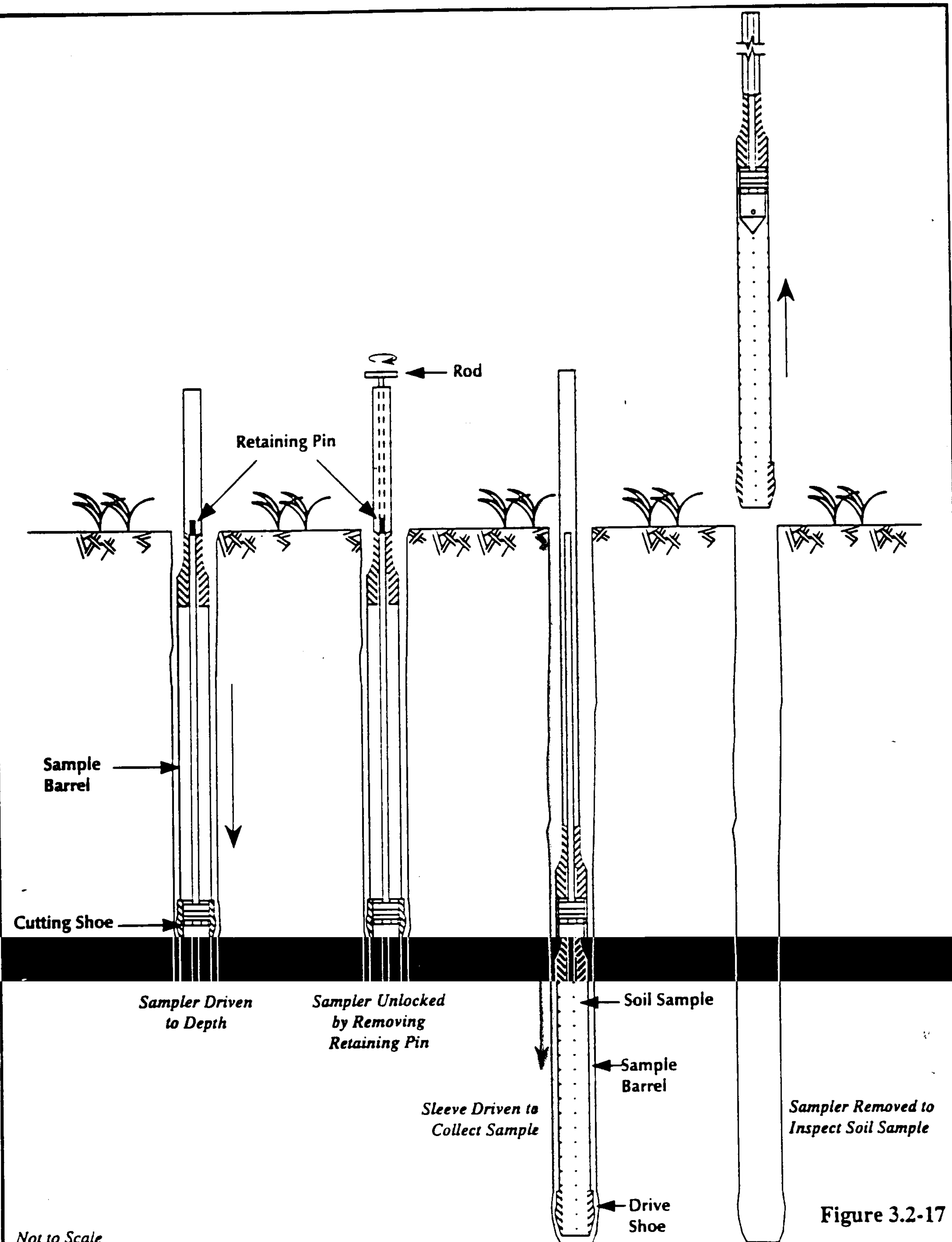


Figure 3.2-16

Schematic of Dual Tube System with Permanent Sampling Assembly.

Not to Scale

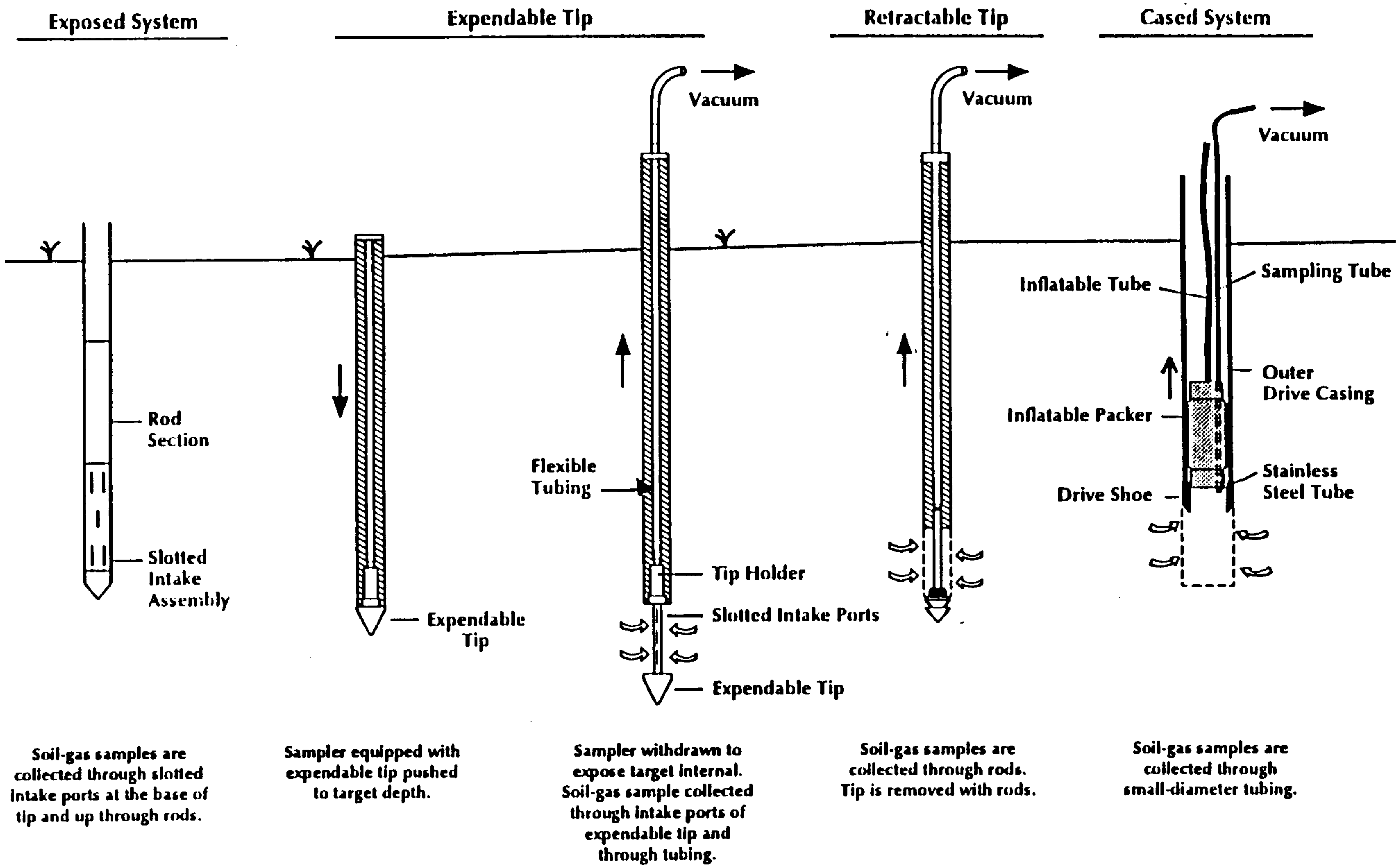
Source: After Geoprobe Systems (1996)



Source: After Geoprobe Systems (1995)

Figure 3.2-17

Schematic of SDDW Soil Sampler.



Not to Scale

Source: After Geoprobe Systems (1995); EPA (1997); and KVA Analytical Systems (1990)

Figure 3.2-18

Types of Soil Gas Sampling Tools.

SECTION 3.3 BORINGS IN CONTAMINATED AREAS (Revised)

3.3-1 Purpose

A fundamental aspect of most contamination investigations is the delineation of the extent of contamination in soil and groundwater. Both the horizontal (areal) and vertical distribution of the contamination must be defined. Geologic heterogeneities, variations in hydraulic conductivity, and contaminant characteristics will significantly influence the subsurface distribution of the contaminants. Accurate evaluation of contaminant migration and distribution requires the isolation and sampling of specific zones within an aquifer. To ensure the collection of representative samples and to prevent cross-contamination of soils and groundwater, special installation techniques may be required. In some cases, additional precautions must be taken during well installation to prevent contamination of nearby existing or potential water supplies. Protection of the health and safety of workers at contaminated waste sites is discussed in Section 2.3, Health and Safety Plans in Standard References for Monitoring Wells, January 1991.

For the purpose of this Supplement, "contaminated areas" are defined as highly contaminated source areas (i.e., oil and hazardous materials spills, landfills, waste lagoons, or zones of highly contaminated groundwater). The contamination may occur in either the saturated or unsaturated zones or both, depending on the location of the source and length of time since the release occurred. In these areas, well installation may alter or mask the existing distribution of contaminants by bridging contamination between aquifers. Some well installation techniques are better suited than others for investigations in contaminated areas. Conventional well installation methods using mud-rotary and air-rotary drilling techniques are undesirable in contaminated areas, due to the problem of inadequate control of fluids and cuttings in the borehole and at the surface (see Section 3.2 in Standard References for Monitoring Wells, January 1991). The more suitable conventional well installation methods for contaminated areas employ casing, either in single or multiple, to seal off the overlying strata during drilling. Small Diameter Driven Wells (SDDWs) use a percussive force that reduces the potential for introducing a preferential migration pathway when compared to conventional monitoring wells because the vibration created during the well installation forms an effective seal around the drive rods. However, the potential to puncture an aquitard may be increased if continuous or frequent soil sampling is being performed. The basic considerations for selecting an appropriate well installation method at a contaminated site are as follows:

- To prevent cross-contamination or migration of contaminants
- To obtain accurate and representative samples of formation materials and contaminants.
- To introduce a minimum amount of water or fluid into the aquifer, preferably none at all.
- To minimize the potential for introducing a contaminant migration pathway when a monitoring well is installed.
- To minimize safety hazards to the work crew, field personnel, workers at the site and residents of abutting properties.

3.3-2 Recommended Drilling Methods

Because each site is unique in terms of geologic material, groundwater characteristics, and types and properties of potential contaminants, the development of the subsurface exploration program may require modification of standard, generally accepted, well installation methods. It is always advisable to plan a well installation program so that the installation progresses from the cleaner areas to the more contaminated areas. Methods generally recommended for application in contaminated subsurface conditions are briefly described in the subsections below.

(3.3-2.1 and 3.3-2.2: See Standard References for Monitoring Wells, January 1991)

3.3-2.3 Small Diameter Driven Well Applications (New Section)

Small Diameter Driven Well methods can be utilized when obtaining subsurface soil, soil gas, or groundwater samples in contaminated areas. The risk of exposure to subsurface contaminants by on-site workers is diminished since spoils are not created or brought to the surface during the well installation process. Due to the small well diameter, the quantity of fluids generated during well development and purging requiring special handling and disposal is less than the quantity generated during development or purging of standard monitoring wells. Reductions in fluid volume and handling may provide significant cost savings when compared to conventional well installation techniques.

Advantages

- No drill cuttings.
- Drilling fluids are usually not required.
- Limited fluids generated during development and purging.
- Limited waste disposal costs.
- Can be used for site characterization or post remedial confirmatory sampling.
- Can be used for some remedial actions including air sparging.
- Reduced potential for cross contamination within the well since vibration during installation creates an effective seal around the drive rods.
- Small diameter driven well installations can reach depths similar to hollow stem augers.

Disadvantages

- Difficult to advance when cobbles and boulders are present.
- Potential depth limitations based on site geology, installation technique, and well size.
- Vertical drift may occur if drive point gets deflected.

(3.3-3 and 3.3-4: See Standard References for Monitoring Wells, January 1991)

SECTION 4.1 MONITORING WELL NETWORK DESIGN (Revised)

4.1-1 Purpose

The following section presents guidelines for the design of monitoring well networks. Monitoring wells are installed for a variety of reasons including:

- To determine horizontal and vertical hydraulic gradients that influence the direction of groundwater flow.
- To monitor changes in water quality over time.
- To define the two- or three-dimensional distribution of contamination in an aquifer.
- To evaluate the effectiveness of remedial measures.

Frequently, not enough attention is given to the design of well networks during the development of a field investigation program. If the network is not properly designed, important features relating to both the hydrogeology and chemical composition of the water within an aquifer may not be identified. If this occurs, one might reach erroneous conclusions about conditions at the site. This could result in inadequate definition of potential receptors and improper design of remedial measures.

The design of a monitoring well network is site-specific. It is important to understand that the conditions at each site are unique and, therefore, site-specific factors affecting groundwater flow and contaminant migration must be considered when designing an appropriate monitoring well network. It also makes a difference whether the network is being designed to define a plume of contamination migrating from a known source or to identify a source from a downgradient point or area of contamination. Design of a network requires input from experienced individuals familiar with the interrelationships of geology, hydrology, and groundwater chemistry, as well as the suitability of various well installation methods.

This section will focus on designing small diameter driven well networks. Guidance on the design of pump test monitoring systems for conventional monitoring wells is available from the DEP, Bureau of Resource Protection, Drinking Water Program.

(4.1-2 through 4.1-3: See Standard References for Monitoring Wells, January 1991)

4.1-4 Methodology

Designing a monitoring well network involves synthesizing information about site geology, hydrology, groundwater and contaminant chemistry, and human activities affecting the area being investigated. Monitoring well network design requires that the following steps be carried out:

- Compilation of available background data.
- Profiling all areas.
- Determination of the number and location of the wells.

- Determination of the most suitable well type, size and construction materials.

Many innovative small diameter driven well installation techniques have been developed over the past few years as a result of the large number of site investigations being undertaken. Well installation technology is continually improving. One of the best resources for deciding on the feasibility of a specific well design is an experienced well installation contractor. Often an experienced contractor can make helpful suggestions on modifications to a design that will improve the quality of well installation.

(4.1-4.1 through 4.1-4.2: See Standard References for Monitoring Wells, January 1991)

4.1-4.3 Selection of Well Type

(4.1-4.3.1 through 4.1-4.3.3: See Standard References for Monitoring Wells, January 1991)

4.1-4.3.4 Small Diameter Driven Well Network Design (New Section)

The term Small Diameter Driven Well (SDDW) is used to describe a temporary or permanent groundwater sampling point, usually up to 1.5 inches in inside diameter, that is installed using one of several direct push techniques. These points can be used to obtain samples of groundwater, measure water-levels, or serve as injection points for air sparging and/or nutrient injection for in-situ bioremediation. SDDWs can be completed to obtain groundwater samples from discrete intervals or used to obtain sequential samples to determine the vertical distribution of contaminants. They can also augment existing monitoring well networks to complement contaminant delineation efforts.

Selection of a SDDW method should be based on the requirements of the project, purpose of the investigation, and data quality objectives. In selecting the most appropriate SDDW applications for a characterization or monitoring program, one must balance the benefits of temporary vs. permanent SDDWs and discrete sampling vs. vertical profiling data.

Also, selection of well diameter must be based upon the site assessment goals. Smaller diameter driven wells may limit accessibility of more sophisticated electronic measuring equipment requiring installers to use measurement techniques like oil paste on wire to measure NAPL. Typically, SDDWs with outside diameters less than 0.5 inch are used for soil gas sampling or as piezometers. Larger outside diameter SDDWs (.82 to 1.5 inches) are used for soil sampling or groundwater monitoring.

Entire monitoring networks of SDDWs can be installed as a cost effective approach to delineate a groundwater plume. SDDW networks also allow delineation of non-aqueous phase liquids (NAPL).

Advantages

- Can be a cost-effective alternative to conventional monitoring wells under favorable geologic conditions.

- Allows network installation in sensitive areas (e.g., wetlands) with minimal impact.

- Representative groundwater samples can be immediately collected from discrete or sequential intervals in the aquifer.

- Ability to perform vertical profiling to define distribution of contamination.

- Generates fewer spoils, no soil cuttings and less purge water.

- Advancement rates are typically faster than conventional techniques in favorable geologic conditions.

Disadvantages

- SDDWs may have diameters which may be too small to allow the use of some equipment, such as electronic interface probes and submersible pumps.

- Absence of a filter pack on SDDWs may result in groundwater samples with elevated turbidity.

- Smearing of well screens when advancing through silts and clays may limit water flow into SDDW and affect groundwater sample quality.

SECTION 4.2 SELECTION OF WELL CONSTRUCTION MATERIALS (Revised)

4.2-1 Purpose

One purpose of this Standard Reference Supplement is to provide guidance on selecting the most economical and chemically inert small diameter monitoring well construction materials. While there are many similarities with the process of selecting materials for water wells and conventional monitoring wells, there are also differences which may be significant, especially in a highly contaminated environment. Monitoring well casing, SDDW drive rods and well construction materials should be selected to meet the following criteria:

- The materials should be resistant to deterioration resulting from long-term exposure to natural or synthetic chemical constituents in the groundwater at the site.
- The materials must have sufficient strength to ensure the structural integrity of the well during installation and long-term monitoring.
- The materials should be selected to minimize their interference with the measurement of the specific chemical parameters expected to be found at the site.
- The rod diameter should be large enough to accommodate commercially available down-hole instrumentation or sampling equipment (e.g. oil/water interface probe).
- The rods should be water-tight.
- The well must be able to be secured against vandalism, leakage, and inadvertent damage.
- The screen and filter pack, if used, must be appropriately sized to provide representative data on hydraulic conductivity and groundwater quality.

This section provides guidance for the selection of materials commonly used in monitoring well installations and discusses the advantages and disadvantages of each. The selection of well construction materials should be site specific. Proper selection requires consideration of project objectives, compliance with regulatory requirements, available data about the site geology, water chemistry, and the project budget. New well materials, filter packs and sealants are continually being developed. Individuals involved in well design and installation should be aware of recent developments in monitoring well technology.

4.2-2 Casing Materials

4.2-2.1 Composition

There are a number of commercially available well casing materials. The advantages and disadvantages of only a few of the most commonly used materials are described below. For conventional monitoring wells, it is possible to combine different materials as long as they are compatible. There is considerable debate over the significance of the adsorption and desorption potential of many well casing materials. However, adequate purging of the well prior to sampling reduces or eliminates the potential for this to have a significant impact on sample chemistry. If in doubt about the suitability of a particular casing material for the intended application, it is advisable to consult chemical compatibility charts or the equipment manufacturer for additional information. The significance of adsorption-desorption must be evaluated based upon monitoring well program objectives, sampling and analytical requirements, and the contaminant concentrations one is trying to measure.

4.2-2.1.1 Polyvinyl Chloride (PVC)

Polyvinyl chloride (PVC) is the most common well casing material used in conventional monitoring well construction. PVC is used to a much lesser extent in SDDW well installations. A limited number of SDDW installers use PVC for screens or riser (casing material). Such wells are usually constructed in the same manner as conventional wells but they are smaller in diameter; generally ranging 1.0-1.5" OD. SDDWs may also use PVC with piezometers for stream gauging and wetlands monitoring. In this type of application, PVC casing material is usually driven 2-5 feet into the soft ground with slam bars.

PVC is the thermoplastically molded casing composed of rigid, unplasticized polymer. PVC casing material offers a combination of chemical resistance, durability, availability, and low cost. There is considerable debate over the reaction of PVC well casing with some ketones, aldehydes, and chlorinated solvents. In some cases, PVC has been shown to adsorb and desorb low levels of organic compounds.

Flush-threaded or coupled PVC casing materials should be used for monitoring well construction. If flush-threaded casing is used, ASTM thread specifications should be used. Under NO circumstances should solvent cement be used to join casing sections together. PVC solvent cements have been shown to contribute significant quantities of organic contaminants to water samples collected from cemented PVC wells. Generally flush-threaded casing is preferred due to the ease of installation and because, if properly joined, it provides a water tight seal.

For all monitoring well applications where PVC is selected, only PVC well casing listed with the National Sanitation Foundation (NSF) should be used. These products are essentially free of readily leachable plasticizers and do not exceed the National Interim Primary Drinking Water Standards in leach tests.

Advantages

- Excellent chemical resistance to weak alkalies, alcohols, aliphatic hydrocarbons, oil and grease.
- Good chemical resistance to strong mineral acids, strong oxidizing acids, and strong alkalies.
- Readily available.
- Lightweight.
- Inexpensive.
- Two wall thickness’ commonly available (Schedule 40 and 80) provide a choice of strengths.

Disadvantages

- May adsorb and desorb low levels of some organic constituents from the groundwater. This may not be a problem if the well is adequately purged prior to sampling.
- Poor chemical resistance to concentrated ketones, esters, and some aromatic hydrocarbons.
- Weaker, less rigid, and more temperature-sensitive than metallic casing materials.

4.2-2.1.2 Stainless Steel

Stainless steel provides an excellent casing material where corrosion resistance and strength are important. The strength provided by stainless steel may be essential when installing conventional wells in deep boreholes (over 300 feet deep) due to the potential for other casing materials with lower strengths to collapse. Similarly, the use of stainless casing material or drive rods in Small Diameter Driven Well (SDDW) applications may be preferred when driving in difficult geologic conditions.

Stainless steel is resistant to most chemicals and is suited for monitoring many types of contaminants. Long periods of exposure to highly corrosive groundwater conditions may result in leaching of chromium or nickel from stainless steel well casing. Therefore, if the pH of the groundwater is low (4 or less), stainless steel is not recommended for long-term monitoring of inorganic constituents. Stainless steel is available in a variety of types, each with a slightly different composition. The basic composition and suggested applications for various types of stainless steel and other metals for well casing and screens is presented in Table 4.2-1 in Standard References for Monitoring Wells, January 1991. As with PVC, stainless steel casing should have threaded, flush joints to assure watertight connections.

Two types of stainless steel alloys are available for SDDW construction: 304 and 316. Both alloys resist corrosion and oxidation. There is little to no performance difference between SDDWs constructed from 304 or 316 stainless steel alloy. SDDWs constructed from stainless steel are typically constructed from the 304 alloy since it is significantly less expensive than the 316 alloy.

Advantages

- Excellent resistance to corrosion and oxidation; will not adsorb or desorb organic contaminants.
- High strength, rigidity.
- Suitable for wide range of temperatures.
- Readily available.

Disadvantages

- Susceptible to galvanic and electrochemical corrosion.
- Heavy; larger diameter casings used in conventional wells may require additional equipment to lower down borehole.

- May leach chromium and/or nickel in acidic waters.
- Moderate to high cost.

(4.2-2.1.3: See Standard References for Monitoring Wells, January 1991)

4.2-2.1.4 Carbon Steel (New Section)

Carbon steel (gas pipe) construction is a common SDDW construction material due to its relatively low cost, excellent durability, and chemical resistance. Carbon steel is stronger than stainless steel and therefore is preferred in applications in difficult geologic conditions. Due to the potential for corrosion, carbon steel may not be appropriate in long-term monitoring, vadose zone, or sparging/injection applications.

Advantages

- more rigid than stainless steel
- inexpensive compared to stainless steel

Disadvantages

- potential for corrosion in vadose zone or sparging/injection applications

4.2-2.1.5 Galvanized Steel (New Section)

Galvanized steel is not commonly used as a SDDW material. However, galvanized steel was formerly used in hand-driven well points at a time when the selection and availability of materials was not as diverse. SDDWs constructed from galvanized steel may still be available from some vendors.

Advantages

- Inexpensive
- High strength

Disadvantages

- Susceptible to corrosion

4.2-2.1.6 Joining Casing Materials and Drive Rods (New Section)

SDDWs are advanced into the ground by joining individual drive rods or sections of casing materials. The sections are joined by either threading, crimping, or welding. Threaded joint connections are a common joining method for direct push applications. Threaded drive rods are joined by screwing two drive rods together. Care must be taken during installation since the threaded portion may be thinner than the rest of the drive rod and may bend or break under extreme stress or if deflected.

SDDW drive rods can also be connected by crimping. Two drive rods are connected together by a external steel sleeve. The sleeve is secured in place by pinching with a hydraulic crimper. The integrity of the seal can be increased by crimping the sleeve in several locations.

Welding is another technique that can be used to join drive rods. In this technique, the ends of two drive rods are connected by a metal sleeve that is welded in place. The welding technique requires additional time and equipment on-site but provides a strong joint which can facilitate SDDW advancement in deep or difficult areas. All SDDW joints should be visually inspected in the field to ensure proper joining.

(4.2-2.2: See Standard References for Monitoring Wells, January 1991)

4.2-2.2.1 Size Selection for Small Diameter Driven Wells (New Section)

When constructing a Small Diameter Driven Well, both the wall thickness and the inside diameter (ID) of the drive rods or casing material must be considered. The wall thickness determines the strength of the casing material. The thicker the casing, the stronger the drive rod. Selection of SDDW diameter is typically limited by the materials available to the well installation contractor. However, the following factors should be considered in selecting a SDDW diameter.

- Subsurface conditions may limit the ability to drive smaller diameter SDDWs. Difficult driving conditions may impede or break smaller diameter SDDWs.
- Groundwater sampling will require a SDDW with a diameter large enough to accommodate the desired sampling equipment.
- For groundwater elevation or product thickness measurement, the SDDW should be of sufficient size to allow insertion of the required measurement equipment.
- Larger diameter drive rods or thicker casing materials provide greater strength and are more resistant to deflection.
- Smaller SDDWs are less costly and easier to handle in remote locations.
- For remedial applications, SDDWs should be sized to allow for the needed flow requirements.

(4.2-3 through 4.2-6: See Standard References for Monitoring Wells, January 1991)

4.2-7 Protective casings (Revised)

A protective well casing is recommended for all SDDWs used as monitoring wells to protect it from damage, leakage, tampering, or vandalism. Protective well casings are generally constructed of steel and have a locking cap. Two basic types of protective casings are used in all monitoring well installations: an above-ground casing and a flush-mount casing, or road box (see Figures 4.2-4 through 4.2-5 in Standard References for Monitoring Wells, January 1991).

Selection of the protective casing is based on the physical conditions of the area. In areas of vehicular or pedestrian traffic, it may be desirable to conceal the SDDW by using a flush mounted completion and roadbox. Flush mounted completion construction is slightly more expensive than stickup construction since it involves the addition of a roadbox. Above-ground and flush-mounted casing constructions should be sealed at the surface (See Section 4.3-5.2.3 in Standard References for Monitoring Wells, January 1991).

4.2-7.1 Above-ground Protective Casing

Above-ground SDDW completions are typically constructed using a portion of the SDDW rod as the protective casing. This type of protective casing is constructed by welding or crimping a metal tab to the top of the SDDW drive rod. A locking cap is then inserted over the top of the SDDW and locked through the metal tab to secure the well. The primary purpose of this construction is to ensure the integrity of the SDDW.

4.2-7.2 Flush-mount or Road-box Casing (Revised)

Flush-mount protective casings for SDDWs must be completed flush or slightly below ground surface. They are primarily used in high traffic areas such as roadways, parking lots, and sidewalks. Typically, flush mount construction uses a roadbox, of which many standard varieties are commercially available. Individual vendors may also offer customized roadboxes which might vary in diameter or depth. Flush-mounted SDDWs can also be constructed utilizing manhole covers. In order to avoid infiltration of surface water into the SDDW, roadboxes or manhole covers usually include a rubber gasket. Water tight caps are placed on the top of the SDDW rod. Granular material is usually placed inside the roadbox or manhole cover system to enable drainage of water that may have entered.

SECTION 4.3 WELL INSTALLATION PROCEDURES (Revised)

4.3-1 Purpose

The proper installation of monitoring wells is an essential part of all hydrogeologic investigations. The proper installation depends upon good communication and cooperation between the well installer and field personnel. Quality well installations require thoughtful consideration of several interrelated topics including the objective(s) of the well installation program, selection of the appropriate installation method, network design, and well construction materials. Information and technical guidance on these aspects of monitoring well construction are contained in other sections of Standard References for Monitoring Wells, January 1991 (SRs) and in this Supplement on Small Diameter Driven Wells (SDDW). Specific sections on construction include: Section 3.2 Drilling Techniques, Section 4.1 Network Design and Section 4.2 Selection of Well Construction Materials. The reader should refer to these sections in both Standard References for Monitoring Wells, January 1991 and this Supplement prior to specifying well materials and installation procedures.

The techniques described in the following subsections are some of the common and effective methods that can be used to install SDDWs. Other methods may be utilized provided that the performance and integrity of the well components are maintained. A contractor experienced in monitoring well installation can offer many helpful suggestions on both standard and innovative well installation methods. Discussions of a proposed well installation program with a contractor prior to undertaking the field program is strongly recommended.

Improperly installed monitoring wells can have serious consequences. Data obtained from such wells can be incorrect and/or misleading, resulting in erroneous interpretations and conclusions concerning potentiometric head conditions, extent of contamination, contaminant concentrations, and the source or receptor of contamination. Adequate attention must be given to the proper preparation and installation of monitoring well seals. Inadequately sealed wells can serve as conduits for the vertical movement of contaminants into uncontaminated portions of an aquifer or into a confined aquifer. A detailed discussion of the preparation and installation of monitoring well seals is contained in Standard References for Monitoring Wells, January 1991 and revisions contained within this document.

4.3-2 Components of the Installation

See Standard References for Monitoring Wells, January 1991, for conventional monitoring well installation components.

4.3-2.1 Components of SDDW Installation (New Section)

SDDWs are driven with percussive force directly into unconsolidated formations. SDDWs may be used as permanent or temporary monitoring points of soil, groundwater, and soil gas. At this time, SDDW technology is not capable of installation into consolidated bedrock.

The two primary types of SDDWs are the single rod system consisting of a drive point and slotted screen with riser pipe or rods and the dual tube or cased system consisting of removable drive casing with interior sampling assembly. The following system components are discussed within this Supplement:

- Single Rod with Slotted Screen
- Drive Casing with Retractable Screen Sampler
- Drive Casing with Permanent Sampling Assembly
- SDDW Soil Sampler

A surface seal, road box, and/or protective casing may be included if any of the above systems are constructed as permanent sampling points for soil gas or groundwater.

4.3-2.1.1 Single Rod with Slotted Screen

Components of a single rod SDDW with an exposed or mill slotted well screen include:

- Drive Point
- Mill Slotted Screen
- Drive Rods or Riser Pipe

This is the simplest and most common SDDW installation for groundwater and soil gas sampling (see Figures 3.2-15-"Slotted Sample Point" and 3.2-18-"Exposed System"). The single rod system is driven to the desired depth and samples of groundwater or soil gas are drawn through the exposed screen and collected at the ground surface.

Vertical profiling of groundwater and soil gas may be conducted by driving the exposed screen assembly to the intended depth, collecting a sample of groundwater or soil gas, and then advancing the SDDW to subsequent sampling depths. Care must be taken to avoid cross-contamination of samples. Over-pumping or excessive purging of the well is perhaps the most convenient method to avoid cross-contamination and obtain a representative sample (see Section 4.5-2.1 in Standard References for Monitoring Wells, January 1991).

Single rod SDDWs are generally constructed of readily available and affordable materials such as carbon steel. This type of single rod SDDW is rarely removed and is generally infeasible to extract even when long-term monitoring is not anticipated. More expensive drive rods such as stainless steel and hardened steel alloys are typically used when the SDDW is to be retrieved.

Due to the inability of this well installation method to retrieve soil samples for examination, caution must be exercised not to perforate confining layers. When installing a single rod SDDW system in contaminated areas, it may be useful to obtain soil samples to determine soil stratigraphy using an alternative method (see Section 3.2-6 in Standard References for Monitoring Wells, January 1991).

If constructed as a permanent monitoring point or remedial well such as a vapor extraction well or sparging point, a surface seal, road box, or other protective casing should be constructed after driving the SDDW to the desired depth.

4.3-2.1.2 Drive Casing with Retractable Screen Sampler

Components of a retractable screen sampler assembly include:

- Drive Casing

- Extension Rod
- Piston Rod
- Expendable Drive Point
- Retractable Screen

The SDDW retractable screen sampler is used as a temporary sampling point for groundwater and soil gas sampling (see Groundwater Figure 3.2-15-”Expendable Point and Screen Sampler” and Soil Gas Figures 3.2-18-“Retractable Tip”). The assembly consists of an expendable drive point and retractable screen which is connected to extension rods and a piston rod within the drive casing. Once the sampler is advanced to the desired sampling depth, the leading end of the drive casing is retracted while the extension rod holds the exposed screen in place. Groundwater or soil gas samples are drawn through the screen section and collected at the ground surface. The SDDW assembly is then retrieved from the subsurface for further use. The expendable drive point is left behind after retrieval of the assembly. Decontamination of the retractable screen sampler assembly is necessary before reuse.

4.3-2.1.3 Dual Tube or Cased System with Permanent Sampling Assembly

A dual tube or cased system SDDW installed as a permanent groundwater sampling assembly is a more recent advancement in small diameter well technology. Wells installed using this technique are driven to the desired sampling depth but well completion involves using conventional monitoring well methods including the addition of grout and sand (see Figure 3.2-16-”Schematic of Dual Tube System with Permanent Sampling Assembly”).

Components of the drive casing with permanent sampling assembly include:

- Dual Tube Drive Casing
- Expendable Tip
- Prepacked Screen Sections
- PVC Riser
- Bentonite Seal
- Protective Well Cover

The objective of this procedure is to install a permanent small diameter groundwater monitoring well that can be used to collect water quality samples, conduct hydrologic and pressure measurements, or perform any other sampling event that does not require large amounts of water at any given time.

To install a permanent sampling assembly SDDW, the drive casing and expendable tip is advanced to a desired depth. Once the drive casing is set at depth, the prepacked screens are lowered through the drive casing as additional PVC riser is added to the well assembly. The prepacked screens are attached to an expendable anchor point by a locking connector threaded to the bottom of the prepacked screens. When the prepacked screens are locked into the anchor point the drive rods are retracted. As the rods are retracted above the screens, either the natural formation collapses or a fine-grain sand is introduced to form a barrier above the prepacked screens. This sand or natural formation barrier prevents bentonite grout from penetrating into the screened interval. Granular bentonite or a bentonite slurry is then installed in the annular space to form a well seal. A protective well cover is then installed at the ground surface to complete the SDDW permanent sampling assembly.

4.3-2.1.4 SDDW Soil Sampler

The SDDW Soil Sampler is used to obtain discrete, stratigraphic soil samples. Components of a SDDW Soil sampler include:

- Drive Casing
- Extension Rod
- Piston Rod
- Sampler Tube, Sampler Sleeve, or Sampler Barrel
- Cutting Shoe
- Drive Point

The SDDW Soil Sampler is driven to a point above the desired sample depth. Extension rods are inserted within the drive casing to engage the piston rod by unlocking a retaining pin. The sample barrel is driven into the undisturbed soil beneath the drive point and the soil sample is retrieved from the borehole (see Figure 3.2-17-"Schematic of SDDW Soil Sampler").

(4.3-3 through 4.3-4: See Standard References for Monitoring Wells, January 1991)

4.3-5 Seals

(4.3-5.1: See Standard References for Monitoring Wells, January 1991)

4.3-5.2 Types of Well Seals

(4.3-5.2.1 through 4.3-5.2.2: See Standard References for Monitoring Wells, January 1991)

4.3-5.2.3 Surface Seals

4.3-5.2.3.1 Surface Seals for SDDWs (New Section)

Above-ground and flush-mounted casing constructions should be sealed at the surface to prevent surface water from entering the SDDW and to prevent short-circuiting of air in soil gas sampling applications.

In general, sealing of the SDDW involves hand grading of the area to eliminate collection of standing water around the SDDW. Bentonite or concrete seals are installed in an excavation around the base of above-ground stickup or roadbox. The surface of the seal should be contoured to divert surface water runoff away from the SDDW. Care should be taken to avoid inadvertent spillage of seal material into the SDDW during installation. A surface seal is not required if the SDDW is fitted with a locking cap.

(4.3-5.3 through 4.3-5.3.2(c): See Standard References for Monitoring Wells, January 1991)

4.3-6 Protective Casing and Surface Seal (Revised)

4.3-6.1 General Considerations

The purpose of a protective well casing is to provide a water-tight, tamper-resistant sleeve around the monitoring well to protect it from accidental damage, infiltration, and vandalism. Protective well casings are generally constructed of steel or cast iron and have a locking cap. The two basic types of protective casings used in monitoring well installations are the above-ground casing and the flush-mount casing or road box. For information on selection of the appropriate protective casing see Section 4.2-7 Selection of Well Materials - Protective Casings in Standard References for Monitoring Wells, 1991.

Important elements in the installation of a protective casing are the inside diameter of the protective casing, the depth of the pro tective casing, and the installation of a concrete surface seal.

Permanent SDDWs are also completed with above-ground and road-box protective casings, similar to conventional monitoring wells. For some steel SDDWs, the well casing may be used as the protective casing, provided a locking cap is present. For other SDDW installations, the inside diameter of the protective casing should be sufficiently large to permit easy access to the SDDW and removal of any caps or plugs.

(4.3-6.1.1 through 4.3-7.7: See Standard References for Monitoring Wells, January 1991)

SECTION 4.4 AS-BUILT NOTES AND RECORDS

4.4-1 Purpose

The purpose of an As-built record is to compile permanent information about the actual location and construction of a specific monitoring well, including the subsurface geology at the well location. There are several reasons for compiling such information:

- To ensure that the minimum construction standards have been met, and that the installation is suitable for the site conditions.
- To provide a historical database of information on existing monitoring wells, subsurface materials, and water quality.
- To enable others to assess the integrity of the well installation so as to be able to evaluate the validity of the environmental data obtained from the well.
- To meet the requirements for well drillers by Massachusetts General Law Chapter 21 Section 16 and the Department of Environmental Management regulations 313 CMR 3.00.

(4.4-2 through 4.4-3: See Standard References for Monitoring Wells, January 1991)

4.4-4 Small Diameter Driven Well Completion Report Information (New Section)

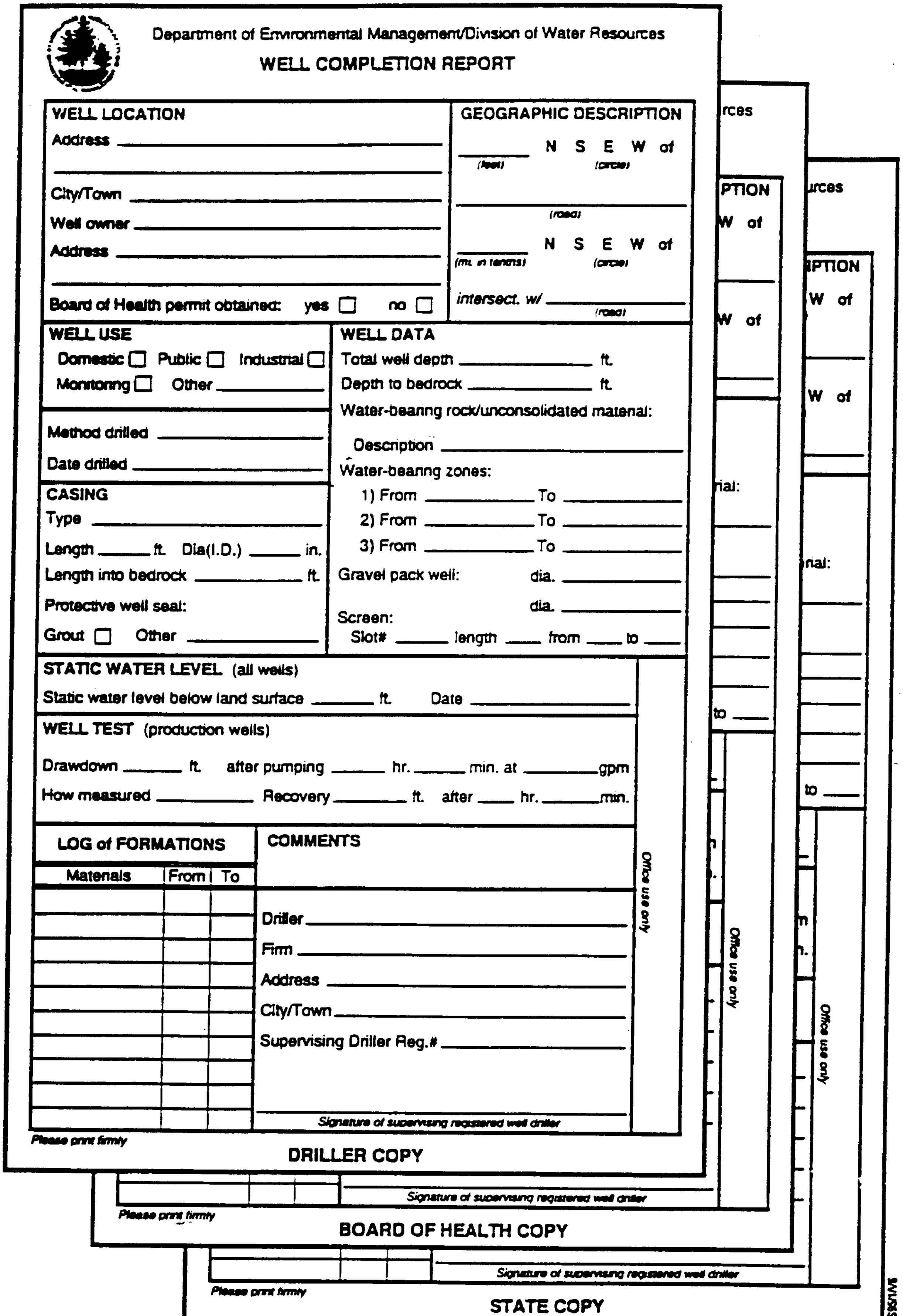
For the installation of any SDDW, a report documenting the completion and results should be prepared. At a minimum, the following information is recommended:

(1) Project name and Client;
(2) Site/well location description;
(3) Well/boring number;
(4) Drilling contractor and equipment;
(5) Site supervisor/geologist;
(6) Drilling method, SDDW development equipment, and sampler description;
(7) Total depth and water table depth;
(8) Start date and finish date;
(9) Screen and riser type, length, depth, and SDDW diameter;
(10) Soil classification (Section 3.5) or sample description, if appropriate;
(11) Field testing results; and
(12) SDDW abandonment description, if appropriate.
(13) Advancement rate (ft/min)
(14) Well development

A separate form should be completed for each SDDW installation or application. Examples of well completion reports and as-built forms can be found at the end of Section 4.4 in Standard References for Monitoring Wells, January 1991.

Readers should note that the Department of Environmental Management (DEM) revised regulations on "Registration of Well Drillers and Filing of Well Completion Reports" (313 CMR 3.00) in May of 1997. The new regulations have several requirements related to the installation of nonproductive (i.e.

monitoring wells) including the completion and filing of "Well Completion Report Forms" (see Figure 4.4-1). A copy of the DEM "Manual on Well Driller Registration and Filing of Monitoring Well Completion Reports" can be found in the Appendix of this Supplement.



Department of Environmental Management/Division of Water Resources

WELL COMPLETION REPORT

WELL LOCATION

Address ____________

City/Town ____________

Well owner ____________

Address ____________

Board of Health permit obtained: yes ☐ no ☐

GEOGRAPHIC DESCRIPTION

______ (feet) N S E W (circle) of ______ (road)

______ (mi. in tenths) N S E W (circle) of

intersect. w/ ______ (road)

WELL USE

Domestic ☐ Public ☐ Industrial ☐ Monitoring ☐ Other ______

Method drilled ______

Date drilled ______

CASING

Type ______

Length ____ ft. Dia(I.D.) ____ in.

Length into bedrock ______ ft.

Protective well seal:

Grout ☐ Other ______

WELL DATA

Total well depth ______ ft.

Depth to bedrock ______ ft.

Water-bearing rock/unconsolidated material:

Description ______

Water-bearing zones:

1) From ______ To ______

2) From ______ To ______

3) From ______ To ______

Gravel pack well: dia. ______

dia. ______

Screen:

Slot# ____ length ____ from ____ to ____

STATIC WATER LEVEL (all wells)

Static water level below land surface ____ ft. Date ______

WELL TEST (production wells)

Drawdown ____ ft. after pumping ____ hr. ____ min. at ____ gpm

How measured ______ Recovery ____ ft. after ____ hr. ____ min.

LOG of FORMATIONS

Materials	From	To

COMMENTS

Driller ______

Firm ______

Address ______

City/Town ______

Supervising Driller Reg.# ______

Signature of supervising registered well driller

Office use only

Please print firmly

DRILLER COPY

BOARD OF HEALTH COPY

STATE COPY

Figure 4.4-1
Well Completion Report Form.

Source: MA Department of Environmental Management

SECTION 4.5 WELL DEVELOPMENT (Revised)

4.5-1 Purpose

Well development is a necessary step in the completion of most groundwater monitoring well installations. Development of a monitoring well helps to remove sediment and enhance the hydraulic connection between the well and the aquifer. Regardless of which conventional well installation method is used, all cause some alteration or rearrangement of the fill or natural soil or rock material in which the well screen is installed. Such alteration or rearrangement is minimal when Small Diameter Driven Well (SDDW) techniques are used. Since monitoring wells are installed to collect physical and chemical data indicative of in-situ aquifer conditions, the methods of drilling and installing wells should minimize the disturbance of aquifer materials which adversely impact the quality of the data collected. Wells not intended for sampling, such as piezometers and observation wells, may not require development.

The objective of well development is to enhance the hydraulic connection between the well screen and the natural formation or fill by removing fine soil materials or drill cuttings and subsequently rearranging the natural or artificial sand filter pack around the well. Well development may increase the hydraulic conductivity in the vicinity of the well screen. This should be considered when in-situ hydraulic conductivity tests are planned. Appropriate mechanical rearrangement of the sand or gravel pack (i.e. development) will allow the groundwater to move through the sand pack more easily and reduce the amount of fines that enter the well. Since groundwater in most New England aquifers travels at velocities too low to retain suspended material, any turbidity associated with monitoring wells is likely to be an artifact of the well installation process. Well development can reduce this turbidity and, therefore, reduce the chance of chemical alteration of groundwater samples caused by suspended sediments. In addition, it can remove fluids introduced during drilling or installation. In this discussion, well development involves preparation of the well for collection of hydrologic and chemical data. If samples are collected for chemical analysis, the well must be purged prior to sample collection (See Section 6.0 Sampling of Monitoring Wells in Standard References for Monitoring Wells, January 1991).

In this discussion, well development involves preparation of the well for collection of hydrologic and chemical data. In order to obtain hydrologic and chemical data that is representative of the aquifer, the hydrologic conditions in the vicinity of the well screen should be restored to their natural state as much as possible. If samples are collected for chemical analysis, the well must be purged prior to sample collection (See Section 6.0 Sampling of Monitoring Wells in Standard References for Monitoring Wells, January 1991).

Use of development methods that introduce additional water into the formation or that cause significant alteration of the natural materials in the vicinity of the screen may be undesirable for some groundwater monitoring applications. If additional water is introduced during development to flush the screen, this volume of water must be removed as part of the development process and may require storage and disposal as a hazardous waste.

The purposes of well development are:

- to reduce the amount of fine grained material entering the well from the surrounding formation; and

- to improve the hydraulic connection between the well and surrounding formation

The following section on well development methodology will specifically address the development techniques for SDDWs. Aquifer conditions and constraints, especially permeability and depth to water table, will dictate the specific applicability of any of these methods. It is expected that variations and combinations of these methods will probably be required at some sites. It should be noted that all equipment placed in a monitoring well for development, purging or sampling should be decontaminated. Decontamination methods are presented in Section 3.3 and Section 6.5 of Standard References for Monitoring Wells, January 1991.

4.5-2 Methodology

SDDWs can use many of the same well development techniques that conventional monitoring wells use. However, SDDWs are usually designed and installed to obtain samples of formation groundwater without introducing fluids during drilling or disturbing subsurface conditions. These sampling points usually require minimal development. As with conventional wells, the primary reasons to develop a SDDW are to remove fine grained sediments and increase water flow. The well development methods usually employed for SDDW development include:

- Over-pumping
- Mechanical surging
- Water jetting
- Purging

Bailing is a technique that is not recommended for well development because it is slow and ineffective in adequately removing suspended sediment. Bailing is generally used for groundwater sampling and often for purging wells prior to sampling.

4.5-2.1 Over-pumping (Revised)

Over-pumping a well involves pumping at a rate faster than the well would normally be pumped or purged for sample collection. This is one of the easiest and most common methods of well development.

Over-pumping increases the hydraulic gradient near the well by drawing the water level down. The steepened hydraulic gradient increases the velocity of the groundwater moving through the screen into the well. The increased velocity entrains fines into the well and clears the screen of this material. Care must be taken not to introduce air into the formation around the screen during development.

Over-pumping is best suited to aquifers comprised of sands and gravels with shallow water tables. The suction line, pump or check valve is lowered into the well and water is removed. If the permeability of the formation is sufficiently high, repositioning of the intake line within the screen may pull material into the well.

Typical problems encountered using this method are the lack of pumping devices that will fit within smaller diameter (less than 2") monitoring wells and produce satisfactory pumping rates. Above-ground peristaltic or centrifugal pumps are effective when the water level is less than 25 feet from the ground surface. If the groundwater contains hazardous constituents, pumping large volumes of contaminated water may pose disposal problems.

4.5-2.1.1 Advantages and Disadvantages

(a) Advantages

- Useful in wells with shallow water-levels (less than 25 feet deep) where a suction line can be used.
- Relatively simple procedure.

(b) Disadvantages

- If the permeability is quite high or quite variable, only a section of the screened zone may actually be developed. This is especially true of wells with long screens.
- Over-pumping may compact fine sediments in the formation around the well screen, restricting groundwater flow into the screen.
- Over-pumping may produce a large volume of contaminated water that must be disposed of as a hazardous waste.

(4.5-2.2: See Standard References for Monitoring Wells, January 1991)

4.5-2.3 Mechanical Surging

Another method which can be used to develop SDDWs is surging. This technique employs a tool called a surge block. This device forces water in the well through the well screen and out into the formation, and then pulls the water back through the screen into the well along with fine soil or rock particles. A typical surge block construction detail and application can be found in Figures 4.5-1 and 4.5-2 in Standard References for Monitoring Wells, January 1991.

The surge block is typically attached to a drill rod, drill stem, or line that has sufficient weight to allow the surge block to rapidly drop through the water column. The surging action should start at a slow pace, near the water level within the well and progress to a faster pace near the well screen. Surging action can be carried out within the well screen if adequate measures are taken to clean out accumulated silt or material prior to surging. Otherwise, the fines may be forced out through the well screen into the surrounding formation. Accumulated material may also bind or lock the surge block in place if precleaning is not performed. Periodic bailing or pumping of the soil or rock particles is necessary regardless of the location of the surging within the well.

A typical surge block has a small clearance between the flexible leather or rubber discs and the inside of the well casing. Violent or too rapid surging in a well situated in a low permeability formation may damage the well. Variations in surge block construction involve the addition of flap valves to allow some water and silts to pass through the block rather than between the block and wall of the well. Additionally, check valves can be added to the surge block to allow removal of development water and associated silts. After surging, additional development can be performed, if desired, using the rawhiding or backflushing technique described in Section 4.5-2.2 in Standard References for Monitoring Well, 1991.

4.5-2.3.1 Advantages and Disadvantages

(a) Advantages

- Gentle surging combined with gentle pumping through the center of the surge block has been very successful for development in formation containing a considerable amount of fine material.

- Inexpensive and relatively simple tool.

- Effective in wells installed in highly permeable homogenous formations.

- Does not require the addition or withdrawal of substantial volumes of discharge water except for flushing.

(b) Disadvantages

- Vigorous surging may damage non-metallic well screens.

- May cause the formation around the screen to become clogged by pushing fines back into the formation, reducing flow into the well.

- If the surge block fits the well too tightly it can damage the well screen.

- May remove sufficient formation material outside and above the well screen causing the seal to collapse, resulting in infiltration of overlying aquifer material.

(4.5-2.4: See Standard References for Monitoring Wells, January 1991)

4.5-2.5 Water Jetting

High velocity water jetting is a rarely used but effective technique for development of conventional monitoring wells and, in even rarer instances, Small Diameter Driven Wells. Jetting consists of the discharge around the well screen of horizontal jets of water under high pressure. The water jets act to dislodge soil particles near the well screen and break up any dense soil resulting from installation. Unless removed, this layer can alter the natural permeability of the aquifer. In order to be effective in developing the well, water jetting must be accompanied by pumping to remove the fines. This development method should be used with caution to avoid damaging the screen or developing voids in the filter pack surrounding the screen.

4.5-2.5.1 Advantages and Disadvantages

(a) Advantages

- Effective in highly stratified, unconsolidated formations.

- Entire section of screened zone can be developed.

(b) Disadvantages

- Introduces water into the formation.
- Requires equipment which may not fit SDDWs.
- More time consuming than other methods.

4.5-2.6 Purging (New Section)

In addition to well development, which is typically conducted at the time of installation, SDDWs are purged immediately prior to obtaining groundwater samples. Purging is the process of removing water from within the SDDW and from the aquifer around the SDDW. Well purging is typically conducted using sample collection tools such as check valves and peristaltic or centrifugal pumps. Purging assures that the water to be sampled is a true representation of current conditions of the local groundwater. This is important since groundwater at the sampling site may not be representative of the overall groundwater due to variable environmental conditions, such as oxidation/reduction near the well, which may differ from conditions in the surrounding water-bearing formation.

As with conventional monitoring wells, the length of time required to adequately purge the SDDW is dependent on many factors including the characteristics of the SDDW, hydrogeologic nature of the aquifer, type of sampling equipment used, and parameters being sampled. It is recommended that the SDDW be purged until the groundwater has cleared of most fine sediment or at least 3 well volumes have been removed.

4.5-2.6.1 Advantages and Disadvantages

Advantages

- Ensures samples are representative of groundwater at the sampling site.

Disadvantages

- Requires additional time during sampling.
- Creates purge water which may require handling as a hazardous waste.

SECTION 4.6 DECOMMISSIONING OF MONITORING WELLS (Revised)

4.6-1 Purpose

Any monitoring well that is no longer in use or that is unfit for its intended purposes should be decommissioned. Plugging the well and surface restoration are the central features of the decommissioning process. For conventional monitoring wells, plugging consists of constructing a low permeability cylinder or plug within that portion of the subsurface occupied by the well and its annulus, including both the uncased portion of bedrock well and the cased portion. For Small Diameter Driven Wells (SDDWs), bentonite grout pumped into the drive rods will provide an adequate plug. Surface restoration consists of the removal of the upper three to four feet of the well and backfilling the area with an effective seal. An abandoned monitoring well is defined in Standard References for Monitoring Wells, January 1991 (SR) as "a well whose use has been permanently discontinued;" as used in this Supplement it includes any Small Diameter Driven Well that is no longer suitable or needed for its original intended purpose such as for water-level measurements, water quality sampling, soil sampling or soil gas sampling.

Proper plugging of such wells will:

- Eliminate physical hazards
- Prevent groundwater contamination
- Conserve the yield and hydrostatic head of confined aquifers
- Prevent the intermingling of potable and non-potable groundwater, and,
- Prevent the migration of contamination through a confining layer separating aquifers.

It should be noted that the objective in Massachusetts differs markedly from the goal established by the American Water Works Association and the statutes, regulations, or guidelines of most other states. Many documents contain the following language: "The basic concept of proper sealing of abandoned wells is restoration, as far as feasible, of the controlling hydrogeological conditions that existed before the well was drilled and constructed. If this restoration can be accomplished, all the objectives of plugging wells will be adequately fulfilled." To accomplish this goal some states have suggested the placement of sand and gravel opposite the more permeable subsurface zones and clay opposite the less permeable zones. While that goal is an admirable one, it is also one which, in DEP's opinion, may be unattainable in practice. In order to meet the objectives of proper decommissioning, DEP has tried to develop a simple, workable approach that will solve the existing and potential problems from unsafe abandoned wells.

Some examples of the types of unsafe wells that may cause problems include:

- Buried uncapped wells: contaminants may enter the well through the buried top of the casing, travel down the well casing, and enter the aquifer through the well screen and wall of the annulus;
- Wells with cracked or corroded casing: surface water may enter the well;

- Improperly constructed wells: an unsealed or improperly sealed annular space around the outside of a well casing or between an inner and outer casing may serve as a channel for surface water to migrate into an aquifer and/or groundwater may be transferred from one aquifer to another;

- Open hole wells in bedrock: may serve to interconnect aquifers in different formations;

- Unplugged abandoned flowing artesian wells: this can result in loss of water, reduction of regional artesian head and localized surface flooding; and

- Uncovered and unplugged abandoned wells with large inside diameter: these may represent a physical hazard to human beings and animals, as well as a disposal receptacle for contaminants, waste and debris.

(4.6-2: See Standard References for Monitoring Wells, January 1991)

4.6-3 Plugging the Well

(4.6-3.1 through 4.6-3.3: See Standard References for Monitoring Wells, January 1991)

4.6-3.4 Decommissioning Small Diameter Driven Wells (New Section)

Small Diameter Driven Wells can be decommissioned by extracting the casing material or, if feasible, by in-place abandonment. If the SDDW needs to be extracted, extra care should be taken to ensure that the remaining hole is completely filled and sealed with grout. Plastic tubing may be used to pump grout into the hole as the SDDW is removed.

If the SDDW is to be abandoned in-place, grout should be pumped into the drive rod or casing material to plug it. As with conventional well decommissioning, if the SDDW is removed, care must be taken to reduce the possibility of borehole collapse, voids, and contaminant migration through a preferential pathway.

Abandonment of SDDWs should be conducted using general protocols outlined for conventional monitoring wells presented in Sections 4.6-2.1 through 4.6-3.3 in Standard References for Monitoring Wells, January 1991.

SECTION 6.2 SAMPLING TECHNIQUES (Revised)

(6.2-1 through 6.2-3.4: See Standard References for Monitoring Wells, January 1991)

6.2-3.5 Sampling Techniques for SDDWs (New Section)

6.2-3.5.1 Groundwater Sampling Methods and Equipment

Groundwater samples can be collected at any desired depth in the aquifer through the screened interval of the SDDW as it is being advanced or withdrawn. SDDWs should be purged prior to sampling to reduce turbidity and obtain more representative samples of groundwater. SDDWs advanced to obtain samples at increasingly greater depths should be purged between sampling intervals to remove stagnant water in the well.

There are generally two approaches used to obtain groundwater samples while advancing the SDDW (Figure 3.2-15). Groundwater samples can be obtained through slotted screen at the lead end of the SDDW or through a screened groundwater sampler with a retractable sleeve. Regardless of whether slotted screen or a screened retractable sleeve SDDWs are used, groundwater sampling can be accomplished using either a small diameter bailer, peristaltic pump, or an inertial pump system. Sampling with bailers and peristaltic pumps is discussed in Sections 6.2-3.1 and 6.2-3.3 of Standard References for Monitoring Wells, January 1991.

Inertial pump techniques use a check valve assembly attached to the bottom of a tubing section that is lowered through the water column (Figure 6.2-3.1 in Standard References for Monitoring Wells, January 1991). When the tubing is pushed in a downward motion, water is allowed to enter into the check valve, pushing the ball up and away from the bottom of the check valve. When the tubing is moved in an upward motion, the ball is forced to the bottom of the check valve where it forms a water tight seal. In higher yielding formations, an oscillating up and down motion can be used to pump groundwater and sustain flow at the surface. In subsurface soil with low permeability, the inertial sampler can also be used as a bailer and retrieved to the surface to obtain the sample. Some advantages and disadvantages of the inertial tubing system are listed below.

Advantages

- Tubing and check valve assemblies are commercially available in various material types for any size SDDW.
- Inertial sampler is easily assembled and used in the field.
- Inertial sampler may be dedicated and stored inside a permanent SDDW for subsequent reuse eliminating the need for decontamination.
- New or dedicated sampling equipment minimizes potential for cross-contamination.

Disadvantages

- Fine-grained sediment can clog the check valve assembly causing the ball to stick and reducing or eliminating flow.

- Not economically feasible to reuse tubing.

- In low yielding formations air can enter the tubing which may purge VOCs from groundwater.

6.2-3.5.2 Soil Sampling Methods and Equipment

For soil sampling applications, either an open tube or closed piston sampler is used at the lead end of the SDDW equipment. The open tube sampler is used in stable, compact or cohesive soils and the piston sampler is used in loose soil conditions.

To obtain an open tube soil sample, a SDDW drive point or preprobe is driven to desired sampling depth and subsequently withdrawn. The drive point is removed and the open tube sampling device is attached to the drive rods. The drive rods are then reinserted into the existing hole to obtain a soil sample. Open tube sampling devices are typically used in compact soil which can be retained within the tube. Excessive penetration of the sampler under the weight of the rods may occur in very soft or loose materials and prevent accurate measurement of penetration depth. Excessive penetration may also disturb underlying material. Sample loss is possible upon retraction of the sample tube.

Advantages

- Simple to use.

- Commonly available.

- Easy to decontaminate sampler.

- Short amount of time required for sampling.

Disadvantages

- Disturbed and intermixed soil materials from the bottom and sides of the borehole may enter the tube as it is lowered into position.

- Total or partial sample recovery is difficult without a supplemental retention system. Catchers are available for some samplers.

- Hydrostatic pressure may disturb the sample during penetration and interfere with collection of a complete sample.

A closed piston sampler is typically used in areas where the subsurface soils are unstable and may collapse as the probe is withdrawn. The closed piston sampler is designed so that the piston tip of the sampler fits into the drive shoe of the SDDW equipment. The drive point or preprobe is driven to depth immediately above the desired sampling interval and then withdrawn. An open hole remains after withdrawal and the closed piston sampler is reinserted. Extension rods are inserted down the drive rods or casing to unlock the piston tip and lift it to the upper portion of the piston sampler. The sample barrel is then driven deeper into the soil while the piston point remains stationary.

The tight seal on the piston creates a vacuum which aids in sample retention (see Figure 3.2-17).

Advantages

- Sample device is sealed during installation preventing contaminated soil and water from entering and corrupting analytical results.
- Reduced potential for sample disturbance in comparison to open tube sampling.
- Improved sample recovery in unstable soils.
- Application commonly available.

Disadvantages

- More mechanically complex than open tube sampling.
- Piston requires maintenance of o-rings or leaks may result.
- Requires more time to sample than open tube sampling.
- More parts to decontaminate.

6.2-3.5.3 Soil Gas Sampling Methods and Equipment

SDDWs can be used for obtaining soil gas samples by advancing the SDDW into the vadose zone below the ground surface. Soil gas samples are obtained by creating an air-tight surface seal around the SDDW and applying a negative pressure or vacuum to promote movement of soil gas to the ground surface for sample collection. Four of the more common soil gas sampling methodologies are illustrated in Figure 3.2-18. These soil gas sampling tools include: an exposed screen sampler, an expendable tip sampler, a retractable tip sampler and a packer or cased system.

When taking soil gas samples, the use of probe tips with a larger diameter than the SDDW rods is discouraged. Larger tips may increase the likelihood of "short circuiting," the mixing of surface air with the contaminated atmosphere, which could dilute soil gas contaminant concentrations.

6.2-3.5.3.1 Exposed Screen Samplers

The exposed screen sampler is the simplest form of soil gas sampling equipment. It consists of a drive point, a slotted intake assembly and drive rods. The drive point is attached to the lead end of the slotted intake assembly which is in turn connected to a series of drive rods. The device is driven to the desired sampling depth and a soil gas sample is collected through the slotted intake ports using negative pressure. The slotted intake ports allow the passage of soil gas into the drive rods for sample collection at the ground surface.

Advantages

- Allows rapid sampling of multiple intervals.
- Minimal equipment required.

Disadvantages

- Screen is exposed to contaminants as SDDW is advanced into the subsurface.
- Screen may become smeared or clogged with fine grain soil during advancement.
- Decontamination is required after each use.
- Soil gas may be collected from intervals other than the targeted zone if the rod joints are not air-tight.
- Extraction of rods using a retrieval jack can be difficult and time consuming.

6.2-3.5.3.2 Expendable Tip Samplers

Expendable tip samplers use a steel or aluminum tip that is held in place by a tip holder as the soil gas assembly is advanced. Flexible tubing for sample collection runs the entire length of the drive rods and is attached to the tip. Slotted intake ports are found at the base of the tip. The assembly is driven into the ground until the desired sampling depth is reached. The drive rods are then retracted and the tip is separated from the tip holder, exposing the soil interval for sampling. Soil gas is drawn in through slotted intake ports at the base of the drive point and up through the flexible tubing. The tubing is typically 3/16-inch O.D. and is made of polyethylene, silicon or Teflon.

If long-term monitoring is required, the well should be completed using conventional techniques. Specifically, a permeable packing material such as silica sand or glass beads is recommended to be set in the annular space around the intake ports of the expendable tip. A bentonite seal is set above the packing material to eliminate the potential for drawing air from intervals other than the targeted zone. The remaining annular space around the flexible tubing should be backfilled and compacted with native soil. A surface seal is also necessary for long-term monitoring.

Advantages

- Screened intake ports are protected while probe assembly is advanced, eliminating the potential for soil clogging.
- When properly completed the likelihood of drawing air from areas other than the targeted interval is minimal.
- Purging volume and sampling time are reduced.

Disadvantages

- More equipment required.
- More expensive.
- More time consuming.

6.2-3.5.3.3 Retractable Tip Samplers

Retractable tip samplers are similar to expendable tip samplers except that the tip is attached to a screen which is held in the tip holder during advancement. As with the expendable tip sampler, the retractable sampler is advanced to the desired depth and the drive rod is retracted to expose the screen. Unlike the expendable tip assembly, soil gas samples are collected directly though the drive rods when a vacuum is applied. When sample collection is completed, the tip is retrieved along with the drive rods.

Advantages

- Retractable screen sampler is not exposed to soil during advancement, eliminating potential for soil clogging.
- Easy sampling of sequential intervals.

Disadvantages

- Does not allow grouting of borehole during retraction.

6.2-3.5.3.4 Cased Samplers

Cased sampling devices for SDDWs are seldom used in Massachusetts. Cased samplers use an inflatable packing device to establish an air-tight seal within the well casing. The SDDW is driven to depth and the packing device is lowered into the casing for soil gas sampling. Flexible tubing runs down the casing, next to the inflatable packer, and protrudes past the end of the packing device. Soil gas samples are collected through the flexible tubing using a vacuum.

Advantages

- Results in less compaction of the soils
- Enables multiple level sampling

Disadvantages

- Slower than exposed rod SDDW soil gas samplers.

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