Chapter 6
Sample Collection

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6.1 Introduction

This chapter details many of the step-by-step procedures to be followed during the collection of environmental samples from various matrices. The use of different kinds of sampling equipment dictates that different factors must be considered for each type of sample collected. Some factors concerning sample collection, however, remain the same regardless of the sample's matrix or device used. This non-site-specific information comprises the first part of this section. For site-specific considerations, contact the appropriate regulatory authority. The general information presented here, when used with information in any of the other sections of this chapter and as dictated by the site-specific conditions, will allow the most representative sample to be collected in a safe and efficient manner.

The New Jersey Department of Environmental Protection (NJDEP) maintains a library of guidance manuals on its website at https://www.nj.gov/dep/srp/guidance/. It is recommended the reader access the website and review the guidance manuals pertinent to the respective task. Additional guidance may also be found at websites of the EPA and the American Society for Testing and Materials (ASTM). Examples of some of the relevant guidance manuals and websites pertaining to this chapter are:

Soil Investigation Technical Guidance https://www.nj.gov/dep/srp/guidance/#si_ri_ra_soils;

Ground Water Technical Guidance: https://www.nj.gov/dep/srp/guidance/#pa_si_ri_gw;

Ecological Evaluation Technical Guidance: https://www.nj.gov/dep/srp/guidance/#eco_eval;

Vapor Intrusion Technical Guidance https://www.nj.gov/dep/srp/guidance/#vi;

Quality Assurance Project Plan Technical Guidance
https://www.nj.gov/dep/srp/guidance/#analytic_methods;

Occupational Safety and Health Administration (OSHA): https://www.osha.gov; and

United States Environmental Protection Agency (USEPA): https://clu-in.org/characterization/technologies/lif.cfm.

6.1.1 Preparation

Thorough preparation before the initiation of a sampling event is undoubtedly one of the most important steps in the sampling process. Additional costs can be incurred if sampling must be continued on another day or completely redone due to inadequate or improper preparation.

Therefore, equipment lists should be prepared, and personnel needs should be projected. In cases where it is questionable which type of sampling device will work best, several should be on hand. If potential obstacles to the timely completion of the job exist, extra personnel should be scheduled.

In addition to procurement of the appropriate equipment, sampling preparation includes assuring that equipment is in good working condition and properly decontaminated. The sampling device should be cleaned per one of the approved methods described in Chapter 5 and properly prepared for transport to the site. Care must be taken in transporting and storing cleaned sampling equipment. It is recommended that sampling equipment not be stored or transported in the same vehicle compartment used to transport generators, gasoline or decontamination solvents. Under such conditions cross-contamination is likely to occur. If one vehicle is used care should be taken to reduce cross contamination.

The material of construction for sampling equipment should be PTFE or stainless steel (see Chapter 5 *Sampling Equipment*, 5.1 *Introduction*). Each sampling device should be used to collect one sample. In some cases, the use of dedicated samplers may be impractical. When collecting numerous surface soil

samples (using trowels) or subsurface soil from boreholes (using direct push or split spoon samplers) it may be necessary to decontaminate equipment in the field. An equipment decontamination area must be set up to accomplish this task. The decontamination area should be established in a non-contaminated zone and should consist of chemical resistant buckets placed on clean plastic sheeting. Solutions required for equipment decontamination must be on hand and should be in easy-to-use squirt bottles. Assorted heavy duty scrub brushes must be available. All rinse fluids should be collected, and provisions made for their proper disposal.

Special sampling considerations should be implemented for situations where following the traditional protocols could result in unexpected contamination of the sample (e.g., sampling for hexavalent chromium or Per- and Polyfluoroalkyl substances (PFAS)).

When decontaminating equipment in the field, extra care must be taken to assure thorough cleaning. Due to the difficulty encountered in cleaning bailers, field decontamination is not recommended for this piece of equipment. Bailers must be new, or laboratory cleaned, wrapped, and dedicated to each well for each day's sampling.

In addition to the site-specific decontaminated sampling device, other equipment is necessary during the execution of a sampling event, which may include but not be limited to:

- laboratory cleaned sample containers of the proper size and composition provided by the laboratory performing the analysis;
- quality control samples (e.g., field and/or trip blanks, duplicates, performance evaluation samples);
- field notes, and camera;
- appropriate paperwork (e.g., Chain of Custody, Logging and Calibration forms);
- sample labels;
- reagents, preservatives, coolers and a means to maintain sample temperature at 4ºC;
- portable instrumentation (e.g., Geiger counter, explosimeter, oxygen level monitor, photoionization detector, flame ionization detector, flow through cell, appropriate parameter meters, GPS);
- narrow range pH paper, that is within the "Use By" time frame indicated by the manufacturer, to check the pH of preserved samples;
- appropriate personal safety equipment (e.g., disposable gloves, eye protection, and respirators);
- decontamination equipment for personnel and/or equipment;
- absorbent pads;
- plastic bags for containerizing contaminated items; and
- packaging materials for sample shipment and custody seals for shuttles. This includes appropriate shipping containers that meet either USDOT or USDOT/IATA standards depending upon the "dangerous goods" classification for packaging and shipping samples to the laboratory.

6.1.2 Type of Samples

6.1.2.1 Environmental and Waste Samples

Environmental: samples of naturally occurring matrices such as soil, sediment, ground water, surface water and air.

Waste: samples, which are comprised of process waste or other manmade materials.

Making the distinction between environmental and waste samples is important when it comes to choosing sampling equipment, the material of construction (see Chapter 5), personal safety

precautions, and for complying with transportation requirements. For waste samples, the volumes needed by the laboratory for certain analysis can be reduced thus minimizing the volumes collected in the field and disposal issues for the laboratory. The actual volumes of waste samples needed by the laboratory should be determined and detailed in the Quality Assurance Project Plan (QAPP).

Environmental and waste samples have the potential to contain significant amounts of hazardous materials. Since these samples pose a safety threat, they should be designated, handled and shipped as dangerous goods according to U.S. Department of Transportation regulations (see Chapter 11, *Sample Shipment*).

6.1.2.2 Grab vs. Composite

Grab sample: a discrete aliquot that is representative of one specific sample site at a specific point in time. Since the entire sample is collected at one particular point and all at one time, a grab sample is representative only of those static conditions. If the source or condition is fairly consistent over a period of time and/or geographical area, the grab sample can be considered to be fairly representative. However, for sources that vary greatly over time, distance, or area (e.g., release of contaminants into moving water or air) the representativeness of a grab sample is not as easily discernable.

Composite sample: a non-discrete sample composed of more than one specific aliquot collected at various sampling points and/or at different times. Composite samples may give an "average" concentration or composition over time or area. When compositing is performed the concentration of contaminant in individual grab samples may be diluted proportionately to the number of samples taken. Not only is contaminant dilution possible, but the detection limits for each individual sample may also be raised proportionally by the number of samples added to the composite.

This concept should be taken into account when determining the data quality objectives of a composite sampling event, to ensure that useful data are collected. It is advisable that if a positive identification is made while analyzing a composite sample, that the discrete samples then be analyzed individually to determine the true distribution of contaminant throughout each component of the composite.

When collecting samples at hazardous waste sites for the Site Remediation and Waste Management Program, grab sampling should be the chosen method. While composite samples may have merit when performed for specific purposes (e.g., waste classification and waste water discharge) and under known conditions, the risks involved may be great (mixing unknown/reactive waste) and the information provided not particularly useful. To improve the quality of the composite sample, follow the compositing considerations offered in ASTM D6051-15 *Standard Guide for Composite Sampling and Field Subsampling for Environmental Waste Management Activities*. Two possible homogenization options to consider for soil are the cone and quarter technique or use of a riffle splitter (laboratory use only). For aqueous samples use of a churn splitter may be a suitable option.

Compositing samples may pose a potential safety risk when samples of unknown content are combined. Changes in the chemical nature of the sample may occur as a result of this combination causing the sample to be non-representative of actual field conditions for a particular time or location. Additionally, contaminants in one aliquot of sample may be masked when this portion is composited with other, cleaner aliquots.

If compositing is allowed in site specific instances, it should occur in the laboratory for hazardous samples, and in the field for wastewater or stormwater samples. Samples should be composited on a weight/weight or volume/volume basis under controlled conditions. Be aware that there are no formal laboratory methods for compositing samples at the laboratory, so procedures will vary from laboratory to laboratory and possibly within a laboratory. Always keep in mind that consistency helps to ensure comparability of data.

Note: For discussion on duplicate, split, and other QA/QC sample collection requirements see

Chapter 2.

6.1.3 Laboratory Procurement

The analytical needs associated with the collection of samples should be clearly defined in the site-specific Field Sampling Plan-Quality Assurance Project Plan (FSP-QAPP). Important information regarding the data quality objectives, analytical methods to be employed, turnaround times, and deliverables must be specified. When choosing a laboratory, these factors act as a guide. Additional considerations include:

- whether the laboratory has maintained the required certifications and approvals for specific parameters for which samples are to be analyzed;
- whether the laboratory's parameter specific detection levels/reporting levels meet data quality objectives;
- whether the laboratory has the capacity to handle all the samples that will be delivered;
- whether the laboratory can perform the analysis within the applicable holding time;
- the lab's proximity to the site or capability to pick up and deliver as needed; and
- whether the laboratory provides DOT/IATA shipping containers and packaging materials.

For additional information on Laboratory Certification see N.J.A.C 7:18 Regulations Governing the Certification of Laboratories and Environmental Measurements at: https://www.nj.gov/dep/rules/rules/njac7_18.pdf .

6.1.4 Quality Assurance Samples

When advising the chosen laboratory of the required analyses, specifications regarding quality control samples should be relayed. The laboratory should be informed as to the rate of inclusion of trip and field blanks, how this water should be provided (e.g., identical sets of filled and empty bottles for field blank collection), the requirements for the quality and origin of the blank water (e.g., the same as the method blank) and the analysis desired (see Chapter 2) for the associated blanks.

The laboratory's procedure for bottle preparation and storage, blank preparation and mechanism for transport and maintenance of temperature should be evaluated and the associated paperwork should be reviewed for adequacy.

Quality assurance considerations must be addressed prior to sampling. If upon initiation of the sampling it is discovered that one or several quality assurance considerations have not been properly addressed, no sampling should occur. In such a situation, with personnel and equipment on standby in the field, the importance of effective communication with the laboratory is crucial.

6.1.5 Quality Assurance Project Plans

Since sampling situations vary widely and no universal sampling procedure can be recommended, it is important that an FSP-QAPP be developed per regulatory authority requirements. As stated in Chapter 2, the development of a QAPP is required prior to the sampling. Please refer to Chapter 2 for the Quality Assurance Project Plan Requirements.

6.1.6 Assuring Health and Safety

The health and safety of sampling and support personnel is the most important priority during collection operations. Appropriate portable monitoring devices, which have been properly calibrated, should be used by properly trained personnel to monitor site conditions. A complete Health and Safety Plan should be developed based on information gathered during the file search and instrument readings from the pre-sampling site visit. This Plan should detail potential hazards, instruments to be used, their calibration and use, level of protection to be worn by personnel during various on-site activities, emergency services

locations and phone numbers, etc. To assure health and safety in unknown situations (e.g., sites with little available historic information or in initial entry situations) a worst-case scenario should always be assumed until instruments confirm otherwise. (See Chapter 4, *Site Entry Activities*.)

For example, test pit excavation sampling or the sampling of containerized materials, may initially require level B personal protection. The results of continuous air monitoring may determine that downgrading personnel protection is acceptable.

6.1.7 Documenting Field Observations

When conducting field activities, the field technician should be aware of any conditions that could impact sample collection. Any observations (i.e., well conditions, nearby activities) or conditions (i.e., weather, humidity) should be properly documented and reported during each field event.

Site conditions (including equipment malfunctions, weather) may warrant sample relocation or modification during actual field activities. If this occurs, additional information should be noted in the field notes documenting the sampling plan modification and new sample location relative to the old as well as fixed objects such as a building or road. This will ensure accurate data interpretation for the modified sampling plan by non-field personnel.

When accessing wells (temporary or permanent) any information that is suggestive of groundwater contamination should be recorded and submitted to DEP in relevant documents. Examples include: 1) the presence of DNAPL or LNAPL product; 2) the presence of DNAPL or LNAPL sheens; 3) odors or vapors; 4) readings from organic vapor analyzers (e.g., PIDs and FIDs); and water appearance (e.g., color-lime green, grey, or texture-frothy, bubbly, etc.). The above information can be generated during well drilling, well development, well purging, well sampling, well sounding, and the collection of depth to groundwater measurements.

6.1.8 Post Sampling Activities

There are several steps to be taken, even after the transfer of the sample into the sample bottle, that are necessary to properly complete collection activities. Once the sample is transferred into the appropriate container, the bottle should be capped and, if necessary, the outside of the bottle should be wiped with a clean paper towel to remove excess sampling material. The bottle should not be submerged in water to clean it. Rather, if necessary, a clean paper towel moistened with distilled or deionized water may be used.

The sample should be preserved immediately (4ºC and/or with appropriate reagent as detailed in the approved QAPP), properly labeled, properly packaged for transportation and custody sealed. Information such as sample number, location, collection time and sample description should be recorded in the field notes. Associated paperwork (e.g., Chain of Custody forms, Sample Analysis Request forms) should then be completed and should stay with the sample. The samples should be packaged in a manner that will allow the appropriate storage temperature to be maintained during shipment to the lab. Samples should be delivered to the lab, so the proper temperature level is assured, and analytical holding times are not exceeded.

6.1.9 Investigation Derived Waste

Investigation Derived Waste (IDW) is any waste material generated during investigation or remediation activities. These items could include (list not exhaustive):

- Purged Groundwater
- Drill Cuttings
- Decontamination Water and Rinse Water

- PPE (disposable glove, tyvek suits, booties, etc.
- Disposable Bailers, Soil Scoops, Mixing Spoons
- Acetate Sleeve from Soil Core
- Absorbent Pads/Booms

It is recommended that an IDW plan be included with the workplan. The materials need to be handled according to local, state and/or federal waste handling rules. If purge water or drilling soils are to be drummed for offsite disposal, check with the disposal company for their specific waste classification sampling requirements. All drums need to be labeled prior to placement of waste into the drums. Disposal of PPE and sampling equipment is specific to the level of contamination at the site. Check with the local solid waste facility if this type of material is accepted or if needs to be disposed of at a specialized facility.

All haulers and disposal facilities should be licensed and approved to accept the waste being sent to them and the hauler should provide documentation for collection and disposal unless incidental supplies, i.e., gloves, are disposed of within municipal waste stream.

It is also important to take into consideration the storage of the materials, especially for offsite activities. All precautions should be made to secure the material from access by the public to protect from exposure, theft, vandalism etc. Be sure that an offsite property owner has provided authorization for waste storage.

For consideration in the IDW Plan it is recommended that the person conducting the investigation:

- Determine what waste will be generated and if it will be hazardous or non-hazardous.
- How it will be managed, i.e., drummed, bagged, stockpiled, etc.
- What sampling is required; what labeling is required.
- Where will it be stored
- Is waste disposal included in the project budget
- Is the person completing the work trained in RCRA or other waste transportation rules
- Is the stored waste accessible for pick up by the waste hauler
- How long can the waste be stored

For more detailed guidance check https://www.epa.gov/sites/default/files/2015-06/documents/Management-of-IDW.pdf.

6.2 Soil Sampling

This recommended protocol outlines procedures, equipment and other considerations specific to the collection of representative surface and subsurface soil samples. When followed, these guidelines serve to maintain sample integrity by preserving physical form and chemical composition to as great an extent as possible. In addition to this section, the reader should refer to the following FSPM chapters to attain a more complete understanding of the requirements associated with soil sampling: Chapter 2, *Quality Assurance*; Chapter 5, *Sample Equipment*; Chapter 7, *Field Analytical Methods*; and Chapter 13, *Personnel Protection*. The reader is also directed to the NJDEP *Technical Guidance for Site Investigation of Soil, Remedial Investigation of Soil, and Remedial Action Verification Sampling for Soil* available at: https://www.nj.gov/dep/srp/guidance/#si_ri_ra_soils. Finally, effective soil sampling cannot be complete without reference to The Technical Requirements for Site Remediation (N.J.A.C. 7:26E, (https://www.nj.gov/dep/srp/regs/).

6.2.1 Selection of Sampling Equipment

New Jersey's soil types range from the principally sandy soils of the southern coastal plain to the more heterogeneous soils in the north. To select the most appropriate sampling device, particular attention should be paid to the soil type being investigated. Generally, the northern region's rocky soil increases the difficulty obtaining a representative sample. Therefore, when sampling outside the coastal plain, extra consideration for the proper selection and advancement effort of the chosen sampling device should be factored into the planning of the sampling effort.

In certain site-specific circumstances, the parameters being investigated, or the reagents being used for decontamination, may influence the type and construction of the sampling device selected. Specifically, the sensitive chemical/physical nature displayed by volatile organic chemicals (VOCs) requires special consideration in sample equipment selection as aeration or heating of soils can easily result in VOC loss.

The slow advancement of split-spoons, macrocores, or sonic drill casing into dry or compact/tight soils can result in significant heating of the soil core collection equipment, and sometimes the soil core within. The temperature of the soil core collecting equipment should be monitored and measures taken to reduce heat buildup when it occurs. Where conditions exist that would facilitate heat buildup of the equipment (i.e., compact/tight soils, dry soils, deep advancement of the soil core collection equipment) the NJDEP recommends that language to address this issue be included in any pertinent work plan.

Specifically, with respect to the use of sonic drilling, such actions could include: 1) collecting soil cores in shorter runs so the soil spends less time in the metal core barrel; 2) use of rigid plastic liners as opposed to extruding into a flexible polyethylene sleeve to insulate the core from heat transfer from the metal casing; and 3) when a very hard zone or object is encountered causing the advance rate of the drill string to significantly slow down, immediate pull the core barrel and remove any core material, core through the resistant material using a now empty and clean core barrel, once the harder material has been penetrated and advance rate increases, pull the core barrel and remove the hard material, then resume drilling with a clean, empty core barrel.

Some sampling devices (e.g., bucket auger) may churn or otherwise alter or destroy certain physical attributes (e.g., pore space, ped formation, soil stratification, color, etc.) and aerate the soil. This can cause an unwanted loss of volatiles from the sample. These devices should not be used for volatile organic sample collection. The recommended device (e.g., split spoon, macrocore, sonic core, etc.) should produce a relatively undisturbed soil core, which will minimize the loss of VOCs and the destruction of soil characteristics (i.e., silt/clay).

If sampling for VOCs and SVOCs and using soft dig methods, please see section 6.2.5.2.1, *Considerations when Clearing for Utilities Prior to Borehole Advancement*.

The chosen device should also be able to present the soil in such a fashion as to lend reasonable accessibility to field screening instruments (e.g., photoionization detector (PID)/flame ionization detector (FID) which in turn will assist in a reasonable interpretation of potential contamination across a measurable segment of the soil horizon. The optimum device will yield a sample, which has been minimally disturbed, where any biased sample may be easily identified and whose depth can be determined for future reference.

Typical soil sampling devices and accessories are illustrated in Chapter 5 of this manual and include but are not limited to the following:

- Scoop or trowel*
- Bucket/hand auger*
- Hand driven soil coring devices
- Split spoon sampler
- Direct push with ridged inner liner

- Sonic drilling with rigid inner liner
- Shelby tube sampler
- Waste pile sampler
- Mixing bowl or tray*
- Spatula*

* Not recommended for use when sampling VOCs. Please see Section 6.2.7.1 *VOC Soil Sampling Considerations* for additional information.

Where available, sampling devices should be of stainless steel construction although disposable scoops or trowels constructed of rigid polyvinyl or polyethylene are acceptable. Another exception to this rule is the split spoon sampler, which is commonly constructed of carbon steel. Be aware that certain compounds may require specific materials or equipment (e.g., hexavalent chromium and PFAS).

6.2.2 Equipment Preparation

After selection of the proper device, consideration should be given to equipment decontamination. When the decontamination procedure is properly performed (see Chapter 5), the potential for cross contamination can be significantly reduced. Care should be taken if a parameter of concern (i.e., acetone) is part of the decontamination process, or equipment damage by the reagents used during decontamination is a possibility (i.e., nitric acid rinse is detrimental to components constructed of bronze or carbon steel). When these site-specific questions arise, discussion with the regulatory authority may be prudent before a sampling plan is finalized. All soil sampling devices used for chemical analysis should be decontaminated prior to use and in between sample locations. Once the equipment has been cleaned, it should be protected from incidental contact by wrapping in aluminum foil or placing in sealed plastic bags.

Additionally, any heavy equipment necessary for the advancement of any sampling device should be steam cleaned or high pressure/hot water washed prior to and between sample locations. This would include, but is not limited to, auger flights, drill rods, backhoe buckets and other respective accessories.

Depending on site conditions or sampling requirements, soil may have to be collected from beneath concrete pads, floors or asphalt paved areas. In these instances, the equipment used to expose the soil beneath should also be decontaminated if the equipment will directly contact the sample. Similar to the treatment of heavy equipment, decontamination of sampling equipment should be performed prior to each sample acquisition. Particular attention should be paid to the lubricating water associated with concrete coring equipment. If a potable water source is not available and the potential integrity of the sample is in jeopardy, analysis of the lubricating water used may be necessary.

It cannot be overstated that costly and lengthy cleanup or permit decisions are based on the soil sampling results. Therefore, initial attention to equipment selection and its preparation can offer a significant reduction in oversight expense while providing the most reliable results.

6.2.3 Soil Logs

The development of geologic logs from geologic borings represent one of the most important informational resources in a remedial investigation and apply to both overburden and bedrock conditions. The logs come from the installation of boreholes associated with subsurface soil sampling and the installation of monitoring wells. NJAC 7:26E-1.6 requires the development and submission of logs for soil borings, test pits and monitoring wells.

The logs should include as much information as possible on the geology, hydrology, and potential contaminant impact to the subsurface. Geologic information should include, but is not limited to, soil texture/sorting, grain size, mineralogic composition, split spoon blow count, borehole advancement rate, soil color, soil stratification/structure, and the presence and depth of any non-native material (e.g., fill,

ash, wood, gravel, trash, asphalt, etc.). Hydrologic information should include, but is not limited to, moisture content, presence of soil mottling, detection of saturated conditions (i.e., water-table depth), and the depth and vertical extent of low yielding and high yielding zones. Potential soil impact information should include, but is not limited to, soil vapor readings (FID, PID), X-ray fluorescence readings (XRF), odors, soil discoloration, sheens, the presence of free or residual product, and any signs of trash, containers, drums or other man-made material. NJAC 7:26E-1.6 requires logs to contain soil/rock physical descriptions and field instrument readings detected during borehole installation. The depth interval where each soil sample is collected should be identified on the log and the soil sample designation listed.

Where split spoons are collected via the Standard Penetration Test (SPT) it is recommended that the procedure follow current ASTM protocols.

Important! ***Soil logs should be completed after sample collection for laboratory analysis to minimize losses due to volatilization and biodegradation as well as cross contamination due to excessive handling of the soil.***

Texture descriptions include the relative angularity, roundness and sorting of the particles as well as their grain size. Description of moisture content include terms such as dry, moist, wet, or saturated. Descriptions of soil fabric should include whether the particles are flat or bulky and whether the particles are stratified, laminated, varved, etc.

It is recommended soil color descriptions reference Munsell color charts. Variations in color, e.g., mottling, can provide information on the extent of water-table fluctuations and geochemical conditions (aerobic vs. anaerobic) or formational changes. Soils with bright and uniform colors generally are well drained. Soils with gray or dull colors may be poorly drained. Color changes may also indicate the presence of contaminants. For example, soils and clay may become darker in a reducing environment ("gleying") caused by the presence of petroleum hydrocarbons. The size, type and condition of rock fragments should also be included (e.g., shale, sandstone, decomposed, and friable, etc.).

Soil texture should be classified according to one of the standard systems discussed below. Since there is some variability between the different soil classification systems, all logs should specify which soil classification system is being used or provide the size ranges on the log. For consistency, it is also important to compare the soil samples in the field with a reference card for the classification system being used. These are commercially available from various sources. The following is a discussion of some of the soil classification systems commonly used to characterize the texture of soils and sediments. Although the terms used in the classification systems (e.g., sand, silt, and clay) have mineralogical connotations, the terms used here refer strictly to soil and sediment textures. An example of a boring log is provided on page 21 to assist field personnel in recording observed soil data.

6.2.3.1 Wentworth Scale

The Wentworth scale is a logarithmic scale in that each grade limit is twice as large as the next smaller grade limit (Folk, 1974, page 25). It is used to describe the texture of sedimentary rocks (e.g., sandstone) as well as unconsolidated sediments. The US Geological Survey uses this classification but has taken the gravel size range and subdivided it into groups as shown in Table 6.1 below.

Table 6.1 Wentworth Scale as Modified from Driscoll, 1986, and Folk, 1974			
Wentworth Size Class	**Millimeters**	**Inches**	**Standard Sieve #**
Boulder	256 +	10.08 +	
Cobble	64 - 256	2.52 - 10.08	
Pebble	4 - 64	0.16 - 2.52	
Very coarse gravel	32 - 64	1.26 - 2.52	
Coarse gravel	16 - 32	0.63 - 1.26	
Medium gravel	8 - 16	0.31 - 0.63	
Fine gravel	4 - 8	0.16 - 0.31	No. 5 +
Granule (v.f. gravel)	2 - 4	0.08 - 0.16	No. 5 - No. 10
Very coarse sand	1 - 2	0.04 - 0.08	No. 10 - No. 18
Coarse sand	0.5 - 1	0.02 - 0.04	No. 18 - No. 35
Medium sand	0.25 - 0.5	0.01 - 0.02	No. 35 - No. 60
Fine sand	0.125 - 0.25	0.005 - 0.01	No. 60 - No. 120
Very fine sand	0.0625 - 0.125	0.002 - 0.005	No. 120 - No. 230
Silt	0.004 - 0.0625	0.0002 - 0.002	analyze by pipette or hydrometer
Coarse silt	0.031 - 0.0625		
Medium silt	0.0156 - 0.0625		
Fine silt	0.0078 - 0.0156		
Very fine silt	0.0039 - 0.0078		
Clay	below 0.0039	below 0.0002	

6.2.3.2 Unified Soil Classification System (USCS)

The USCS differentiates soils into three major divisions: coarse-grained, fine-grained and highly organic soils as shown in the table below. Fine-grained soils are classified as those that will pass through a No. 200 U.S. standard sieve (0.074 mm). Organic material is a common component of soil, but it has no size range. Each type of soil is given a two-letter designation based primarily on its particle-size distribution (texture), Atterberg limits, and organic matter content. Tables 6.2 and 6.3 below describe the USCS. Although the USCS is approved for soil classification, the use of "Group Symbols" to describe the soil texture significantly reduces the value of the logs to those not well versed in the USCS. To maximize use of the soil boring logs, NJDEP recommends using soil descriptions that provide as much textural information as possible (i.e., proportions and sizes of the constituents). If the USCS is used, textural descriptions of the soil should be included in addition to the "Group Symbol".

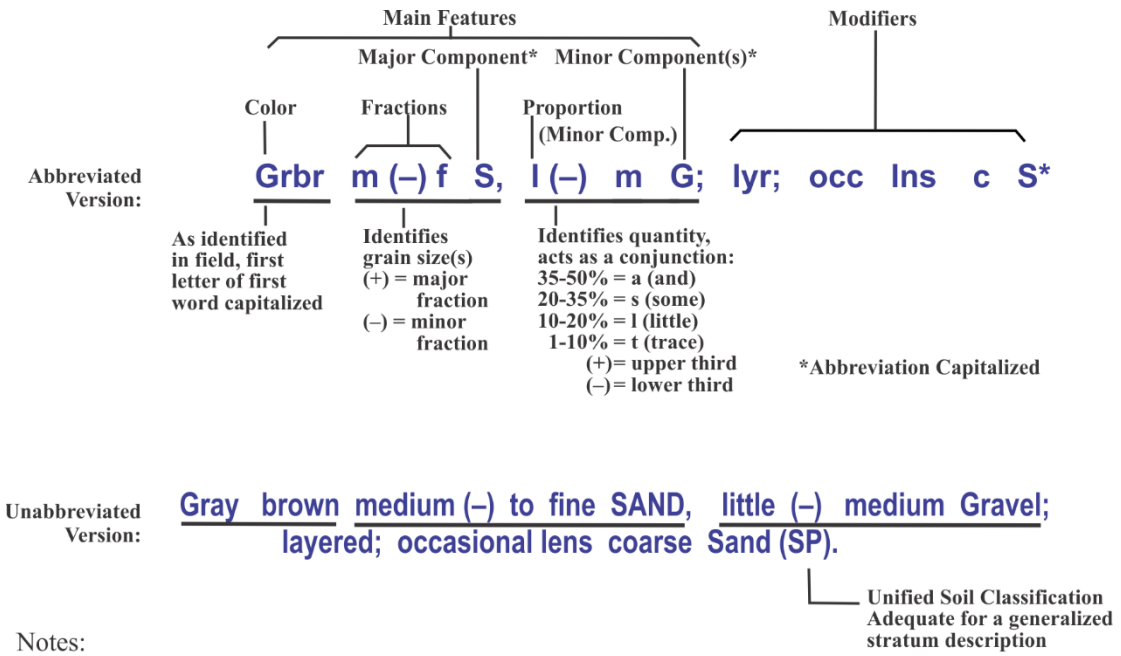
Table 6.2 Unified Soil Classification System; from American Society for Testing and Materials, 1985				
Major Divisions			**Group Sym.**	**Group Name**
Coarse Grained Soils–More Than 50% Retained on No.200 Sieve	Gravel–More Than 50% of Coarse Fraction Retained on No.4 Sieve	Clean Gravel	GW	Well-Graded Gravel, Fine to Coarse Gravel
			GP	Poorly-Graded Gravel
		Gravel with Fines	GM	Silty Gravel
			GC	Clayey Gravel
	Sand–More Than 50% of Coarse Fraction Passes No.4 Sieve	Clean Sand	SW	Well-Graded Sand, Fine to Coarse Sand
			SP	Poorly-Graded Sand
		Sand with Fines	SM	Silty Sand
			SC	Clayey Sand
Fine Grained Soils–More Than 50% Passes No. 200 Sieve	Silt and Clay Liquid Limit Less Than 50	Inorganic	ML	Silt
			CL	Clay
		Organic	OL	Organic Silt, Organic Clay
	Silt and Clay Liquid Limit 50 Or More	Inorganic	MH	Silt of High Plasticity, Elastic Silt
			CH	Clay of High Plasticity, Fat Clay
		Organic	OH	Organic Clay, Organic Silt
Highly Organic Soils			Pt	Peat

Table 6.3. Unified Soil Classification System (USCS)			
	Millimeters	**Inches**	**Sieve Size**
Boulders	> 300	> 11.8	-
Cobbles	75 - 300	2.9 - 11.8	-
Gravel:			
Coarse	19 - 75	0.75 - 2.9	-
Fine	4.8 - 19	0.19 - 0.75	3/4" - No. 4
Sand:			
Coarse	2.0 - 4.8	0.08 - 0.02	No. 4 - No. 10
Medium	0.43 - 2.0	0.02 - 0.08	No. 10 - No. 40
Fine	0.08 - 0.43	0.003 - 0.02	No. 40 - No. 200
Fines:			
Silts	< 0.08	< 0.003	< No. 200
Clays	< 0.08	< 0.003	< No. 200

6.2.3.3 Burmister System

The Burmister System uses similar textural size ranges as the Wentworth scale (see Tables 6.4 through 6.7). In addition, it adds a specific nomenclature to describe the soil's texture, color, plasticity, mineralogy, and even geologic origin, etc. as shown below.

Table 6.4 Burmister Soil Classification Naming System (source: Dunn Geoscience Corporation)



Notes:
Major Component (>50%): all letters are capitalized.
Minor Component: first letter is capitalized.

Table 6.5 Burmister Soil Classification System Coarse-Grained Soils, Gradation of Components

Coarse to fine	cf	All sizes
Coarse to medium	cm	Less than 10% fine
Medium to fine	mf	Less than 10% coarse
Coarse	c	Less than 10% medium and fine
Medium	m	Less than 10% coarse and fine
Fine	f	Less than 10% coarse and medium

Table 6.6 Burmister Soil Classification System Fine-Grained Soils, Plasticity of Components

Component	Symbol	Overall Plasticity	Plasticity Index
Silt	$	Non-plastic	0 to 1
Clayey Silt	Cy$	Slight	1 to 5
Silt & Clay	$ & C	Low	5 to 10
Clay & Silt	C & $	Medium	10 to 20
Silty Clay	$yC	High	20 to 40
Clay	C	Very High	over 40

Table 6.7 Burmister Soil Classification System, Components and Fractions, Modified from Burmister, 1950		
	Millimeters	**Sieve Size**
Gravel (G):		
Coarse		1" - 3"
Medium		3/8" - 1"
Fine		No.10 - 3/8"
Sand (S):		
Coarse	0.590 - 2	No.30 - No.10
Medium	0.250 - 0.59	No.60 - No.30
Fine	0.074 - 0.25	No.200 - No.60
Silt ($):		
Coarse	0.074	0.02mm - No.200
Fine	< 0.020	< No. 200

6.2.3.4 U.S. Comprehensive Soil Classification System

The U.S. Department of Agriculture (USDA) developed the U.S. Comprehensive Soil Classification System. It established ten soil orders (e.g., alfisols and ultisols, etc.) and uses soil profiles to characterize topsoil and subsoil horizons. Textural descriptions for the USDA system are shown in comparison to the other soil classification systems in Table 6.8 below.

Table 6.8 Textural Descriptions for USDA System					
Granular Soils		**Cohesive Soils**		**Grain Size (USCS)**	
Blows/ft	Density	Blows/ft	Density	silt/clay	<0.08 mm
0-4	v. loose	>2	v. soft	f. sand	0.43 - 0.08 mm
4-10	loose	2-4	soft	m. sand	2.0 - 0.43 mm
10-30	m. dense	4-8	m. stiff	c. sand	4.8 - 2.0 mm
30-50	dense	8-15	stiff	f. gravel	19 - 4.8 mm
>50	v. dense	15-30	v. stiff	c. gravel	75 - 19 mm
		>30	hard	cobble	300 - 75 mm
				boulder	>300 mm
Proportions					
trace	0-10%				
little	10-20%				
some	20-35%				
and	35-50%				

6.2.3.5 Comparison of the Soil Classification Systems

As shown in Table 6.9, comparison of the different size classification systems shows that, although there are some similarities, there are some differences between them as well. Notably, for most of the classification systems, the upper limit of coarse sand is 2.0 mm while the upper limit of coarse sand using the USCS is 4.8 mm, which is in the gravel range of most other systems.

Sands and gravels have different hydraulic conductivity, which can affect the fate and transport of contaminants in the subsurface. For this reason, it is important to accurately describe the soil samples and reference the appropriate classification system being used to describe the soil samples in the soil boring log. When more than one mobilization of field equipment occurs or when different consulting firms are employed at a site, the same soil classification system should be used at a site for consistency. In addition, a trained and competent sampling technician should perform logging of soils and sediments. A recommended soil-boring log is provided following Table 6.9.

Some of the classification systems allow for the soils to be characterized simply through the use of non-descriptive language, (e.g., Unified Soil Classification System and parts of the Burmister System). Additionally, technical language is sometimes entered on geologic logs in a technical shorthand (e.g., coarse to fine sand may be written as "cf"). Geologic logs developed for environmental projects are frequently reviewed by people that have not been trained in the use of the aforementioned classification systems or technical shorthand. To address this issue, the NJDEP strongly recommends that language on geologic logs be written out in such a manner that the geologic descriptions are detailed, comprehensive and clearly defined. Technical shorthand terminology should not be used unless space restrictions prohibit a more detailed description.

Given that most soil classification systems are based on determining the percentages of samples that pass through specified sieve sizes, balanced against the reality that very few personnel determining and recording soil descriptions have sieves or scales with them at the drill site, the NJDEP's preferred methodology is to describe/record soil descriptions using language similar to the unabbreviated version of the Burmister Classification System.

6.2.4 Field Notes

In addition to soil logs, accurate field notes are essential to the evaluation and interpretation of analytical results after sampling is complete. Information compiled in the field notes or soil logs (for an example see Figure 6.1) for each sampling point should include:

- Date/time/weather
- Sampler/geologist/soil scientist name(s)
- Location in state plane coordinates
- Sample identification (as specified in sampling plan)
- Sketch showing the sampling location (including reference distances)
- Depth to water and/or bedrock (refusal) when encountered
- Soil profile using Wentworth, USCS, Burmister, or USDA classification, etc.
- Sample recovery and interval submitted for analysis
- Sampling equipment used
- Field measurements of any direct reading instruments, their calibration, and settings
- General comments (e.g., odor, staining, etc.)

Table 6.9 Comparison of the Soil Classification Systems compiled from various sources

Wentworth	Burmister	USCS	USDA	mm	in	US Stan. Sieve Size
boulders		boulders	cobbles	4026		No. 5+
				2048		
				1024		
				512		
				256	10.08	
cobbles		cobbles		128	2.52	
				64		
v. coarse	coarse gravel	coarse gravel	medium gravel	32	1.26	
coarse pebble gravel	medium gravel	fine gravel	fine gravel	16	0.63	
				8	0.31	
medium fine	fine gravel			4	0.16	
gran. (vf) gravel		coarse sand		2	0.08	No. 5-10
v. coarse sand	coarse sand	medium sand	v. coarse sand	1	0.04	No. 10-18
coarse sand			coarse sand	0.5	0.02	No. 18-35
medium sand	medium sand	fine sand	medium sand	0.25	0.01	No. 35-60
fine sand	fine sand		fine sand	0.125	0.005	No. 60-120
v. fine sand			v. fine sand	0.031	0.002	No. 120-No. 230
	coarse silt	silts & clays	silt			
coarse silt	fine silt			0.0625		<No. 230
medium silt				0.0156		
fine silt				0.0078		
v. fine silt				0.0039	0.0002	
clay			clay	<0.0039	<0.0002	

Borehole Log

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Project Name:	**Project No:**	**Boring No**:
Location:	State Plane Coords.: X= Y=	**Well No**:
Drilling Contractor:	Water Table Depth:	Date Started:
Geologist:	Drilling Equip.:	Date Comp.:
Sampling Method:	Size/Type of Bit:	Weather Cond.:
FID/PID Used:	Development Method:	Hammer Weight/Fall:
Soil Class System:		Total Depth:
	Well Yield:	Ref. Elevation:
Screen Length/Type:	Riser Stickup:	Notes:
Sand Pack Amount/Type:	Riser Length/Type:	
Screen Slot Size:	Permit No.:	Sump Installed/Length:

Depth (ft.)	Sample No.	Blows per 6 in.	Penetration/ Recovery	FID/PID Reading (ppm)	Sample Description	Well Construction	Remarks

Figure 6.1 Bore Hole Log example

Site conditions (including equipment refusal) may warrant relocation or modification of the sampling plan during actual field activities. If this occurs, additional information should be noted in the field notes noting the sampling plan modification and new sample location relative to the old as well as fixed objects such as a building or road. This will ensure accurate data interpretation for the modified sampling plan by non-field personnel.

6.2.5 Soil Sample Collection

Determination of sample location is the first step in proper sample collection. In general, sampling should be conducted in potentially contaminated areas of concern, whether relating to former or current uses of the site to determine whether contaminants are present above applicable standards. Locations should be biased to suspected areas of greatest contamination based on professional judgment, site history, stressed vegetation, soil discoloration, odor, etc. (N.J.A.C. 7:26E-3.4).

6.2.5.1 Surface Soil Selection

Surface soil samples should be collected using decontaminated or dedicated sampling equipment dependent on the chosen analytical parameter and sampling locations. All inconsequential surface debris (e.g., vegetation, rocks, etc.) should be removed from the surface before commencing with sampling. Disposable gloves should be changed between each sample location. Care should be taken to minimize contact of disposable gloves with soil to be sent for laboratory analysis.

Initial characterization soil sampling, with the exception of Area Specific Requirements and soil to be analyzed for VOCs, should be collected from the 0 to 6 inch interval below grade. Additional sampling of soil below the 0 to 6 inch interval or those specified in the Area Specific Requirements may be necessary where the surface has been regraded or physical evidence indicates the possible presence of deeper contamination. Typically, VOC samples are not collected from the 0 to 6 inch interval due to potential for volatilization. If a soil sample for VOCs is needed from the 0 to 6 inch interval below grade, technical justification is required.

Soil samples should be collected from discrete six-inch intervals. Deviations from this recommendation due to poor sample recovery or logistical problems should be noted in the soil log and field notes. If additional sample volume is required from a particular sampling interval due to poor recovery or high laboratory soil volume requirements, it is an option to advance a second boring immediately adjacent to the initial boring at the minimum distance required by the drilling method. Soil from the same depth interval from the two borings should be compared to verify uniformity and then homogenized before filling sample containers. Any VOC samples should be collected from the first boring. For other analyses, the soil collected from the second boring should be homogenized with the first boring prior to sample collection.

Composite sampling is not allowed except in the case of waste characterization analysis for proper disposal and for characterizing donor material for alternative fill. For additional information about characterizing donor material for alternative fill see "*Fill Material Guidance for SRP Sites"* available at: https://www.nj.gov/dep/srp/guidance/#fill_srp. Surface soil collected for parameters other than VOC analysis should be homogenized in-situ or in a decontaminated stainless steel bowl or tray. Sampling should occur in progression from the least contaminated area to the most contaminated area, if this information is available.

Soil logs should be completed after sample collection to minimize losses due to volatilization and biodegradation, and cross contamination due to excessive handling of the soil.

Soil samples collected for VOC analysis should be handled in a manner that will minimize losses due to volatilization and biodegradation. See section 6.2.7., *VOC Sample Collection for Soils*, for appropriate sample collection procedures.

Soil samples collected for analytical parameters other than VOCs should be homogenized before

being placed into the appropriate sample container. See section 6.2.8., *Non-VOC Sample Collection for Soils*, for appropriate sample collection procedures.

6.2.5.2 Subsurface Soil Selection

NJDEP recommends the advancement of downhole large-diameter sampling devices follow relevant ASTM procedures (e.g., #D1586-11 for disturbed (split spoon) samples, ASTM #D1587/D1587M-15 for undisturbed (Shelby tube) samples, etc.). In addition, all borings must be installed in accordance with the procedures and regulatory requirements outlined in N.J.A.C. 7:9D. Soil boring permits are required for borings greater than 50 feet in depth or greater than 8.5 inches in diameter. Borings greater than 25 feet deep must be sealed with approved sealing material pursuant to N.J.A.C.7:9D-3.4. Borings less than 25 feet deep may be sealed by backfilling with cuttings or sand pursuant to N.J.A.C. 7:9D-3.4. However, NJDEP recommends that contaminated soils not be returned to the borehole. If the contaminated soils are returned back to the borehole, the requirements of N.J.A.C. 7:26E-1.5(h) must be followed.

6.2.5.2.1 Considerations During Borehole Clearance

A number of methods are employed to ensure that utilities are not encountered during bore hole advancement. A common non-intrusive method used is the Soft Dig Technique. Soft-dig techniques employ methods to loosen and remove unconsolidated material (soil, gravel, etc.) without causing harm to buried objects, such as buried utilities, foundations, or piping. This technique is usually performed by directing piped high-pressure fluids (predominantly air, and to a lesser extent, water) to the base of the borehole to break up the subsurface soil structure, followed by the use of a vacuum system to remove the loose material. A flexible hose with a rigid steel pipe at the fluid discharge end allows the operator to direct a small focused stream of high-pressure fluid into the subsurface, cutting up the soil in the borehole like a knife (hence the nickname for this device “air or water knife”). After several inches of material at the bottom of the borehole have been cut up the loose material at the bottom of the borehole is removed through the use of a vacuum hose. The process is repeated until the desired depth of the soft dig interval is achieved.

The act of injecting high-pressure fluids (air, gas, or liquid) into a borehole to cut up the material will cause volatilization of VOCs, and the more volatile (i.e., higher vapor pressure/lower boiling point) SVOCs, from the material surrounding the borehole and the material removed from the borehole. The amount of VOC and SVOC loss from the material depends on:

1) the fluid pressure or amount of fluids used to cut up the material;
2) the length of time it takes to advance that portion of the borehole where soft-dig technology is used;
3) the nature of the geologic material; and
4) the nature of the contaminant.

Loss of material VOCs or SVOCs can be severe. The goal of any soil sampling procedure for VOC or SVOC analysis is the acquisition of an undisturbed representative sample by minimizing any alteration or impacts to soil sample quality.

Collecting a soil sample for VOC or SVOC analysis from a borehole interval advanced using a soft-dig method will not meet the goal of collecting an undisturbed representative sample. Accordingly, it is the position of the NJDEP that the collection of VOC or SVOC soil samples from a borehole interval advanced via a soft-dig technique is inappropriate and is not recommended.

Where it is known, or has been previously confirmed, that the area under investigation does not contain VOCs or higher vapor pressure SVOCs (i.e., compounds structured as naphthalenes, amines, phenols, ethers, 1,4-dioxane, etc.), the SVOC analysis of soil collected from a soft-dig

advanced borehole should not be significantly affected. Any soil sample tested for VOC or volatile SVOC compounds that is collected from a borehole interval advanced via soft-dig technique must be identified as such, and a description of exactly how and where the soil sample was collected must be detailed for each soil sample collected in this manner. Where VOC or SVOC results are presented for such a soil sample, the results must be footnoted to identify that the sample was collected from a soft-dig advanced portion of the borehole.

Where a soil sample is collected from a borehole interval advanced by a soft dig method, and that soil samples are analyzed for VOCs or volatile SVOCs, an explanation detailing why that soil sample had to be collected in that manner will need to be included in documents containing the soil sampling results. Specifically, the language must explain why the soil sample could not be collected from another borehole advanced nearby using a VOC appropriate method.

The NJDEP recommends that all boring logs and well installation logs identify how the borehole was installed. Where multiple methods were used, the logs should identify the specific interval where each method was used. Where high-pressure water was used to advance the borehole, that use should be highlighted as the addition of water to the borehole may lead to a false interpretation with respect to the depth or occurrence of perched water or the water table.

Use of Hand Auger or Post Hole Digger for Collection of Soil VOC Samples

Soil samples collected for the analysis of VOCs, or the more volatile SVOCs, by hand auger or post hole digger will be considered field screening quality since there is no way to assure integrity of the soil collected. The characteristic of the soil (i.e., clayey vs sandy, hard vs soft, moist vs dry), will have a significant effect on the ability of the two aforementioned methods to collect an undisturbed soil sample. The ability to retrieve a large piece of undisturbed soil is much easier in a moist, soft, clayey sand than a dry, hard, clay or sand. The ability to collect large soil pieces with a post hole digger decreases as hole depth increases. The type of hand auger bit used (i.e., classic 2 blade auger bit, single blade sand auger bit, low angle mud auger bit) will also have an effect on how the auger advances into the soil, and consequently how much the soil is disturbed during its collection.

Collection of VOC or SVOC Soil Samples in Areas of Subsurface Concern

In areas where a soil boring is to be installed near a subsurface object of concern (e.g. septic, utility, underground storage tank), and VOC or volatile SVOC analysis of boring soil samples is proposed, NJDEP recommends using the soft-dig method to either 1) identify the exact location by exposing (i.e., potholing or daylighting) the object of concern to determine depth, diameter, and directionality, and then install a separate boring a safe distance away using a VOC appropriate advancement method, or 2) install two soft-dig borings parallel to the subsurface object of concern. If neither of the borings encounter the object of concern, install a third boring using a VOC appropriate advancement technique midway between the two soft-dig boreholes. The borehole installed for VOC or SVOC soil sampling should be installed a sufficient distance away from the location of previously installed soft-dig boreholes such that the soft-digging process does not affect the soils where VOC or SVOC sampling is to occur.

Another option is to perform surface geophysical surveys (e.g., Ground Penetrating Radar (GPR), electromagnetics, terrain conductivity, etc.) at the proposed soil boring location and the location of nearby utilities (after the utility mark-outs have been performed). This will help to confirm the locations of any buried utilities and check for the presence of any subsurface objects in the area of the proposed boring.

Surface/Non-intrusive Methods

- **GPR Imaging**

  Advantages:

  - GPR data are relatively inexpensive to gather
  - Gathering GPR data is non-destructive
  - GPR can be used to identify metallic and non-metallic objects, as well as excavations
  - GPR can be used on a multitude of sites with varying ground cover, including soil, asphalt, and concrete
  - FINDAR® Ground penetrating radar linked to a GPS system. Creates 3D images of subsurface anomalies onsite, pinpointing position and depth. Real-time interpretation

  Limitations:

  - GPR equipment is sensitive and can receive interference from structures, such as walls and ceilings, or from large equipment
  - GPR may not be effective in collecting data below reinforced concrete
  - Depending on subsurface soils, GPR may have a relatively low depth range. Moist clays restrict the GPR

- **Electromagnetic (EM)**

  Advantages:

  - EM data are relatively inexpensive to gather
  - Gathering EM data is non-destructive
  - EM can be used on a multitude of sites with varying ground cover, including soil, asphalt, and concrete
  - Good lateral resolution

  Limitations:

  - EM equipment is sensitive and can receive interference from vehicles, metal fences, metal structures, and reinforced concrete
  - EM will only identify metallic objects; it will not identify fiberglass or PVC
  - Poor vertical resolution

Intrusive Methods

- **Manual Excavation** (i.e., digging with a hand auger, post hole digger, shovel, or similar)

  Advantages:

  - Hand augering is relatively inexpensive
  - Equipment can be used in areas inaccessible to larger equipment (e.g., indoors and areas with overhead power lines)

  Limitations:

  - Prohibitive in soil with large gravel, cobbles, construction debris, or hard rock
  - Not appropriate for collection of VOCs (further details above in this section)

- **Excavation with a backhoe**

  Advantages:

- Most common method for projects requiring excavation
- Efficient means of excavation

Limitations:

- Potential to damage utilities and other obstructions; operator must use extreme care
- Overhead power-line restrictions
- Contaminated soil requires stockpiling and proper characterization and disposal

- **Air Knifing and Vacuum extraction**

Advantages:

- Quickly and safely excavate to determine location of utility or obstruction
- Less potential to damage utilities than other means of excavation
- Less expensive than using water for hydro-excavation
- Automates pot-holing, less manual labor

Limitations:

- Potential access
- Can affect soil vapor samples

6.2.5.2.2 Collection of Soil Cores

Subsurface soil samples can be collected via standard drill rig techniques (e.g., split spoon, Shelby tube or soil corer), direct push drilling techniques (e.g., macrocores), or sonic drilling techniques (e.g., advancement of inner drill casing). When soil samples may be collected for analysis, the soil sampling equipment should be decontaminated between collection of soil cores. A decontaminated core catcher/retaining basket should be used to prevent loss of the soil back into the borehole while raising the sampling device to the surface. Upon retrieval to the surface, the sampling device (e.g., split spoon, soil corer, Shelby tube) should be handled and transported in such a way as to prevent loss while opening or during shipment preparation. When sampling for VOCs or SVOCs using direct push or sonic drilling techniques, rigid liners should be used. The soil corer sampling devices should be opened with caution to ensure that soil remains within one half of the split barrel or liner for later screening and sample collection. Soil that has fallen out of a sampling device cannot be used for laboratory analysis and should be discarded to prevent cross-contamination.

The top few inches of soil collected either via split spoon or soil core liner sampling device may contain material (often referred to as slough, pronounced sluff) that may have fallen back into the borehole. In addition, "mud or water" used during rotary drilling may infiltrate into the surrounding formation. This infiltration may also be visible in the top few inches of the core or as coating on the core's outer edges. This "slough or mud/water impacted soil" is not representative of in-situ conditions, should not be used for laboratory analysis, and should be discarded to prevent cross contamination.

Upon opening the split spoon or soil core liner, the soil core should be screened with a direct reading instrument (DRI) to determine the sample interval of interest. Where possible, soil samples should be collected from discrete six-inch intervals. Deviations from this requirement due to incomplete sample recovery or logistical problems should be noted in the field logbook. See section 6.2.5.2.3, *Incomplete Soil Core Recovery*, for further details. Disposable gloves should be changed between each sample location. Care should be taken to minimize contact of disposable gloves with soil to be sent for laboratory analysis. Soil logs should be completed after sample collection to minimize losses due to volatilization, biodegradation, and cross contamination due to excessive handling of the soil.

Shelby tubes are typically used to collect undisturbed solid soil cores in cohesive soil types for laboratory analysis such as geotechnical parameters. Shelby tubes, once collected, should not be opened by field personnel. Upon retrieval from the borehole, the Shelby tubes should be wiped clean, and the ends sealed with melted wax to prevent leakage or drying of the soil core. Endcaps should be placed on both ends and taped prior to shipment to the laboratory.

Composite sampling is not allowed except in the case of waste characterization analysis for proper disposal and for characterizing donor material for alternative fill. For additional information about characterizing donor material for alternative fill please see "*Fill Material Guidance for SRP Sites"* available at: https://www.nj.gov/dep/srp/guidance/#fill_srp.

Soil samples collected for VOC analysis should be handled in a manner that will minimize VOC loss due to volatilization and biodegradation. See section 6.2.7, *VOC Sample Collection for Soils*, for appropriate sample collection procedures.

Soil samples collected for analytical parameters other than VOCs should be homogenized before being placed into the appropriate sample container. See section 6.2.8, *Non-VOC Sample Collection for Soils,* for appropriate sample collection procedures.

6.2.5.2.3 Incomplete Soil Core Recovery

Soil coring devices allow for soil cores to be collected in lengths from 2' (split-spoon) to 20' (sonic drill casing). It is not uncommon for the collected core to be significantly shorter in length than the length of geologic interval cored. When it appears that a full length of core was not captured within the soil coring device, that information should be clearly identified on the soil boring/geologic log (e.g., 18" of 48", or 18/48).

Causes of poor recovery can be:

1) failure to use a core catcher retainer at the opening of the core collecting device;
2) blockage of the opening of the core collecting device by rock pieces, subsurface debris, backfilled gravel, or other obstruction; and
3) the presence of running sands.

Actions that can be taken to address poor core recovery include:

1) using a core catcher retainer;
2) using a larger diameter soil coring device;
3) moving the boring location; and
4) maintaining a hydrostatic head of water in the drill rods to prevent running sands from heaving up into the coring device.

When collecting a soil sample from a soil core where recovery of the cored interval is poor or incomplete, the true depth interval of the sampled soil cannot be determined. To address this issue NJDEP recommends that the collection of soil cores from which soil samples may be collected, not exceed lengths of more than 5 feet. Limiting the soil core to 5 feet limits the range of the sampled soil depth to that 5-foot interval. Where soil core recovery is less than 40%, it is the NJDEP's position that the true depth of a soil sample collected from that soil core cannot be estimated. In this situation the soil sample depth should be assigned to the base of the cored interval. Accordingly, if the soil sample from a soil core yielding less than 40% recovery is found to be impacted (i.e., contains an exceedance of a NJDEP soil remediation standard), the NJDEP will consider the depth of that exceedance to be the bottom depth of the cored interval unless documentation can be provided to support an identification of the depth intervals. Recovery should be documented on the borehole log for each cored interval.

6.2.5.2.4 Soil Core Issues

When collecting soil cores for VOC or SVOC analysis, two issues of concern should be addressed: 1) heating of the soil core during drilling, and 2) disturbance of the soil core during drilling, extraction, and handling.

The collection of soil cores using certain drilling techniques, such as hammered split-spoons, direct push core barrels, and sonic drill casing advancement can result in the generation of soil cores that are hotter than the natural subsurface soil environment. This phenomenon is most common in tight or hard soils that contain little or no water. When the soil core being collected may potentially be sampled for VOCs or SVOCs, heating of the soil core may result in the loss of contaminant mass through degassing. To evaluate the potential for contaminant loss due to heating of the soil core, NJDEP recommends that the soil core temperature be measured with a device, such as an infrared thermometer, immediately upon access to the soils. This information should be recorded on the boring log and linked to the sample in reports where the respective soil sampling results are listed.

The longer a soil core resides in the coring device, the greater the potential for heating of the soil core. The effects of drilling generated heat may be reduced by using rigid liners (e.g., acetate), maximizing drilling advance rates, shortening sampling runs (i.e., collecting shorter soil cores), changing vibration frequency, changing rotation speed, using cooled sampling barrels, and collecting larger diameter cores to reduce heat buildup in the soil core interior.

If a hard or dry interval is encountered that results in very slow advance rates, it is recommended that:

1) the existing soil core be extracted, sampled if needed, and logged,
2) the resistant interval be cored and extracted, and
3) a new soil core run be started below the resistant interval.

To minimize the loss of VOCs or SVOCs in soil cores, NJDEP recommends that all subsurface soil cores collected for soil sampling purposes be collected in a manner that preserves soil core integrity. In split-spoons the integrity of the soil core is preserved by the soil core remaining in one half of the ridged steel split-spoon after it is opened. In direct push and sonic drilling applications core integrity is preserved by use of an extractable rigid inner liner.

6.2.6 Field Screening Soil Samples

Each soil core should be screened with a properly calibrated direct reading instrument (DRI) equipped with a PID or FID detector or other suitable field-screening instrument capable of detecting the contaminants of concern. Pursuant to N.J.A.C. 7:26E-2.1(b)ii, field screening shall be used to bias sample location to the location of greatest suspected contamination. The NJDEP guidance manual on soil investigation and sampling lists several criteria that should be considered when selecting the soil interval to be sampled.

To obtain the most representative soil vapor reading, use a decontaminated stainless steel spoon, knife or other appropriately constructed device and make a longitudinal score deep enough to expose an undisturbed surface of native material the length of the core. Alternatively, make very small divots at six-inch intervals to expose an underlying undisturbed surface of native material. Simultaneously, place the probe of the DRI immediately above the opened area being careful not to touch the sample, and move the probe slowly above the lateral scoring and note any peaks. Record results of peaks in 6-inch intervals to determine sample location. Instrument readings will be biased low and not representative of in-situ conditions if the soil core is not scored or inner core not exposed for proper field screening. Other methods of field screening (e.g., bag headspace, jar headspace, warming, UV light, dye testing, etc.) may be used in conjunction with the DRI, but should not be used in lieu of it.

Soil boring locations will be previously defined by the data quality objectives (DQOs) and sampling plan developed for the site. In the field, the individual soil sample collected from the soil boring for volatile organic laboratory analysis will be based on field screening with a DRI. The most common sample interval is six inches; however, this will be determined by the DQOs. The sample interval should be documented in field notes and on the soil boring log.

Soil samples should be collected at the interval with the highest reading on the DRI. If a boring is continuously cored to 20 feet below grade, depending on the length of the individual cores, there could be four to five individual soil cores waiting to be opened and screened. In this instance, special attention should be paid to labeling and storage of each soil core. In many instances, soil cores can be produced faster than they can be opened, logged, screened and sampled by a technician. In situations where a backlog of cores is generated, care should be made to protect the cores from direct sunlight, excessive ambient temperatures and rain as these conditions may have an adverse effect on highly sensitive volatile organics within the core or the instruments used for screening. Always keep the cores labeled so that the up/down orientation is not lost. Proceed carefully, but quickly, when field screening. Additionally, as part of the pre-planning and development of the sampling plan, if the plan calls for continuous cores to be collected, logged and screened with the DRI, allow adequate time in the field to minimize the chance for soil cores to backlog. Also, to reduce loss of VOCs from the soil core, the NJDEP recommends logging soil cores for lithology information *after* sample collection. Always calibrate the DRI at the start of each day.

It is not uncommon for field staff to bring only enough soil sampling devices and containers to the site as is necessary to meet the requirements of the work plan. Uncertainty or variation in site geology, contaminant nature, contaminant concentrations, or contaminant distribution can all lead to potential field changes in the scope of work, resulting in a need to change the number or depth of the collected soil samples. The result can be samplers assessing multiple soil cores before committing to collect the planned soil sample(s) due to a limitation in the number of sampling containers. The longer the time period between soil core extraction and soil sample collection, the greater the potential VOC loss from the soil core. To minimize soil core VOC loss, once the soil core has been extracted, soil samples should be collected as soon as possible. NJDEP recommends that subsequent split-spoons or soil cores encased in rigid liners not be opened/exposed until a decision is made whether or not to collect a sample from the current soil core, and if so, that soil sample is collected.

To address this sampling issue NJDEP recommends extra soil sampling devices and containers be available onsite during soil sampling events. Having extra sampling devices and containers onsite allows samples to be collected quickly from a given soil core, eliminating the need to assess multiple soil cores before committing to the interval sampled. A decision on which soil samples actually get sent to the laboratory for analysis can be made at the end of each boring (NJDEP recommended) or at the end of the day. Alternatively, all the samples could be sent to the laboratory with specific samples put on hold, pending preliminary results.

6.2.6.1 Organic Vapor Analyzers (OVAs)

A common direct reading instrument (DRI) used during contaminated site field investigations is the organic vapor analyzer (OVA). The majority of OVAs can be subdivided into two types, photo ionization detectors (PIDs) and flame ionization detectors (FIDs). Portable/field designed OVAs can measure volatile organic compounds (VOCs) over a wide concentration range. The units continuously draw in a sample of air through an internal air vacuum pump to the detector. Compounds in the air stream are then ionized by the energy source of the detector. The resulting positively charged ions and electrons are attracted to nearby electrodes producing a measured electrical current which is converted to a reading. The response readings (i.e., output) of the units represent the concentration of volatile organics in the air sample, relative to the calibration gas. The DRI readings do not identify specific compounds or their concentrations, unless the component of the sample gas is known. The readings from a DRI represent the total concentration of compounds

ionized in the sample. Reported concentrations are relative to the calibration gas used for the unit. As such, unit readings likely vary from the actual compound concentrations in the air stream.

The OVA readings represent the concentration of VOCs for the air that is at the detector inside the unit. When testing a location, the air intake hose should remain at the testing location for a sufficient amount of time for the air to be pulled up through the sample line and ionized in the unit. Response times for standard units are generally in the 3-5 second range. If hose extensions are used, the unit response time will be proportionally longer. Response times are typically provided in the manufacturer's operation manuals for the instruments. Response times can also be tested during a bump test (e.g., testing the response of the unit to a gas of known concentration).

While the purpose of these two types of OVAs is the same (the detection and quantification of organic vapors), they have different sensitivities and are calibrated with different gases, so they may generate different results from the same sample. In broad terms, PID response varies by functional groups, whereas FID response varies by carbon chain length. In general, FIDs are usually used when evaluating easily combustible hydrocarbons such as methane, gasoline, and diesel. PIDs are more commonly used when evaluating non-combustible compounds such as chlorinated solvents. In addition, PID units can usually detect lower concentrations than FIDs.

Calibration

At a minimum, OVA units should be calibrated daily before use in accordance with the manufacturer's recommendations and instructions. Thereafter, the unit should be "bump" tested at least one time during the day's activities. The bump test is a qualitive test to verify sensor performance. The results of the bump test should be within a predetermined percentage of the calibration gas standard concentration which may vary depending upon the use of the data being produced by the DRI. This percentage should be presented in the site specific Quality Assurance Project Plan (QAPP). If the results fall outside the established range, the unit should be re-calibrated.

6.2.6.2 Photoionization Detectors (PIDs)

PIDs use a high energy ultraviolet (UV) light source to ionize compounds in the air stream pulled into the unit by an air vacuum pump. PIDs only detect those compounds that can be ionized by the UV lamp in the respective unit. UV lamps of different electron voltages (eV) can be installed in the unit. Common PID lamp electron voltages are 9.8, 10.6, and 11.7. The PID will only ionize compounds that have an electron voltage (voltage/energy needed to ionize the compound) below that of the unit lamp. Therefore, the compounds the unit can detect is directly linked to the eV of the UV lamp installed in the unit. Equipment manufacturers have generated lists that provide the eV needed to ionize certain compounds. Comparing these lists to the eV of the PID lamps will allow one to determine what eV lamp is appropriate for the intended work.

PIDs do not require hydrogen or other fuel sources to operate. PID units are commonly calibrated with isobutylene, but may be calibrated to a site specific compound.

PIDs are better (i.e., higher sensitivity) at detecting chlorinated hydrocarbons, formaldehyde, amines, methanol, and aromatic compounds than FID units.

PID sensitivity is: aromatics & iodine compounds > olefins, ketones, ethers, amines & sulfur compounds > esters, aldehydes, alcohols & aliphatics > chlorinated aliphatics & ethane.

PIDs can detect some substances for which FIDs are not effective, such as ammonia and hydrogen sulfide.

PIDs cannot detect methane. As such, PID units are good for detecting non-methane organic compounds in anaerobic locations, such as landfills, where methane generation is common. Caution should be exercised in these situations. Though PIDs cannot detect methane, methane will quench the PID signal. For example, at methane concentrations of 1.0% (20% of the LEL), the PID signal will

be reduced by 10%. When using a PID in the presence of high methane concentrations or high VOC readings, a dilutor may be employed. This device dilutes the sample stream with ambient air to bring concentrations within operational range of the detector. To obtain accurate readings using a dilutor, a dilution factor will need to be determined with calibration gas.

Readings from PIDs can be affected by moisture and relative humidity. This is a common problem with PIDs and its negative effects on the data quality cannot be overstated. PIDs have reduced responses as humidity increases. This means as the humidity increases, the response of the unit to a fixed compound concentration will decrease, producing a bias low reading. Water vapor scatters and absorbs photons, reducing the PID output, this is called "quenching". At high humidity PIDs can error in the opposite direction, developing false positive readings that appear as a rising drift. This is caused by current leakage along the sensor walls, resulting in higher than actual readings. These issues are likely due to moisture condensing on the sensor or the UV lamp (i.e., fogging) inside the unit. For the PID unit to produce accurate readings, the internal sensor and UV lamp need to be maintained in a clean and dry condition. Examples of situations where the PID response may be affected include:

- screening monitor well head space;
- monitoring a borehole during or just after is has been drilled;
- screening soils or water on a humid day; and
- moving the unit from a cooler environment (e.g., air-conditioned building or vehicle) to a warmer environment.

To address the aforementioned problems: 1) maintain a clean dry sensor and UV lamp; 2) reduce the potential for condensation to develop inside the unit by acclimating the unit to site conditions before being operated. Sometimes turning on the unit and warming it up prior to entering the humid environment may prevent internal condensation from occurring.

Drying the sample air using desiccant filter tubes attached to the air intake tube can address responses for non-polar compounds like gasoline and TCE. However, high molecular weight and polar compounds tend to adsorb to the desiccant material, resulting in a slower response, particularly at low temperatures and concentrations. Some compounds, such as amines adsorb completely to the desiccant and cannot be measured using desiccant tubes. Desiccant filter tubes may only be usable for 15 minutes to an hour, because water saturates the media exceeding its capacity.

Preventing dirt and dust from entering the PID sensor is the best measure to reduce the potential for moisture issues. It is recommended to use a moisture filter when operating a PID in high humidity conditions.

Where the chemicals of concern for an area under investigation have not been determined, NJDEP recommends that the PID unit used at the site contain a higher eV lamp. It should be noted that higher eV lamps (e.g., 11.7 eV) increase the number of detectable VOCs at the cost of a shorter lamp life and a shorter operational battery cycle.

When using a PID at a site where the chemicals of concern have been identified, the PID unit used should possess a UV lamp that is of sufficient energy to ionize the compounds of concern. This can be accomplished by reviewing tables of compound ionization potentials/eVs prior to conducting the field work.

Due to common field issues with PIDs, NJDEP recommends that a backup PID unit be available during field work where a PID unit is needed.

Operators of PID units should be aware that the units may detect naturally occurring compounds that can be volatilized during drilling and excavation activities. An example would be aromatic oils released from the tree roots of sassafras trees.

6.2.6.3 Flame Ionization Detectors (FIDs)

Air is pulled into the unit via an air vacuum pump and passed through a flame (usually fueled by a hydrogen tank). Organic compounds in the air stream are burned forming positively charged ionized compounds. The positively charged ionized compounds come in contact with an ionization detector and result in the production of electrical current. The magnitude of electrical current represents the output reading of the unit.

Unlike PIDs, FIDs are generally free from humidity effects except if water condenses in the sensor. This may cause the unit to flame out or not ignite.

FIDs are usually calibrated to methane but may be calibrated to a site specific compound.

Modern units' concentration ranges are 1 to 50,000 ppm. The units are non-compound specific. Responses represent total ionizable compounds. Detection linearity is good throughout the concentration range.

FIDs principally measure compounds containing carbon. The FID's sensitivity is highly dependent on the chemical structure and bonding characteristics of the compound being burned. The combustion efficiency of a compound determines its sensitivity. Simple saturated hydrocarbons (methane, ethane, etc.) possess high combustion efficiencies and are among the compounds that produce the highest FID response. Organic fuels (acetylene, refined petroleum products, etc.) also burn easy and produce good responses.

Generally the FID can detect aromatics (e.g., benzene, toluene, xylene), ketones and aldehydes (e.g., acetone, methyl ethyl ketone, acetaldehyde), amines and amides (e.g., compounds containing carbon and nitrogen such as diethylamine), saturated hydrocarbons (e.g., methane, ethane, butane), unsaturated hydrocarbons (e.g., butadiene, isobutylene), alcohols (e.g., methanol, ethanol, isopropanol), combustible sulfur compounds (e.g., mercaptans), and chlorinated/halogenated solvents (e.g., TCE, PCE).

FIDs do not respond well (i.e., poor sensitivity) to organic compounds that contain nitrogen, oxygen, sulfur, or halogen (e.g., F, Cl, Br, I, etc.) atoms, and they cannot detect inorganic compounds that do not contain a carbon atom. As such, FIDs exhibit poor sensitivity to highly halogenated organic compounds such as PCE, TCE, carbon tetrachloride, and freons. The release of halogen atoms during the combustion process can damage the FID detector/sensor.

Since the operation of the unit is based on the combustion of vapors in the air stream, FID units are not sensitive to non-combustible gasses such as hydrogen sulfide, ammonia, and water vapor.

FID sensitivity is: aromatics and long chain compounds > short chain compounds > chlorine, bromine and iodine compounds.

In addition to the standard OVA, PID, or FID field screening, there are other screening techniques that may be implemented at sites. These techniques are discussed in Chapter 7 *Field Analysis*.

6.2.7 VOC Soil Sample Collection

VOCs can be mobile as either gas or liquid phases in a non-aqueous environment. Because unique physical and chemical characteristics associated with each of these phases contribute to a contaminant's behavior in a non-aqueous environment, accurate identification and quantification of VOCs in this matrix becomes essential. Sampling VOCs in soil is very time and temperature sensitive, and any delay in soil sample collection can result in a loss of VOCs due to volatilization and biodegradation. The longer the time period between soil core extraction and soil sample collection, the greater the potential VOC loss from the soil core. To minimize soil core VOC loss, once the soil core has been extracted, soil samples should be collected as soon as possible from the undisturbed soil core (preferably within 5 minutes).

Precise characterization of VOCs in soil, and other non-aqueous matrices (e.g., sediment), is critical since decisions for remediation are based on analytical measurement. Unfortunately, some acts of soil collection and storage can alter VOC concentration. These acts may enhance volatilization and biodegradation of VOCs in the sample.

To improve sample collection procedures and storage requirements of soils and other non-aqueous matrices for VOC analysis, samples should be handled in a manner that will minimize losses due to volatilization and biodegradation. Many environmental professionals have conducted and are continuing research to determine how to best maintain the integrity of samples collected for VOC analysis. This ongoing research has resulted in analytical and sampling procedure updates. Current sample preparation and analytical methods can be found in the USEPA Office of Solid Waste and Emergency Response's (OSWER), *Test Methods for Evaluating Solid Waste Physical/Chemical (SW-846)* and, *USEPA Contract Lab Program (CLP) Statement of Work (SOW) for Organic Analysis, Multi-Media, Multi-Concentration*.

6.2.7.1 Soil Coring Considerations for VOC Sampling

Soil sample collection for VOC analysis is a two-step process consisting of the collection of the larger soil core and sub-sampling this larger soil core for submittal to an analytical laboratory.

The collection of soil cores for VOC analysis should be performed with a decontaminated or dedicated large-diameter coring device such as a split spoon or soil corer, which does **not** break up the structure of the matrix. These soil coring devices typically have a diameter range of 1.5 to 4 inches. Use of a soil collection device that causes mixing, such as a hand auger, cannot be used for VOC sample collection since the tool will break up the soil structure and aerate the soil causing significant VOC loss.

When sampling for VOC analysis, the device should be retrieved from the borehole as soon as possible. Each large-diameter soil core should be screened with a properly calibrated DRI equipped with a PID or FID detector or other suitable field-screening instrument capable of detecting the contaminants of concern pursuant to N.J.A.C. 7:26E-2.1(b). Field screening data should be recorded on the soil boring log or other field documentation for eventual reporting in the investigation report.

For the most up to date information for sampling refer to the Technical Guidance for Site Investigation of Soil, Remedial Investigation of Soil, and Remedial Action Verification Sampling for Soil available at: https://www.nj.gov/dep/srp/guidance/#si_ri_ra_soils.

Contaminants that cannot be detected with field screening instrumentation must be sampled from locations or depths that are most likely to be contaminated based on the location and nature of the discharge or type of matrix to which the contaminant was discharged (N.J.A.C. 7:26E-3.4(a)). Include this information in the appropriate field documentation for eventual reporting in the investigation report.

Soil to be collected for laboratory analysis **cannot** be stored for extended periods in the large-diameter sampling device or a capped liner (brass, acetate, lexan, polycarbonate etc.) for later sample collection. In addition, the soil **cannot** be transferred to an intermediate container such as another empty sample bottle, zip lock bag, aluminum foil, etc., for later sample collection.

Research has shown leaving samples in core tubes, split spoons, covered liners or intermediate containers will lead to VOC losses and thus yield poor quality data. Therefore, soil samples for VOC analysis should be collected immediately after field screening. See Section 6.2.6., *Field Screening Soil Samples*, for more information.

6.2.7.2 VOC Soil Sample Collection Devices - Small Diameter Core Samplers

Sampling of the soil core for VOCs should be performed with the use of a dedicated or decontaminated small-diameter core sampler. Examples of acceptable small-diameter core samplers

include a modified 10-ml disposable plastic syringe, a Purge and Trap Soil Sampler, En Core® sampler, Easy Draw Syringe® or other small-diameter tube/plunger sampler. The small-diameter core sampler should be capable of collecting the required amount of sample from the soil core or from freshly exposed soils. The small-diameter core sampler should be capable of delivering the sample quickly and directly into the sample container, if applicable, without disturbing the native soil structure.

All small-diameter core samplers used in the collection of samples for VOCs should be constructed of non-reactive materials that will not sorb, leach or alter the concentration of VOCs in the sample. Examples of these materials are stainless steel, glass and brass. Other materials, such as Viton, PTFE, and some rigid plastics, which have demonstrated limited absorptive or diffusive passage of VOCs, can be used as long as the contact time between the sample and the sampler is minimized, or the materials are used for an airtight seal of the sampler.

The small-diameter core sampler should be able to deliver a minimum of 5- gram sample (≈3cm^3 of sample assuming a density of 1.7g/cm^3) into a 40-ml VOA vial. While most small-diameter core samplers can only be used for sampling and placement into the appropriate sample containers, only the En Core® sampler can be used for sampling, storage and transportation of the sample to the lab. Small-diameter core samplers should be selected based upon the properties of the matrix, the type of preservation method (field vs. lab) and personal preferences

6.2.7.2.1 Disposable Syringe

A disposable syringe is an easy and inexpensive tool for sample collection and transfer to appropriate sample containers. It can be prepared by cutting off the injection tip, removing the rubber plunger tip, and removing the retaining post on the plunger. If the plunger maintains a tight seal with the barrel of the syringe, the plunger should be flush with the opening of the barrel for sampling. This position will prevent air from being forced through or around the sample plug during sample collection and extruding into the sample container. If a modified disposable syringe is used, syringes with less than 5 cm^3 total volume cannot be used. Research has demonstrated that high surface area to total volume ratios in soil cores create significant volatilization loss within seconds of exposure to such devices.

The disposable syringe is a one-time use device and should not be decontaminated and reused. The disposable syringe should not be used for storage or shipment to the laboratory. The soil sample should be transferred into appropriate sample containers immediately upon sample collection for proper preservation.

6.2.7.2.2 Easy-Draw Syringe, Power-Stop Handle, and Terra Core

The Easy-Draw Syringe®, Power-Stop Handle®, and Terra Core® a volumetric coring system for sample collection of a fixed volume and transfer into appropriate sample containers. The device consists of two parts, the sampling syringe and handle. The polypropylene syringe is used to collect and transfer the sample. The handle allows for easier sampling and controls the volume of soil collected. The handle has three positions to control the volume of soil collected based on the density of the matrix and can be set to collect 5, 10 or 13-gram samples.

Once the sample is collected, remove any excess material that extends beyond the end of the syringe and cap. Remove the syringe from the handle and extrude the sample into the appropriate sample container. The Easy-Draw Syringe® and Power Stop Handle Purge and Trap Sampler® should not be used for storage or shipment to the laboratory. The soil sample should be transferred into appropriate sample containers immediately upon sample collection for proper preservation.

6.2.7.2.3 Purge and Trap Soil Sampler®

The Purge and Trap Soil Sampler®is a 5-gram volumetric coring system for sample collection and

transfer into appropriate sample containers. The device consists of two parts, the coring tube and the handle. The coring tube is removable from the handle, so numerous core tubes can be used with one handle. The sampler is also capable of sampling harder materials than other sampling systems. If sample weights other than 5 grams are required, the device can be adjusted so sample sizes of 1 to10 grams can be collected. The supplied plunger is used to extract the sample into the sample container.

The Purge and Trap Soil Sampler® is constructed of stainless steel, which allows the sampler to be decontaminated for reuse.

The Purge and Trap Soil Sampler® cannot be used for storage or shipment to the laboratory. The soil sample should be transferred into appropriate sample containers immediately upon sample collection for proper preservation.

6.2.7.2.4 En Core® Sampler

The En Core® sampler is a one-time-use volumetric sampling and storage device. The En Core® sampler is made of an inert composite polymer designed to collect, seal and store a 5-gram sample, with no headspace, prior to preservation or analysis. The En Core® sampler is designed to extrude the sample directly from the coring body into the sample container without disturbing the matrix structure. The sampler has three components: the coring body, the plunger and the cap. A specially designed "T" handle, available from the manufacturer, is used to push the En Core® sampler into the soil matrix and to lock the sampler after collection. Three Viton® O-rings, two on the plunger and one on the cap, seal the sampler preventing the loss of VOCs. Each En Core® sampler is packaged in an airtight, resealable foil package to prevent contamination during storage and shipping.

Prepare the En Core® sampler in accordance with the manufacturer's recommendations. **The plunger bottom should be flush with the bottom of the coring body <u>before</u> sampling**. This prevents air from being trapped behind the sample during coring. Trapped air can potentially cause a loss of VOCs when air passes through the sample. If air is trapped behind the sample, it may cause the sample to be prematurely expelled from the coring device.

Use of En Core® sampler is ideal for reducing the handling of preservation chemicals in the field. The practice of immediate field preservation of samples can lead to the creation of hazardous materials if all samples are not sent for laboratory analysis. The En Core® sampler can be effectively used during soil boring operations to store samples on-site until field analytical results are available, potentially reducing the number of samples sent for laboratory analysis. Upon review of the field analytical results, the field sampler can either extrude the soil stored in the En Core® sampler into the appropriate containers or retained in the En Core® sampler for later shipment to the laboratory. If an En Core® sampler is used to ship a soil sample directly to the laboratory for VOC analysis, the soil should be extruded from the En Core® sampler and preserved by the laboratory within 48 hours of sample collection.

The En Core® sampler cannot be used on cemented or consolidated materials, or coarse materials large enough to interfere with proper coring techniques.

The En Core® sampler is a single use sampling and storage device and cannot be decontaminated for reuse. The T-handle and laboratory-extruding device can be decontaminated and reused.

6.2.7.3 VOC Soil Sample Collection Technique

Small-diameter VOC sampling devices should be selected based upon the properties of the matrix, the type of preservation method (field vs. lab) and personal preference. The small-diameter core sampler should fit inside the mouth of the sample container to avoid loss of sample, prevent damage to the sealing surfaces or container threads and ease the soil transfer process.

Once the sampling interval has been selected, trim off the exposed surface of the matrix to expose a

fresh surface. A loss of VOCs from the surface of the matrix will occur even if the matrix has been exposed for a short period of time (during screening, etc.). Removal of the unwanted surficial material can be accomplished by scraping the matrix surface with a decontaminated spatula or trowel. Soil sampling should commence immediately once a fresh surface has been exposed.

Push the small-diameter core sampler into the matrix to collect a volume of material which will yield the required mass of sample (wet weight) as determined by the analytical method. If the small-diameter core sampler does not have a seal between the barrel and plunger, the plunger of the coring device can be pulled back, positioned flush with the opening of the barrel, or completely removed allowing the open barrel of the sampler to be inserted into the matrix. If the small-diameter core sampler has a seal between the core barrel and plunger, the plunger should be flush with the end of the core barrel to avoid pushing air through the sample during collection. Depending upon the texture, depth or moisture content, the small-diameter core sampler can be inserted straight into the matrix, on an angle or multiple insertions can be made to obtain the required sample weight.

After sample collection, wipe the outside of the small-diameter core sampler to remove any excess material adhering to the barrel. Immediately open the sample container and extrude the soil core into the sample container. If present, avoid splashing any preservative out of the sample container by holding the container at an angle while slowly extruding the soil core into the sample container. Do not immerse the small-diameter core sampler into the preservative. If an En Core® sampler is to be used for storage and shipment, prepare the sampler for shipment according to manufacturer's instructions (see below for additional information). Collect the required number of sample containers or En Core® samplers based on the chosen preservation and analytical methods as discussed in section 6.2.7.4., *VOC Soil Sample Preservation Methods*. Include an additional sample volume for percent moisture determination and sample screening as discussed in the sections below.

Ensure the threads and cap of the sample container or En Core® sampler are free of soil particles. Use a clean paper towel to remove soil particles from the threads and sealing surface of the sample container or En Core® sampler. The presence of soil particles will compromise the container's seal and may result in preservative or VOC loss. This loss ultimately may invalidate the sample analysis. Always make sure the sample lid is firmly secure.

Record the laboratory and field identification numbers in the field notes and on the chain of custody. Container labels with wire or rubber band attachments should be used provided they can be removed easily for sample weighing. **Do not attach any additional adhesive backed labels or tape to the sample containers unless requested by laboratory or specified in manufacturer instructions. This will increase the weight of the sample container and the laboratory will not be able to determine the sample weight.**

After sample collection, immediately return the containers to an iced cooler. Sample containers from different locations should be placed in separate zip lock bags to help avoid cross contamination. The laboratory sample number or field sample identification number may be placed on the bag and cross-referenced on the chain of custody. The laboratory performing the analysis will determine the sample weight.

If the laboratory has determined a sample container has leaked by noting a visible reduction in preservative or unusually low weight, the sample may be rejected for analysis by the laboratory. The sampling team leader or project manager should be notified immediately of any problems with the sample condition. Only the suspect vial will be in question, not the entire sample shipment.

6.2.7.4 VOC Soil Sample Preservation Methods

The preservation of samples for VOC analysis can be initiated either at the time of sample collection or in the laboratory. This section deals with the preservation of soil samples for VOC analysis in the field using chemical and physical preservation methods. Please note the first three preservation methods (1 through 3) are the preferred sample preservation methods under the *USEPA Contract Lab*

Program (CLP) Statement of Work (SOW) for Organic Analysis, Multi- Media, Multi-Concentration. The last three preservation methods (4 through 6) though not preferred are acceptable under specific circumstances as outline below.

It is important that the laboratory analytical methods, field preservation methods, appropriate sample containers and sample holding times are determined and agreed upon prior to mobilizing to the field. Also, additional sample containers may be required for various quality control/quality assurance (QA/QC) samples such as matrix-spike and matrix-spike duplicates (MS/MSD). The number of extra containers required vary by laboratory and analytical procedure. It is up to the laboratory and sampling team to determine the required number of containers for each QA/QC sample submitted.

In addition to the various chemical preservation methods, samples should be physically preserved (e.g., iced, or frozen) in the field immediately upon sample collection. Physical preservation methods such as "icing" or freezing" are accomplished by placing sample containers in insulated coolers containing "wet ice", "blue ice" or "ice gel packs". It is important to match up the correct physical preservation method with the appropriate sample container and field chemical preservation method. According to USEPA CLP Guidance for Field Samplers, the physical preservation methods are described as:

Iced – soil and sample containers are cooled to 4°C (± 2°C)

Frozen – soil and sample containers are cooled to between -7°C and -15°C

Sample containers, which will be frozen, should be placed on their side prior to freezing process to prevent breakage. Additional aliquots for screening and moisture determination need only be iced and kept cooled at 4°C (± 2°C): these sample containers should not be frozen. ***Sample containers and En Core® sampler should not be frozen below -20 ° C as the integrity of the container seals, o-rings and septum may be compromised by the freezing, resulting in the loss of VOCs upon sample thawing.***

In addition, the use of dry ice to freeze samples immediately upon sample collection or for use during shipment is not recommended. Dry ice, which is at a temperature of -78.5°C, will lower the temperature of the sample container below the design specifications causing damage to the glass, septum, seals O-rings and cap. In addition, dry ice has specific handling, storage, and shipping requirements that far out-weigh its usefulness to the field sampling team.

6.2.7.4.1 Closed-System Vials, No Chemical Preservation

This preservation and sampling method employs the use of tared unpreserved 40-ml glass vials with PTFE-lined septum screw cap and a magnetic stir bar. A minimum of three (3) sample containers with a stir bar should be used for each sample location. An additional sample aliquot is also necessary for screening and moisture determination. ***This is a preferred method of preservation by USEPA CLP SOW.***

Using a small-diameter core sampler as described above, 5-grams of soil should be placed in each of the vials. Care should be taken when placing the soil in the vial to limit loss of soil. Each vial should also contain a clean magnetic stir bar. If the laboratory instrumentation has a sonicator or other mechanical means of mixing the sample, the stir bar may be omitted.

Vials (with stir bars and septum caps) should be tared (or weighed) before use. Each sample vial should be weighed by the laboratory (to the nearest 0.01 grams) and by field personnel (to the nearest 0.1 grams). After soil, has been placed in the vial, the vial should be capped, wiped clean and reweighed. The pre- and post-sampling weights should be recorded in field notes, chain of custody or electronic file with the corresponding numerical designation and supplied to the laboratory.

The vials should also have a label affixed by the laboratory or vendor with a unique numerical

designation which corresponds to associated table of tared weights for each vial. The weight of any markings added to this label in the field is negligible. However, additional labels should not be attached to the vial by the field sampling personnel. If needed an easily removable tag may be attached by wire or string to the neck of the vial. After sample collection, the vials should be iced (cooled to 4°C [± 2°C]) or frozen (-7°C and -15°C) for later shipment to the laboratory. The holding time for non-chemically preserved, iced (cooled to 4°C [± 2°C]) and frozen (-7°C and -15°C) samples is 48 hours from sample collection to chemical preservation, freezing or analysis by the laboratory. The holding time for soil sample can be extended to 14 days if the soil is chemically preserved or kept frozen until actual analysis. This method is appropriate for low- and medium-level analysis under USEPA CLP SOW and low- and high-level analysis for USEPA SW846 Methodologies.

In addition, the sample containers should be stored in a contaminant free environment before use and during shipment. It is the responsibility of the field sampling team and sample container provider to ensure contaminant free sample container integrity. The analytical laboratory or a vendor can supply sample containers with a stir bar.

Limitations:

- Increased possibility of breakage during shipment due to freezing the sample below -20° C.
- Difficult to maintain freezing temperatures (-7°C and -15°C) in the field or during shipment.
- A 48-hour holding time for non-chemically preserved, soil samples cooled to 4°C (± 2°C) or frozen (-7°C and -15°C) require the laboratory to chemically preserve, freeze or analyze the samples quickly.

6.2.7.4.2 Closed-System Vials, No Chemical Preservation with Organic Free Water (OFW)

This preservation and sampling method employs the use of tared, unpreserved 40-ml glass vials with PTFE-lined septum screw cap, a magnetic stir bar and reagent water (organic free water-OFW). A minimum of two (2) sample containers should be prepared with the required OFW and stir bar for each sample location. The USEPA CLP Guidance for Field Samplers also recommends collecting one additional vial without OFW for backup analysis. Additional sample aliquot is also necessary for screening and moisture determination. ***This is a preferred method of preservation by USEPA CLP SOW.***

Using a small-diameter core sampler, 5-grams of soil should be placed in each of the vials. Care must be taken when placing the soil in the vial to limit splashing or loss of the OFW. The volume of OFW is dependent upon the analytical method, however USEPA CLP SOW recommends 5ml of water for each vial collected. Each vial should also contain a clean magnetic stir bar. If the laboratory instrumentation has a sonicator or other mechanical means of mixing the sample, the stir bar may be omitted.

Vials with OFW (with stir bars and septum caps) should be tared (or weighed) before use. Each sample vial should be weighed by the laboratory (to the nearest 0.01 grams) and by field personnel (to the nearest 0.1 grams). Once the OFW and/or stir bar is added to the vial by the laboratory or vendor, a mark can be made on the vial corresponding to the level of the liquid meniscus to assist the field personnel in determining if OFW has been lost from the vial. Prior to placing the soil in the vial, each sample vial should be weighed by the field personnel to check on the potential loss of OFW. The loss of greater than 0.2 grams is an indicator that OFW has been lost and the vial should not be used for sampling. After soil, has been placed in the vial, the vial should be capped, wiped clean and reweighed. The pre- and post-sampling weights should be recorded in field notes, chain of custody or electronic file with the corresponding numerical designation and supplied to the laboratory.

The vials with OFW should also have a label affixed by the laboratory or vendor with a unique

numerical designation which corresponds to associated table of tared weights for each vial. The weight of any markings added to this label in the field is negligible. However, additional labels should not be attached to the vial by the field sampling personnel. If needed an easily removable tag may be attached by wire or string to the neck of the vial. Record the lot number of the preservative used in the preparation of the sample containers. This information can be used for future reference in the event of suspected contamination. After sample collection, the vials should be iced (cooled to 4°C [± 2°C]) or frozen (-7°C and -15°C) for later shipment to the laboratory. The holding time for non-chemically preserved, iced (cooled to 4°C [± 2°C]) and frozen (-7°C and -15°C) samples is 48 hours from sample collection to chemical preservation, freezing or analysis by the laboratory. The holding time for soil sample can be extended to 14 days if the soil is chemically preserved or kept frozen until actual analysis. This method is appropriate for low- and medium-level analysis under USEPA CLP SOW and low- and high-level analysis for USEPA SW846 Methodologies.

In addition, sample containers should be stored in a contaminant free environment before use and during shipment. It is the responsibility of the field sampling team and sample container provider to ensure contaminant free sample container integrity. The pre-preserved sample containers with OFW and a stir bar can be supplied by the analytical laboratory or a vendor.

Limitations:

- Increased costs due to the addition of a preservative and magnetic stir bar into each sample container.
- Increased possibility of breakage during shipment due to freezing the sample below -20° C.
- Difficult to maintain freezing temperatures (-7°C and -15°C) in the field or during shipment.
- A 48-hour holding time for non-chemically preserved, soil samples cooled to 4°C (± 2°C) or frozen (-7°C and -15°C) require the laboratory to chemically preserve, freeze or analyze the samples quickly.

6.2.7.4.3 Small Diameter Core Sampler for Storage and Transport (e.g., En Core® Sampler)

This preservation and sampling method employs the use of a small-diameter core sampler known as the En Core® sampler. The En Core® sampler is a one-time-use, volumetric sampling, storage and transportation device. It is designed to collect and store soil samples for transportation to the laboratory. (See previous discussion on use of the En Core® sampler as a sample collection tool.) ***This is a preferred method of preservation by USEPA CLP SOW.***

Please note: Prior to using any other small-diameter core sampler not mentioned here for storage and transportation to the laboratory, a comparison data and an equivalency study should be provided to NJDEP in accordance with N.J.A.C. 7:26E-1.6(c) and deemed acceptable by the NJDEP.

Soil should be collected using the En Core® sampler in accordance with the manufacturer's recommendations. A specially designed "T" handle, available from the manufacturer, is used to push the En Core® sampler into the soil matrix and to lock the sampler after collection.

A minimum of three (3) individual 5-gram En Core® samplers should be collected for each soil sample. Upon sample collection, label each En Core® sampler cap with the label provided by the manufacturer and return it to the airtight, resealable foil package. Additional sample aliquot is also necessary for screening and moisture determination as discussed below. En Core® samplers should be iced (cooled to 4°C [± 2°C]) or frozen (-7°C and -15°C) for later shipment to the laboratory. En Core® samplers can be shipped directly to the laboratory for VOC analysis; however, laboratory should extrude the soil from the En Core® sampler and analyze, chemically preserve, or freeze the soil within 48 hours of sample collection. The soil samples should be extruded from the En Core® sampler into appropriate sample containers using a specially designed "T" handle push-rod tool

available from the manufacturer. Soil should **not** be scooped out of the En Core® sampler using a trowel or spatula as this can cause a significant loss of VOCs. The holding time for soil stored in an En Core® sampler can be extended if the soil is extruded by the laboratory within 48 hours to a sealed vial and frozen or chemically preserved until actual analysis. This method is appropriate for low- and medium-level analysis under USEPA CLP SOW and low- and high-level analysis for USEPA SW846 Methodologies.

En Core® samplers should be stored in a contaminant free environment before use and during shipment. It is the responsibility of the field sampling team and sample container provider to ensure contaminant free sample container integrity. The En Core® samplers can be supplied by the analytical laboratory or a vendor.

Limitations:

- The En Core® sampler should not be used on cemented or consolidated materials, or, coarse materials large enough to interfere with proper coring techniques.
- Any "alternative" to the En Core® sampler should have a plunger to allow for proper mechanical dispensing at the laboratory, and should be approved for use by NJDEP.
- A 48-hour holding time for non-chemically preserved, soil samples cooled to 4°C (± 2°C) or frozen (-7°C and -15°C) require the laboratory to chemically preserve, freeze or analyze the samples quickly.
- Currently the En Core® sampler is the only small-diameter core sampler approved for use by NJDEP for sampling, storage, and transport.
- Difficult to maintain freezing temperatures (-7°C and -15°C) in the field or during shipment.

6.2.7.4.4 Closed-System Vials, Chemical Preservation – Sodium Bisulfate

This preservation and sampling method employs the use of tared, pre-preserved 40- ml glass vials with PTFE-lined septum screw cap, a magnetic stir bar and sodium bisulfate (ACS reagent grade or equivalent). A minimum of two (2) sample containers should be prepared with the required preservative and stir bar for each sample location. The USEPA CLP Guidance for Field Samplers also recommends collecting one additional unpreserved vial for backup analysis. Additional sample aliquot is also necessary for screening and moisture determination.

Using a small-diameter core sampler, 5-grams of soil should be placed in each of the 40-ml vials (with or without preservative). Care should be taken when placing the soil in the vial to limit splashing or loss of the preservative. The volume of sodium bisulfate is dependent upon the analytical method, however USEPA CLP SOW recommends 1 gram of sodium bisulfate in 5ml of water for each vial collected. Each vial should also contain a clean magnetic stir bar. If the laboratory instrumentation has a sonicator or other mechanical means of mixing the sample, the stir bar may be omitted.

Pre-preserved vials (with stir bars and septum caps) should be tared (or weighed) before use. Each sample vial should be weighed by the laboratory (to the nearest 0.01 grams) and by field personnel (to the nearest 0.1 grams). Once the preservative and/or stir bar is added to the vial by the laboratory or vendor, a mark can be made on the vial corresponding to the level of the liquid meniscus to assist the field personnel in determining if preservative has been lost from the vial. Prior to placing the soil in the vial, each sample vial should be weighed by the field personnel to check on the potential loss of preservative. The loss of greater than 0.2 grams is an indicator that preservative has been lost and the vial should not be used for sampling. After soil, has been placed in the vial, the vial should be capped, wiped clean and reweighed. The pre- and post-sampling weights should be recorded in field notes, chain of custody or electronic file with the corresponding numerical designation and supplied to the laboratory.

The pre-preserved vials should also have a label affixed by the laboratory or vendor with a unique

numerical designation which corresponds to associated table of tared weights for each vial. The weight of any markings added to this label in the field is negligible. However, additional labels should not be attached to the vial by the field sampling personnel. If needed an easily removable tag may be attached by wire or string to the neck of the vial. Record the lot number of the preservative used in the preparation of the sample containers. This information can be used for future reference in the event of suspected contamination. After sample collection, the vials should be iced (cooled to 4°C [± 2°C]) for later shipment to the laboratory. The holding time for chemically preserved, iced (cooled to 4°C [± 2°C]) samples is 14 days from sample collection to analysis by the laboratory. This method is appropriate for low- and medium-level analysis under USEPA CLP SOW and low- and high-level analysis for USEPA SW846 Methodologies.

This is not a preferred method of preservation by USEPA CLP SOW. Sodium bisulfate preservation of soil may result in the destruction or creation of certain target VOCs. As a result, sodium bisulfate should not be used in the following circum- stances:

- If contaminants of concern include VOCs such as vinyl chloride, trichloroethene, styrene, 2-chloroethylvinyl ether, trichlorofluoromethane, or cis- and trans-1, 3- dichloropropene. Low pH conditions caused by the preservation of soil with sodium bisulfate cause the destruction or breakdown of these VOCs resulting in biased low analytical data.
- Soils with a higher proportion of decayed matter where acetone is a contaminant of concern should not be preserved with sodium bisulfate. Decomposition of the decayed matter due to sodium bisulfate preservation results in the creation of a false positive acetone artifact yielding biased high analytical results.
- If the soils contain carbonaceous material. The carbonaceous material present in the soil, either natural or amended, will react with the sodium bisulfate and cause the sample to effervesce resulting in a loss of VOCs.

Pre-preserved sample containers should be stored in a contaminant free environment before use and during shipment. It is the responsibility of the field sampling team and sample container provider to ensure the container's contaminant free integrity. The pre-preserved sample containers with stir bar can be supplied by the analytical laboratory or a vendor.

Limitations:

- Sodium bisulfate should not be used on carbonaceous soils as effervescence may ensue with subsequent VOC loss.
- Sodium bisulfate creates low pH conditions that may result in the destruction of certain target VOCs.
- Increased costs due to the addition of a preservative and magnetic stir bar into each sample container.

6.2.7.4.5 Closed-System Vials, Chemical Preservation – Methanol

This method employs the use of tared, pre-preserved 40-ml glass vials with PTFE- lined septum screw cap and methanol (purge and trap quality grade or equivalent). A minimum of two (2) sample containers should be prepared with the required preservative. Additional sample aliquot is also necessary for screening and moisture determination.

Using a small-diameter core sampler, 5-grams of soil should be placed in each of the 40-ml pre-preserved vials. Care should be taken when placing the soil in the vial to limit splashing or loss of the preservative. The volume of methanol is dependent upon the analytical method. The USEPA CLP SOW recommends 5 to 10 ml of methanol in each vial collected.

Pre-preserved vials (with septum caps) should be tared (or weighed) before use. Each sample vial should be weighed by the laboratory (to the nearest 0.01 grams) and by field personnel (to the

nearest 0.1 grams). Once the preservative is added to the vial by the laboratory or vendor, a mark can be made on the vial corresponding to the level of the liquid meniscus to assist the field personnel in determining if preservative has been lost from the vial. Prior to placing the soil in the vial, each sample vial should be weighed by the field personnel to check on the potential loss of preservative. The loss of greater than 0.2 grams is an indicator that preservative has been lost and the vial should not be used for sampling. After soil, has been placed in the vial, the vial should be capped, wiped clean and reweighed. The pre- and post-sampling weights should be recorded in field notes, chain of custody or electronic file with the corresponding numerical designation and supplied to the laboratory.

The pre-preserved vials should also have a label affixed by the laboratory or vendor with a unique numerical designation which corresponds to associated table of tared weights for each vial. The weight of any markings added to this label in the field is negligible. However, additional labels should not be attached to the vial by the field sampling personnel. If needed an easily removable tag may be attached by wire or string to the neck of the vial. Record the lot number of the preservative used in the preparation of the sample containers. This information can be used for future reference in the event of suspected contamination. After sample collection, the vials should be iced (cooled to 4°C [$\pm$ 2°C]) for later shipment to the laboratory. The holding time for chemically preserved, iced (cooled to 4°C [$\pm$ 2°C]) and samples is 14 days from sample collection to analysis by the laboratory. This method is appropriate for medium-level analysis under USEPA CLP SOW and high-level analysis for USEPA SW846 Methodologies.

This is not a preferred method of preservation by USEPA CLP SOW. Methanol preservation of soil results in higher detection limits and is therefore not applicable to low-level analysis. Additional problems associated with the use of methanol include:

- Soils with high moisture content (>10 %) that are field preserved with a water miscible solvent such as methanol are diluted by the total volume of the solvent/water mixture. The detected contaminant concentrations should be corrected to account for the solvent/water dilution factor. If this calculation is not made, the additional dilution by soil pore water will result in biased low analytical data.
- Leakage of methanol from the container during sampling or in shipment causing the loss of VOCs in the methanol and resulting in biased low analytical data.
- Possible contamination of methanol by other sampling related activities including the absorption of diesel fumes from running equipment or vehicles on to the sample containers.
- The preservation of soil by methanol results in the reclassification of the sample as a hazardous waste. This hazardous waste classification results in increased shipping and disposal costs.

Pre-preserved sample containers should be stored in a contaminant free environment before use and during shipment. It is the responsibility of the field sampling team and sample container provider to ensure contaminant free sample container integrity. The pre-preserved sample containers can be supplied by the analytical laboratory or a vendor.

Limitations:

- Methanol preservation is applicable to medium- and high- level analysis only. Low-level concentrations are not detectable with this preservation method.
- Biased low analytical data due to the loss of methanol after sampling or high moisture content in the soil.
- Increased costs due to the addition of a preservative and the classification as a hazardous waste resulting in higher shipping and sample disposal costs.

6.2.7.4.6 Glass Containers, No Chemical Preservation, No Headspace

This preservation method employs the use of unpreserved-glass sample containers with a PTFE-lined screw cap. A minimum of two 4-oz glass containers should be used for each soil sample. Soil should be placed in the containers using decontaminated stainless steel spoons or spatulas in such a manner as to minimize the headspace (e.g., the containers should be completely filled). Additional sample aliquot is also necessary for screening and moisture determination as discussed below. The samples are then iced and cooled to 4°C (±2°C) for later shipment to the laboratory. The holding time for non-chemically preserved, cooled to 4°C (±2°C) soil samples is 48 hours from sample collection to preservation or analysis in the laboratory. This method is appropriate for low- and medium-level analysis under USEPA CLP SOW and low- and high-level analysis for USEPA SW846 Methodologies.

This is not a preferred method of preservation by USEPA CLP SOW as losses of VOCs from biodegradation and volatilization may occur when the sample containers are opened in the laboratory. Due to the configuration of the container as the volume of soil within, the laboratory should open the container to remove the required sample volume for analysis. Studies had shown that substantial loss of VOCs occur during this laboratory procedure. However, circumstances exist where chemical preservation or freezing is not recommended. In these instances, best professional judgement should be used in the selection of this method as pursuant to N.J.A.C. 7:26E-1.6(c). The circumstances which may result in the use of this method include:

- Waste characterization sampling under Subtitle C of RCRA, the use of specific test methods for some applications are required in 40 CFR parts 260 through 270.
- Sampling unknown wastes or oily wastes (from containers, drums, etc.) when the reactivity of the waste with chemical preservative or freezing is not known. After initial laboratory analysis has characterized the waste, subsequent sampling using preservation can be performed if the waste is found to be non-reactive to the chemical preservative.
- During emergency response actions when there is no time for prepared sample containers to arrive from the laboratory. Resampling of potential impact areas may be required using approved preservation procedures after the emergency has been mitigated.

Sample containers should be stored in a contaminant free environment before use and during shipment. It is the responsibility of the field sampling team and sample container provider to ensure contaminant free sample container integrity. The sample containers can be supplied by the analytical laboratory or a vendor.

Limitations:

- Potential loss of VOCs when the sample containers are opened at the laboratory.
- Biased low analytical results due to the loss of VOCs.
- Holding time of 48 hours for non-chemically preserved, soil samples cooled to 4°C (± 2°C) requires the laboratory to preserve or analyze samples quickly.

6.2.7.5 Sample Aliquot for Moisture Determination and Sample Screening

This sample aliquot will be used for laboratory screening and percent moisture analysis. They will first screen the sample to determine the appropriate analytical level of analysis, which will be dictated by the concentration of VOCs in the sample. To accommodate the laboratory's preparatory steps, additional sample matrix should be provided to the laboratory from each sample location. The additional sample aliquot should be collected using a decontaminated stainless steel trowel or spatula and place into an unpreserved sample container, usually a 60- ml wide mouth PTFE-lined glass container. This sample is not chemically preserved. The sample should be obtained from the same interval and location as the sample for VOC analysis. The sample container should be completely

filled with sample to minimize headspace and loss of VOCs. The laboratory should report the analytical results for soil and sediments (non-aqueous) samples on a dry weight basis.

Ensure the threads and cap of the sample container are free of soil particles by wiping with a laboratory grade wipe. The presence of soil particles will compromise the container's seal and may result in preservative or VOC loss. Always make sure the sample lid is firmly secure. The sample aliquot for moisture determination and sample screening should be placed and shipped on ice at 4°C (± 2°C).

6.2.8 Non-VOC Sample Collection for Soils

Contaminants such as semivolatile organic compounds (SVOCs), Per- and Polyfluoroalkyl Substances (PFAS), pesticides, PCBs, metals or cyanide that cannot be detected with field screening instrumentation should be sampled from locations or depths that are most likely to be contaminated. These locations should be based on the location and nature of the discharge or type of matrix to which the contaminant was discharged.

The sampler should include in the field notes any information noted during sampling activities that aided in the determination of non-VOC sample location selection. This will ensure accurate data interpretation by non-field personnel at a later time.

It is important that the laboratory analytical methods, field preservation methods, appropriate sample containers and sample holding times are determined and agreed upon by the sampling team and laboratory prior to mobilizing to the field. Also, additional sample containers maybe required for various quality control/quality assurance (QA/QC) samples such as MS/MSDs. The number of extra containers required vary by laboratory and analytical procedure. It is up to the sampling team to know the required sample volume and number of containers for each QA/QC sample submitted.

In instances where a soil sample is collected for VOC analysis as well as other non-VOC parameters, the soil sample for VOC analysis should be collected first to minimize volatilization and biodegradation. Once VOC soil sampling is complete the remaining soil to be analyzed for non-VOC parameters such as SVOCs, pesticides, PCBs, metals or cyanide should be homogenized to create a representative sample. In case of limited sample quantity, prioritization of analytical parameters should be determined beforehand by the project leader or case manager.

Homogenization or mixing of the soil with a decontaminated spoon or spatula can take place either in-situ (in the case of shallow soil sample) or in a decontaminated stainless steel bowl or tray. The bowl or tray should be large enough to hold more than the required sample volume and to allow proper mixing without spillage. It is important that mixing of soil be as thorough as possible. The mixing technique will depend on the physical characteristics of the soil including moisture content, particle size and distribution; however, the goal is to achieve a consistent physical appearance over the entire soil sample. Prior to homogenization, twigs, roots, leaves, rocks and miscellaneous debris (glass, bricks, etc.) should be removed from the sample using the decontaminated stainless steel spoon or spatula. Care should be taken to minimize contact of disposable gloves with soil to be sent for laboratory analysis.

Homogenization of the soil includes a series of mixing and quartering steps. The soil should be scraped from the sides, corners and bottom, rolled into the middle of the decontaminated stainless steel bowl or tray (or in-situ hole) and mixed. The soil should then be quartered (divided into 4) and moved to the sides of the bowl/tray/hole. Each quarter should then be mixed individually, and then rolled to the center of the bowl/tray/hole and mixed with the entire sample again. These steps of quartering the soil, mixing individually and then mixing the entire sample again should be repeated at least twice. Once a consistent physical appearance over the homogenized soil has been obtained, the soil should be transferred into the appropriate sample container using the decontaminated stainless steel spoon or spatula.

Once the sample containers are full, ensure the threads, lid and outer edges of the sample container are free of soil particles. Use a clean paper towel to remove soil particles from the threads and sealing

surface of the sample container. The presence of soil particles will compromise the container's seal and may result in loss of soil moisture, cross contamination or the lid opening in transit. Always make sure the container lid is firmly secure.

After sample collection, immediately place the container in an iced cooler in an upright position. Sample containers from different sample locations should be placed in separate zip lock bags to protect other containers in case of leakage during transport. The laboratory sample number or field sample identification number may be placed on the bag and cross-referenced on the chain of custody. Record the laboratory and field identification numbers in the field notes and on the chain of custody. The laboratory performing the analysis will determine percent moisture.

6.2.9 Sampling Alternatives for Situational and Matrix Variations

Sample collection procedures discussed above are appropriate in a majority of cases. However, situational or matrix variations require some modification to the sampling methods. Documentation of using any alternative sampling procedures is critical to aid in data interpretation. The data generated from non-core samples should be used with caution due to the potential for significant VOC loss. Anytime a coring device is not used for VOC sample collection an explanation of the procedure and reasons for its use should be provided to the NJDEP.

6.2.9.1 Sampling Hard or Cemented Material

Sampling of cemented materials may be too hard to allow sample collection via previously discussed methods. Therefore, other techniques may be employed. Collecting a sample of this material can be performed by fragmenting the sample with a decontaminated chisel to generate aggregate of material for placement into the sample container. Caution is warranted due to potential injury when performing sampling using this method due to flying particles during the fragmentation process. The aggregate material can be transferred to the sample container with the use of a stainless steel spatula or small trowel. A small funnel can be used to channel the sample into the container. The funnel should not restrict the passage of the larger pieces of sample aggregate. Loss of VOCs may occur when sampling this matrix during the fragmentation process and the increased exposure of surface area of the material.

6.2.9.2 Sampling a Mixture of Fines and Gravel

Sampling of poorly sorted material consisting of large aggregate and fines may not allow a core sampler to be used. In these conditions, a stainless steel spatula or trowel can be used for sample collection. The sample collection process should be performed quickly to prevent a loss of VOCs. A small funnel can be used to channel the sample into the container. The funnel should not restrict the passage of the larger pieces of sample aggregate. A separation of coarse and fine-grained material will be inherent to the process, which will bias the data due to non-representation of all size material. As a result, data generated from samples of this matrix should be used with caution. Loss of VOCs may occur when sampling this matrix due to the increased exposure of surface area of the material.

6.2.9.3 Sampling Dry Non-Cohesive Material

For material such as dry sand, packing a cohesive plug will be very difficult. In these situations, obtain a core sample or push the sample into the barrel of the sampler with a spatula, packing the sample into the barrel. Then cover the opening of the core sampler with the spatula so the material does not fall out of the sampler until the material is extruded into the sample container. A small funnel can be used to channel the sample into the container. The funnel should not restrict the passage of the larger pieces of sample aggregate. Loss of VOCs may occur when sampling this matrix due to the increased exposure of surface area of the material.

6.2.9.4 Sampling Sediments

When sampling sediment, a wide variety of materials may be encountered. The matrix may include fine grained material, a mixture of coarse and fine grained material which may include dead vegetative material (leaves, sticks, etc.) or peat moss. The bulk sampling of sediments can be collected with a core sampler or clamshell dredge. The method of collecting the discrete sample will depend upon the type of material encountered. Therefore, various sampling tools should be available to ensure the collection of representative samples.

One of the problems encountered when sampling sediments is the amount of water in the sample. The high level of moisture will increase the detection limits of the analysis due to the concentration calculation on a dry weight basis.

In some cases, the density of the material may not allow a sample to be collected within the required weight range of the analytical method or the required weight of material may not be fully submerged in the preservative. These cases may require the addition of preservative by the laboratory to submerge the sample which will increase the detection limits of the sample.

6.2.9.5 Sampling Oil Waste, Tars and Other Waste Material

The collection of a discrete waste sample may be successful using one of the methods mentioned previously. The type of material will dictate the best sampling method. If none of the discrete core sampling methods is applicable to the matrix, then a sample can be collected in an unpreserved glass sample container with a PTFE lined lid. Headspace in the container should be minimized. The laboratory will collect a sub-sample from the material for analysis. Documentation of using this sampling procedure is critical to aid in data interpretation. Loss of VOCs may occur when sampling this matrix due to the increased exposure of surface area of the material.

6.2.9.6 Sampling from Test Pits

Test pit excavation is useful in the identification of waste material buried on site and for direct observation of the soil horizons for any apparent band of soil contamination. However, this method does have limitations. Due to the amount of disturbance involved, test pit samples are not reproducible and are not considered to represent the undisturbed formation. Additionally, equipment, visual observation, distance and the integrity of the trench walls limit the depth of the evacuation. The health and safety hazard associated with test pits is great. Because the trench walls may be unstable, no personnel should enter any test pit that is deeper than three (3) feet. Care should be taken in working near the backhoe. All personnel should be alert to the machine's movement and be prepared for any potential contaminant release from the excavation. During test pit operations, the potential exists to leave contaminated soils at the surface where it may not have been present before excavation. Consideration should be given to potential exposures from the contaminated surface soils. Finally, in areas where surface soil contamination is a problem, this contamination may be carried deeper by excavation and backfilling. In such a situation, test pits should not be used.

For these reasons, test pits should only be used as a sampling approach to locate specific hot spots of contamination or to locate specific buried waste. To most efficiently collect representative soil samples at depth, a drill rig or direct push should be used.

If it is determined that test pits will be utilized to access samples at depth, the backhoe used should be equipped with a protective shield and its operator properly trained in the use of level B respiratory and dermal protection. The backhoe bucket and arm should be thoroughly decontaminated by steam cleaning or standard cleaning procedures for non-aqueous sampling equipment prior to use and between each test pit location.

The operator should be directed to excavate until the sampler indicates that the desired depth has been reached. All excavated material should be placed on a tarp or plastic sheeting. If the pit is shallow

(less than three feet) the sampler can enter the pit and collect the soil sample using a decontaminated trowel for non-VOCs or small a diameter soil coring device. As the pit gets deeper, the sampler may collect the soil directly from the bucket of the backhoe in an area where the sample material is not in contact with the bucket. The sample should be transferred from the bucket following appropriate collection techniques for each analytical parameter to be analyzed.

6.3 Rock Core Sample Collection

Rock core drilling is a drilling method that can provide core samples of the bedrock under investigation. The core samples can be obtained from specific depth intervals. Rock coring is conducted in materials that are too hard to permit the use of direct-push or split-spoon coring techniques.

Since core samples provide an actual rock sample, the geologist can observe and evaluate the true character of the bedrock material (Wells 1991). The evaluation can include analyses and descriptions of lithologies, rock textures, stratigraphy, bedding plane structure, fracture characteristics, primary and secondary porosities, permeability, rock fluids, and contaminant content.

Advancements in the amount and quality of borehole information collected by optical and acoustic televiewers has allowed these instruments to determine a lot of the information that has traditionally been determined through the collection of bedrock cores. The collection of actual bedrock cores would allow the images and data produced by optical or acoustic televiewers to be confirmed, and may provide additional information related to bedrock competency and mineralogy that the televiewers cannot provide.

6.3.1 Coring Methods

There are two fundamental rock-coring methods: drill string coring and wireline coring.

6.3.1.1 Drill String Coring

Drill string coring is a procedure where the core sample is obtained from the bottom of the borehole. This sampling is accomplished by attaching tube-type coring equipment to the end of the drill string. The core sample is obtained while the coring device drills the borehole.

6.3.1.2 Wireline Coring

Wireline coring techniques utilize a cable to lower and/or raise the coring tools through an existing borehole. The coring tools used in wireline coring can be either tube-type tools or sidewall coring tools. Wireline coring is generally faster and less costly than drill string coring methods.

6.3.1.3 Sonic Drilling Coring

The sonic drilling method is a duel casing advancement technique employing an inner (primary) core barrel and related drilling casing, and an outer over-ride (secondary) cutter head and associated drill casing. The drill casing is advanced using a combination of vibration, rotation, and downward force. The inner drill casing is cored into the ground to a desired depth (5’ to 20’ run depending on casing length used and drill rig size). Once the inner drill casing has been advanced to the desired depth, the outer override casing is advanced down to a matching depth and the inner drill casing is removed. The over-ride casing provides borehole stability while the inner drill casing is removed. The core of drilled material (e.g., soil, boulder till, waste material, sedimentary bedrock, or weathered hard bedrock) is then extracted. The core can be vibrated out of the casing, pushed out of the casing using air or water under pressure, or removed from the casing intact through the use of a rigid inner liner. The cores generated by this method are typically larger than traditional coring methods as the sonic core size is just slightly smaller than the inner diameter of the inner casing. Common casing combination sizes are 3”-5”, 4”-6”, 6”-8”, so the cores generated would be slightly less than 3”, 4”, or

6" in diameter.

While more expensive than most other drilling techniques, the advantages of this method include: 1) In complex geological conditions the drilling rate may be significantly faster than other drilling techniques; 2) Advancement of the borehole usually generates a complete core of the material being drilled; 3) The core produced is generally larger than most produced from other coring devices; and 4) This drilling technique allows coring of the overburden to proceed directly into the underlying bedrock without stopping or changing drilling technique.

Water is sometimes added during the drilling process to 1) keep the drill bit cool, 2) minimize the amount of material getting caught between the inner casing and the override casing during advancement of the over-ride casing, and 3) help push the core out of the inner casing. Water added during the drilling process should be of a potable quality.

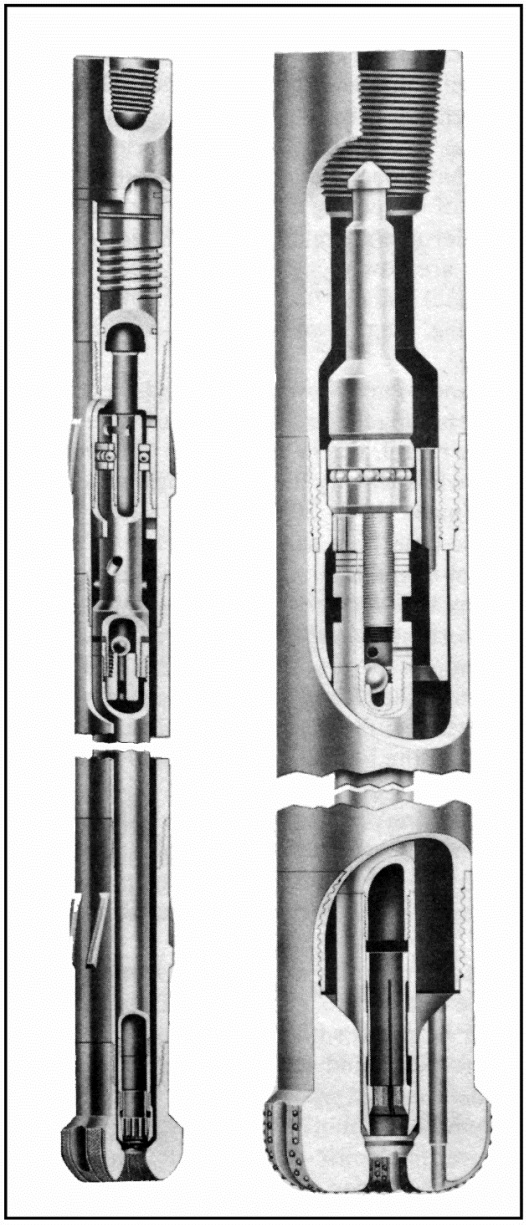


Figure 6.2 Double tube coring tool. Anderson, 1975, printed with permission.

6.3.2 Coring Tools

6.3.2.1 Tube-Type Coring Tools

Tube-type coring tools can be either a single, double, or triple -tube design (Lapham, et. al., 1997). Most rock coring operations associated with ground water remedial investigation work is completed using double-tube coring tools and drill string coring methods. Double-tube coring tools basically consist of a rotating outer sleeve with a circular diamond coring bit and a swivel- mounted stationary inner sleeve (i.e., core barrel). See Figure 6.2. Usually double-tube coring tools are constructed in 30-foot lengths.

Tube-type coring provides a continuous vertical section of the formation under study. During the coring procedure, the outer sleeve simultaneously drills the borehole and cuts the core sample. As the coring tool descends, the core sample is pushed into the stationary inner barrel. The core sample is held in place by a core retaining device (a.k.a. core lifter). When the inner sleeve is full, the drill string and coring tool are pulled from the borehole to permit core recovery. The core barrel can also be extracted from the cutting tool and borehole by means of wireline methods.

Descriptions of specifications for various types of tube-type tools can be found in the ASTM standard practice reference designation **D2113-14** *Standard Practice for Rock Core Drilling and Sampling of Rock for Site Exploration* on the ASTM.org website, "Practice for Diamond Core Drilling for Site Investigation." or in the American Association of State Highway and Transportation Officials (AASHTO) T 225.

Most conventional coring tools are fitted with a circular diamond core bit as shown in Figure 6.3. Diamond core bits consist of a diamond-impregnated, hardened matrix. The circular shape allows a

core sample to pass into the core barrel during the drilling operation. A detailed discussion of the various types of bits and their applications can be found in Acker, 1974.

The main disadvantage of tube coring is the high cost.

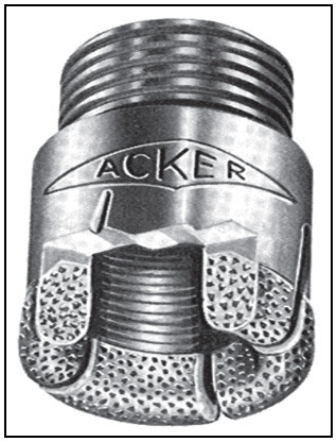


Figure 6.3 Impregnated diamond bit. Acker, 1974, printed with permission.

6.3.2.2 Sidewall Coring Tools

Sidewall coring tools obtain core "plugs" from the side of the existing borehole by means of either explosive charges detonated at predetermined depths or by use of a rotating core bit. Since these tools are generally run into the borehole on a wireline, the core sample plugs are extracted by removing the tool from the borehole with the cable.

Sidewall coring is faster and less expensive than conventional coring methods. In addition, sidewall core samples can be taken from predetermined zones of interest and over a large borehole interval. Sidewall methods are often employed to verify and correlate the results of downhole electric and nuclear logging procedures.

The explosive method of sidewall sample collection often causes compression and distortion of the material's structural integrity. Consequently, the accuracy of structural and permeability analyses is compromised.

Sidewall coring methods were developed for the petroleum industry and are not generally employed for use in ground water remedial investigations.

6.3.2.3 Oriented Coring Tools

Oriented core samples can be used to obtain strike and dip data for fractures, bedding, joints, formation contacts, and other planar features present in the bedrock. This type of information is important for use in the evaluation of contaminant fate and transport and the determination of additional well locations.

The orientation of the sample is established relative to magnetic north by means of a continuous scribe etched onto the core during the drilling process. A magnetic survey instrument that is located within the core barrel orients the scribe. Borehole inclination and directional orientation of the reference scribe on the core are also recorded on film by the survey tool.

The core analyst can later determine the orientation of the planar features by placing the core sample in a goniometer. The core sample can be physically oriented in the goniometer relative to its original position within the borehole. A sighting ring on the goniometer is then aligned so it appears as an extension of the planar feature to be measured. The strike and dip can then be determined by means of a graduated base ring and protractor mounted on the goniometer.

6.3.3 Coring Procedures

The following list contains general guidelines that should be addressed during the coring process (ASTM Standard **D5434-12 (or most recent update)** *Standard Guide for Field Logging of Subsurface Explorations of Soil and Rock*):

- The borehole shall be cased through the entire thickness of any overburden present. The casing shall also be firmly seated into the bedrock prior to the coring operation.
- The coring pressure of the drilling rig shall be adjusted to maximize core recovery.
- Coring shall not be conducted with worn or damaged bits and core lifters.
- Potable water should be used as a drilling fluid.

- To prevent possible damage to a core sample, a full core run should not be drilled if it suspected that part of a core from a previous run is still in the borehole. The next run shall be shortened by a factor equal to the length of any core still remaining downhole.
- Thread lubricants should be comprised of food grade and/or other environmentally friendly components to minimize contamination (i.e., vegetable shortening, environmentally safe thread grease etc.).

6.3.4 Rock Core Logging

A field log of each core should be completed and maintained by the project geologist. Table 6.10 lists and describes the information that NJDEP is recommending for entry into each core log. The necessary information should be recorded on an appropriate rock core log form.

6.3.5 Rock Core Storage

Rock cores should be placed into wooden boxes constructed with partitions designed to hold core samples. The cores should be stored in stratigraphic order and labeled in such a way that indicates the stratigraphically up direction.

Wooden blocks should be placed in the storage boxes between each core run sample. The blocks should be marked with the appropriate depths and run number. Each box should be labeled with the facility name and location, boring identification number, depth range, box number, and RQD.

6.3.6 Special Tests and Analyses of Rock Cores

The following analytical procedures can be applied to further examine rock core samples:

- Thin section analysis
- Observing stratigraphic direction or fossil indicators
- Chemical analysis
- Plotting fracture sets, joint sets and/or faults on stereographic projection or rose diagrams
- Radiometric age determinations
- Regional structural analysis
- Correlating facies changes
- Strain analysis

Table 6.10 Recommended Rock Coring Information	
Information Required	**Notes**
Names of contractor, driller, and project geologist	
Core identification number and location	
Date and time of core commencement and completion	
Depth and size of casing	
Description of equipment used	
Type of drilling fluid used	
Type and condition of bit	
Depth of start and finish of each core run	
Core diameter	
Time required to drill each foot of core	
Total core recovery with information as to possible location of core losses	
Details of delays and breakdowns	
Macroscopic description of core	This description should include, but not be limited to, a photographic record of each core sample.
Depth to the water table and any other distinct water-bearing zones	
Characteristics of structures and fractures present	Fracture information should include the frequency, spacing, size, continuity and relative orientation of the fractures within the core sample. Any open fractures and joints should be noted. The description should note whether or not the fractures are due to natural or mechanical breaks. Calculating the Rock Quality Designation (RQD) can approximate the structural integrity of the rock. The RQD is equal to the total length of all core pieces exceeding four inches in length as a result of natural breaks (r) divided by the total length of the coring run (l). This result is converted to a percentage. RQD = (r/l)x100 The log shall include descriptions of the contacts between different rock units.
Description of lithology	The description of the rock should include information on rock type, color, composition, degree of stratification, hardness, fracturing, and degree of weathering. Any changes in lithology shall be noted.
Description of stratigraphy	Characteristics such as clarity and thickness of bedding should be described. The angle of bedding and other planar features in a non-oriented core should be measured from the perpendicular to the core axis (e.g., horizontal fracture in core equals 0°).
Description of any evidence of contamination present in core	Any evidence of contamination should be noted including elevated air monitoring instrument readings, odors, visual observations, and the presence of NAPL, etc.

6.4 Direct Push Technology Considerations

Use of direct push technology to obtain soil samples in cored segments has gained wide acceptance. The relative ease to collect minimally disturbed soil samples at depth plus, the ability to visually determine geological data has made this system attractive. While various manufactures make and distribute their own soil sampling equipment and accessories, the same general principles still apply when collecting soil samples. Chief among them is following NJDEP required decontamination procedures. When using direct push technology, the decontamination procedure discussed in Chapter 5, Section 5.2., *Decontamination Procedures* should be followed.

One of the special applications of direct push technology relative to soil sampling is the ability to obtain vertical profile contaminant information while working within the same bore hole. This process only further stresses the need to eliminate all possible sources of extraneous or cross contamination. High pressure, hot water (100° C) cleaning is recommended to decontaminate direct push sampling equipment and maintain confidence that data are not influenced by unwanted variables. In addition, equipment should be maintained in good working order to ensure its performance. This means (but is not limited to) all rods used for boring advancement should have unworn O-rings (if applicable) at each connection and undamaged threads to ensure that each connection can be drawn tight. All downhole equipment should be decontaminated between each use.

The driller must have a license in good standing from the Bureau of Water Allocation, and copies of all permit approvals must be available at the drilling location pursuant to N.J.A.C.-7:9D. Extreme caution should be taken to ensure that communication between various water bearing zones within the same boring does not take place. Some shallow borings are allowed to be backfilled with cuttings from the boring. If the shallow boring encounters multiple water bearing zones, NJDEP recommends the boring be grouted. Where one portion of the shallow boring shows impact and the other portion of the borehole does not, NJDEP recommends that the impacted soils not be placed in the non-impacted portion of the borehole, especially if the non-impacted portion of the borehole is below the water table. In situations where impacted soils are detected, NJDEP recommends the non-impacted portions of the borehole be grouted.

Specific guidance on direct push technology for both soil and ground water sampling can be referenced through the USEPA document, *Expedited Site Assessment Tools for Underground Storage Tank Sites: A Guide for Regulators*, EPA 510-B-16-004. Available at: https://www.epa.gov/ust/expedited-site-assessment-tools-underground-storage-tank-sites-guide-regulators.

Released by the USEPA's Office of Underground Storage Tanks, this 60-page document contains "how to" discussion on soil and ground water sampling and the geotechnical tools and accessories available for direct push applications. The document can be viewed at: https://www.epa.gov/sites/production/files/2014-12/documents/wellstdy.pdf.

Considerable general guidance on direct push technology can be referenced through the following USEPA website: http://www.epa.gov/superfund/programs/dfa/dirtech.htm. Additional information on direct push technology can be obtained through ASTM D6282-14/D6282M-14, *Standard Guide for Direct Push Soil Sampling for Environmental Site Characterizations*, ASTM D6001-05 (2012) *Standard Guide for Direct-Push Groundwater Sampling for Environmental Site Characterization*, and Well Construction and Maintenance; Sealing of Abandoned Wells (N.J.A.C. 7:9D).

6.4.1 Sonic Drilling – Unconsolidated Material

Sonic drilling is increasingly being used to install overburden boreholes, and for the generation of soil cores from which soil samples will be collected. Sonic drilling uses a dual casing advancement technique where an inner drill casing captures a soil core as it is advanced into the subsurface. The core barrel is advanced using vibration, rotation, and downward force to collect continuous soil cores up to 20 feet in length. The bit at the end of the core barrel contains carbide teeth allowing the core barrel to be advanced through most overburden material, soft bedrock, and minor obstructions such as bricks and boulders.

Once the core barrel has been advanced to the desired depth, a secondary or over-ride casing is advanced down to the same depth as the inner core barrel. The over-ride casing keeps the borehole from collapsing while the inner core barrel is removed. Once the core barrel is removed from the borehole, the soil core can be extracted using vibration, pressurized air or water, or use of a rigid inner liner.

The use of multiple over-ride casings of increasing diameter allows the borehole to be telescoped down through multiple confining units. Continuous soil cores to over 400 feet have already been installed in New Jersey using this method.

The setup used in sonic drilling makes this drilling method amenable to collecting soil cores and installing angled boreholes. With only the bottom of the inner and outer core barrel exposed to the aquifer at any given time, determining the depth of the water table can be difficult.

When using this drilling method to produce soil cores that will be used to collect soil samples for VOC or SVOC analysis, two issues of concern should be addressed, heating of the soil core during drilling, and disturbance of the soil core during drilling, extraction, and handling.

While this drilling method has the capability of drilling through and providing samples of coarse gravels, boulders, and tight clays, these situations will result in slow drilling/advancement of the core barrel. The result is a hotter core barrel and a longer contact time between the core barrel and the encased soil core. The aforementioned conditions will increase the probability that the sonic method will raise the temperature of the soil core and cause VOC and SVOC loss. If heating of the soil core is a concern, the following mitigation procedures should be considered:

- Collect soil cores in shorter runs. While some sonic rigs have the capability of collecting 20 feet of soil core at a time, the process of collecting the longer core results in the core being in contact with the core barrel for a longer period of time and consequently absorbing more heat from the core barrel itself.
- Add potable quality water between the inner core barrel and the outer override casing. This water would reduce friction and adsorb heat between the inner core barrel and the outer override casing.
- Maximize the drilling advance rate. The faster the core barrel is advanced, the less contact time the soil core has with the core barrel. Drilling with a 3-inch diameter core barrel and a 5-inch diameter override casing, instead of the standard 4-inch core barrel and 6-inch override casing, may increase advance rates and reduce the potential for soil core heating. If a significant decrease in drilling advance rate is observed, stop drilling and remove what soil core has accumulated in the core barrel. Resume drilling through the resistant material (gravel, boulder, hard clay, etc.). When the resistant material has been penetrated and the drilling advance rate increases, stop drilling and remove what material has accumulated in the core barrel. Wash down the core barrel with cool potable quality water to cool the core barrel and associated casing, and resume drilling.
- Consider collecting a larger diameter core. Collecting a larger diameter soil core may help shield the central portion of the core from heat buildup. If heating of the core is an issue, VOC samples should be collected from the cooler, undisturbed central portions of the core.

When sampling for VOCs or SVOCs, assessment of the soil core for heat buildup should be performed. It is recommended that the soil core temperature be scanned with a portable infrared measuring device as soon as the core is extracted. The core temperatures should be recorded and included on the soil boring log. If the soil sample is collected from an interior portion of the core, a temperature measurement of the core interior near the sample location should be conducted and recorded just after the sample is collected. This temperature measurement should be included on the soil boring log and depicted as being affiliated with the respective soil sample.

Disturbance of the soil core is most likely to occur during removal of the soil core from the core barrel. The soil cores are usually vibrated out of the core barrel into plastic bags approximately 5 feet in length. As the plastic bags are a little larger than the soil core itself, fragmentation of the soil core may occur as the core is extruded into the bag or while the bagged core is being moved in an unsupported manner. Soil conditions that are prone to disturbance include wet or dry zones that contain little or no fines, and well graded sands that contain significant volumes of water.

When a soil sample may be collected from a soil core, soil core integrity should be a concern, and the following procedures should be implemented:

- Rigid inner liners are available for some core sizes and should be used to hold the core together during removal from the core barrel. If there is a possibility that a sample may be collected from a soil core, the use of a rigid inner liner to extract and transport the soil core is the recommended procedure.
- Measures should be taken to ensure that the soil core, from the time the inner drill casing is removed from the borehole, is rigidly supported through the use of some type of cradle or carrying device. The core should not be removed from its cradle until all sampling of the core has been completed.

Water is sometimes added during the drilling process to 1) keep the drill bit cool, 2) minimize the amount of material getting caught between the inner casing and the override casing during advancement of the over-ride casing, 3) reduce the potential for heaving sand to push up into the override casing during removal of the inner drill casing, and 4) help push the core out of the inner casing. Water added during the drilling process should be of a potable quality.

6.5 Sampling Containerized Material

Sampling containerized materials presents a unique obstacle to field personnel, whether the container involved is a fiber drum or vacuum truck. Container staging, identification and opening are all issues to be considered. Health and safety precautions associated with sampling containerized materials are generally more stringent. Quality assurance guidelines for waste samples, as opposed to environmental samples are unique and each site should be considered individually. When sampling waste materials, high levels of contaminants can be expected. Therefore, trip and field blanks may be inappropriate. However, if residual or low-level waste/chemicals are expected (e.g., sampling contaminated soils in drums or containers) trip and field blanks may be appropriate. Reference to Division of Solid & Hazardous Waste Rules. N.J.A.C. 7:26 Solid Waste Rule; 7:26A Recycling; 26G Hazardous Waste; and 26H Utility Regulations. Refer to OSHA for applicable, local, and site-specific safety protocols (https://www.osha.gov).

Be advised that when sampling various containers, multiple phases may be encountered. It is recommended that all phases be sampled according to the specific matrix guidelines.

6.5.1 Drums, Bags, Sacks, Fiberdrums and Similar Small Containers

Prior to the initiation of the sampling event, all containers should be inventoried. All available information concerning each container should be recorded in the field notes including the type of container, total capacity estimate, actual capacity (if container is open), markings, labels, color, origin, condition, etc. Photographs should be taken to provide a permanent record and can prove valuable in documenting the containers' condition.

Drums should be labeled correctly pursuant to RCRA and/or Department of Transportation (DOT) based on hazard class, as required by law. It is recommended that the container(s) be marked with a unique identification number for present and future reference. Permanent marking tools such as enamel spray paint or marker may be suitable for non-regulated, non-RCRA or non-hazardous wastes, as applicable.

Depending on the location and position of the containers, it may be necessary to upright and/or relocate them prior to sampling. ***Drums Containing Liquid Waste Can Be Under Pressure or Vacuum. A Bulging Drum Should Not Be Moved or Sampled Until the Pressure Can Be Safely Relieved.*** Containers that can be moved should be positioned so that the opening or bung is upright (if the integrity of the container will allow). Containers should not be stacked.

The procedure used to open a container will depend directly upon the container's condition. The sampling team leader should determine which drums will be opened using a remote opening device or penetrating apparatus. If such devices are used, an experienced operator must be used and specific procedures for assuring health and safety must be clearly defined. All containers should be opened with utmost care. For drums, the bung opening should be loosened slowly with a non-sparking bung wrench. If the bung is badly rusted or frozen, it may be necessary to use a non-sparking hydraulic penetrating device. During container opening operations organic vapor concentrations should be monitored with portable instrumentation. Results should be recorded in the field notes.

The integrity of the drums may dictate that overpacking is necessary prior to sampling, therefore overpack drums should be available.

6.5.1.1 Containerized Solids

The sampling of containerized solid materials (sludges, granular, powder) is generally accomplished through the use of one of the following samplers:

- Scoop or trowel
- Waste pile sampler
- Sampling trier
- Grain sampler

Once the container to be sampled is opened, insert the new or decontaminated sampling device into the center of the material to be sampled. Retrieve the sample and immediately transfer it into the sample bottle. Each container should be sampled discretely. Depending on the objective of the sampling event (e.g., characterization for disposal) compositing of samples in the laboratory may be permissible. Compositing on a weight/weight or volume/volume basis will be made prior to analysis.

6.5.1.2 Containerized Liquids

The sampling of containerized liquids is generally accomplished through the use of one of the following samplers:

- COLIWASA
- Open tube sampler (drum thief)
- Stratified sample thief (multiple liquid layer sampling)
- Liquid/sludge sampler
- Bailer

Once the container to be sampled is opened, insert the decontaminated sampling device into the center of the liquid contents to be sampled. Retrieve the sample and immediately transfer it into the sample bottle. It should be noted that dedicated laboratory decontaminated samplers offer the least potential for cross contamination. Each container should be sampled discretely. Depending on the objective of the sampling event (e.g., characterization for disposal) compositing of samples in the laboratory may be permissible. Compositing on a weight/weight or volume/volume basis will be determined prior to analysis. Please be sure to have appropriate sampling devices for possible layering within the containers.

6.5.2 Tanks, Vacuum Trucks, Process Vessels and Similar Large Containers

Sampling of tanks, vacuum trucks, process vessels, and large containers present unique health and safety considerations due to height and contents. Please refer to applicable OSHA, local, and site-specific safety protocols. Prior to the initiation of the sampling event, all containers should be inventoried. All available information concerning each container should be recorded in the field notes including type of container, total capacity estimate, actual capacity (if container is open), markings, labels, color, origin, condition, existence and condition of ladders and catwalks, etc. Photographs of the numbered vessels can prove useful in documenting the containers' condition and can provide a permanent record.

The procedure used to open a large containment vessel to provide access to its contents will vary with different containers. Most large tanks and vacuum trucks will have valves near the bottom of the tank and hatches near the top. It is most desirable to collect samples from the top of a tank for several reasons. The integrity of valves near the bottom of the tank cannot be assured. The valve may be immobile or may break or become jammed in the open position resulting in the uncontrolled release of the tank's contents. Secondly the contents of a large vessel may become stratified. Collecting a sample from the bottom will not permit the collection of a sample of each stratum. Instead, a cross-sectional sample of the tank's contents should be obtained from the top access.

In opening and sampling larger containment vessels precautions should be considered to assure personal health and safety.

Prior to opening the hatch, the sampler should check the tank for a pressure gauge. If necessary, the release valve should be opened slowly to bring the tank to atmospheric pressure. If the tank pressure is too great or venting releases gas or vapor, discontinue venting immediately. Measure releases to the atmosphere with portable field instrumentation and record in field notes.

If no release valve exists, slowly loosen hatch cover bolts to relieve pressure in the tank. Again, stop if pressure is too great or if a release occurs. Do not remove hatch cover bolts until the tank is at atmospheric pressure.

If a discharge to ambient air occurs, sampling may need to be postponed until the proper equipment is available to control the release.

Once the tank has been stabilized, sample collection may begin using one of the previously recommended samplers for containerized liquids and solids and employing the proper safety precautions and backup personnel. If the contents of the tank have stratified, each stratum should be sampled discretely. At a minimum, a top, middle, and bottom sample should be collected. If the container has separate compartments, each should be sampled separately at varying depths, as required. Depending on the objective of the sampling event (e.g., characterization for disposal) compositing of samples in the laboratory may be permissible. Compositing on a weight/weight or volume/volume basis will be determined prior to analysis. Unless compositing in the field, immediately transfer the sample into the sample bottle

6.5.3 Transformers

Sampling of transformers present unique health and safety considerations. Please refer to applicable OSHA, local, and owner/site-specific safety protocols. Due to the different types of transformer configurations, appropriate sampling equipment and best access to collect a sample should be evaluated prior to field activities, if possible. As required with sampling of hazardous and non-hazardous materials which chemical and physical concerns, appropriate PPE should be worn during field activities.

Collection of dielectric oils and/or fluids from transformers may be necessary as part of an investigation, spill response, or cleanup activity. If transformer sampling is necessary, special considerations regarding safe access to the transformer should be evaluated. The sampler must confirm that the transformer is de-energized, grounded, and any possible stored energy is dissipated prior to sampling activities. In addition, transformer fluids are designed to work under high temperatures. Coordination with the owner and/or

utility of the transformer should be conducted to discuss the electrical and thermal concerns as well as appropriate sampling methodology and safe access to the transformer oil/fluid prior to sample collection. If electrical and thermal safety cannot be confirmed, the sampler should wait for the local utility or qualified electrician to provide safe access to collect a transformer oil/fluid sample.

Transformers vary in size, construction, and configuration. Transformers may contain different dielectric oils or fluid types depending on manufacturer, age, and type of transformer. Depending upon the age of the transformer, PCB-containing fluids may be encountered. An evaluation of the fluid type should be performed to confirm if there may be PCB-containing fluids or non-PCB containing fluids such as mineral oil or other dielectric type fluid. The sampler should evaluate the potential hazards, handling, and disposal requirements associated with each type of fluid.

The peculiarities that are associated with transformers warrant that these containers be considered separate from drums and tanks. Because transformers are often located in secured, out-of-the-way locations, access may present a problem. For all transformers contact the appropriate owner/utility for access.

The toxic nature and degree of hazard posed by PCBs and thermal concerns from transformer oils which may be present in a transformer dictate that a high level of caution be used. Sampling and support personnel should wear appropriate protection. Spill prevention and control must be planned; plastic sheeting and sorbent pads should be employed. And most importantly, the transformer must be certified as "off-line" and de-energized by the owner/utility, an electrician, or other responsible person.

Once the power source to the transformer is cut and spill control measures (plastic sheeting on ground and/or floor surface of lift) are in place, the cover or other appropriate access port of the transformer can be removed with hand tools. The sampling device should be drummed along with protective clothing, sheeting, and absorbent pads, and disposed of at a predetermined approved location.

Care should be taken if a sample is collected at the bottom of a transformer. The integrity of these valves cannot be assured, and they may be rusty, break or become jammed in the open position resulting in the uncontrolled release of the transformer's contents. It is also likely that transformer contents may have stratified. Since PCBs are heavier than other insulating oils this stratification may prevent the collection of representative samples. As such, samples obtained from near the bottom of the transformer might reveal higher PCB concentrations than towards the top and/or other layers.

6.6 Waste and Beneficial Reuse Pile Sampling

This recommended protocol outlines general procedures for collecting samples from beneficial reuse materials, waste piles and other waste materials, the equipment necessary for sampling, and the adequate representation of the material. Because of the variability involved in pile sampling, exact procedures cannot be outlined for every sampling situation. For waste that is outside the typical waste stream of soil that is normal for the NJDEP, a technical consult may be necessary. Also refer to the EPA guidance on collecting a representative sample available at: https://www.epa.gov/sites/production/files/2016-03/documents/superfund-samp.pdf.

6.6.1 Considerations for the Sampling Plan

The physical and chemical make-up of the pile and the purpose of sampling should be considered in planning for the sampling event (i.e., end use for material). Information about these items is presented below. Also refer to the discussion on composite sampling in Section 6.1.2.2. of this chapter.

6.6.1.1 Shape and Size

Shape and size of material and piles may vary greatly in areal extent and height. The pile may be cone shaped, long and rectangular, square, oval or irregularly shaped. State and federal regulations

often require a specified number of samples per volume of waste; therefore, size and shape must be used to calculate volume and to plan for the correct number of samples. Shape must also be considered when planning physical access to the sampling point and the type of equipment necessary to successfully collect the sample at that location.

6.6.1.2 Characteristics of the Material

6.6.1.2.1 Type of Material

Material to be sampled may be homogeneous or heterogeneous. Homogeneous material resulting from known situations (e.g., process wastes) may not require an extensive sampling protocol if the material remains homogeneous. Heterogeneous and unknown wastes require more extensive sampling and analysis to ensure the different components of the sample are being represented.

6.6.1.2.2 Chemical Stability

Materials may be affected by their inherent chemical stability. Exposure to the elements and leaching over time may cause older material to differ in chemical composition from newly deposited material in the same pile. Heterogeneous material may undergo chemical reactions resulting in pockets or layers of different compounds.

6.6.1.2.3 Particle Size

The particle size of the material affects sampling by preventing certain volumes from being analyzed. Large chunks of material, which are left behind and not sampled, may result in positive or negative bias of contaminants in samples. If it is necessary to sample larger material, provisions must be made in the planning stage to render the larger material capable of producing a sample. Additional information on handling particle size issues is available at: https://www.epa.gov/sites/production/files/2016-03/documents/superfund-samp.pdf. Also refer to the example found at https://crustal.usgs.gov/projects/minewaste/pdfs/kathy.pdf.

6.6.1.2.4 Compactness/Structure of Material

The compactness/structure of the material may vary across the diameter of the pile. The material may range from monolithic to free flowing, and of a consistency from muddy to compact and dry. This should be considered when planning sampling procedures.

6.6.1.3 Purpose of Sampling

During the investigation of a site, areas of waste materials or waste piles are often encountered. For complete evaluation of a site, these areas must be characterized. Often information about the waste is available, thus providing insight to its chemical composition. If sufficient information is known about the process generating the waste and it is homogeneous, sampling may not be required for classification. This can be performed at or about the same time as the first round of sampling for the rest of the site. From the analytical data generated, two scenarios are commonly encountered: contaminant concentrations below specific action levels which usually allows the material to remain on site after delineation; or contaminant concentrations above action levels requiring additional evaluation of the waste. For additional information see "*Fill Material Guidance for SRP Sites*" available at: http://www.nj.gov/dep/srp/guidance/#fill_srp.

When additional evaluation is required, the next step is to determine whether a material is a hazardous waste in accordance with New Jersey Administrative Code (N.J.A.C.) 7:26G et. seq. This is performed under the direction of NJDEP and the Division of Solid and Hazardous Waste/Bureau of Resource Recovery and Technical Programs, which promulgates the requirements necessary to render a waste classification. The main objective at this point is to quantify the contaminants of concern, to

look for the presence of wastes listed in N.J.A.C. 7:26G et. seq. and look for any other characteristics that would give reason to consider the waste hazardous.

For additional information on hazardous waste sampling see "*EPA, Waste Analysis at Facilities that Generate, Treat, Store, and Dispose of Hazardous Waste*" available at: https://www.epa.gov/sites/production/files/2015-04/documents/tsdf-wap-guide-final.pdf.

Additional information on RCRA is available at: https://www.epa.gov/sites/production/files/2015-10/documents/rwsdtg_0.pdf.

For sampling procedures of hazardous waste that is going for disposal and needs to be comply with Land Disposal Restrictions see "*EPA's Guidance on Demonstrating Compliance with the Land Disposal Restrictions (LDR) Alternative Soil Treatment Standard*" available at: https://www.epa.gov/sites/production/files/2016-01/documents/soil_f4.pdf.

Additional information on NJDEP Solid Waste Regulations is available at: https://www.state.nj.us/dep/dshw/resource/rules.htm.

6.6.2 Sampling Procedures

As with soil sampling, pile samples can be collected at the surface or at depth, and different equipment is required in each instance. Surface samples can be collected most efficiently with a trowel or scoop. For samples at depth, a decontaminated bucket auger may be required to advance the hole, then another decontaminated auger used for sample collection. For a sample core, pile samplers or grain samplers may be used.

Pile sampling is generally accomplished using one of the following samplers:

- scoop or trowel
- waste pile sampler
- sampling trier
- soil auger
- grain sampler
- split spoon sampler
- soil coring device
- mixing bowl
- sieve

6.6.2.1 Surficial Sample Collection

At the desired location, clear surface debris. Collect the adequate volume of material from an appropriate surficial zone (i.e., 0-2 feet) using a trowel, scoop, or auger. For a core sample from the surface use the waste pile sampler, trier, or other Chapter 5 listed corer/sampler. Transfer the sample directly into the sample container, or use a decontaminated trowel or spatula for transfer if necessary. A wide mouth bottle is preferable for containing the sample, as it requires less disturbance of the sample transferred into the bottle.

6.6.2.2 At Depth

At the sampling location, advance the hole to the desired sampling depth with a decontaminated bucket auger or power auger. Use another decontaminated bucket auger or corer/sampler to collect the sample, and, if necessary, a decontaminated spatula to transfer the sample into the sample bottle. For samples greater than three feet, a hand operated hammer and extension rod or direct-push drill rig may be utilized with a split spoon or core barrel for deeper sample collection.

6.6.3 Required Analytes and Frequency

6.6.3.1 Waste Classification

Requirements to render a waste classification pursuant to N.J.A.C.7:26G et. seq. are promulgated by the Division of Solid and Hazardous Waste. The applicable requirements, in terms of frequency of sample, analysis and quality assurance are specified in the *Guidance Document for Waste Classification*. This document is available from the Bureau of Resource Recovery and Technical Programs within the above noted Division and is also available at: http://www.nj.gov/dep/dshw/resource/hwm009.htm.

The requirements consist of a sampling plan and an analytical test of the material. The sampling plan specifies the number of samples to be taken per volume of waste. Required analyses will be dictated by a certified disposal facility. Further details on the testing requirements and for the development of a site-specific sampling plan can be obtained from the Bureau of Resource Recovery and Technical Programs.

6.6.3.2 Quality Assurance

For the purpose of analytical quality assurance, the NJ Laboratory Certification Program must certify the laboratory performing the requested analysis for that specific contaminant or parameter. The analytical results and the corresponding reporting limits should be submitted on the stationery of the laboratory performing the analysis with the laboratory's certification ID number. Chain of custody and quality control procedures as specified by EPA SW-846 5th (or most recently approved) Edition should be submitted along with analytical results. See Chapter 2 for additional information.

6.6.3.3 Characterization

When the material that is being evaluated to determine if it can be left on site, then the considerations previously mentioned in this section should be used to plan a sampling strategy. The characterization may require one or several phases of sampling, but the first phase should be positively biased or statistically random. For additional information see "*Fill Material Guidance for SRP Sites*" available at: http://www.nj.gov/dep/srp/guidance/#fill_srp.

Once contaminants of concern have been identified and quantified, additional sampling and analysis may be necessary. Due to the site-specific aspects of waste pile sampling and the various reasons for which it is performed, the number of required samples and analytes should be determined by the personnel accumulating the data and directing the investigation from the NJDEP Site Remediation Program.

If the party desires to obtain a Certificate of Authority to Operate (CAO) for a beneficial use project, contact the Bureau of Resource Recovery and Technical Programs at 609-984-6985. The CAOs are issued pursuant to N.J.A.C. 7:26-1.7(g) for the beneficial use of materials which otherwise must be disposed of as waste. Guidance on the CAO/BUD process is available on the DSHW web site at http://www.nj.gov/dep/dshw/rrtp/bud.htm.

6.7 Surficial Sampling

This recommended protocol outlines procedures and equipment for the collection of representative wipe, chip, and sweep samples.

Surficial sampling is used to assess the existence and/or extent of contamination on various surfaces rather than in a soil, water or air matrix. For example, collecting wipe samples of the process vessels and interiors of ventilation ducts may assess the interior of a building. Though all three types of samples are for similar

purposes, the three types of sampling are performed in very different ways because they are intended to assess different surface areas.

Please note that there may be other required parameters that may need to be sampled to characterize the building interior materials (i.e., caulking, soil, sand, air) for demolition. It is recommended that you contact the analytical laboratory to discuss the necessary requirements for each sample type. Please note that building demolition is often permitted and regulated through local and state requirements and there may be additional sampling needs.

6.7.1 Wipe Samples

This method of monitoring surficial contamination is intended for non-volatile species of analytes (e.g., PCB, TCDD, TCDF, and Metals) on non-porous surfaces (e.g., metal, and glass). Sample points should be carefully chosen and should be based on site history, manufacturing processes, personnel practices, obvious contamination, migration pathways and available surface area. Suggested sampling points include process vessels, ventilation ducts and fans, exposed beams, windowpanes, etc. The area wiped should be large enough to provide a sufficient amount of sample for analysis (smaller sample volumes cause higher detection limits). See ASTM standards for specific sampling procedures at ASTM.org.

For additional information on the Standard Operating Procedures (SOP) for collecting wipe samples see the following links:

The SOP for wipe samples from the Scientific Engineering Response and Analytical Services https://clu-in.org/download/ert/2011-R00.pdf.

Policy and Guidance for PCBs can be found at https://www.epa.gov/pcbs/policy-and-guidance-polychlorinated-biphenyl-pcbs.

6.7.2 Chip Samples

This method of monitoring surficial contamination is intended for non-volatile species of analytes (e.g., PCB, TCDD, TCDF, and Metals) on porous surfaces (e.g., concrete, caulk, brick, wood). Sample points should be carefully chosen and should be based on site history, manufacturing processes, personnel practices, obvious contamination, and available surface area. Suggested sampling points include floors near process vessels and storage tanks, loading dock areas, etc. The sampling area should be large enough to provide a sufficient amount of sample for analysis (smaller sample volumes cause higher detection limits). To facilitate the calculations once the analytical data are received, the area sampled should be measured. See ASTM standards for specific sampling procedures at ASTM.org.

For additional information on the SOP for collecting chip samples see the following links:

The SOP for wipe samples from the Scientific Engineering Response and Analytical Services https://clu-in.org/download/ert/2011-R00.pdf.

Guidance for Characterization of Concrete and Clean Material Certification for Recycling see: https://www.nj.gov/dep/dshw/resource/guidance/concrete%20demo%201210.pdf.

Paint chip sample collection see: https://www.epa.gov/sites/production/files/documents/paintchip.pdf.

SOP for sampling porous surfaces for PCBs see: https://www3.epa.gov/region9/pcbs/disposal/cleanharbors/pdfs/application/2011-appendix-k-epa-guidance.pdf.

6.7.3 Sweep Samples

This method of monitoring surficial contamination is intended for non-volatile species of analytes (e.g., PCB, TCDD, TCDF, and Metals) in residue found in porous (e.g., asphalt) or non-porous (e.g., metal)

surfaces. Sweep sampling allows collection of dust/residue samples that may help in the assessment of contaminant determination and delineation. Sample points should be carefully chosen and should be based on site history, manufacturing processes, personnel practices, obvious contamination, migration pathways and available surface area.

Suggested sampling points include ventilation systems where dust can collect, floor surfaces near process vessels and storage tanks, or street gutters where contaminated sediments may have migrated and accumulated. The area sampled should be large enough to provide a sufficient amount of sample for analysis. Keep in mind that on linoleum floors a solvent cannot be used or too much residue may exist for a sweep sample to be easily collected. See ASTM standards for specific sampling procedures at ASTM.org.

For additional information on the SOP for collecting sweep samples see the following links:

The SOP for wipe samples from the Scientific Engineering Response and Analytical Services https://clu-in.org/download/ert/2011-R00.pdf.

6.7.4 Tape Lift Sampling

This method of sampling is typically used when testing for mold, spores, fungi or fungal structures. The sampling is performed using a laboratory provided sampling tape to lift mold, spores, or fungal material from various surfaces that are selected for sampling. The test method is qualitative for the reported fungal material loading. See ASTM standards for specific sampling of fungal structures on tape lift samples.

Care should be taken to avoid touching the sticky side of the tape. The sampler should wear gloves and apply the central portion of the tape to the sample location with pressure applied to the back of the tape for increased contact with the surface. The tape should then slowly be removed as to not damage the sampling surface. Depending upon the sampling tape provided by the laboratory, care should be taken to place the sticky side of the tape back to the cover or original package for proper sealing and shipment. Make sure there are no creases or folds in the tape prior to enclosing in the packaging.

6.8 Surface Water and Sediment Sampling

This section outlines the recommended protocols and equipment options for the collection of representative aqueous and non-aqueous samples from standing lakes, ponds and lagoons, and flowing streams, rivers, estuaries, marine waters, channels, tidal ditches, sewers, landfill leachate seeps and ground water seeps. For additional information on surface water and sediment sampling see the Ecological Evaluation Technical Guidance available at: http://www.nj.gov/dep/srp/guidance/#eco_eval. While working in and around water, certain hazards exist. It is recommended that OSHA guidelines be followed.

6.8.1 General Considerations and Requirements for NJDEP Programs

The collection of samples from these sources presents a unique challenge. Often sampling can be quite easy and routine, e.g., collecting a surface water or sediment sample from an easily accessible, very shallow, very slow-moving stream. At other times more dynamic site-specific conditions may dictate that special equipment or more formalized sampling plans be in place prior to sample collection. Personal safety associated with surface water and sediment sample collection will always be the first priority when selecting the appropriate equipment and related procedures to use. Study objectives and logistics, while important, play a secondary role.

6.8.1.1 Health and Safety Considerations

Refer to Chapter 1, *The Sampling Plan*, and the site-specific or program-specific health and safety plan: this plan must be accessible to all personnel during the sampling event which must conform to

OSHA guidelines (https://www.osha.gov/about.html). Chapter 4, *Site Entry Activities,* offers additional considerations, especially when sampling at sites associated with the Site Remediation and Waste Management Program.

6.8.1.2 Physical Characteristics and Water Quality Measurements for Monitoring

Generally, a sampling plan includes measurements of the water body's physical characteristics (e.g., size, depth, and flow), and water quality. These measurements must be properly documented as per Chapter 10, *Documentation*. Non-aqueous data should be accompanied by laboratory-analyzed total organic carbon (TOC) and particle grain size for each sample. Prior to sample collection, a QAPP is developed which includes, but is not limited to project objectives, sampling design, analytical and field methods.

6.8.1.3 Sample Number and Location

Refer to Chapter 1, *The Sampling Plan*, to assist in the development of a site-specific or program specific field sampling and quality assurance plan that addresses the appropriate State regulation(s). The sampling network design must be adequate to achieve the project and data quality objectives for the sampling event.

6.8.1.4 Sampling Sequence

Sampling should proceed from downstream locations to upstream locations so that disturbance related to sampling does not affect sample quality. If surface water and sediment samples will be collected during the same sampling event, they must be co-located, and the aqueous samples must be collected first. If samples are being collected from a landfill seep, collect the sediment sample first and then create a small excavation to collect surface leachate. This will allow for the partial submersion of leachate sample containers. The objective of collecting a leachate sample is typically for contaminant identification purposes, not necessarily to categorize ambient surface water condition. It is important to understand the objective prior to sample collection.

6.8.1.5 Surface Water Flow Conditions

Personnel may encounter situations where rate of flow affects their ability to collect a sample. For fast flowing rivers and streams, it may be nearly impossible to collect a mid-channel sample at a specific point. For low flowing shallow streams, the sampler should attempt to find a location where flow is naturally obstructed, and a pool created which affords some depth from which to better submerge sample bottles. In no way should the environmental setting be altered with the intent to construct an artificial condition which aids in capturing a naturally occurring surface water sample unlike the leachate sample above.

6.8.1.6 Tidal Influences

Salinity and tides can be strong factors in the distribution of contaminants. The delineation of the point at which these effects are most pronounced, and the distribution of the highly contaminated sediments, might be confounded by these factors. For example, as contaminated water moves downstream, an abrupt increase in salinity can cause a sudden change in contaminant solubility. When less soluble, a contaminant may precipitate and appear in the sediment at substantially higher concentrations than the previous (i.e., upstream) location. These factors should be taken into consideration and assessed when making decisions regarding the selection of sample locations and relation of contaminants to the site. Tidal influences should be considered and their potential effect on sample collection should be detailed in the sampling plan. At a minimum, the stage of the tide at the time of sample collection should be recorded. For information on sampling varied tidal stages refer to https://www.nj.gov/dep/srp/guidance/#eco_eval.

6.8.1.7 Equipment Selection

The factors that will contribute to the selection of the proper sampler include the physical configuration of the location being sampled and the location of the personnel performing sampling. The factors that contribute to the selection of an ambient water sampler include the width, depth, flow and bed characteristics of the impoundment or stream to be sampled, and whether the sample will be collected from the shore, dock, bridge, or a vessel. For selection of appropriate sampling apparatus, refer to Chapter 5, *Sampling Equipment.*

6.8.1.8 Considerations for Wastewater Point Source Sampling

The first step in preparing for compliance sampling is to verify that the sample location is appropriate. Every surface water discharge permit requiring compliance sampling must specify the sampling location for compliance sampling. This sampling location must be representative of the actual discharge from the facility. If the sample location specified in the permit is not adequate to collect a representative sample, the permitting authority should be advised promptly, and an alternative location should be recommended. In this case, as well as in sampling to characterize a waste stream for purposes of obtaining a permit, the determination should be based on the investigator or applicant's knowledge of the facility itself, the on-site processes, and the outfalls.

For permit application and compliance monitoring, in which some of the sampling equipment may remain in place between sample events, care is needed to remove accumulated sediment or floating material, which may have accumulated after any previous sample.

Sample taps and lines should be flushed with a small volume of the wastewater to be sampled, prior to beginning actual sample collection.

When possible, sumps and monitoring manholes at which sampling is required should be suctioned to remove any accumulated silt or floating layer, then allowed to refill before sampling begins. It is essential to prevent accidental intake of such material into a sampler when intending to assess qualities of bulk liquids or waste streams.

If the samples are being taken to determine compliance, all associated flows should be measured. Personnel should always collect samples from a sampling location or locations that reflect the total regulated effluent flow (i.e., is representative). Convenience and accessibility are important considerations, but are secondary to the representativeness of the sample. The most representative samples will be drawn from a wastewater depth where the flow is turbulent and well mixed and the chance of solids settling is minimal. Depending on the sampling location, ideally, the depth of sample collection should be 40 to 60 percent of the waste stream's depth. To avoid contamination, personnel should take care to collect samples from the center of the flow. Wide channels or paths of flow may require dye testing to determine the most representative-sampling site. If dye testing is inconclusive, multiple samples may need to be collected by cross sectional sampling. Stagnant areas should be avoided as well, particularly if the wastewater contains immiscible liquids or suspended solids. If it is absolutely necessary to sample from a sump or other standing liquid, take care that the sample is representative of the material you intend to sample. This may entail sealing the sample container while it is below any floating layer, or sampling floating and lower layers separately for later combination in representative proportions at the laboratory. It may also be possible to pump down or drain standing liquid, then allow the pool or sump to refill before sampling.

Samples can be collected either manually (grab or composite) or with automatic samplers. See Section 6.1.2.2 for additional information on grab vs composite samples. The following general guidelines apply when taking samples:

- If you have a permit, samples should be taken at the locations specified in the permit. If the sample locations are not specified in the permit, they should be selected by the investigator to yield a representative sample.

- To obtain a representative sample, sampling must be conducted where wastewater is adequately mixed. Ideally, a sample should be taken in the center of the flow where the velocity is highest and there is little possibility of solids settling. The investigator should avoid skimming the surface of the waste stream or dragging the channel bottom. Mixing of the flow is particularly important for ensuring uniformity. Sampling personnel should be cautious when collecting samples near a weir because solids tend to collect upstream and floating oil and grease accumulate downstream.
- List the sampling method (grab or composite) required by the permit (or the method which the investigator deems most appropriate if the method has not yet been specified in a permit). Note that is some cases, sampling methods and locations may be specified or defined by regulation and should change only with the explicit approval of the permitting authority.
- Samples of certain pollutant parameters may not be taken by automatic samplers, but must be taken by manual grab samples. These parameters include dissolved oxygen, residual chlorine, pH, temperature, oil and grease, fecal coliforms, purgeable organics, and sulfides.
- To maintain sample integrity, avoid disturbing stagnant liquids, or flowing liquids upstream of the sample point. When sampling in multiple locations, begin with the downstream sample point.
- The opening of the sampling device or container should face upstream.
- Avoid collecting large nonhomogeneous particles and objects.
- Do not rinse the sample container with the effluent when collecting oil and grease and microbiological samples, but fill the container directly to within 2.5 to 5 cm from the top.
- Do no rinse the sample container when pre-preserved.
- Fill the container completely if the sample is to be analyzed for purgeable organics, dissolved oxygen, oxygen demand, ammonia, hydrogen sulfide, free chlorine, pH, hardness, sulfite, ammonium, ferrous iron, acidity, or alkalinity.
- When taking a grab sample, the entire mouth of the container should be submerged below the surface of the waste stream. When a pre-preserved sample bottle is being used, it should not be submerged below the surface of the waste stream as the preservative will be lost. A wide mouth bottle with an opening of at least two inches is recommended for this type of sampling. When using a composite sampler, the sample line should be kept as short as possible and sharp bends, kinks, and twists in the line (where solids can settle) should be avoided. The sample line should be placed so that changes in flow will not affect sample collection.
- The volume of the samples collected depends on the type and number of analyses needed. The volume will be determined by the parameters to be measured and the method requirements guiding the analytical laboratory. Sample volume must be sufficient for all analyses, including QA/QC and any repeat analyses used for verification. Laboratory personnel should be contacted for the sample volume required to complete all analyses, since the laboratory is in the best position to estimate the necessary volume of sample.

6.8.2 Surface Water and Sediment Sampling Procedure Selection

The objectives of the surface water and sediment monitoring, which determine sampling procedures, are generally to:

- bracket a stream segment traversing a particular geomorphologic zone or land use area;
- bracket known or potential point and nonpoint sources of pollution;
- evaluate streams or stream segments sensitive to water quality changes or consistently exceeding a water quality standard;
- define the rates of nutrient deposition at lake or reservoir inlets and outlets;

- sample at the confluence of a tributary to the mainstream river;
- sample in segments of the river determined to be representative of larger segments;
- sample to assess designated use impairment, overall water quality, status, and trends; and
- sample for stressor identification and source track-down.

6.8.2.1 Aqueous Samples

6.8.2.1.1 Stream/Flowing Water

For a stream, channel, river, etc., refer to the "*Characterization of Contaminated Ground Water Discharge to contaminated Ground Water Discharge to Surface Water Guidance*", available at: https://www.nj.gov/dep/srp/guidance/#gw_discharge_sw, and the "*Ecological Evaluation Technical Guidance*" available at: https://www.nj.gov/dep/srp/guidance/#eco_eval for sample depth. Once the sample is obtained, transfer it directly into the sample bottle. Decontaminate or dispose of the sampling device before taking the next sample. If there is potential for the water body to be stratified, a sample at each stratum should be collected. One of the depth samplers listed will allow collection of discrete representative liquid samples at various depths. Proper use of the sampling device chosen includes slow lowering and retrieval of the sample, immediate transfer of the liquid into the sampling container, and logbook notation of the depth at which the sample was collected.

6.8.2.1.2 Composite Grab Sampling

When regularly scheduled sampling from a wastewater tank, pipe or very narrow channel is required, an automatic composite sampler is generally preferred, and flow-weighted samples are usually preferred. The remainder of this section is applicable to manual sampling or sampling from wider streams.

The characterization of a water column generally requires the representation of a cross section of a water body. This characterization is most often achieved with a composite sample procedure.

Water samples can be collected by either wading in the stream using a hand-held sample container or by lowering a depth-integrating sampler (a mechanism designed for holding and submerging the bottle such as a weighted bottle sampler) into the stream from the bridge. When wading, position the sample container upstream relative to stream flow and the wader. When using a depth-integrating sampler the sample should be collected on the upstream side of the bridge, unless stream or site conditions preclude sampling from the upstream side. These methods will minimize the possibility of sample contamination.

The collection of cross section water quality samples should be accomplished using the Equal Width Increment (EWI) sampling method, depending on stream velocity, and a churn splitter to obtain cross sectional composite samples. Refer to USGS' *Techniques for Water Resources Investigations*, Book 9, Chapter A4 at: http://pubs.er.usgs.gov/publication/twri09 or the "*Ecological Evaluation Technical Guidance*" available at: https://www.nj.gov/dep/srp/guidance/#eco_eval as applicable.

6.8.2.1.3 Grab Sampling

This alternative to composite sampling is used when:

1) natural stream conditions (i.e., uniform mixing, high velocity) make compositing unnecessary;
2) requested parameters require special handling or;
3) project specific samples are desired.

Pre-rinse the sample container with water from the site (if not for oil, grease, microbiological or

pre-preserved samples). Position the appropriate sample container upstream below the surface and allow the container to fill as required. The grab sample may also be taken, as a dip or surface sample when the stream velocity is too high for sampler penetration to any significant depth, when there is large floating and submerged debris, or when the stream is very shallow.

6.8.2.1.4 Depth Sampling

Depth sampling is used to obtain a water sample from a specific depth in the liquid column. A Kemmerer sampler or similar device is lowered to the appropriate depth and a weighted messenger is sent down the suspension line to trigger the closing mechanism. The sample may be composited with other depth samples or placed directly into the sample containers pre-rinsed with water from the same point in the water column. A depth sample may also be taken in shallow waters by holding a sample container with the top still on below the surface at the desired depth. Remove the top and allow the container to fill to the required volume then replace the top and remove the container from the liquid.

6.8.2.1.5 Lake/Standing Water Sampling

The sampling of lakes/other standing water is performed with methods similar to those of stream sampling. Lake surface water samples should be taken at a depth of one meter; for shallower standing water bodies, collect the sample from just below the surface or at mid-depth. If stratified samples are to be collected, per projection specific design, temperature recordings at varied depths should be measured. If temperature measurements indicate a stratification of the lake, point (discrete) samples shall be taken in the observed layers using a Kemmerer sampler. These samples may be composited or analyzed individually. A PVC sampler may be used to lower a bottle through a vertical or several verticals, which may then be composited depending on the purpose of the sampling program. Care should be taken when sampling from a boat that water is not disturbed by the wake of the boat.

6.8.2.1.6 Estuarine and Marine Water Sampling

The sampling of estuaries and marine waters is performed with the methods used in the sampling of streams and lakes. Stratification in estuaries is observed with the recording of specific conductivity/salinity along a vertical to the estuary bed. Sampling schedules must consider tidal stages and currents. Sampling from a boat should be performed as far from the stern as possible to minimize contact with engine fluids and only after the turbulence from the wake has subsided. The site should be approached from downstream.

6.8.2.1.7 Bacteriology

Bacteriology samples are to be collected directly into the special bacteriological container. Sample collection devices (i.e., composite samplers, sewage samplers, etc.) are not to be used for bacteriological sampling unless otherwise stated. The following methods are to be employed:

When sampling a stream, lake, bay or wastewater discharge, a grab sample is obtained in the following manner:

Take a bacteriological sample container and remove the covering and closure (protect from contamination). Grasp the container at the base with one hand and plunge the container (opening down) into the water to avoid introducing surface scum. *Do Not Rinse the Container*. Position the mouth of the container into the current away from the hand of the collector and away from the sampling platform or boat. The sampling depth should be 15 to 30 cm (6 to 12 inches) below the water surface. If the water body is static, an artificial current can be created by moving the container horizontally in the direction it is pointed and away from the sampler. Tip the container slightly upward to allow air to exit and the container to fill. After removal of the container from the

water, pour out a small portion of the sample to allow an air space of 2 to 3 cm (1 inch) above the sample for proper mixing of the sample before analysis. Tightly close and label the container.

When collecting a sample at a depth greater than an arm's reach, use a Kemmerer or weighted container sampler. The devices are lowered into the water in the open position, and a water sample is collected in the device. A drop messenger closes the Kemmerer sampler. The Kemmerer sampler should not be used to collect bacteriological samples without obtaining data that supports its use without sterilization.

Sample collection frequency for bacteriological samples should be appropriate for the project objectives.

6.8.2.1.8 Trace Element Sampling

Sampling for trace elements requires a more rigorous sampling procedure recommended by USEPA (see USEPA Method 1669: *Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels,* EPA 821-R-96-011, July 1996).

6.8.2.2 Non-Aqueous Samples

6.8.2.2.1 Sediments

Sediment (a.k.a. "bottom material") is a heterogeneous media and therefore care must be taken when designing an adequate sampling plan to ensure collection of representative samples. There are numerous factors such as particle size, organic content, stream flow, resuspension rate, biological activity, and physical/chemical properties, which affect the concentration and distribution of contaminants in a sediment system. For some applications, organic material should be sieved using a sieve with a maximum 2mm opening mesh. (See the *USGS National Field Manual for the Collection of Water-Quality Data, Techniques of Water-Resources Investigations, Book 9 Chapter A8* at http://water.usgs.gov/owq/FieldManual/). The EPA's Sediment Quality Triad is available at: https://cfpub.epa.gov/si/si_public_record_report.cfm?Lab=ORD&dirEntryId=18028.

The goals of sediment sampling are to:

1) identify areas of highest contamination/impact;
2) delineate the full spatial extent of contamination/impact; and/or
3) determine ambient conditions.

The areas of greatest contamination will occur in depositional areas in aquatic systems and these areas must be specifically targeted by the sampling plan except in ambient monitoring where a spatial composite would be appropriate. However, sand and gravel sediments rarely reflect pollution loading. The sampling team should specify the location of samples, the collection protocol, and the type(s) of sampling apparatus in the sampling plan. The plan should be thoroughly reviewed prior to implementation.

An adequate assessment of sediment quality involves four components:

- The concentration of contaminants (Bulk chemistry)
- Potential for contamination of the environment (elutriate, Extraction Procedure [EP] and Toxicity Characteristic Leaching Procedure [TCLP])
- A measure of bioavailability and toxicity of environment samples via tissue analysis and/or toxicity testing (ASTM 2000; USEPA 2000)
- Assessment of resident biota (USEPA 1997; USEPA 1999)

These four components provide complementary data and no single component can be used to

predict the measurements of the other components. For instance, sediment chemistry provides information on the extent of contamination but not on biological effects. Sediment toxicity tests provide direct evidence of sediment toxicity but cannot discriminate among contaminants nor predict actual in-situ responses. In-situ responses of resident biota, measured by infaunal community analysis, provide direct evidence of contaminant-related effects, but only if confounding effects not related to pollution can be excluded. Sediment evaluation must be based on several techniques to provide strong evidence for the identification, delineation, and ranking of pollution induced degradation.

It is imperative that in sediment sampling, all data be collected considering the overall needs of the assessment. Each bulk sediment sample must be analyzed for total organic carbon, pH, and particle grain size, in addition to site specific analytical parameters, to fully characterize each sediment sample and to assist in subsequent modeling and assessment efforts.

If the contamination event or the greatest contamination occurred in the past, it is likely that recent actions have resulted in the deposition of a layer of relatively uncontaminated sediment on top of the sediments of concern. Commonly used dredges collect only near-surface sediments and will result in data biased low. In these situations, a sediment corer may be the most appropriate sampling device. Additionally, the analysis of the sediment can include fractionating of the various layers found in the sediment cores (i.e., oxic and anoxic zones).

Particular attention should be paid to chemicals that are very persistent in the aquatic environment, have high bioaccumulation potential, have high toxicity to aquatic organisms, and have a high frequency of detection.

Surface water data should be included in the overall hazard assessment for sediments. However, in aquatic systems that contain quiescent waters such as lakes, wetlands, ponds, and intermittent or slow moving streams, the release of contaminants from the sediment may play a significant role in surface water quality. Lake stratification and associated anoxia may affect the exchange of contaminants at the water sediment interface. Under these conditions, it may be necessary to collect seasonal samples or discrete samples at various depths. Elevated concentrations of contaminants in the water column are indicative of a higher degree of concern associated with contaminated sediments.

Note: When sampling for both surface water and sediment at the same location, always collect the surface water sample first. If the samples being collected are from a flowing stream, always start from a downstream location and proceed upstream. If samples are being collected from a landfill seep, collect the sediment sample first and then create a small excavation. This will allow for the partial submersion of leachate sample containers. After the excavation disturbance has had time to fill with leachate, proceed with sampling.

Once contaminants of concern for sediments have been identified, further evaluation of the ecosystem in question should be performed. It must be emphasized that the screening level criteria can only evaluate the potential for biological effects to occur. In the environment, many factors such as bioavailability, species composition, natural physical and chemical characteristics will determine whether actual adverse effects become expressed.

In collecting sediment samples from any source, care must be taken to minimize disturbance and sample washing as it is retrieved through the liquid column above. Sediment fines may be carried out of the sample during collection if the liquid above is flowing or deep. This may result in collection of a non-representative sample due to the loss of contaminants associated with these fines. While a sediment sample is usually expected to be a solid matrix, sampling personnel should avoid placing the sample in the bottle and decanting off the excess liquid. Decantation promotes the loss of water-soluble compounds and volatile organics present in the sediment. If the sample is collected properly, any liquid that makes it into the bottle is representative of sediment conditions.

As with aqueous sampling, a determination of tidal influences on the impoundment being sampled should be made and its effect on sample collection should be detailed in the sampling plan. At a minimum, the stage of the tide at the time of sample collection should be recorded. Consideration should be given to sampling at varied tidal stages.

6.8.2.2.1.1 Onshore

If liquid flow and depth are minimal and sediment is easy to reach, a trowel or scoop may be used to collect the sediment. Generally, where the liquid above the sediment collection point is flowing or is greater than four (4) inches in depth, a corer or clam shell should be used to collect the sample in an attempt to minimize washing the sediment as it is retrieved through the water column. This assumes sufficient sediment accumulation to accommodate the sample device. In some cases, a corer is not the appropriate device when collecting sediments associated with ambient surface water quality. Confer with the proper oversight program, approved sample plan objectives or assigned case manager prior to sample collection should the question of selecting the correct sampling device arise. (See the *USGS National Field Manual for the Collection of Water-Quality Data, Techniques of Water-Resources Investigations, Book 9 Chapter A8* at http://water.usgs.gov/owq/FieldManual/.

6.8.2.2.1.2 Offshore

In some instances, the dimensions of an impoundment or channel dictate that a barge or boat must be used. The device used for the sample collection in this case will, again, depend upon the depth and flow of the liquid above the sample location and the bed characteristics of the impoundment. Generally, trowels or scoops cannot be used in an offshore situation. Instead, cores or dredges are more efficient means for sample collection. The barge or boat should be positioned just upstream (if it is a flowing impoundment) of the desired sample location. As the corer or dredge is lowered it may be carried slightly downflow, depending on the force of the flow. Upon retrieval, transfer the contents of the corer or dredge directly into the sample bottle using a decontaminated trowel of appropriate construction. Decontaminate the corer, dredge, and trowel before collecting the next sample.

6.8.2.2.1.3 General Procedures

Sediment samples should be collected from the 0-6” interval (biotic zone) of the water body bottom and may be obtained using an Eckman dredge Ponar dredge or hand scoop. If deeper sediment samples are required, a core sampler should be used. Loss of contaminants should be avoided by utilizing plastic bottles when sampling for metals or PFAS and using brown borosilicate glass containers with Teflon® lined lids for other organics. Check with your laboratory for method specific bottle requirements.

If compositing or homogenization of sediment samples is necessary, the optimal methods will depend on the study objectives. Important considerations include: loss of sediment integrity and depth profile; changes in chemical speciation via oxidation and reduction or other chemical interactions; chemical equilibrium disruption resulting in volatilization, sorption, or desorption; changes in biological activity; completeness of mixing; and sampling container contamination. Several studies of sediment toxicity suggest it is advantageous to subsample the inner core area since this area is most likely to have maintained its integrity and depth profile and not be compromised by contact with the sampling device. Subsamples from the depositional layer of concern, for example, the top 1 or 2 cm should be collected with the appropriate sampling tool. Samples are frequently of a mixed depth, but a 2-cm sample is the most common depth obtained.

For some studies, it is advantageous or necessary to composite or mix single sediment samples. Composites usually consist of three to five grab samples. Subsamples collected with a decontaminated appropriate sampling scoop should be placed in a decontaminated appropriate

bowl or pan. The composite sample should be stirred until texture and color appears uniform. Due to the large volume of sediment, which is often needed for toxicity or bioaccumulation assays and chemical analyses, it may not be possible to use subsampled cores because of sample size limitations. In those situations, the investigator should be aware of the above considerations and their possible biased effect on assay results as they relate to in-situ conditions.

If samples are to be analyzed from a certain particle size fraction or if the laboratory has maximum particle size limitations (generally 2 mm) the samples must be sieved before transfer to the sample bottles. Properly decontaminated, sieves of the appropriate construction (i.e., metal for organics and plastics or PFTE for metals) must be used. All sediment samples should arrive at the laboratory within the specified analytical method holding time, at 4º Celsius and in the appropriate containers.

6.8.2.2.2 Sludge

All sludge samples shall be representative for the chemical and physical characteristics of the sludge removed from the treatment unit process immediately preceding ultimate management. For example, if a treatment works discharges dewatered filter cake for land application, then sampling activity must focus on the output sludge stream from the dewatering device (that is, vacuum filter, bed press, etc.)

All domestic and industrial treatment works are required to develop and maintain a sludge sampling plan on-site. The plan must identify sludge sampling points that are established at locations which ensure sample homogeneity and best represent the physical and chemical quality of all sludge, which is removed from the treatment works for use or disposal. The plan must identify the equipment to be utilized for sampling, and the plan must demonstrate adherence to quality assurance and quality control requirements and procedures for sampling and analysis.

For sludge sample preservation, samples generally should not by chemically preserved in the field because the sludge matrix makes it difficult to thoroughly mix the preservative into the sample. Therefore, requirements for field preservation will be limited to the chilling of samples at 4º Celsius during compositing, holding, and transporting. Samples requiring preservation shall be preserved upon receipt in the laboratory that will be conducting the analysis.

Sampling locations shall be as follows unless the NJDEP approves alternate sampling locations:

- Sampling points for liquid sludge shall be at taps on the discharge side of the sludge pumps.
- For treatment works utilizing drying beds, one-quarter cup sludge samples should be taken at five-foot intervals across the bed surface. Neither the weathered surface nor sand should be included in the sample.
- For treatment works processing a dewatered sludge cake, sampling of the sludge should be taken from the point of sludge cake discharge.
- For treatment works with a heat-treated sludge, samples shall be taken from taps on the discharge side of positive displacement pumps after decanting for the heat treatment unit.

When a treatment works generates several different types of sludge (for example primary, secondary, or advanced wastewater treatment sludges) each of which is removed separately for ultimate management, separate composite samples shall be collected and analyzed.

The sample collection, handling and preservations techniques set out in Chapter 2, Appendix 2-1, shall be followed for all sludge analyses. Samples requiring preservation shall be preserved at the time of collection. If a preservative cannot be utilized at the time of collection (that is, incompatible preservation requirements), it is acceptable to initially preserve by icing the entire sample during compositing and immediately ship it to the laboratory at the end of the sampling period. Upon receipt in the laboratory, the sample shall be properly preserved.

All samples shall be chilled at four degrees Celsius during compositing and holding. For dewatered

or dried sludge samples, preservation shall consist of chilling to four degrees Celsius. Use of a chemical preservative is generally not useful due to failure of the preservative to penetrate the sludge matrix.

6.8.2.3 Flow Measurements

During the course of site investigations, it is often necessary to assess the quality and quantity of liquids flowing in channels. While the quality of liquid is determined through sampling and analysis, determinations of quantity of flow are made through the use of field measurements.

Flow information should be gathered when samples are collected to allow a full characterization of the channel. Flow measurements also may be made without the collection of samples when assessing the channel's potential as a migratory pathway for pollutants.

Flow is the amount of liquid going past a reference point during a period of time. It can be calculated by measuring both the average velocity and the area through which the liquid is moving. Flow is reported as volume per unit time and is expressed in units such as cubic feet per second (CFS), gallons per minute (GPM) and million gallons per day (MGD).

Flow is measured by a flow metering system. The "primary element" is the measuring structure that contains the liquid. The "secondary element" is used to make measurements from the primary element and convert them to flow.

Flow methods fall into two broad categories: open-channel flow and closed-pipe (pressure conduit) flow. In open-channel flow the liquid has a free surface; in closed-pipe flow the water completely fills the conduit.

6.8.2.3.1 Open-Channel Flow Measurement

The open-channel primary element creates a known relationship between flow and depth. Under these conditions, the channel width is known, and the velocity does not need to be measured. The secondary element is used to measure depth at a specific measurement point.

All open-channel primary elements create observable flow profile characteristics by manipulating the channel slope and size. The flow is constricted and made to drop through a steep and precisely dimensioned section (the primary element) before flow through the regular channel is resumed. A known and repeatable relationship between depth and flow results.

Starting some distance upflow of the primary element, the liquid will be relatively deep and slow moving. As it passes through the primary element, it will become much shallower and faster. Downflow from the primary element the liquid will return to a deeper and slower condition.

The flow is "subcritical" in the upflow and downflow reach and "supercritical" when it is moving shallower and faster. A hydraulic lift occurs as the flow changes between subcritical and supercritical. In all cases the approach flow must be subcritical and the change from subcritical to supercritical must be clearly evident.

The depth of the liquid in the primary element is measured at a particular location in the channel. The depth-to-flow relationship is only accurate at the measuring point. The depth can be measured directly from the throat or it can be measured at a stilling well.

A stilling well is a small, circular well, connected to the throat or to an upstream measuring point of the flume or weir, generally through a small-diameter pipe. The stilling well provides a calm pooling area where the depth can be accurately measured. The water level in the stilling well is the same as in the flume or weir at the measuring point. The stilling well should only connect to the flume or weir at the measuring point for the device being used. Stilling wells are not affected by wave action, foam or floating or partially submerged debris. Frequent cleaning may be necessary to keep the well and the connection to the flume or weir clean to ensure accurate measurements.

The accuracy of both the primary and secondary elements should be checked. Observe the flow through the primary element for certain characteristic flow conditions described in the following sections. Check the secondary element by comparing the depth reading with and independent depth measurement. Convert depth measurements to flow using hydraulic equations for the measuring device and evaluate the calculated flows with those indicated by the measuring device or the attached totalizer, recording disk, or discharge meter.

6.8.2.3.2 Open-Channel Flow Meters

6.8.2.3.2.1 Palmer-Bowlus Flumes

This type of flume is designed to be installed in an existing channel providing the channel is on an acceptable slope and the flows do not exceed the flume's capacity. The dimension of the channel sizes the flume. For example, a six-inch Plamer- Bowlus flume is used in a six-inch channel. Smaller Palmer-Bowlus flumes of the "quick-insert" type are often used due to the ease with which their inflatable collar is inserted into the exit section of a pipe.

When installed, a Palmer-Bowlus flume is preceded by a section of straight pipe (about 25 pipe diameters long) and on an acceptable (subcritical) slope. The point of measurement for a Palmer-Bowlus flume is located at a distance D/2 upstream from the top of the flume, where D is the size of the flume.

The depth-to-flow relationships for Palmer-Bowlus flumes are available in tabular form. The depth, H, *is the vertical distance between the floor of the flume and the water surface at the measuring point*. The distance from the channel bottom to the floor of the flume is approximately D/6. This dimension may vary considerably due to the way the flume is installed or to corrosion or deposition.

Subcritical flow should be observed upstream of the flume with the hydraulic drop starting to be just noticeable just downstream of the measuring point. The water should drop more noticeably with supercritical flow obvious around the downstream portion of the flume. The water surface will often show a "V" section formed by standing waves as the water enters the flume. The hydraulic jump also often has a "V" shape to it. At flumes installed in sewer lines, the supercritical section tends to be less evident and to be located further downstream than average. On steeper lines, it will be more pronounced. A hydraulic jump that occurs upstream of the flume may be an indication that the upstream piping was laid at too steep a slope or that accumulated debris needs to be removed.

In some cases, the change from subcritical to supercritical flow will be evident, but the hydraulic jump will not be visible. That is perfectly acceptable. The jump may occur farther downstream in the discharge pipe. A steeply sloped discharge pipe may carry supercritical flow a considerable distance.

If the hydraulic jump seems to be within the flume itself, or if the supercritical section does not seem to exist, the flume may be operating in a submerged condition. If the submergence is too great, the flume will no longer be accurate, as measured by a single measurement. A submerged condition can occur when the discharge pipe is not able to carry the flow. This can happen because of an improper slope of the pipe, debris in the pipe, or from flow conditions in the sewer line father downstream that cause a backup of water in the flume. Any of these unusual conditions should be promptly investigated.

The dimensions to which a Palmer-Bowlus flume is constructed have been standardized, but in a generic sense, the term Palmer-Bowlus-type flume can apply to any flume of this general shape and size. Be aware, however, that head-to-flow tables are not identical for different manufacturers due to slight differences in style. For instance, another similar type of flume, the Leopold-Lagco flume, also is occasionally installed in an existing line. It has a rectangular cross-

section rather than a trapezoidal cross-section and, consequently, produces a different head-to-flow reading than a Palmer-Bowlus flume of the same nominal size.

6.8.2.3.2.2 Parshall Flumes

A Parshall flume operates on the same principle as the Palmer-Bowlus flume. The main advantage of a Parshall flume is that the flume will handle a wide range of flows. The flumes are available already installed in prefabricated manholes and vaults but installation in an existing sewer line may involve replacing some of the line because of the required drop in the floor of the flume.

Subcritical flow should occur upstream of the flume, the hydraulic drop (drop in flowing water surface) occurs in the converging section of the flume, and supercritical flow occurs in the throat of the flume. The hydraulic jump generally occurs in the throat, the diverging section, or farther downstream.

As with the Palmer-Bowlus flume, the hydraulic jump does not have to be within view. Parshall flumes are often installed to discharge to a sump or to a more steeply sloping line to prevent submergence of the flume due to water backing up in the downstream pipe.

Many flumes have a staff gauge installed on the side of the flume for depth of flow measurements. If a staff gauge is not available, measure the water depth at the appropriate location with a steel rule. The use of a wooden yardstick to measure water depth should be avoided because these devices may create a wave in the flowing water, which could lead to erroneous depth measurements. Record the depth reading from the steel rule. Using the proper table or rating curve for the size of the flume, use the depth of flow reading to determine the flow.

A Parshall flume is not always installed to carry the maximum flume capacity. For instance, a flume that can accommodate a depth of three feet at the measuring point could be cut at two feet if space limitations so necessitated, although this reduces its capacity.

Parshall flumes were initially designed to be installed in irrigation systems on relatively flat surfaces and are capable of operating partially submerged. However, such operations require additional depth measurement. Most instrumentation is not designed for that circumstance, so the flume should not be operated past a certain degree of submergence. If the hydraulic jump is located well up the throat of the flume, further investigation is advised.

A number of other types of flumes have been developed. These are the cutthroat flume, the San Dimas flume, and trapezoidal flumes. Many other flumes have been designed for specific applications. All of these flumes control the cross-sectional flow area and convert the depth of flow measurement to a rate of flow.

6.8.2.3.3 Weirs

Weirs differ from flumes in that a weir is essentially a dam across the flow, as compared to reshaping the channel. See Figure 6.4. Weirs are either broad-crested (wide in the direction of flow) or sharp-crested. The sharp-crested weir is more commonly used in measuring industrial wastewater flow than the broad-crested weir. The V-notch weir is the most common of the sharp crested weirs because it is the most accurate flow measuring device for the small, fluctuating flows which are common for small industries.

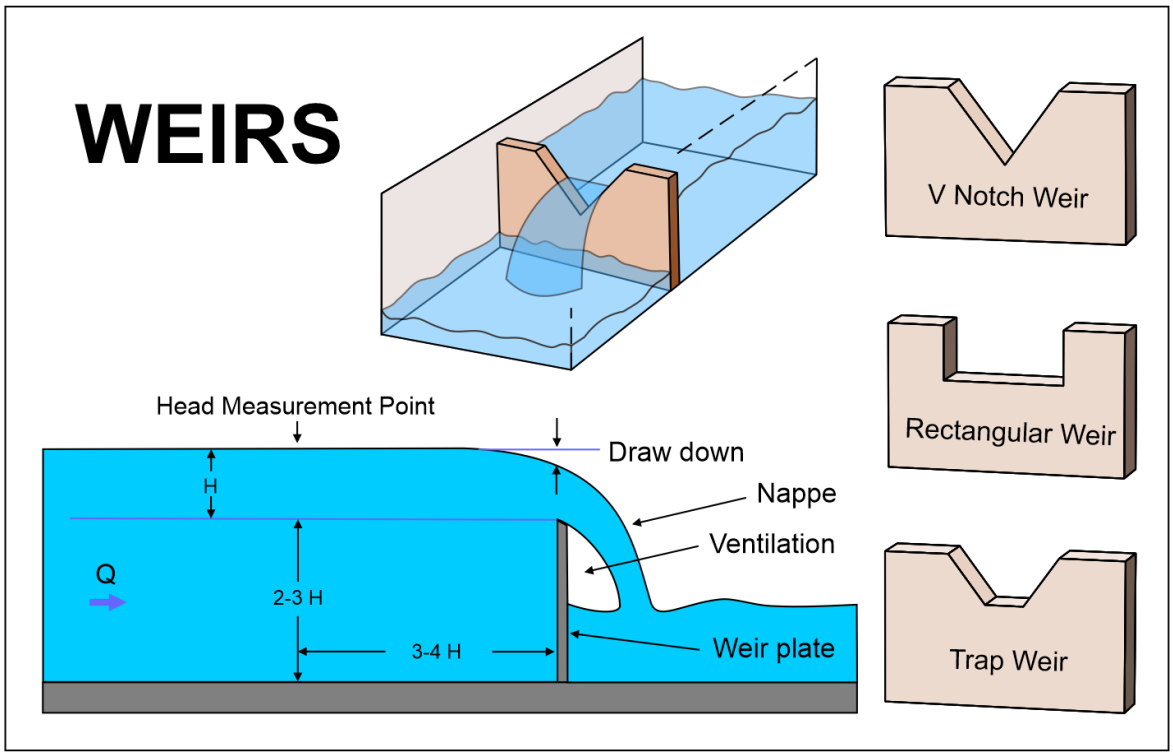


Figure 6.4 Weir, any control or barrier placed in an open channel to permit measurement of water discharge. Illustration by Paul Bauer

Weirs can be installed in a variety of situations; often an existing sump will be large enough to serve as a weir box. Always provide adequate clearance below the notch for a free discharge to occur. This requirement may limit the installation in existing lines if the backup of water would flood or submerge the weir.

Weirs operate on the same principle as flumes; however, they can look quite different. The approach section, which is sized so that the approach velocity is minimal, has subcritical flow. Supercritical flow occurs as the water pours through the weir notch. The flow returns to subcritical flow in the afterbay of the weir.

Under normal conditions, you will see that the flow through the notch, called the nape (pronounced NAP) of the flow, springs away from the weir plate. This means that the weir is operating with a free discharge and that the nape is well ventilated, or aerated; that is, air can move freely beneath the nape. Only at low flows should the water cling to the face of the weir plates.

A weir cannot be operated under submerged conditions. The nape of the water must fall freely into the weir afterbay. If the level in the afterbay rises too high, aeration of the nape may cease and the measured discharge will be greater than the actual discharge. A weir should be constructed with several inches clearance between the crest of the weir (the bottom of the notch) and the afterbay level. In general, a weir should be constructed with the top of the downstream pipe at least six inches below the crest of the weir. If the discharge pipe is not visible and the afterbay level is approaching the crest of the weir, it is likely that the proper depth-to-flow relationship does not exist.

To develop the proper depth-to-flow relationship with a weir, it is generally necessary that an upstream pool be formed to dissipate the approach velocity of the flow. The dimensions (determined by qualified design engineers) of this pool are based on the maximum capacity, expressed as the depth (head) behind the weir. The absence of this pool may cause the weir to

measure a lower than actual flow.

The measurement point for all types of weirs is located at a distance of about 3H to 4H upstream (or to the side) of the weir. H is the maximum head on the weir. The depth of flow (head) through a weir is measured from the crest (bottom or lowest point) of the weir to the water surface at the measuring point.

6.8.2.3.3.1 V-Notch Weirs

Cutting a 22 ½ °, 30°, 45°, 60° or 90° notch in a metal plate and fixing the plate in appropriate supports forms a V-notch weir. Other materials are used for weir plates, including polycarbonate (a plastic material like plexiglass). The edges of the notch must be cut and beveled to the correct dimensions. For permanent installations, the weir plates should be made of metal since the accuracy of a weir is affected by the gradual rounding of the edges of the notch. The angle of the weir and the depth of the notch fix the dimension of the upstream pool.

The actual formula that should be used by the secondary measurement device should be determined when checking the accuracy of the system. (Use the formula that is recommended by the manufacturer.) The cone formula for 90° V-notch weirs is Q=2.49H2.48.

6.8.2.3.3.2 Rectangular Weirs

Another common type of weir is the rectangular weir. The rectangular opening may span the width of the channel in which case the weir is known as a suppressed (without end contractions) weir. Aeration of the nape is achieved by installing vent pipes beneath the nape. When the opening spans only a portion of the width of the channel, the weir is known as a contracted (with end contractions) weir. As with the V-notch weirs, the weir pool dimensions depend on the type and capacity of the rectangular weir. The measuring point is located at about 3H to 4H upstream of the weir. The weir should be sized so that the minimum depth is about 0.2 foot and the maximum depth is about one-half the length of the crest, although greater depth can be adequately measured. Rectangular weirs will measure larger flows than V- notch weirs.

The depth-to-flow formula for suppressed rectangular weirs is usually given as:

$$Q = 3.33\ LH1.5$$

The formula for contracted rectangular weirs is usually given as:

$$Q = 3.33\ (L - 0.2H)H1.5$$

In these formulas, H is the depth in feet from the crest of the weir to the water surface at the measuring point, L is the crest length in feet, and Q is the flow in cubic feet per second.

A Cipolletti weir is quite similar to a contracted rectangular weir, but has a trapezoidal-shaped opening rather than a rectangular opening. The discharge formula for this weir, with the same units as above is usually given as:

$$Q = 3.367LH1.5$$

Several other types of sharp-crested weirs are occasionally used in flow measurement work, but because of their unusual shapes, and a resulting difficulty in construction, they are not usually selected for installation.

6.8.2.3.3.3 H-Type Flumes

H-type flumes were developed to measure the runoff from agricultural watersheds and have found use in other applications. The H-flume, HS-flume and HL-flume combine features of both weirs and flumes. Flow control is achieved at a sharp-edged opening and the flat floor allows passage of solids. The maximum depth of the flume designates these flow measurement devices;

for instance, the 1.0-foot H-flume has a maximum head of 1.0 foot. The dimension to which the flume is constructed, and also the point of measurement, depends on the maximum depth. For the H-flume, the measurement point is located at a distance of 1.05D from the discharge tip of the flume, where D is the size of the flume (maximum head). For the HS-flume the distance is D; for the HL-flume the distance is 1.25D. The discharge formulas for the H-type flumes are complicated, thus tables that are easy to read should be used to relate depth to flow. The depth of flow is measured from the floor of the flume to the water surface. The flume should discharge in a free flow condition, as with a weir, and without submergence.

H-flumes are more correctly classified as flow nozzles. Two other types of flow nozzles, the Kennision nozzle and the parabolix nozzle are also occasionally used to measure flow.

6.8.2.3.4 Instrumentation for Open-Channel Flow

Several different types of instruments are available for measuring open-channel flow. Generally, all of them can be installed on any type of flume or weir, at either the channel or the stilling well, although the characteristics of a particular wastewater may preclude the use of certain types of instrumentation. The function of the instrumentation is to secure the level of the water; convert the depth to flow; and to indicate, record and totalize the flow. The instrumentation may also be used to activate an automatic sampler, and outputs are usually available for other uses.

The totalizer, indicator, and recorder should be properly labeled to prevent problems in interpreting their readings. Also, the pulse output for a contact closure used in flow proportional sampling should be clearly labeled. Totalizer readings usually require that a multiplier factor be used and this factor should be posted. Analog readout indicators often use a span of zero to 100 percent. The flow at 100 percent should be posted. The recorder often has the same span as the indicator, but when it differs it should be posted. The chart paper on the recorder should be regularly annotated with the time and date and the totalizer reading. Some meters are constructed without indicators and instantaneous readings of the flow must be taken directly from the recorder. The timer operation generated by the flow must be taken directly from the recorder. The timer operation generated by the flow meter to activate an automatic sampler should also be posted.

The methods described above are not equally accurate. Errors related to the reading of a staff gauge are assumed to be minor and therefore this means of determining a flow rate should be considered very accurate, provided the staff gauge is properly installed and can be accurately read. Errors related to the determination of head by means of a reference point should be considered minor as long as the flow rate remains fairly constant during the check. Errors related to the use of a long tapered pole should be considered minor as long as the flow rate remains fairly constant during the check. Errors related to the use of a long tapered pole should be considered to be the greatest since the insertion of any obstruction into the flow can affect flow conditions.

6.8.2.3.5 Closed-Pipe Flow Metering Systems

Closed-pipe (pressure conduit) flow meters are installed in a section of pipe that remains full under all normal discharge conditions. The pipe may flow from gravity conditions or from a pump discharge. Closed-pipe flow meters are divided into two categories, (1) those that measure the average velocity of the flow (which is applied to the cross-sectional area of the pipe to determine flow) and (2) those that produce a differential of pressure across the meter by constricting the flow. The flow can be determined from that differential pressure.

A closed pipe meter should be preceded and followed by five to ten pipe diameters of straight pipe to develop and maintain a satisfactory flow profile. A satisfactory profile means that the velocity is fairly uniform across the pipe. An unsatisfactory profile could occur near a bend or elbow. Manufacturers of such devices recommend that certain distances of straight pipe equal to so many pipe diameters be installed upstream and downstream of their meters.

As with open-channel meters, closed-pipe flow meters should also be hydraulically calibrated with known flows when first installed. Instrument calibrations and hydraulic calibrations should be performed at regular intervals thereafter.

A general disadvantage of a closed-pipe flow meter in the measurement of industrial wastewater is the difficulty in determining if the meter is clean. The material present in some wastewaters can coat, clog, or corrode a meter in an undesirably short period of time. This possibility should be considered in the selection of a meter. Flow meters must be calibrated regularly (every six months) after installation.

6.8.2.3.6 Types of Meters, Methods and Systems

6.8.2.3.6.1 Electromagnetic Flow Meters

Electromagnetic flow meters use Faraday's Law to determine flow rates. This principle states that if a conductor, in this case the water is passed through a magnetic field, voltage will be induced across the conductor and the voltage will be proportional to the velocity of the conductor and the strength of the magnetic field. Electromagnetic flow meters produce a magnetic field and measure the voltage created by the movement of the water; the voltage reading is translated to a flow measurement based on the pipe diameter. The mag meter does not have any intrusive parts and operates over a wide range of velocities and is not sensitive to viscosity, density, turbulence, or suspended material. A minimum conductivity of the fluid is necessary; most wastewater is adequately conductive. Deposits of grease or oil can affect results, and some electromagnetic flow meters are equipped with self-cleaning probes to remove these deposits from the measuring area.

6.8.2.3.6.2 Turbine Meters and Propeller Meters

Both of these meters operate on the principle that a fluid flowing past an impeller causes it to rotate at a speed proportional to the velocity of the flow. On some models the axis of the impeller is located in the direction of the flow; the other is perpendicular to the flow. The motion of the impeller is conveyed through a mechanical device or a magnetic coupling to the register of the meter. These meters are commonly used in water measurement. The accuracy of the meter is affected by a poor flow profile, misalignment of the impeller, and accumulation of solids, especially oil and grease, on the impeller. Turbine and propeller meters are not used to measure flows in wastewaters that carry rubber or plastic goods, and other abrasive debris or corrosive liquids.

6.8.2.3.6.3 Rotating Element Current Meters

Of the various types of meters that exist for measurements of flow velocity, rotating element current meters are perhaps the most commonly used. The principle of operation is based on the proportionality between the velocity of water and resulting angular velocity of the meter rotor. In conventional current meters, there is a wheel which rotates when immersed in flowing water and a device which determines the number of revolutions of the wheel. The general relation between the velocity of the water and number of revolutions of the wheel is given by:

$$V = a + bN$$

Where: V = velocity of water meter per second a and b are constants

N = number of revolutions per second

These current meters can be grouped into two broad classes: 1) vertical-axis rotor with cups and vanes, and 2) horizontal-axis with vanes. Figure 6.5 shows the propeller current meter, which is typical of a horizontal-axis current meter with vanes. Figure 6.6 shows the Price current meter, which is typical of a vertical-axis rotor current meter with cups.

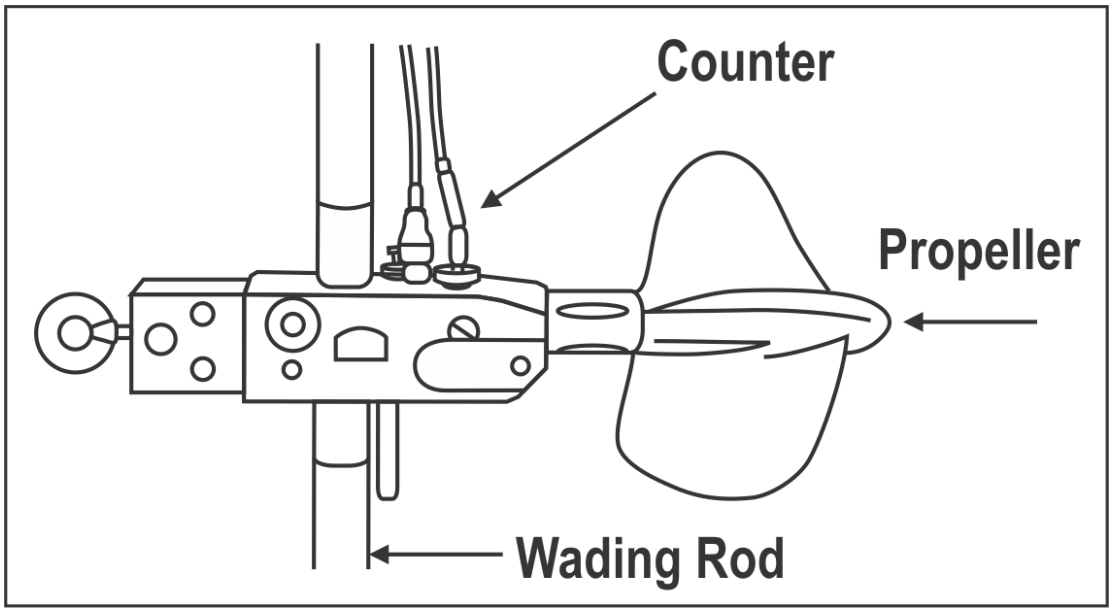


Figure 6.5 Propeller Current Meter

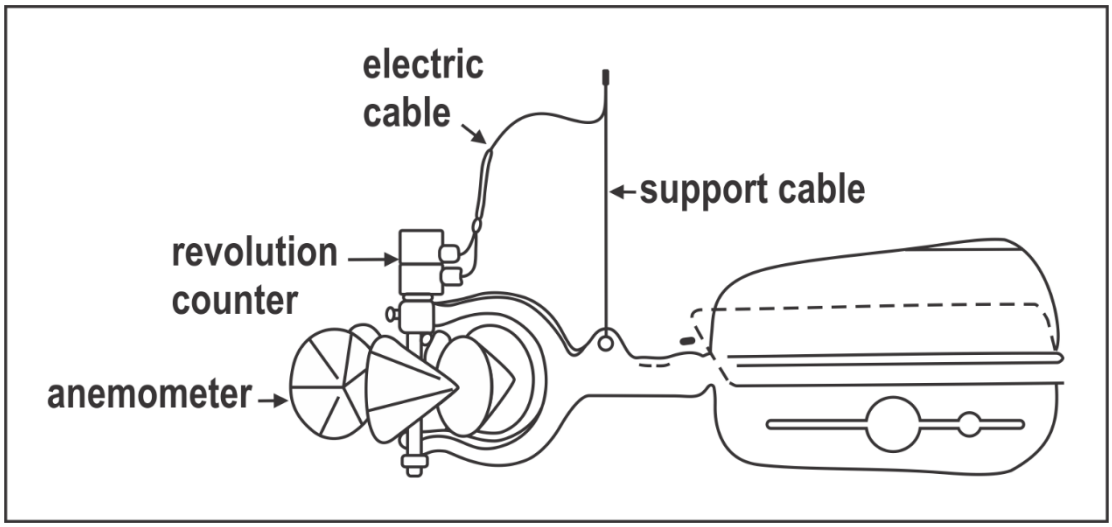


Figure 6.6 Price Current Meter

Practical considerations limit the ratings of these meters to velocities of 0.030 m/s (0.11 fps) to about 4.57 m/s (15 fps). The comparative characteristics of these two types are summarized below:

Vertical-axis rotor with cups or vanes:

- Operates in lower velocities than do horizontal-axis meters
- Bearings well protected from silty water
- Rotor is repairable in the field without adversely affecting the rating

- Single rotor serves for the entire range of velocities

Horizontal-axis rotor with vanes:

- Rotor disturbs flow less than do vertical-axis rotors because of axial symmetry with flow direction
- Rotor is less likely to be entangled by debris than are vertical-axis rotors
- Bearing friction is less than for vertical axis rotors because bending moments on the rotor are eliminated
- Vertical currents will not be indicated as positive velocities as they are with vertical-axis meters
- They have a higher frequency of mechanical problems

6.8.2.3.6.4 Ultrasonic Meters

Ultrasonic flow meters for closed-pipe flow use sonic waves to measure the velocity of the water. In comparison, ultrasonic meters for open-channel flow measure distance. The velocity of the water is measured either by the travel time of the sound waves, or by the Doppler Effect. With the former type of meter, two transducers, each of which includes a transmitter and a receiver, are located along the pipe. One transducer sends a signal in the direction of flow and the other transducer sends a signal opposite to the flow. The signal sent with the flow is received sooner than the signal sent against the flow. The difference in transit time is used to determine the velocity of the flow.

The Doppler type of ultrasonic flow meters makes use of the principle that a frequency shift of an ultrasonic signal occurs when the signal is reflected from a moving object; in this application, suspended solids or entrained air bubbles in the wastewater reflect the signal. The frequency shift results in a higher returned frequency if the water is moving toward the transducer, and a lower frequency if the water is moving away from the transducer. The velocity of the water can be determined from the frequency shift.

Ultrasonic flow meters are sensitive to flow profile effects. The manufacturer's recommendations for distances of upstream and downstream pipe diameters should be followed. The type of meter's accuracy is affected by pipe wall buildup and particle solid absorption. The in-line type of transducer is affected by a buildup of solids in the transducer. The clamp-on type of transducer is affected if the pipe and liner have sonic discontinuities in them or between them.

6.8.2.3.6.5 Pitot Tube Meters

The pitot tube, and similar devices, measure the velocity at a single point within the pipe. With a proper length of straight pipe upstream, a pitot tube installed approximately 30 percent of the pipe radius from the inside pipe wall will give an average velocity reading. However, it may be necessary to profile the flow to find the location at which this average velocity occurs. Pitot tubes are appropriate for measuring clean water or gasses rather than wastewater since they are sensitive to fouling.

6.8.2.3.6.6 Differential Pressure Systems

These systems use pressure differentials and their relationship to discharge to determine flow in closed systems. Differential pressure systems are used for measuring clean matrices rather than wastewater. Problems with fouling and deposition in the devices affect the configuration and hence the relationship between the pressure in the device and the flow. For these reasons the measurement ports and the device itself must be kept clean for accurate measurements.

An orifice plate meter consists of a thin plate with a hole drilled through it, with the pressure

differential measured through access ports on both sides of the plate. A venturi meter creates this differential by gradually decreasing the cross-sectional area of the pipe. Flow nozzles use a curved inlet and short throat to create the pressure differential. Flow tubes use an even shapelier curved inlet and a very short tube to create the pressure differential.

Differential pressure systems are subject to fouling in wastewater situations and are therefore most appropriate for gases and clean water matrices. The pressure taps must be kept clean in order for the system to work properly.

6.8.2.3.6.7 Velocity Modified Flow Meters

These are a cross between open and closed channel devices. These meters are used to measure both water depth and velocity. Typically, the meter consists of a velocity sensing element and a depth-sensing device (such as a pressure sensor or a bubblier). The meter is inserted into a tube, which is inserted into the pipe. These meters are useful when the pipe is submerged or buried.

As with the differential pressure systems, the velocity modified flow meter systems work well with clean matrices, but they also work well with wastewater (but not wastewater with high solids contents). These devices must be kept clean and must be installed on nearly level pipe systems to work properly.

6.8.2.3.6.8 Float Methods

There are three types of float methods used for estimating flow measurements: surface floats, subsurface floats, and integrating floats. To determine the flow velocity, one or more floats are placed in the stream and their time to travel a measured distance is determined. These methods are simple but from an accuracy standpoint, they should be used only for estimating the discharge.

Various surface floats, such as corks and stoppered bottles, and submerged floats like oranges, measure surface velocity. The mean velocity of flow is obtained by multiplying with a coefficient, which varies from 0.66 to 0.80.

A more sophisticated version is the rod-float, which usually uses round or square wooden rods. These rods have a weighted end so that they float in a vertical position with the immersed length extending about nine-tenths of the flow depth. Velocity measured by the time of travel of these rods is taken as the mean velocity of flow. These floats are used in open channels and sewers.

To obtain better results, the velocity measurements should be made on a calm day and in a sufficiently long and straight stretch of channel or sewer of uniform cross-section and grade with a minimum of surface waves. Choose a float, which will submerge at least one-fourth the flow.

A more accurate velocity measurement is obtained by using integrating float measurements. The method is simple and consists of the release of buoyant spheres resembling ping-pong balls from the channel floor. As these spheres rise, the flow velocity carries them downstream. The time from the moment of the release to the moment when they surface and the distance traveled downstream are measured, and inserted into the following equation to determine flow rate.

$$Q = DV \quad \text{and} \quad V = L / t$$

Where: Q = discharge per unit width of channel (in cubic meters per second or cubic feet per second)

D = flow depth (meters or feet)

V = terminal velocity of the float (meters per second or feet per second)

t = time of float to rise (seconds)

In flows of large depth and velocity, integrating float methods weigh two floats of different velocities of rise are used. The discharge is calculated using the relationship:

$$Q = \frac{D(L2-L1)}{t2-t1}$$

where L2 and L1 are distances traveled downstream by float 2 and float 1 respectively; t2 and t1 are times of rise of float 2 and float 1 respectively.

The integrating float method is simple and does not require any laboratory calibration. It integrates the vertical velocity profile and yields the mean velocity or discharge per unit width of the section. The method is suited to low velocity profiles, and it has practically no lower velocity limit. To get better accuracy, the reach of the stream to be measured should be sufficiently long and straight and the bed fairly uniform. Use a fast-rising float so that distance traveled downstream is of short length. The shape of the float should be spherical.

6.8.2.3.6.9 Salt Velocity Method

The method is based on the principle that salt in solution increases the conductivity of water. This method is suitable for open channels of constant cross-section and for flow in pipes. For additional information https://www.usbr.gov/tsc/techreferences/mands/wmm/chap12_06.html.

6.8.2.3.6.10 Color Velocity Method

The color velocity method is used to estimate high velocity flows in open channels. It consists of determining the velocity of a slug of dye between two stations in the channel. This velocity, taken as the mean velocity, multiplied by the cross-sectional area of flow gives an estimate of discharge. For additional information https://www.usbr.gov/tsc/techreferences/mands/wmm/chap12_06.html.

6.8.2.3.6.11 Discharge Methodology

To determine the discharge (flow volume), in addition to the velocity of flow, it is necessary to determine the area of flowing water or wastewater. This applies especially to large flows in rivers, lakes, and wide and deep channels. A depth sounding is necessary at each vertical and width measurement of the cross-section of flow to determine the area of flowing water or wastewater. Sounding rods, sound weights and reels, handlines, and sonic sounders are common equipment for depth determinations. Marked cableways and bridges, steel or metallic tap or tag lines are used for width determinations.

To determine the discharge at a particular cross section, it is necessary to determine the mean velocity of flow at that section. In drag body current meters such as vertical-axis deflection vane, horizontal-axis pendulum type deflection vane and pendulum current meters, it is possible to integrate velocities at different depths in a particular section to obtain the mean velocity of flow. On the other hand, an inclinometer, drag sphere, rotating element current meters and pilot tubes measure the velocity at a point. Therefore, to obtain the mean velocity of flow at a particular vertical section, it is necessary to take velocity measurements at different depths. The various methods of obtaining mean velocities are:

- vertical-velocity curve
- two-point
- six-tenths depth
- two-tenths depth
- three point
- subsurface

Table 6.11 compares these methods in relation to application, flow, depth, velocity, measuring point(s) and accuracy.

Table 6.11 Comparison of Various Methods to Obtain Mean Velocity

Methods Considerations	Vertical Velocity Curve Method	Two Point Method	Six-tenths Depth Method	Two-tenths Depth Method	Three Point Method	Subsurface Method
Applications	Not for routine discharge and measurements, used to determine coefficients for application to results from other methods	Generally used	Primarily used for depths less than 2.5 ft.	During high velocities when unable to measure at 0.6 and 0.8 ft. depths	When velocities in a vertical are abnormally distributed	When unable to obtain soundings and depth cannot be estimated to 0.2 ft. setting
Flow depth requirements	> 2.5 ft.	> 2.5 ft.	0.3 ft. to 2.5 ft.	No depth constraint	> 2.5 ft.	> 2.5 ft.
Velocity measuring point(s)	At 0.1 ft. depth increments between 0.1 and 0.9 ft. deep	0.2 and 0.8 ft. depth below the water surface	0.6 ft. depth below the water surface	0.2 ft. depth below the water surface	0.2, 0.6 and 0.8 ft. depth below the water surface	At least 2 ft. below the water surface
Mean velocity	From vertical velocity curve	$\frac{V0.2+V0.8}{2}$	Observed velocity is the mean velocity	Vmean = C x V0.2 C = Coefficient obtained from vertical-velocity curve at that vertical for flow depth	$\text{Vmean} = \frac{\frac{\{V0.2+V0.8\}+V0.6}{2}}{2}$	Vmean = C x V observed from vertical velocity curve at that vertical for flow depth
Accuracy	Most accurate	Consistent and accurate results	Gives reliable results	If C is known gives fairly reliable results	Gives reliable results. When more weight to 0.2 and 0.8 ft. depth observations is desired an arithmetic mean may be calculated	Gives estimate, difficult to determine

V0.2 = velocity at 0.2 ft. depth
V0.6 = velocity at 0.6 ft. depth
V0.8 = velocity at 0.8 ft. depth
Vmean = mean velocity

6.8.2.3.7 Miscellaneous Flow Measurement Methods

6.8.2.3.7.1 Water Meters

An estimate of the flow can be obtained from water meter readings where an instantaneous flow rate is not critical. This technique is used in a confined area, such as an industrial plant. Water meters should be certified periodically. When using the incoming and outgoing flow for an initial estimate of the flow rate, all changes in the water quality that occur in various processes must not be over- looked. These changes may be due to water actually consumed in the process, for example, cement manufacturing, conversion of quick lime to slaked lime.

6.8.2.3.7.2 Measure Level Changes in Tank

In some instances, the level change in a tank can be used to estimate flow. To accomplish this,

To determine the volume of a stationary liquid in a partially filled horizontal cylinder, use the following formulas

Volume = $\alpha/360\ \alpha R^2 - 2\ [1/2\ h_2\ (R^2 - h_2^{\ 2})\ 1/2]\ L$
Where: R = Tank Radius

h_1 is less than R:

$\alpha = 2\cos -Lh_2/R$

h_2 = R - depth of liquid or h_1

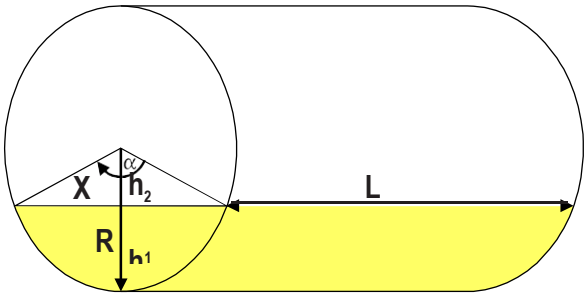
$$X = \frac{[R^2 - h_2^{\ 2}]}{2}$$

h_1 is greater than R:

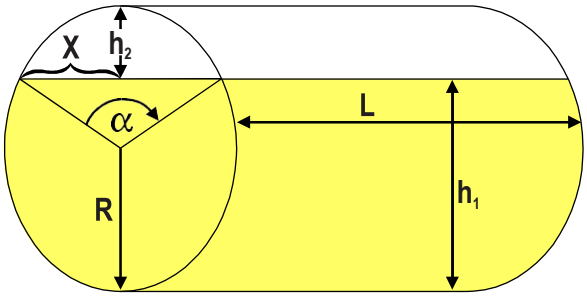
$\alpha = 360 - 2\cos -Lh_2/R$

h_2 = Tank Diameter - depth of liquid or h_1

$$X = \frac{[R^2 - (D - R)^2]}{2}$$



Partially filled horizontal cylinder where h_1 is less than R



Partially filled horizontal cylinder where h_1 is greater than R

Figure 6.7 Stationary Volume of Liquid in Horizontal Cylinders

the volume of the tank related to depth must be established; then the flow is allowed to enter and the level change with time is recorded. Figure 6.7 gives the relationship of depth to the stationary volume of a liquid in a horizontal cylinder.

6.8.3 Site Remediation and Waste Management Program Requirements

6.8.3.1 Sampling Objectives

Identification of sampling goals, objectives, and data quality objectives (DQOs) is critical. A minimum number of surface water and sediment samples may be appropriate during the Site Investigation phase, but may require a comprehensive suite of analytes. In contrast, a greater number of surface water and sediment samples may be required during the remedial investigation phase but only require a focused list of parameters. Compliance monitoring associated with permit requirements follows strict sampling procedures thereby necessitating thorough and complete understanding of sampling objectives.

Sampling of aqueous and non-aqueous matrices performed for, or by, the Site Remediation Program (SRP), must be pursuant to the requirements set forth in *Technical Requirements for Site Remediation*, N.J.A.C. 7:26E-3.6.

6.8.3.1.1 Site-Related Sample Locations

During the Site Investigation (SI), the objective of surface water body sampling is to determine whether site related contaminants have migrated to wetlands and surface water bodies associated with the site. During the Remedial Investigation (RI), the objectives of sampling are to further delineate and characterize contamination, as well as to evaluate the relationships among contaminated surface water, sediments, ground water, and soil. Surface water body and wetland samples are generally discrete and biased towards depositional areas, discharge points, etc., where contaminants are expected to accumulate, but the site-specific conditions may dictate the need for other sampling approaches. Investigations may require the use of the sample transect approach, described in NJDEP's *Ecological Evaluation Technical Guidance.*

6.8.3.1.2 Reference Sample Location

When investigating surface water, sediment, or wetland soil contamination to determine if it is linked to site operations, it is important to establish the chemical composition of upgradient sediments. These data also aid in the assessment of the site's contamination relative to the regional quality of the water body being investigated and in the development of remedial goals. The SRP recognizes that many of the State's water bodies, especially in urban/industrial settings, have become contaminated by historic point and non-point discharges, resulting in the diffuse, anthropogenic contamination of sediments at concentrations greater than natural background. Additionally, upgradient sediments can be contaminated by the site because of tidal influences. While it is difficult to distinguish between site and non-site-related contamination at these settings, it is the policy of NJDEP to make a reasonable attempt to investigate the site's contribution above ambient. If potential sources of contamination are present upstream of the site, and it is believed that these sources have contributed to the contamination detected on-site, these upgradient areas should be sampled, and professional judgment should dictate how these data are to be interpreted/utilized. Note that these results will not be considered representative of true reference (i.e., natural background) conditions.

For upgradient and offsite reference locations, SRP recommends the collection of a minimum of three (3) to five (5) samples to establish a range of reference location contaminant concentrations (the larger number of samples is recommended due to sediment heterogeneity). Samples shall be collected from areas outside the site's potential influence. The samples must not be collected from locations directly influenced by or in close proximity to other obvious sources of contamination (i.e., other hazardous waste sites, sewer/storm water outfalls, tributaries, other point and non-point source discharges, etc.). If a local reference site is included in the sampling plan, it must be of comparable habitat to the study area. Upstream areas influenced by tides shall be sampled at locations determined to be within the mixing zone to delineate upstream migration of contaminants

as well as upstream of any mixing zone to assess local ambient conditions. At a minimum, upgradient and local reference samples shall receive the same chemical analyses as site-related samples. See applicable guidance per media.

SRP requires, to the extent practicable, that surface water, sediment/wetland soil, and biological samples are co-located spatially and temporally.

6.8.3.2 Aqueous Samples

Samples shall be collected pursuant to N.J.A.C. 7:26E 3.6 and 4.4. Procedures in Section 6.8.3.1 above, shall be followed with the following additional requirements and considerations.

The number, locations, depths, equipment, procedure, and quality control/quality assurance protocol shall be specified in the site-specific field sampling plan after likely surface water migration pathways and discharge points have been identified. Aqueous samples should generally be discrete (not composited) and biased to detect contamination from the suspected sources under investigation (for example, point source discharges, non-point/sheet flow runoff, discharge of contaminated ground water to surface water body, landfill leachate seeps, etc.). Unless otherwise specified in the site-specific field sampling plan, surface water samples should be collected directly above sediments, near banks/other depositional areas where water current is slower and there is greater retention time for the surface water to accumulate contaminants from sediment. The site-specific field sampling plan must account for seasonal/short-term flow and water quality variation (i.e., dry vs. wet weather patterns), the need for determining flow-apportioned data, and contaminant characteristics (e.g., density, solubility). Sample volume must be adequate to allow for the measurement of both dissolved and total recoverable metals.

6.8.3.2.1 Flowing Non-Tidal Water Bodies

A minimum of two data sets (during critical, low flow conditions unless otherwise specified in the site-specific field sampling plan), are required from locations upgradient, downgradient, and adjacent to the known discharge point.

6.8.3.2.2 Standing Water Bodies

Inlet, outlet, and other areas appropriate for detecting worst-case contamination shall be targeted.

6.8.3.2.3 Tidal Water Bodies

Biased sampling with a minimum of two data sets (high and low tides) is required, unless otherwise specified in site-specific field sampling plan. There may be situations when two data sets acquired at consistent tidal stages (i.e., high or low tide) may be appropriate, and if used, must be justified in the site-specific field sampling plan. The tidal stage must be recorded.

6.8.3.2.4 Determination of Contaminated Ground Water Discharge Points

The discharge of contaminated ground water is a potential cause of continuing contaminant source to a surface water body. The determination of discharge/seep locations can be aided by the use of diffusion bags. Additional information available at:
https://www.nj.gov/dep/srp/guidance/#gw_discharge_sw.

6.8.3.3 Non-Aqueous Samples

Samples shall be collected pursuant to N.J.A.C. 7:26E 3.6 and NJDEP's *Ecological Evaluation Technical Guidance*. Procedures in Section 6.8.2.2 above, shall be followed, with the following additional requirements and considerations.

6.8.3.3.1 General

The number, locations, depths, equipment, procedure, and quality control/quality assurance protocol shall be specified in the site-specific field sampling plan after likely contaminant migration pathways to sediments and discharge points have been identified. Sediment/non-aqueous samples should generally be biased to detect contamination from the suspected sources under investigation (for example, point source discharges, non-point/sheet flow runoff, discharge of contaminated ground water to surface water body, landfill leachate seeps, etc.). Sampling the surficial interval (0-6" biotic zone), specified in Section 6.8.2.1 above is required. Contaminant delineation requirements may dictate the need for subsurface sediment sampling. It is recommended that subsurface sediments be collected with a coring device where water depths permit, to best ensure sample integrity. A ponar dredge (or equivalent device) can be used provided that measures are taken to limit loss of fine sediment during dredge recovery.

6.8.3.3.2 Flowing Non-Tidal Water Bodies

A minimum of two data sets (during critical, low flow conditions unless otherwise specified in the site-specific field sampling plan), of three samples are required from locations upgradient, downgradient, and adjacent to the known discharge point.

6.8.3.3.3 Standing Water Bodies

Inlet, outlet, and other areas appropriate for detecting worst-case contamination, shall be targeted areas.

6.8.3.3.4 Tidal Water Bodies

Biased sampling with a minimum of two data sets (high and low tides) is required, unless otherwise specified in site-specific field sampling plan. There may be situations when two data sets acquired at consistent tidal stages (i.e., high or low tide) may be appropriate, and if used, must be justified in the site-specific field sampling plan. The tidal stage must be recorded.

Non-aqueous samples must be collected from depositional areas (e.g., inter-tidal areas along the shoreline, which are often marked by emergent vegetation and muddy or organic bottoms, as well as mudflats, etc.).

6.9 Ground Water Sampling

6.9.1 Sampling Considerations

This section outlines NJDEP recommended procedures, equipment, and other considerations specific to the collection of representative ground water samples. In addition to this section, the reader should refer to the following FSPM chapters to attain a more complete understanding of the requirements associated with ground water sampling: Chapter 2, *Quality Assurance*; Chapter 5, *Sample Equipment*; Chapter 7, *Field Analytical Methods*; and Chapter 13, *Personnel Protection*. The reader is also directed to the SRP Guidance Library for other applicable guidance.

6.9.1.1 Sampling Equipment Disclaimer

The names and descriptions of specific products or brands used in this document are for illustrative or descriptive purposes only and do not constitute a recommendation or requirement for a specific product or company. The NJDEP is cognizant that the process of environmental sampling is an evolving science, and that new or redesigned sampling equipment is always coming to market. Therefore, it is not practical for this document to be all inclusive and stay up to date.

6.9.1.2 Implementation of NJDEP Recommended Practices

Now that Licensed Site Remedial Professionals (LSRPs) are responsible for making sure that NJDEP rules and guidance are followed and remedial objectives met, it is the responsibility of the LSRP to make sure that samples are collected with as little negative bias (factors that can underestimate parameter results) as possible. This is especially important with respect to the collection of samples for VOCs. Actions that can be taken to minimize negative bias include, but are not limited to:

- following manufacturer's instructions;
- using sampling equipment appropriate for the contaminant(s) tested; and
- implementing sampling procedures appropriate for the contaminant(s) tested.

When samples are collected using a procedure or device that is not specifically discussed in this manual, documentation on how the samples were collected should accompany the sampling results in any report submitted to the NJDEP that contains the sampling results. It is recommended that the requested documentation be included in the aforementioned reports as an appendix. The documentation should describe the sampling device and the process used during sample collection. Documentation should be as specific as possible and may include, but is not limited to:

- make and model of the sampling device;
- composition of the sampling device;
- volume of sampling device;
- depth in water column of sample collection;
- total volume of water purged prior to sample collection;
- residency time of sampling device in the water column;
- purge rate;
- maximum well draw-down produced prior to sample collection;
- manufacturer's instructions; and
- published studies about the sampling device.

Inappropriate application of a sampling device or failure to provide adequate supporting documentation to the NJDEP can result in rejection or downgrade (i.e., lower quality data not used for decision making) of the data by the NJDEP. Sample results generated by procedures or equipment that are "not recommended", or not "recommended" by the NJDEP for a specific type of compound (e.g., VOCs) may be rejected or viewed as screening quality data. The data generated from this action should be clearly identified as being collected by a "not recommended" action, or an action that is not "recommended". This label should be used any time the data are presented or referenced.

When professional judgement is used to justify the use of equipment, procedures, or applications that are listed as "not recommended" in this Field Sampling Procedures Manual, supporting technical or scientific justification should be submitted to the NJDEP in submittals that include the generated data. The justification language should be clearly identified in the submittal.

When implementing a "not recommended" action yields results over the GWQS, the data may be used as screening quality data only and should always be labelled as such wherever it is presented. When implementing a "not recommended" action yields results that are below the GWQS, the data may be rejected. In this scenario the data should not be used to:

- show that ground water quality exceedances do not exist, or no longer exist at the respective location;
- show that ground water quality delineation has been achieved; or
- show that a remedial goal has been met.

An example of this issue would be the use of a peristaltic pump to collect a sample for VOCs.

Sample results from a temporary well point can carry the same weight as sample results from a permanent monitoring well when the ground water samples from the temporary well points are collected using a method and equipment acceptable for collecting a similar sample from a permanent monitoring well.

6.9.1.3 Rules

Ground water sampling related to the investigation and remediation of contaminated sites is subject to the requirements outlined in the Technical Requirements for Site Remediation (N.J.A.C. 7:26E).

All ground -water monitoring wells shall be constructed in accordance with current NJDEP specifications found in the *Subsurface and Percolating Waters Act*, N.J.S.A. 58:4A-4.1 et seq., implemented through N.J.A.C. 7:9D (Well Construction and Maintenance; Sealing of Abandoned Well), and any NJDEP approved changes to these specifications including repeals, new rules, and amendments. The NJDEP's Bureau of Water Allocation and Well Permitting administers the above Act and oversees all related well licensing and permitting activities. Any deviation from the well construction or well decommissioning standards outlined in N.J.A.C. 7:9D must be approved by the Bureau of Water Allocation and Well Permitting prior to the initiation of said activities. Monitoring well specifications for Bedrock Formations, Unconsolidated Formations, and Confined Formations are provided in Appendix 6.1 of this chapter.

6.9.1.4 Policy

The NJDEP recommends the following guidelines:

1. During any groundwater field event prior groundwater sampling data (i.e., depth to water, well yield, LPH measurements) should be brought onsite.
2. When permanent ground water wells are installed for investigative or contamination delineation purposes, volume-averaged sampling should be used for the first two sampling events.
3. To address the concern for seasonal variation and work with the fact that analytical turnaround for ground water samples is typically around four weeks, the NJDEP recommends that the requested second sample be collected a minimum of 90 days after the first sample. The NJDEP does not view the collection of duplicate samples during the first sampling event as meeting the criteria for a second sample. That said, the responsible party always has the option to collect additional samples at a shorter timeframe, but these samples would not meet the policy recommendation stated above.
4. The NJDEP also recommends the use of volume averaged sampling for the sampling of temporary well points (where possible). Ground water purged from a temporary well point in an attempt to develop the well point can be used to meet the purge requirements associated with volume average sampling. The need to minimize drawdown in the well intake interval may dictate the rate at which water can be purged from the temporary well.
5. Additionally, when a permanent well is being sampled for well or site close-out purposes, (i.e., sampling results intended to be used to justify an aspect of site closure, or abandonment of a specific well), the well should be sampled using volume averaged sampling.
6. The aforementioned volume-averaged sampling policy does not apply when ground water sampling is limited to non-volatile turbidity sensitive parameters (e.g., metals, PCBs, total organic carbon, pesticides, and larger molecular weight SVOC compounds). In this situation sampling methods that may reduce sample turbidity (i.e., Low Flow Purge and Sampling (LFPS) or passive grab samples) may be used at any time.

7. The first two sampling rounds of each permanent well should also include the following "analyze immediately" water quality indicator parameters: pH, oxygen reduction potential (ORP), dissolved oxygen, and turbidity. This information should be recorded and included with the next ground water submittal. This field data should be used to help develop the site conceptual site model. Per N.J.A.C. 7:18, a certification for the analyze immediately parameters is required.
8. When electrically powered submersible pumps are used for the collection of ground water samples that will be analyzed for temperature sensitive compounds (e.g., VOCs), the water temperature of the discharge should be monitored and recorded. Temperature readings of the discharged water should be performed throughout the period of pump operation (i.e., beginning, middle, and just prior to sample collection). This information should be included in the field sampling report and the first document submitted to NJDEP that contains the sampling results.
9. Aside from the first two sampling events for each well, other ground water sampling methods may be used.
10. The first round of LFPS or passive sampling where the well contains greater than 5 feet of standing water in the well intake interval (e.g., 7 feet of standing water in a water table well with 10 feet of screen, or a well with 10 feet of well screen where the top of the well screen is below the water table) should include the collection of multiple samples collected at different well intake interval depths (i.e., vertical water quality profiling) to evaluate the presence of significant (i.e., greater than 20%) vertical changes in water quality across the well intake interval (i.e., stratification). At a minimum, one sample should be collected for every 5 feet of standing water column in the well intake interval (e.g., standing water column in well intake interval greater than 5' but less than 10' = 2 samples, standing water column in well intake interval is greater than 10' but less than 15' = 3 samples, etc.). For additional detail see language in Section 6.9.5 Vertical Profiling, Section 6.9.6.5.2 Low Flow Purging and Sampling, and Section 6.9.6.5.3 No Purge Sampling.

    Where the vertical assessment shows significant variation (i.e., greater than 20%) in water quality with depth, future LFPS or passive sampling should target the most contaminated interval.
11. LFPS or passive sampling may be performed, even when volume-averaged sampling produces higher contaminant concentrations, when routine sampling is being performed (e.g., fixed schedule or O&M sampling), and the sampling data will not be used to make regulatory decisions (e.g., determination of a ground water exceedance, basis for remedial action, or closeout of a well or site).

6.9.1.5 Background for NJDEP Recommendations

Variations in geology, hydrology, and contaminant behavior can result in the heterogeneous distribution and migration of contaminated ground water. This heterogeneity can result in different sampling methods producing significantly different sampling results from the same well.

Ground water sampling results submitted to NJDEP have shown that LFPS and passive sampling can produce sampling results that are:

- significantly lower than volume-averaged sampling,
- similar to volume-averaged sampling, and
- significantly higher than volume averaged sampling.

These different scenarios are likely due to the following factors:

- higher contaminant concentrations existing outside the footprint of the well;

- LNAPL/DNAPL behavior of the contaminant;
- vertical or cross-flow within the well intake interval; and
- stratification of the contamination in the aquifer material surrounding the well (usually due to permeability heterogeneity in the surrounding aquifer).

Where a change in sampling method results in concentration changes beyond normal analytical variation, the NJDEP prefers the sampling method that produces the highest contaminant concentration be used.

Ground water contaminant concentrations commonly decrease with time due to plume migration and monitored natural attenuation (MNA). This decrease is independent of any remedial action. Determining contaminant concentration differences related to sampling methodology becomes problematic with increasing time between the sampling events. Therefore, where VOCs are a concern and the well has never been tested by the traditional volume averaged purge method, the NJDEP recommends that a volume averaged sample also be collected during the next sampling event. The volume averaged sample should be collected immediately after the LFPS or passive sample is collected. Collecting samples using the two different sampling methods during the same sampling event will allow for a direct comparison of the data.

Acknowledging that different sampling methods may produce different sampling results in a given well, the NJDEP is requiring that tables of ground water sampling results (current and historical data) identify the method of sample collection for each well (per 7:26E1.5(d, e, f)). Where a common sampling method was used for a common sampling event, a footnote documenting the sampling type will suffice.

6.9.1.6 Guidance Documents

The NJDEP has developed several guidance documents that discuss ground water related issues. Relevant guidance documents in the SRP Guidance Library include, but are not limited to:

- Analytical Methods
- Commingled Plume Technical Guidance
- Ground Water SI/RI/RA
- In-Situ Remediation: Design Consideration and Performance Monitoring Technical Guidance
- Monitored Natural Attenuation
- Off-Site Source Ground Water Investigation Technical Guidance
- CEA Guidance
- Remedial Action Permit for Ground Water
- NJPDES Discharges to Ground Water Technical Manual for the Site Remediation Program

The guidance documents are available at: https://www.nj.gov/dep/srp/guidance/.

General guidance on the construction of temporary wells installed via direct push technology can be found in ASTM D6001-05(2012) *Standard Guide for Direct-Push Groundwater Sampling for Environmental Site Characterization*. Additional information for the construction of temporary wells can be found at:

Well Construction and Maintenance; Sealing of Abandoned Wells, N.J.A.C. 7:9D
https://www.nj.gov/dep/rules/rules/njac7_9d.pdf

https://clu-in.org/s.focus/c/pub/i/1207/

http://epa.gov/swerust1/pubs/esa-ch5.pdf

http://geoprobe.com

http://www.ams-samplers.com

6.9.1.7 Use of Combustion Power Sources When Sampling

Wells are frequently located far away from dedicated sources of electrical power, and many ground water sampling devices require electrical power. This situation has resulted in the frequent use of gasoline powered energy sources (e.g., gasoline powered generators or vehicles) during well sampling events. Gasoline contains many volatile compounds. The volatility of gasoline promotes its evaporation and production of vapors.

If ground water samples are being collected for VOC or SVOC analysis, and gasoline powered engines are used to power the sampling equipment, or bulk fuel containers are nearby, NJDEP recommends that an appropriate direct reading instrument (DRI), such as an FID or PID, be used as follows:

1) Before any well purging or sampling device is used, the area should be scanned for VOC vapors. This would include:
   a) the gasoline fill port of any nearby vehicle,
   b) the area where any nearby bulk full container is located and the location of any nearby vehicle where a bulk fuel container was recently transported; and
   c) the area around a gas generator once it is positioned, but prior to use. If VOC vapors are detected between the well/sampling location and the aforementioned areas, an assessment of the situation should be performed with consideration of movement of the vehicle, fuel container, or generator as appropriate. Generally, the way to address any detected VOC vapors from a vehicle, generator, or fuel container is to move the source of the VOCs downwind as far as logistically possible.
2) If there is a pre-existing well at the location, the well should be opened, and an assessment of well head space VOC vapors should be performed. If head space vapors are detected, a quick DRI scan of the well area should be performed to determine the horizontal extent of vapors dispersing from the well. This step is needed to help distinguish the extent of vapors emanating from the well and those emanating from other nearby sources.
3) Once the generator or vehicle is running, the area between the well and the combustion source should be monitored with the DRI. If readings from the DRI suggest that vapors from the combustion source are migrating toward the well, an assessment of the situation layout should be performed, and action taken to reduce vapor migration toward the well.

If a gasoline powered energy source is used, it should be located downwind of the sampling location as gasoline vapors diffuse easily. Use of a 50 to 100' heavy duty extension cord would facilitate placement of the generator a safe distance from the well. Placing a vehicle between the generator and the well will help to block generator exhaust and fuel vapors from the well area.

Where sampling equipment is being powered from a battery in a vehicle, it is recommended that the vehicle not be running when the sample is being collected. When an automotive battery is being used to power the sampling device, it is preferred that a stand-alone separate auto battery be used. This would negate the need to have a generator or vehicle close to the well.

If the well is being purged using a device that requires use of a gasoline powered energy source, but the device used to collect the actual sample does not (e.g., purging with submersible followed by sampling with a bailer), it is recommended that the gasoline powered energy source be turned off prior to collection of the ground water sample.

6.9.2 New Well Construction and Stabilization

Actions associated with the installation and development of monitoring wells can aerate volatile compounds, oxidize metals, and temporarily change the distribution of ground water contamination in and immediately around the well intake interval. The length of time needed for well conditions to become representative of aquifer conditions (the stabilization period) will vary depending on site hydrogeology, and the drilling and development methods used for during well installation. Ground water flow velocities (i.e., flushing rates) are generally slow, typically less than one foot per day.

For example, if a monitoring well is drilled, installed and developed such that a 14-foot radius around the well is impacted by drilling operations, and the natural ground water flow rate is one foot per day, it would take 14 days for unaffected ground water to reach the well. Sampling a monitoring well immediately after well development will generally not yield samples that are representative of the static ground water quality conditions at the horizontal and vertical location of the monitoring well's intake interval. Therefore, all newly constructed and developed, or redeveloped monitoring wells, should be allowed to stabilize and equilibrate with the aquifer prior to sampling. Industry guidelines usually call for a minimum of 14 days of stabilization time prior to sampling.

In tight or low yielding material the stabilization time may be significantly longer due to low ground water flow rates. The method used to install the well may also have a significant effect on how long it will take for the well to stabilize. Drilling using mud rotary, air rotary, or air percussion can result in drilling effects reaching significant distances into the formation. NJDEP's position on this issue is that the greater the time difference between well development and sampling, the greater the odds the well has had time to stabilize to pre-development conditions. Information on the hydrologic conditions of the well intake interval that were determined during well development should be used to estimate if a longer stabilization time period is necessary.

Underground Utility Markout Prior to Subsurface Intrusion

Before any intrusion into the subsurface can begin, consideration for underground utilities must be taken. To accomplish this, the New Jersey One Call underground utility markout service must be contacted at 1-800-272-1000, or 811. They must be provided the following information: Name of caller, title, phone number, fax number, best time to call back, contractor name, contractor address, name of facility/company work is being done for, their phone number and address, the dig location, municipality, street address, nearest intersection, type of work, extent of work, start and end date. More information can be obtained by going to their website at: http://www.nj1-call.org. The local municipality in which the work is being conducted must also be notified so they can identify and mark out any ancillary underground utilities falling under their jurisdiction.

6.9.2.1 Well Development

"Well development" means the removal of sands and drilling materials from the water bearing zones of any well to produce water that is free of visible sand and/or silt and increase its productivity (N.J.A.C. 7:9D). Following well construction, development of the well is necessary to remove drilling effects and construction residues remaining in the borehole or surrounding aquifer and restore the hydraulic properties of the formation immediately surrounding the well intake interval. The goal of well installation and development **is to construct a well that produces turbid-free water.**

It should be noted that well development water can be discharged to ground under a NJPDES permit by rule per N.J.A.C. 7:14A-7.5. More detailed language concerning this issue can be found in the Chapter 5 Section on Decontamination Procedures.

The NJDEP's preferred method of well development includes surging the well with a surge block followed by ground water extraction using a downhole submersible pump. Well development that

consists of pumping only results in ground water moving only in one direction (water flowing into the well via recharge). The movement of ground water in only a recharging direction can result in sand bridging within the sand pack. The development of sand bridging may reduce ground water flow into the well. In certain circumstances (e.g., formation with fine grained material, well intake interval that spans the water table, etc.) it may be necessary to surge-block within the well intake interval. When using a surge block within the well intake interval (screened interval for many wells), care should be taken not to damage the well screen. Certain well development techniques may result in fine-grained material (i.e., sediment) accumulating on the bottom of the well. It is important to remove this material prior to pumping water from the well as this material may damage any well pump used in the well, and it may lead to turbidity problems during future sampling events. The best method to remove sediment from the bottom of the well can vary with well construction and the characteristics of the aquifer. Sediment can be removed from the bottom of the well by:

- blowing it out of the well using pressurized air or potable water;
- vacuuming up the sediment using a double diaphragm or centrifugal pump sitting next to the well; or
- rapidly moving a bailer up and down near the bottom of the well such that the sediment gets trapped in the bailer above the check valve.

In low-yielding wells, or wells installed in tight formations, water may need to be added to the well to facilitate the development process. Where water is added to the well, the water shall be of potable quality (7:9D-2.11).

The processes of well drilling and or well development may result in the entire water column of the well becoming turbid. As water turbidity can result in samples having a positive bias for sediment sensitive parameters, it is important to remove all turbid water from the well during the well development process. To remove all the turbid water in the well, pumping of the entire water column (i.e., moving the pump to different depths in the water column while pumping water) may be needed. Only a licensed well driller can carry out well development in the state of New Jersey (N.J.A.C 7:9D-2.11(b)) ["Subsurface and Percolating Waters Act", N.J.S.A. 58:4A-4.1].

Since construction of monitoring wells is frequently viewed as merely an extension of water supply well construction techniques, the chosen well development technique is often not given appropriate weight in the overall well installation process. The goal of most monitoring wells is not water supply, but the detection, delineation, or monitoring of ground water quality. Consequently, monitoring wells are frequently installed in shallow, low yielding, fine grained material. To produce low turbidity samples in these situations, wells may need screens with thinner/smaller slots, finer grain sand pack, and more aggressive and extensive well development.

Site-specific subsurface conditions should be used to determine the appropriate well development technique. Many times, a combination of different well development techniques may be necessary to produce a properly developed monitoring well.

More often than not, a submersible pump is lowered into the well and pumping is continued until the well water clears. This one-directional, high-stress flow is not effective in proper well development since over-pumping causes sand grains to bridge openings in the formation and filter pack.

Once the well is put in service, agitation by pump cycling (dormancy followed by purging and sampling) can break down the bridges, causing reduced permeability and sand pumping. Effective development requires movement of water in both directions through the screen openings. Reversing flow during well development helps break down the sand bridges. See Figure 6.8.

A horizontal zone may exist that has a higher permeability than the rest of the screened interval. Once pumping is commenced, this zone preferentially recharges the well (i.e., yields most of the water), thus reducing the influence of pumping on other areas in the screened interval. This condition or *piping effect*, as it has sometimes been termed, can be minimized if more attention is given to

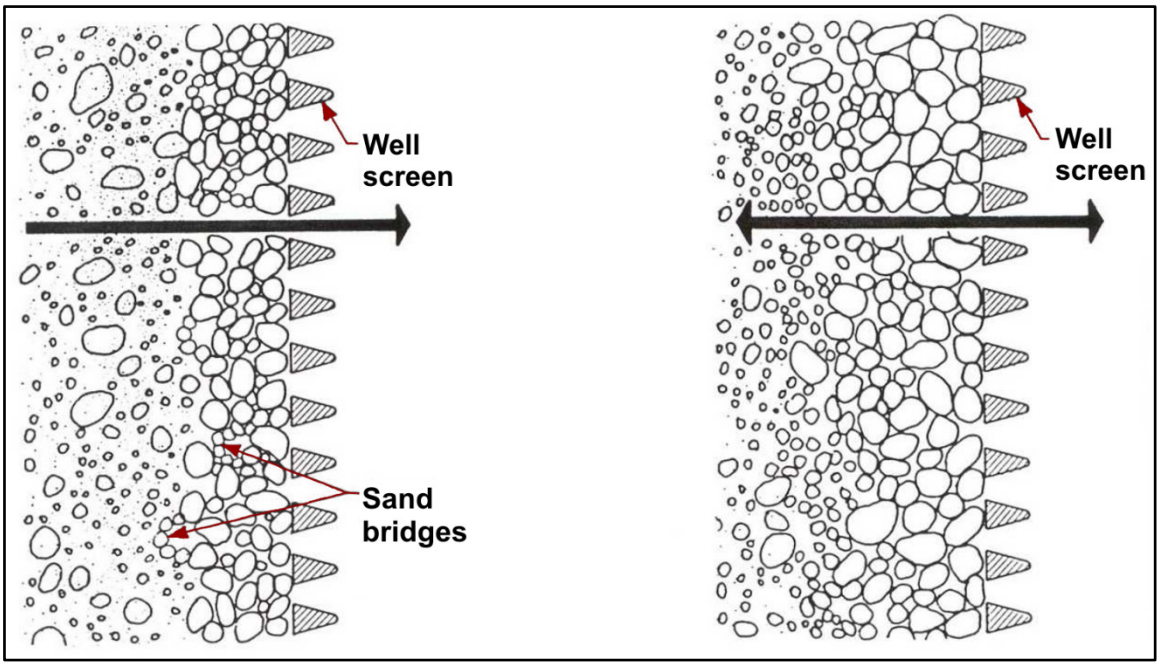


Figure 6.8. On the left, overpumping has formed sand bridges, which eventually collapse reducing the permeability of the filter pack. On the right, bi-directional flow-through the screen and filter pack removes the bridges (illustration published with permission of Johnson Screens, from *Groundwater and Wells*).

proper well development. As stated above, the most desirable technique causes the movement of water across the screen in two directions rather than the unidirectional movement afforded by using only a submersible pump. Use of a surge block in tandem with a pump may be one method to avoid the *piping effect* and create a monitoring well capable of delivering a better ground water sample.

6.9.2.2 Other Well Development Considerations

High-velocity air jetting or air-lift development methods may introduce air into the aquifer surrounding the monitoring well, and this air has the potential for altering ground water quality, particularly volatile organic compounds and dissolved oxygen. Since air may become entrapped in filter pack materials, these well development methods should be followed up by an extensive pumping of the well to remove any air entrapped in the surrounding formation.

Over-pumping of a monitoring well for development may draw ground water to the monitoring well from considerable distances and draw ground water of quality not representative of the horizontal and vertical location of the monitoring well, especially in anisotropic and/or bedrock aquifers.

Organic drilling fluid residues and inorganic residues of bentonite have been found to remain in and near wells, even after proper development, and these residues have been found to affect water quality, including chemical oxygen demand, for up to 100 days after completion of development. If organic drilling additives are used during the drilling of the well borehole, this information should be listed on the well log and record.

Non-aqueous phase liquid contaminants may be pushed away or drawn to a monitoring well location during development depending on the development method selected.

Construction-induced suspended sediment, which is not completely removed by development, may affect the quality of ground water samples obtained from the well.

Ground water pollution investigations in New Jersey often base expensive site related investigation and remedial action decisions on initial (first sampling event after construction) ground water sample analyses. Therefore, before ground water samples are collected, a complete understanding of the monitoring well's design, construction, development, and aquifer characteristics is necessary to properly interpret the analytical testing results.

6.9.3 Technical Considerations

Documenting Potential Contamination

When accessing wells (temporary or permanent) any information that is suggestive of groundwater contamination should be recorded and submitted to DEP in relevant documents. Examples include: 1) the presence of DNAPL or LNAPL product; 2) the presence of DNAPL or LNAPL sheens; 3) odors or vapors; 4) readings from organic vapor analyzers (e.g., PIDs and FIDs); and water appearance (e.g., color-lime green, grey, or texture-frothy, bubbly, etc.). The above information can be generated during well drilling, well development, well purging, well sampling, well sounding, and the collection of depth to groundwater measurements.

6.9.3.1 Documenting Depth of Sample Collection

Ground water samples are frequently collected from within the well intake interval (e.g., LFPS, Grab, Diffusion, etc.). That said, monitor well intake intervals can extend up to 25 feet. For submerged well intake intervals this represents a potential variation of 25' for the depth of sample collection. The sample depth within the well intake interval may be a function of the sampling goal (e.g., VI assessment, vertical profiling, evaluating the impact or presence of DNAPL, etc.). Acknowledging the fact that aquifer heterogeneity and contaminant type can promote a non-homogeneous vertical distribution of the contamination in the aquifer, NJDEP recommends that all samples collected from within the well intake interval (this includes all temporary well point samples) link the depth of the sampling device at the time of sample collection to the well sample ID (i.e., MW-1/22-24'). Pursuant to N.J.A.C. 7:26E 1.6, the depth listed must be relative to ground surface (i.e., bgs.) The sample depth must be included in the presentation of well sampling results on maps and tables (especially tables of historical sampling results). The NJDEP recommends identifying sample depth anytime a specific ground water sample is discussed in report text. For additional information on documenting sample depth see 7:26E 1.6.

6.9.3.2 Well Drawdown Issues

As many of the monitor wells installed in the environmental field are low yielding, historical efforts to purge the wells prior to sampling frequently resulted in significant drawdown of the water table in the well prior to sample collection, sometimes even to dryness. Drawdown in the well intake interval can result in ground water trickling down the sides of the well intake interval or associated sandpack. This action results in a degassing of VOCs and the oxidation of metals in reduced valence states from the ground water recharging the well, resulting in the collection of biased low samples (i.e., non-representative). The magnitude of VOC loss likely increases with increasing drawdown in the well intake interval and increasing volatility of the compound being sampled. The overall goal is to limit well drawdown in the well intake interval to **no more than 0.3 feet**. The NJDEP cannot overemphasize the importance of minimizing water level drawdown in the well intake interval. As mentioned throughout this sampling manual, there are measures that can be taken to address water level drawdown issues. Below is a list of actions that should be taken to minimize well drawdown:

1. Accurately determine well yield. An accurate determination of well yield should be performed during initial well development. If an accurate determination of well yield was not determined during well development, this information should be determined the next time the well is sampled. Well specific yield information should be included in well logs and tables of well as-built information. These tables should be a part of well sampling work plans and

submitted reports. Having tabulated well yield information in the work plan will help in the determination of an appropriate sampling device/method for each well in a given sampling event. The range in well yield for a given sampling episode may dictate the need for multiple well sampling devices or methods.

2. The yield information for each well being sampled should be known prior to sampling so that the sampling staff are aware of the yield limitations of each well being sampled. Use purging and sampling devices capable of operating at or below the well yield.
3. Use of purging and sampling pumps that can operate at variable speeds. A variable speed pump allows the sampler to adjust the pump discharge rate to match the well yield. Fixed rate pumps should only be used in wells where the discharge rate of the pump is at or below the well yield.
4. Any time a well is sampled using a device or method that involves purging the well (i.e., not passive or grab sampling), depth to water measurements should be collected throughout the purging and sampling process. The depth to water information collected during well purging should be recorded and included in field sampling reports. At a minimum, the respective field sampling report should be included with the first document submitted to NJDEP that presents the sampling results.
5. Well purging rates that limit well drawdown to no more than 0.3' in the well intake interval should be used. Tidal or other external influences on groundwater levels should be considered when assessing drawdown. In wells that screen the water table, limiting drawdown to 0.3' may be quite difficult which should be documented in the field notes if it occurs. In deeper wells where the top of the well intake interval is submerged, well drawdown to the top of the well intake interval is acceptable as that action should not result in any water trickling down the interior of the well intake interval. For submerged well intake intervals, ideally well drawdown should not extend below the upper depth of the well sandpack (per regulation, up to five feet of sandpack may be installed above the well screen). The amount of sandpack installed above the well screen should be identified on the table of well as-built information, which should be with the respective well sampling staff at the time of well sampling.

6.9.3.3 Measurement of Well Headspace Vapors

The installation of monitor wells frequently results in the development of a large airspace between the top of the water column and the top of the well casing. This area is commonly referred to as the well headspace. Organic vapors can accumulate in the headspace when ground water that is contaminated with volatile compounds intersects the well intake interval.

While not required, NJDEP recommends well vapor headspace measurements be collected and recorded at sites where VOCs are a concern, even if the VOCs are not attributable to the site being investigated. Headspace vapor measurements should be collected immediately after the well has been opened since the vapors will vent and diffuse into the atmosphere upon opening of the well. Vapor headspace measurements are commonly collected during episodes of well depth to water measurement associated with well sampling events. Refer to Chapter 4 for appropriate field monitoring equipment.

Headspace vapor readings are principally conducted for two reasons, 1) they provide a quick VOC assessment of the water quality in the well, and 2) the aforementioned assessment allows for workers accessing the wells to make informed decisions concerning health and safety considerations.

The magnitude of the vapor reading can be affected by several variables:

- In general, the higher the vapor pressure/volatility of the compound in the water, the easier it is for the compound to degas from the ground water, potentially leading to higher vapor readings;
- The higher the VOC compound concentration in the well water, the higher the equilibrium VOC concentration in the overlying air; and
- Lower barometric pressures facilitate degassing of volatile compounds from the ground water.

Head space measurements should be taken immediately, due to health and safety concerns. However, the accuracy of such measurements can be impacted by environmental considerations, such as temperature, humidity, and moisture. Opening the well will allow accumulated vapors in the well to escape which may bias the headspace vapor concentrations high or low. The collection of VOC headspace measurements does not need to be collected every time the well is accessed.

For additional information about the collection and use of well headspace VOC vapor readings, see the discussion of Direct Reading Instruments in Chapter 9.

6.9.3.4 Turbidity

Elevated turbidity can result in biased-high ground water sampling results for compounds that have a high affinity for soils. Ground water testing results for metals, PCBs, total organic carbon, pesticides, and some SVOCs can be affected by sample turbidity. This problem is most prevalent for the testing of total metals in ground water. NJDEP does not have a standard for turbidity in groundwater samples, however, high turbidity can cause skewed groundwater results. Therefore, it is recommended that turbidity be minimized so that a representative groundwater sample can be obtained.

Evaluation of ground water metals samples by the NJDEP is based on the results of acidified non-filtered samples. Because the samples are acidified, water turbidity can significantly affect the metals analysis results. To address this issue monitoring wells should be constructed and developed with the goal of producing low turbidity water. Ground water sampling for metals should be performed in such a manner that turbidity is minimized. To facilitate the review of ground water metals results, the NJDEP recommends that turbidity measurements be collected, recorded, and submitted for each ground water sample. The turbidity data should be incorporated into the tables of ground water metals results. The turbidity results should be incorporated into the tabulated data such that turbidity results can be correlated to a specific sample (i.e., well name, sampling date, depth, etc.).

The New Jersey Ground Water Quality Standards (GWQS) are based on "Total Metals" results. The data submitted to the NJDEP for comparison to the GWQS must be from a non-filtered ground water sample. This requirement attests to the importance of constructing and developing wells such that they produce water with low turbidities.

Ground water samples collected from temporary well points are frequently turbid because well points are usually not developed. If a well point is to be sampled for a sediment/turbidity sensitive parameter, the NJDEP recommends that the temporary well be developed prior to sample collection.

6.9.3.5 Assessment of Well Yield

Well yields can vary considerably. Well yields are largely dependent on the nature of the material the well is screened in and the screen length. Knowing the well yield and well diameter is a critical component of the well sampling plan as it allows for the determination of appropriate sampling/purging equipment. Differing well yields and well construction may necessitate bringing multiple pumps of different size and capacity to the site during a single ground water sampling event. Effort should be undertaken during post-installation well development to determine the maximum sustainable well yield that does not result in runaway drawdown. If this information was not

generated during well development, a separate well pumping event should be performed on the well to determine this information. Pumps that can only operate at purge rates above the yield of the well should not be used as the pumps may induce uncontrolled well drawdown. The uncontrolled drawdown may result in partial or complete exposure of the saturated well screen or open borehole interval and the subsequent cascading of recharging ground water down the sides of the well screen. Well purging should be a balance of inducing stress on the aquifer to draw formation water into the well and minimizing exposure of the saturated screen or open bedrock borehole interval.

6.9.3.6 Collection of Water Quality Indicator Parameters (WQIPs)

The 2012 revision of the Technical Requirements for Site Remediation (7:26E) does not require field measurement of water quality indicator parameters during the collection of each ground water sample. This change does not negate the need to collect water quality indicator parameters in the field when performing LFPS since that action is critical to the implementation of the method (i.e., stabilization of the water quality indicator parameters during well purging). Because ground water chemistry can affect the speciation and mobility of some metals (e.g., pH), as well as the biotic and abiotic degradation of organic contaminants (e.g., dissolved oxygen), it is the position of the NJDEP that determination of the water quality indicator parameters is important in understanding contaminant behavior at the site, and the development of an accurate Conceptual Site Model (CSM).

An early measurement of the water quality indicator parameters can provide valuable insight into the potential for contaminant degradation and mobility. The NJDEP recommends that the first two sampling rounds of all wells installed for remedial investigation or delineation purposes include field sampling for the water quality indicator parameters. The field collection of certain water quality indicator parameters may be required in a Permit-by-rule (PBR) or a Remedial Action Permit (RAP). The recommended sampling of certain water quality indicator parameters, as related to the performance monitoring of in-situ remedial actions is outlined in NJDEP's In-Situ Remediation Technical Guidance document (see chapters 5 & 6 of that document).

Examples of the information that can be determined by measuring water quality indicator parameters include:

- A high ground water pH may be a sign of a well grout problem if a cement-based grout is used in the well construction. A high ground water pH may also result from the discharge of caustic compounds. Conversely, a low ground water pH may result from the discharge of acidic compounds.
- A low dissolved oxygen concentration or oxidation reduction potential (ORP) may be an indicator of:
  - an area where the bioremediation of contamination has used up the available dissolved oxygen;
  - an area where a contaminant that can be aerobically degraded has migrated through; and
  - ground water that has been affected by septic systems or landfill leachate.
- An elevated ground water conductivity may be a sign of salt water intrusion or metals discharge. An elevated ground water conductivity may also occur when naturally occurring metals are mobilized through the development of low DO or low ORP conditions, such as commonly seen in landfill leachate.

6.9.3.7 Laboratory Certification Requirements for Water Quality Indicator Parameters (WQIPs)

Based on N.J.A.C. 7:18, any business generating analytical data for a NJDEP program must be certified by the New Jersey Office of Quality Assurance (OQA) for the parameters measured. This requirement applies to any laboratory or business (i.e., consultant) that is measuring the following

water quality indicator parameters in the field: pH, temperature, dissolved oxygen, turbidity, and conductivity. Any laboratory or business measuring the aforementioned indicator parameters in the field must be certified for those parameters through the New Jersey Environmental Laboratory Certification Program (NJ-ELCP) pursuant to N.J.A.C. 7:18. Environmental laboratory is defined as any laboratory, facility, consulting firm, government or private agency, business entity or other person that the NJDEP has authorized, pursuant to N.J.A.C. 7:18., to perform analysis in accordance with the procedures of a given analytical method using a particular technique as set forth in a certain methods reference document and to report the results from the analysis of environmental samples in compliance with a NJDEP regulatory program.

This requirement applies to all laboratories and businesses performing this activity, regardless of whether the equipment used is rented or owned. The laboratory certification is not related to the source or calibration certification of the equipment used to collect the water quality indicator parameters. For example, a company that conducts LFPS in NJ must still obtain and maintain laboratory certification even if water quality instruments are rented from an equipment vendor that also maintains laboratory certification.

Certification of a specific business will not be granted until all applicable requirements of N.J.A.C. 7:18 have been met. This includes having an acceptable on-site audit completed, the submittal of acceptable Standard Operating Procedures (SOPs), raw data records, and Proficiency Test results (https://www.nj.gov/dep/enforcement/oqa/docs/low_flow_letter.pdf). All certification documentation must accompany the instrument into the field and accompany all WQIP data submitted to the NJDEP.

6.9.3.8 Ground Water Sampling Plan

A sampling plan should be developed prior to conducting any ground water sampling event. When a ground water sampling event is being repeated with no change, (e.g., quarterly sampling for statistical assessment, remedial performance monitoring, long term Operation and Maintenance (O&M)/remedial action permit, etc.), the same sampling plan may be used and should be referenced. It is recommended that a copy of the pertinent sampling plan be available in the field during the sampling event.

The complexity or amount of detail in the sampling plan may vary depending on what task the sampling plan is developed for (e.g., Preliminary Assessment (PA), Site Investigation (SI), Remedial Design, Remedial System Efficiency, Remedial Performance, O&M, etc.), as that may determine the data quality objectives of the sampling event (e.g., contaminant detection, delineation, remediation, monitoring, etc.). The main issues that the sampling plan should address are:

- Why is the ground water being sampled (i.e., what is the objective of the sampling event)?
- What parameters are being targeted in the sampling event and what analytical methods will be used for their analysis? The target parameter behavior (e.g., LNAPL, DNAPL, turbidity sensitive, oxygen sensitive, volatility sensitive, etc.) should be considered when determining the most appropriate sampling depth and method.
- Documenting the locations being targeted for sampling:
  - Ground water sampling points of all types including, but not limited to, monitoring wells, temporary wells, potable wells, and direct-push drive points should be clearly identified on a map. In general, the greater the map detail the better.
  - The maps should contain a north arrow and a scale.
  - Where well clusters exist, an accurate spatial relationship of the wells should be shown, and the individual wells of each cluster should be clearly identified.
- How will the samples be collected (e.g., volume averaged, LFPS, PDB, etc.)?
  - To facilitate the actual sampling, the sampling plan should contain information on every well that is proposed for sampling. This information should include, but is not limited to,

well yield, well diameter, screened or open borehole interval (i.e., depth of top and bottom of well intake interval), and past ground water depths. When possible, proposed sample depths for each sampling point should be listed.

- For drive-point wells, sampling depths should be proposed based on surrounding information (e.g., elevations of nearby streams and wetlands, local topography, depth to water data from nearby wells, etc.) and may need to be adjusted based on actual findings.
- For wells with fixed in-well dedicated sampling equipment, the primary variables are purging rate and time, which can be used to calculate the total volume of water removed from the sampling point prior to sample collection.

6.9.3.8.1 Depth to Water Considerations

Seasonal Effects

While the hydrologic situation at every well is unique, in New Jersey it is common to see water table elevations rise in the Spring and drop in the Fall. This situation has been seen in multiple wells throughout the state where ground water elevation data have been plotted over large time spans. The highest ground water elevations typically occur in April-June with the lowest ground water elevations typically occurring in October - December.

The seasonal changes in the depth to water may result in seasonal changes in well water quality. Therefore, the NJDEP stresses the importance of collecting ground water samples during different times of the year. The changes in well water quality due to seasonal water level changes mainly affect wells that screen the water table (i.e., first water). Wells that are installed in deeper aquifers or confined aquifers generally do not have large variations in depth to water.

With respect to wells that have well intake intervals that intersect the water table, wells installed in locally low-lying areas generally have the least variation in ground water depth. These wells are commonly situated in hydrologic discharge areas where ground water is shallow and is flowing toward, and discharging to, nearby streams, rivers, ponds, or wetlands. The action of ground water flowing toward these areas acts to maintain stability in the ground water depth.

In contrast, wells installed in locally high areas may show significant seasonal changes in ground water depth. These wells are commonly located in hydrologic recharge areas where ground water migrates downward and away from the area. Depth to water in these areas is usually deeper than wells installed in low lying areas and may change by more than 10 feet seasonally. Depending on the length of the well intake interval installed below the water-table, a drop in the water-table may result in the well going dry during periods of drought.

Where soil contamination exists near the water table, a rise in the water table can result in the ground water coming in contact with the impacted soil. The resulting contact may lead to increases in ground water contaminant concentrations. When the water table drops, a decrease in ground water contaminant concentration may be observed.

In the springtime the water-table frequently rises. The rise in the water table may be due to:

- a thawing of the shallow ground allowing water to percolate down to the water table;
- infiltration of melting snow; and
- increased infiltration due to springtime rain events.

Contaminant concentrations in the aquifer may decrease due to the development of a clean water layer at the top of the aquifer, or contaminant dilution due to the added volume of clean water.

In areas of shallow ground water, a rise of the water-table surface can cause the water-table to come in contact with man-made subsurface infrastructure (e.g., buried storm water, sanitary sewer, gas,

electric, and communication lines [cable, telephone], building foundations and basements). It is common for the backfill around the buried infrastructure, both imported and reused excavated material, to have a higher hydraulic conductivity/permeability than the adjacent native material. Therefore, the backfill can act as a preferred pathway for ground water flow. Stormwater and sanitary sewer lines designed to operate under gravity flow conditions may allow for ground water to seep into the lines at pipe joints, causing the lines to act as small ground water recovery systems and bias local ground water flow toward the lines.

Based on the above situation, periods of higher ground water elevation can produce times where the distribution and movement of contaminated ground water is different than at periods of lower elevation. If site data indicate that this scenario could happen, or may be occurring, the NJDEP recommends that data logging well transducers be used to determine whether this situation is occurring. Given the large amount of subsurface infrastructure in New Jersey, this situation is more common than most people realize.

During late Summer and Fall the water table usually drops due to reduced recharge to the aquifer. The reduction in aquifer recharge may be due to:

- increased evaporation of soil moisture;
- increased water/soil moisture usage due to tree transpiration; and
- reduced rainfall.

Tidal Effects

In areas of tidally influenced ground water, sampling a well at high tide may produce different sampling results than sampling the same well at low tide. The potential for a difference in water quality increases the closer the well is to a tidally influenced body of water. Where the ground water is more contaminated than the nearby surface water, a rising tide may result in cleaner water being recharged into the aquifer. In this situation the water quality may improve by either displacement or dilution of the contaminated ground water near the well.

Accordingly, when assessing the results of a ground water sampling event collected in a tidally influenced area, it is important to know where a ground water sample was collected with respect to the lunar tide cycle.

It is important to determine as soon as possible if there is a potential for a well to be tidally influenced. This determination can easily be made by placing a water level transducer in the well for several days and then reviewing the data against local lunar tide charts. Depending on the transducer used, barometric pressure corrections may need to be performed to account for changes in ground water level due to changes in barometric pressure. Once it has been determined that a well is tidally influenced, that information should be clearly denoted whenever the data are presented.

To collect a representative ground water sample, the NJDEP recommends that wells samples be collected at their lowest water level in the tidal cycle (i.e., peak low tide). Wells closest to the tidal water body likely have the shortest time window for sampling due to a quicker response of the aquifer to changes in tide at that location.

At sites where multiple wells are tidally influenced it is recommended that actions be taken to assure that the tidally influenced wells are sampled at their lowest ground water level of the tide cycle. Such actions could include spreading the sampling event out over several days or using multiple sampling crews so that multiple wells are sampled simultaneously.

Where ground water sampling data show that changes in ground water quality appear to be affected by changes in ground water elevation, ground water sampling should be biased to times that appear to produce higher contaminant concentrations, and that point should be highlighted and discussed in NJDEP submissions.

6.9.3.9 Filtering Ground Water Samples

The NJDEP requires metals analysis to be performed on unfiltered ground water samples pursuant to the requirements of the Safe Drinking Water Act and the Clean Water Act. Additionally, standards for metals listed in the NJGWQS are based on total metals concentrations. Therefore, samples that are filtered must be labeled and identified as such (i.e., identified as filtered or dissolved fraction). The purpose is to obtain a representative sample as it actually occurs in the aquifer and to maintain consistency in sample handling for samples collected for both inorganic and organic analysis. Filtration is recommended only when dissolved metals (0.45 microns or smaller) are needed for evaluation against the NJDEP and USEPA surface water quality criteria for discharge of ground water to surface water or the determination of bioconcentration factor for aquatic life criteria. There are numerous articles in the scientific literature discussing the various problems with sample filtration relative to obtaining accurate, representative samples. Because the objectives of specific monitoring programs may vary, it is difficult to establish a standard for filtering that will apply to all situations.

Studies have also shown the ineffectiveness of bailers for collection of representative metals samples. Inconsistent operator usage, together with high purge rates can result in excessive turbidity. For these reasons, the Site Remediation Program recommends that low-flow purging and sampling (LFPS) methods be used to collect ground water samples for total metals analysis where ground water is turbid, rather than collecting samples for both total and dissolved metals analysis.

If a particular situation demands consideration of dissolved metals, both filtered and unfiltered samples should be collected for analysis. The relevant document under which the sampling is being conducted (i.e., NJPDES permit, Administrative Consent Order (ACO), or QAPP) should be consulted for monitoring requirements.

The differences obtained as a result of sample handling (filtered vs. non-filtered) are dependent on the type of association between the specific inorganic ion and the particulate matter. Studies show that when an inorganic ion is not closely associated with particulate matter (i.e., sodium), the differences between total and dissolved concentrations are small and random.

If filtering is to be performed, the sample should be split into two portions, one for filtration and the other for immediate preservation and subsequent analysis for total metals concentration. By analyzing the two fractions separately, differences between dissolved and total metals can be compared.

The decision whether to filter metal(s) samples should be based on the physical quality of the samples, the objective of the monitoring program and the policy of the NJDEP Program controlling the specific event. If filtering is allowed and is chosen, it is imperative that it be performed in a manner that will preserve the integrity of the sample and allow consistent reproduction of the technique.

6.9.3.9.1 Total Metals Sampling

Analyzing for total metals concentrations provides an element of consistency when comparing data and evaluating water quality. Also, both the National Primary Drinking Water Standards (NPDWS), the National Secondary Drinking Water Standards (NSDWS) for metals, and the New Jersey Ground Water Quality Standards for metals are based on total metals concentration. Any assessment of water quality should take this into account.

The difference between dissolved and total metals can be attributed to the absorption or adsorption of various metals species onto fine-grained particles (i.e., silt, clay). There has been a general assumption that water and soil are the only distinct constituents of an aquifer system; there is also a false assumption that water and completely solvated solutes are the only constituents of the system that are mobile. In fact, components of the solid phase in the colloidal size range may be mobile in subsurface environments. The colloidal state refers to a two-phase system in which one phase in a very finely divided state, (1 nm to 1000 nm particles), is dispersed in a second phase. In ground

water, colloidal particles are generally smaller than one micrometer (1 µm) in diameter. In unconsolidated aquifers, mobile colloids are usually those in the range of 0.1 to 1.0 µm. Since the clay fraction is defined as being two-micrometer (2 µm) and smaller, not all clay colloids are mobile. But even the larger clay particles have colloid-like properties.

There are two distinct types of colloidal matter, inorganic and organic, which exist in an intimate intermixture. The inorganic fraction is present almost exclusively as clay minerals of various kinds; the organic portion is represented by humus. These colloidal particles can adsorb organic and inorganic contaminants and stabilize them in the mobile phase of the aquifer.

Association of contaminants with mobile colloidal particles may enhance the transport of highly adsorbed pollutants, in contrast, deposition of colloidal particles in porous media may decrease permeability and reduce contaminant transport.

An objective of many sampling episodes is to assess water movement in an aquifer. Analysis of total metals concentrations are useful in the event of a change in aquifer conditions (i.e., pH decrease) that may cause adsorbed ions to become dissolved, thereby raising the total metals concentration.

6.9.3.9.2 Dissolved Metals Sampling

The effect of filtration on inorganic ion content must be considered. The aeration that occurs during filtration may increase the oxidation-reduction potential of the water through the introduction of oxygen. This, in turn, may change the valence state of some inorganic ions, which then could lead to the loss of dissolved analytes through precipitation (e.g., oxidation of ferrous ion to ferric ion after aeration). This same effect occurs during sample transport if the sample is not immediately preserved. For this reason, transport of the sample to a laboratory for subsequent filtration and preservation should not be done.

In addition, the filtering apparatus itself may adversely affect the quality of the sample. The filter paper and filter cake that accumulates during filtration could absorb dissolved metal ions resulting in lower than actual dissolved metals concentration in the filtrate. The filter itself may leach inorganic compounds, raising the metals concentration in the water sample. Also, the filtration apparatus and procedures, especially if performed by an unskilled technician, are an additional source of error potentially affecting the quality of the sample. In general, handling samples between collection and analysis should be minimized.

Note: If the results of metals analyses are to be reported as dissolved metals concentration, samples should be field filtered immediately after sampling and prior to preservation.

Note: The Safe Drinking Water Act program does not allow filtered samples.

6.9.3.9.3 Filtering Procedures for Dissolved Metals Analysis

A device made of polyethylene, polypropylene or borosilicate glass should be used when filtering ground water samples for metals. The apparatus should be pre-cleaned by rinsing with a 10% HNO3 solution, followed by a demonstrated analyte-free deionized water rinse, and should be cleaned in the same manner between samples. Also, a field blank should be collected for this apparatus.

When filtration is performed, aeriation effects on water chemistry dictate that it must be done immediately upon sample collection and prior to preservation. The sample should not be transported to the laboratory for filtration and preservation, nor should it be preserved prior to filtration. The sample should be collected, filtered, preserved, placed on ice and shipped to the laboratory for analysis.

Filtration is best accomplished using an in-line filter apparatus (NJDEP preferred method) equipped with an ungridded, 0.45-micron pore diameter filter. Filtering the sample at the point of discharge

minimizes sample handling and aeration of the water prior to sample collection.

If the use of an in-line filter is impractical, pressure filtration may be performed. Vacuum filtration of ground water samples, a third alternative, is the least preferred method of filtration. Care must be taken to strictly follow the manufacturer's recommended procedures if vacuum filtration is used. All filter apparatus should be laboratory cleaned and dedicated. Disposable filters are acceptable. Caution must be used when filtering samples as to prevent the "filter cake" from becoming too thick during filtration. After filtration, samples must be preserved immediately with nitric acid to a pH less than 2. While total metals analysis may bias the metals concentrations higher than what is actually mobile in ground water, filtering the sample may result in the sampling being biased low, depending on how the sample is filtered and what filter pore size is used.

6.9.4 Ground Water Level Measurements

Pursuant to N.J.A.C. 7:26E-3.5 and N.J.A.C. 7:26E-4.3, if ground water contamination is confirmed, a ground water investigation must be performed. The NJDEP cannot overstate the importance of collecting accurate depth to water measurements as these measurements are used to determine ground water flow direction, and ground water flow direction determines where investigative activities take place to evaluate the presence and extent of a contaminant plume. The flatter the hydraulic gradient and the closer the wells are to each other, the more important the readings be accurate. In the aforementioned cases, a measurement mistake of 0.05' can result in an incorrect ground water flow direction being calculated. Various measuring devices and methods can be used to determine well depths, depths to ground water, as well as product thickness, if any. It is recommended that initial ground water measurements be taken with one specific water level indicator instrument to remove a source of error. However, all ground water level measurements should be made from the same marked reference point at the top of the inner well casing. A surveyor licensed in New Jersey should mark the reference point. If no discernable survey mark is observed on the inner casing, the ground water level measurement should be read from the highest point of the inner casing. If no survey mark is observed on the inner casing, it should be noted with the ground water level data and the highest point of the casing should be marked for future reference.

Where the well casing is sealed with an expansion plug or airtight cap, once opened the well should be allowed to equilibrate with atmospheric pressures for several minutes before the depth to water measurement is taken. Measurements should be made three to four times to confirm the measurement. Each time a measurement is made it should be determined to the nearest one-hundredth of a foot (0.01') and the time of measurement should be recorded. All well measurements should be performed the same day, and prior to the evacuation of any wells which may influence ground water elevations in the area of the investigation. The key to accurate readings by any method is proper collection of the measurements. Measurements should be collected from the same survey point, and to avoid any procedural differences, preferably by the same person and measuring equipment. The following is a discussion of some of the equipment and techniques used to measure ground water levels in monitoring wells and piezometers. The use of steel tape to determine ground water levels is not recommended because the chalk or paste may impact ground water quality analyses and the lack of accuracy with this method.

Tidal Effects

Ground water levels in tidally influenced areas change with the lunar tide cycles. The rate and magnitude of the change may be influenced by such factors as: 1) proximity of the well to a tidally influenced body of water; 2) the permeability of the aquifer material connecting the well to the tidal water body; and 3) magnitude of the tidal cycle (i.e., some tides are higher than others).

Based on the above, water levels in a well installed in permeable material located close to a tidal water body will potentially change more, and faster, than a well installed in finer grained material farther from the tidal water body.

Contouring ground water elevation data derived from depth to water measurements collected during different portions of a tidal cycle will result in the production of ground water contour maps that are not

representative of actual flow conditions. To address this issue, depth to ground water measurements collected in tidal areas should be collected over a short as timeframe as possible (i.e., close to simultaneously) because the water levels are continuously changing. When sampling events are performed in tidally influenced areas, the NJDEP recommends that all the wells have their depth to water measurements collected before ground water sampling begins. Where a tidally influenced site contains enough wells that they cannot all be opened and measured in a short period of time, the NJDEP recommends that enough staff be used such that the depth to water measurements are collected in a short period of time. To document the interval over which the measurements were collected, the depth to water data should be presented with accompanying time listing.

To assess variation in ground water flow due to the tidal effects, it is recommended that multiple depth to water data sets be collected over a single tide cycle. This information is important in developing an accurate conceptual site model.

> The need to collect accurate ground water level measurements cannot be overstated as these measurements form the basis for the determination of ground water flow direction.

6.9.4.1 Electronic Ground Water Level Indicators

A commonly used device is the electronic ground water level indicator. These units usually have a cable divided into incremental measurements of 0.01 feet and two conductors forming a probe. When ground water is encountered, the circuit is completed, and a light or audible buzzer is activated. The depth to ground water is then measured from this point to the reference mark on the inner casing of the monitoring well. Occasionally, the cable may need to be raised and lowered a few times to obtain an accurate reading.

6.9.4.2 Helpful Hints

Ground water flow direction is used to determine the majority of ground water sample locations. Most ground water level measurements are collected from electronic ground water level indicators that can be affected by several factors. The following is a discussion of some helpful techniques that may be considered when using these units.

Most electronic ground water level indicators produce both an auditory and a visual response when the ground water surface is contacted. Weak batteries in these units frequently produce weak or gradual auditory and/or visual responses, making it difficult to accurately determine when the probe of the unit has come in contact with ground water. Therefore, it is recommended that electronic ground water level indicators be tested before they are brought out into the field. Note that electronic ground water level indicators will not respond to distilled water, so distilled water should not be used to test these units.

Wells that are not plumb may result in probe contact with the side of the well casing providing a false measurement. Once the probe has come in contact with ground water in the well, water may be trapped by capillary action between the probe and the well casing. If this happens, the unit may continue to signal even after the probe has been raised above the ground water surface. The deeper the well, the more likely this problem may occur. To correct this, the cable should be raised several feet above the water and shaken to remove water from the probe. A new ground water level measurement should then be collected. If the signals from the unit are not abrupt or reproducible, the probe may need to be reeled up to the surface and dried off before re-attempting another measurement. Accumulation of sediment, organic material, or floating debris on the probe may also result in gradual or non-reproducible readings.

Wells that are constructed with metal inner casings may lead to difficulties in collecting reproducible ground water level measurements because the inner sides of the well casing are conductive. In some

cases, a rubber grommet or metal centralizer may need to be placed on the probe so that the probe is not allowed to come in contact with the inner casing.

Ground water level measuring equipment should be properly decontaminated between wells and piezometers to avoid cross contamination. In certain circumstances, sensitive components of an interface probe may be compromised by the use of standard decontamination solvents.

Field Observations

Once a well has been located and properly identified, the field measurements listed below should be noted in field notes. Be certain that the proper well is being measured. The misidentification of a sampling point in the field will result in erroneous data that may result in incorrectly constructed contour maps.

Field measurements to be recorded:

- Diameter of protective outer casing
- Security and integrity of the well
- Well number & well permit number
- Inner diameter and construction material of the inner well casing
- Total depth of the well from the top of the inner casing or surveyor's mark, if present (measured to 0.01 foot)
- Depth from the top of the inner casing to ground water (recorded to 0.01-foot accuracy)
- Thickness of NAPL, if any
- Calculation of the linear feet of water in the well by subtracting the depth to ground water from the total depth of the well

It is recommended that information on the well(s) being measured be brought to the well location by the person collecting the depth to water measurement(s). The following information should be brought to the well location:

- A map showing the well location and listing the site-specific well name
- Information on the well diameter
- Information on the well depth
- Information on the well construction material
- Results of past/previous depth-to-water measurements

If the well casing does not have a clearly marked spot identifying where the depth-to-water measurement should be collected, the measurement should be collected from the highest point of the well casing.

> Ground water levels should be obtained from all wells prior to sampling the first well, thus avoiding interference problems. This also allows one to determine if any well, upon inspection, is damaged or may pose a problem prior to sampling a well.

6.9.4.3 Ground Water Level and Light Non-Aqueous Phase Liquid (LNAPL) Measurements

Monitoring points with Light Non-Aqueous Phase Liquids (LNAPLs) can pose a problem when measuring the level of ground water. Floating LNAPLs can depress the ground water level in a monitoring well or piezometer and distort the measurement. Therefore, the corrected depth (CDTW)

formula shown below should be applied to ground water level measurements in monitoring points where LNAPLs are present:

- CDTW = Static DTW – (PT x G)
- CDTW = Corrected Depth to Ground water
- DTW = Depth to Ground Water (Static)
- PT = Measured Product Thickness
- G = Specific Gravity (density of LNAPL/density of water)

When an LNAPL thickness is measured in a monitoring well it will usually exhibit an apparent thickness rather than an actual thickness. This apparent thickness is caused when LNAPL from within and above the capillary fringe migrates into the monitoring well causing the ground water level to become depressed below the surrounding capillary fringe area. As a result, LNAPL will continue to flow into the well until equilibrium is reached causing an apparent LNAPL thickness, which is greater than the actual thickness**.** In addition, LNAPL thickness can be affected by fluctuations in the water table. In some cases, an LNAPL's thickness may decrease when the water table rises, while its thickness increases as the water table drops. In other cases, fluctuating water tables may cause sudden appearances and disappearances of LNAPL layers.

Below are examples of some of the equipment and techniques used to measure ground water levels and/or NAPL thickness in monitoring wells. Since electronic ground water level indicators will not work in these situations, alternate methods must be used. Clear bottom-fill bailers and interface probes offer two alternatives.

Interface Probes

This probe uses an optical sensor to determine if the probe is in NAPL and a conductivity sensor to determine if the probe is in water. When using this probe, each phase can be measured independently, including Dense Non-aqueous Phase Liquids (DNAPLs) that may be present at the bottom of the well. The hydrocarbon/air interface reading should be measured first upon going from air to the LNAPL surface to prevent dripping hydrocarbons from enhancing the thickness reading. The hydrocarbon/water reading is best collected when moving up from the water to the hydrocarbon layer to prevent hydrocarbons from coating the conductivity probe which would also enhance the hydrocarbon thickness reading. Lowering the probe quickly through the LNAPL layer minimizes the contact time of the probe within the hydrocarbon phase.

The optical sensor on Interface Probes may become damaged if solvents are used to clean NAPL from the probes. Additionally, the optical sensor may become smeared when used to measure product, rendering pinpoint accuracy to an estimate at best. The battery located in the interface probe may affect the performance. A battery with a full charge is recommended for proper operation. In either case, close attention to decontamination procedures will improve accuracy, operational life and reduce the risk of cross contamination with other wells.

Clear Bailer

Once the surface level of the LNAPL layer has been determined, a clear bailer can be lowered into the well and slowly into the product, being careful not to submerge the entire bailer. The bailer is then raised out of the monitoring well, and the product thickness can be visually confirmed. Once the approximate product thickness is known, the depth to ground water may be determined. This method has inaccuracies because successful use of the bailer is dependent upon the expertise of the operator and assumes the check valve does not leak upon retrieval. Also, the narrow opening of a traditional bailer may not accurately obtain the LNAPL due to the viscosities associated with weathered LNAPL. A hydrocarbon bailer is suggested to be used to better recover the LNAPL. This bailer has a larger diameter opening on the bottom of the bailer to better provide a measurement of LNAPL thickness within a well. The images below are examples of the bailers used to visually provide a measurement

of LNAPL thickness within a well. See Figure 6.9.

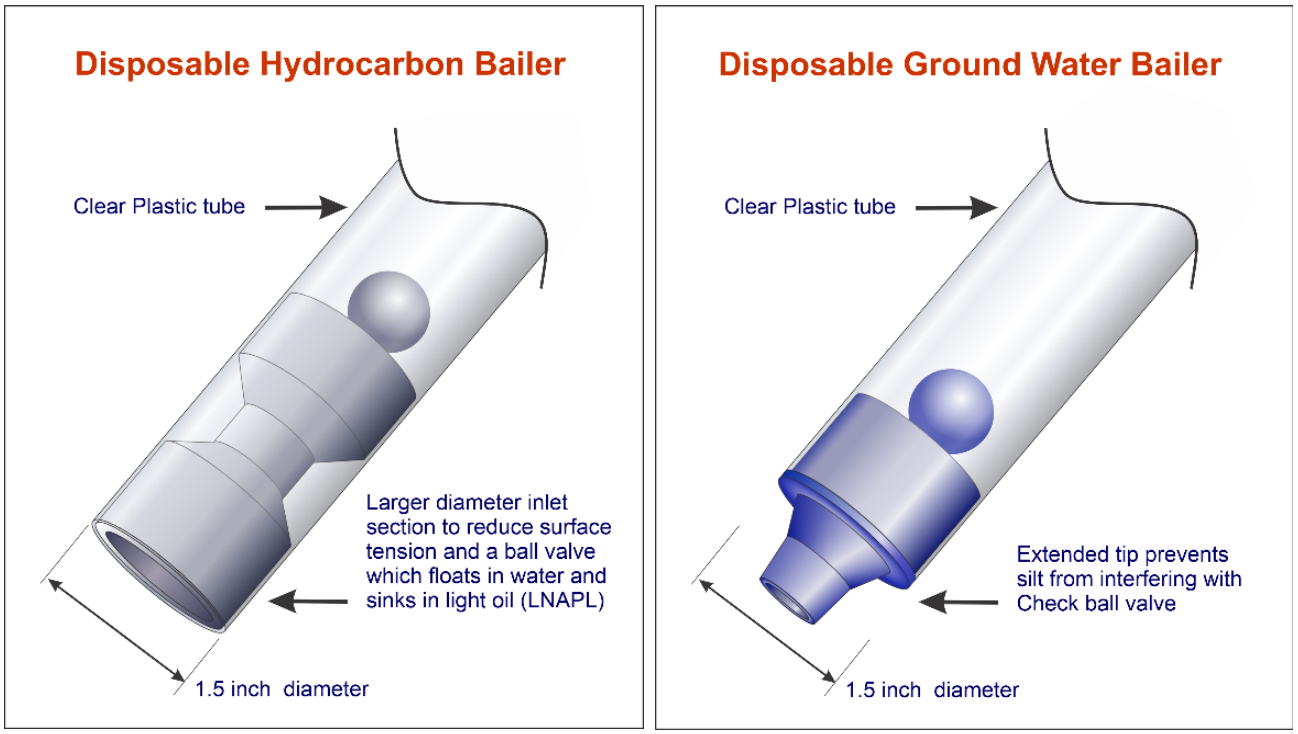


Figure 6.9. Wide Mouth Clear Hydrocarbon Bailer Traditional Clear Disposable Bailers

Illustrations by Paul Bauer

Steel Tape

The technique of putting chalk or water indicator paste on flexible steel measuring tapes to measure depth to water in wells has been around for a long time, and pre-dates the use of modern electronic water level indicators. This method is easier to perform if the depth to water in the well is roughly known, and the metal tape has a weight at the end. Several feet of the beginning of the metal tape are coated with chalk or water indicator paste. The tape is lowered into the well such that the marked section of the tape enters the ground water. The tape is then lowered into the well to a point where an easy number to read on the tape reaches the survey reference mark at the top of the well casing. The stop point is noted, and the tape is reeled up to the point where the tape is wet. The depth to water is the tape stop point noted at the top of the well casing minus the amount of tape that went below the water table. This method is generally not as accurate as newer electronic water level indicators that are usually incremented every 1/100 of a foot.

Given the complexity, and usually lower accuracy, of this method, the NJDEP recommends that this method only be used for depth to water screening measurements, or assessments of heavier LNAPL (e.g., #4 or #6 fuel oil) which might be too thick for most interface probes to produce accurate measurements. This method is not recommended for monitoring wells which may be sampled for metals.

6.9.5 Vertical Profiling

6.9.5.1 Vertical Profiling - Multiple Depth Sample Collection to Assess Contaminant Stratification

Contaminants do not always flow uniformly through an aquifer. Studies presented in Part 2 of the U.S.G.S. Water Resources Report, *User's Guide for Polyethylene- Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells,* demonstrated that it is not uncommon to see a high degree of contaminant concentration variability within a saturated well intake interval of 10 feet. Samples collected via methods such as LFPS, passive, or fixed depth dedicated equipment may represent a point sample from the saturated section of the well intake interval where the sampling device is positioned. Because of the potential small vertical zone monitored by these devices, LFPS, passive, and fixed depth sampling devices may not detect contaminant stratification within the well. If contaminants are migrating through the aquifer above or below the depth where a sample is proposed to be collected via LFPS, passive, or fixed depth sampling device, the contamination results may be biased low, or the contamination may not be picked up by the sampling device. Therefore, the sample may underrepresent the contaminant concentration at that location.

If LFPS, passive, or fixed depth sampling is to be used in a well, the NJDEP recommends that the well be vertically profiled **first** to determine if significant changes in water quality with depth exist in the subject well intake interval. It is recommended that the sampling method that will be used is also the method used to vertical profile. When ground water samples are collected from within the well intake interval the depth interval of the sampling device should be linked to the well sample (i.e., MW-1/22-24'). See Section 6.9.3.1 titled Depth of Sample Collection for more detail.

The collection of multiple vertically distinct samples within the well intake interval can provide valuable information on vertical stratification of contaminants within the surrounding aquifer. Vertically profiling the water quality within a well is needed to identify the presence of contaminant stratification and to document the most appropriate depth interval for future sample collection (usually the most contaminated) Identifying zones of preferential contaminant transport in an aquifer can be useful when modeling site contaminant fate and transport, refining the site conceptual model, or optimizing the performance of remedial systems.

In similarity to historical regulatory guidance on this issue, the NJDEP recommends that vertical profiling include the collection of one ground water sample per 5.00 feet of standing water in the well intake interval.

To determine the number of samples to collect, the standing column of water in the well intake interval should be measured and rounded up to the next five-foot interval (e.g., greater than 5' should have at least two samples collected, greater than 10' should have at least three samples, etc.). The calculated number of samples should be considered a minimum, the option to collect more samples is always available.

When deciding on what depth to collect the samples all available information should be considered, with a goal of biasing the sample depths to those that have the highest probability of producing the most contaminated sample. The biasing of ground water samples to locations and depths of suspected greatest concentration is required per N.J.A.C. 7:26E-3.5(a)1. This objective is then balanced with a secondary goal of assessing water quality throughout the water column within the well intake interval. Arguments used to bias a sampling depth may include, but are not limited to:

1. **Borehole information suggesting the presence of contamination** – The depth location of stained or colored soils observed during the advancement of site boreholes, and the depth location of soil/sediments samples that show impact should be used to bias ground water sample depths.

2. **Nature of the contamination (LNAPL or DNAPL)** – The density and solubility of ground water contaminants may affect where the contamination is detected. The contaminant may be biased toward the top of the water column, the base of the well, or a low permeability horizon/layer that intersects the well intake interval. Where the contamination properties lean toward LNAPL behavior, a sample should be biased toward the water table. Where the contamination properties lean toward DNAPL behavior, a sample should be biased toward the bottom of the well. Where a low permeability layer intersects the saturated section of a well screen, DNAPL behavior would dictate that sampling at the top of, or just above, the low permeable layer may be an appropriate location. It is worth noting that compounds that exhibit LNAPL or DNAPL behavior may not behave in that manner at lower concentrations. At lower concentrations, the movement of these compounds is frequently controlled by the flow of the ground water. The dominance of ground water flow controlling where the contaminant is likely to be found commonly increases as distance downgradient of the release location increases.

3. **The complexity of the geology** – Differences in the ability of geologic layers to transmit fluids can affect where and how the contaminated ground water migrates/moves within the subsurface. Ground water seeks the path of least resistance. A plume of contaminated ground water may preferentially migrate along a layer of higher permeability. Where layers or zones of geologic material exist that possess a slightly lower permeability, vertical movement of the contaminated ground water may be restricted from downward migration, or the contaminated ground water can be focused within a zone bounded by lower permeable layers, resulting in the contaminated ground water migrating within discrete layers. Identifying and mapping layers of lower permeability material may be able to be performed by use of downhole electrical conductivity logging or gamma logging. Zones with higher proportions of fine-grained material commonly have higher electrical conductivities and higher gamma emissions. The downhole gamma tool will detect the higher potassium content frequently associated with many clay minerals, but elevated potassium levels can also be found in felspar rich sands and gravels, so the gamma results should be compared against the boring geologic logs.

4. Where the ground water contamination exists vertically can sometimes be a function of distance from the source area. In the source area, where contamination concentrations are usually highest, the contamination may be vertically spread throughout the aquifer. This is especially common when the compound is of a DNAPL type and is released at a high concentration. As the heterogeneity of the aquifer increases, the ability of the contamination to migrate vertically decreases, and high concentrations may accumulate in zones where the permeability changes vertically. As the plume migrates downgradient, there is a tendency for the plume to become more focused in zones/layers having relatively higher permeability. The contamination in these zones of higher permeability may run out farther than the rest of the plume and may exist in higher concentrations than the surrounding zones. As such, the farther downgradient the plume migrates, the higher the probability that the ground water contamination is not distributed evenly throughout the aquifer.

5. **Variability in bedrock permeability** – Bedrock sample depths should be biased toward the zones where fractures have been identified. To identify fracture depths, the borehole should be logged with downhole geophysical equipment such as caliper tools and optical or acoustic televiewers. The high permeability differences frequently found within different zones of a bedrock borehole create the potential for vertical ground water movement within the well intake interval. To address this concern, NJDEP recommends that vertical profiling in open hole bedrock boreholes be conducted through the use of bedrock packers. Characteristics of the borehole geology should be used to bias the depths and intervals to set the packers. Where a bedrock well will be completed by installing a well screen and associated riser casing, the borehole packer testing should be completed, and the data reviewed prior to

installation of the well screen. To reduce the potential for cross-flow contamination within the open bedrock borehole prior to well completion, a blank FLUTe liner can be temporarily installed in the borehole, or the ground water samples collected from the packer testing can be analyzed using an expedited/shortened time frame.

When the information available does not provide technical support for a depth bias, the samples may be collected from the middle of each 5-foot interval (default sampling depth). An example of this situation would be the detection of 1,4-dioxane in a well graded sand that is vertically and horizontally homogeneous and does not show a significant vertical gradient in the aquifer. Having a density close to water and an infinite water miscibility, the distribution of the 1,4-dioxane should be largely controlled by dispersion, diffusion, and ground water flow.

To properly choose a sampling depth using the arguments provided above, post well installation assessment work may need to be performed via downhole logging tools (gamma, conductivity, etc.).

The rational for the chosen sampling depths should be discussed in the report that includes the respective sampling results.

Where profile results show variation in contaminant concentrations, future LFPS, passive or fixed depth samples should be collected from the interval(s) showing the highest contaminant concentration(s). If the profile results are similar (i.e., within 20%) throughout the water column, future LFPS, passive or fixed depth sample locations should be biased based on contaminant characteristics and the geology of the well intake interval. Although vertical profiling is only needed during the initial LFPS or passive sampling round, it should be recognized that for long-term monitoring applications the NJDEP recommends that it should be conducted periodically to document that conditions have not changed, and that the chosen sampling interval remains appropriate. The frequency of confirmation should be based on the length of the monitoring program, historic data trends, fluctuations in ground water elevation, contaminant distribution, and fate and transport factors.

6.9.5.2 Vertical Profiling Bedrock Open Holes Through the Use of Packer Sampling

Under certain circumstances, ground water contamination in bedrock aquifers can migrate to considerable depth. The presence of contaminants denser than water, high angle fractures, nearby pumping, or a downward hydrologic gradient within the aquifer can all facilitate the downward migration of contaminants. NJDEP regulation N.J.A.C. 7:9D limits monitor well open borehole or screen length to 25 feet. The NJDEP recommends that the borehole be packer tested before installation of the well screen where drilling of the bedrock indicates that the borehole has notable vertical differences in hydraulic conductivity, and completion of the bedrock well will involve the installation of a well screen and associated riser pipe. Once the well screen and associated sandpack are installed, isolating and testing of specific bedrock intervals cannot be accurately performed.

Open borehole packer testing can be broken down into two different applications. One application involves the packer testing of open borehole intervals associated with the initial drilling of a large length of bedrock borehole. This application is usually performed with the goal of defining the distribution of ground water contamination within the borehole to provide data that will be used to decide at what depth to complete the well. The other application involves the packer testing of an existing open borehole bedrock well for the purpose of vertically profiling the well intake interval prior to the use of LFPS, or passive sampling techniques.

If the packers are not well seated against the borehole, water will leak around the packer during the test. To determine if leakage around the packer(s) is occurring, transducers should be placed above and below each packer. If the water level above the upper packer or below the lower packer drops while water is being pumped from within the packered interval, it is likely that water leakage around the packer is occurring. Packers used in cored bedrock borehole are less likely to develop leakage problems due to the uniformity and smoothness of the borehole. Where the borehole intersects vertical or high angle fractures, effort should be undertaken to not set/inflate the borehole packer at

the same depth as the fracture. Leakage of water around the packer, via the fracture, is likely to occur when a packer is set against bedrock containing fractures.

The name of the collected ground water sample should reflect the location and the depth interval the sample represents (e.g., MW-13D /42-47'). For additional related information see the Chapter 5 section on Packers.

6.9.5.3 Initial Bedrock Borehole Assessment

To help determine the vertical extent of ground water contamination in bedrock aquifers, bedrock boreholes are frequently drilled to lengths much greater than 25', packer tested, and then completed as a well with a well intake interval of 25' or less, is the NJDEP recommends that at least three to five volumes of the packered interval, if possible, be purged before the sample is collected when ground water samples are to be collected from a newly installed borehole. The goal of this purging is to remove ground water from the packered interval and surrounding formation that could have been aerated by the drilling process, and to remove any ground water that has migrated via cross-well migration during the period from when the well was drilled to when the well was packer tested. The vertical resolution of the ground water quantity and quality within the open borehole is based on the length of the bedrock borehole interval tested.

Packer testing of the initial bedrock borehole is usually conducted using one of two different methods. The first method includes advancing the borehole to a predetermined total depth. This method requires the packer assembly to contain an upper and a lower packer. Once the borehole has been completed to total depth, information generated from the drilling and logging of the borehole should be used to develop/bias bedrock intervals for packer testing. The information used to determine the bedrock intervals to packer test should include information obtained during the drilling of the borehole (e.g., changes in borehole ground water yield, changes in drilling rate, the occurrence of weathered zones, the presence of odors or sheens, the occurrence of elevated PID/FID readings, etc.), and information obtained by post borehole installation downhole logging (e.g., downhole caliper, resistivity, camera, or acoustic televiewer, etc.).

The second method involves alternating the advancement of the borehole with the packer testing of the borehole interval that was just installed. In this method a single packer is used to set the top of the packered interval, and the bottom of the borehole acts as the bottom of the packered interval. The packered interval usually consists of the newly drilled bottom section of the bedrock borehole and may represent 5 to 20' of the bottom of the borehole. Since the packer testing is alternating with advancement of the borehole, the packered intervals are frequently predetermined, but can be changed in the field based on the bedrock conditions encountered during drilling. This method is less prone to packer leakage because only one packer is used. This method is usually slower and more expensive than testing the borehole after the borehole is advanced to total depth. For additional related information see the Chapter 5 section on packers.

6.9.5.4 Assessment of Existing Open Hole Bedrock Well

The NJDEP recommends that existing open boreholes with a saturated open bedrock borehole interval greater than 5' be vertically profiled before being sampled using LFPS or a passive sampling method. While logistically a bedrock open hole could easily be evaluated using several LFPS or passive samples collected at different depths in the open borehole, the NJDEP preferred method of bedrock open borehole vertical profiling is the use of packer sampling. NJDEP prefers the use of packer sampling because packers have the ability to isolate specific fractures and bedrock zones, increasing the likelihood that the water quality of the sample represents the water quality of the packered interval.

In similarity to the guidance on the vertical profiling of wells in unconsolidated material, the general guidance would be one packer sample per every five feet of saturated bedrock open hole. Given the

potential for large differences in borehole hydraulic conductivity due to individual fractures or bedding planes, adjustment, or variation within the placement of the packered zones may be appropriate. A discussion explaining the basis for the chosen packered intervals should be included in reports that contain the sample results.

Pumping of water from within a packered interval can be used to estimate yield of the packered zone, and the analysis of ground water samples collected from each packered zone can be used to determine the vertical heterogeneity of the ground water contamination. To reduce potential artifacts of cross fracture flow within the borehole, the NJDEP recommends the purging of a minimum of three packer volumes before the sample is collected. Ideally, the more water purged from the packered zone, the more representative the sample will be. For additional related information see the Chapter 5 section on Packers.

6.9.5.5 Vertical Flow Within the Well

In some instances, vertical flow can be present within the well. This condition is more common in bedrock aquifers, but it can also be present in unconsolidated formations where the screened interval of the well intersects zones of differing hydraulic head. It must also be recognized that the potential for vertical flow within the well increases as the length of well screen or open borehole increases. If vertical flow is occurring in a well, the contaminant concentration in a given sample will be more representative of the water flowing vertically past it from another portion of the aquifer rather than from the adjacent formation. If vertical profiling is conducted in a well and the results show all samples to have similar concentrations regardless of depth, the presence of vertical flow within the well should be suspected. In these cases, it is important to know where the water is coming into the well, and where it is leaving the well. This can be accomplished by using a borehole heat pulse flow meter to take readings at multiple intervals within the well screen or open borehole. These data can be used in conjunction with vertical profiling to provide a better understanding of contaminant distribution within the aquifer. It will also help to ensure that generated data are not misinterpreted. If vertical flow is suspected in an unconsolidated well having greater than 10 feet of well screen, flow testing should be conducted. The recommended frequency of flow measurements along the screened interval or open borehole is one measurement every 2 feet.

6.9.6 Sample Collection

6.9.6.1 Sampling Order

When several wells of known contamination will be sampled, it is recommended that the least contaminated well be sampled first, and the wells then sampled in order of increasing contaminant concentrations. This recommendation is made to reduce the potential for cross-contamination between wells. Monitoring wellhead vapor readings with photo- or flame- ionization detectors can aid in determining sample order by providing information on contaminant levels in the wells.

Outlined below is a suggested order of compound specific sampling. The actual sampling order can be changed to accommodate well specific conditions.

With respect to the order in which analytical samples are collected from a given well, several factors should be considered. Are the compounds being sampled: volatile; sensitive to oxygen exposure; and/or turbidity sensitive?

Volatility sensitivity - Purging a well at a higher pump rate may shorten sampling time and help evacuate well-water turbidity, but it may also induce unwanted water level drawdown in the well and make it difficult to fill small sample vials. Accordingly, it may be prudent to sample for volatile compounds at a reduced pumping rate so that flow into the sample vials occurs in a controlled laminar flow. In low-yielding wells it may also be prudent to sample for volatiles compounds early, so they are sampled before significant water level drawdown occurs. Compounds that are volatile should not

be sampled during periods of significant well drawdown.

Oxygen sensitivity –Some compounds can be affected by exposure to atmospheric oxygen. Exposure to atmospheric oxygen can occur when water drawdown in the well intake interval occurs and recharge water cascades down the open borehole, well screen, or well sandpack. Exposure to atmospheric conditions can volatilize chlorinated solvents and BTEX, facilitate bioremediation of BTEX, and oxidize and precipitate some metals (e.g., iron, manganese). Compounds that are oxygen sensitive should not be sampled during periods of significant well drawdown.

Turbidity sensitivity - Some compounds are sensitive to water turbidity and should be sampled under conditions where the purge water has its lowest turbidity, irrespective of purge rate (e.g., total metals, PCBs, and total organic carbon). Increasing or decreasing purging rates may trigger increases in turbidity levels.

Compounds like bacteria, cyanide, and chloride are generally not sensitive to well drawdown, turbidity, or oxygen, and are frequently sampled last. These compounds could be sampled at any time.

A suggested order for the collection of various analytical samples is listed below**:

1. Volatile organic compounds (VOCs)
2. Purgeable organic compounds (POC)
3. Purgeable organic halogens (POX)
4. Total organic halogens (TOX)
5. Total organic carbon (TOC)
6. Base neutrals/acid extractables
7. TPHC/EPH/Oil & Grease
8. PCBs/pesticides
9. Total metals
10. Dissolved metals
11. Phenols
12. Cyanide
13. Sulfate and chloride
14. Turbidity
15. Nitrate and ammonia
16. Preserved inorganics
17. Radionuclides
18. Non-preserved inorganics
19. Bacteria

****PFAS (Per and Poly Fluorinated Alkyl Substances) -** PFAS represent a large class of compounds. Some are volatile, some are not. Some are turbidity sensitive; some may not be. Early research suggests that PFAS adsorption to sediment can be affected by many factors (e.g., PFAS type, water chemistry such as calcium content and pH, anionic exchange capacity and iron oxide content of the sediment, total organic carbon, etc.).

Given the variation in behavior within this group of compounds, it is difficult to define a generalized position for these compounds in the sampling order. The most appropriate sampling position may depend on the PFAS of concern.

The principal concern relating to PFAS sampling is cross-contamination during the sampling episode from things like sticky notes, Fluoropolymer (e.g., Teflon) containing tubing,

Fluoropolymer lined septa caps on VOA vials, or weather-proof field notebooks that may contain PFAS. PFAS from these items could be transferred to the sampler's gloves or sample bottles during the sampling process. Therefore, gloves should be changed immediately prior to PFAS sampling and care should be taken not to touch anything that would impact the sample. To limit the potential for PFAS transfer during sampling it may be beneficial to sample for PFAS compounds as early as possible in the sampling process.

Attention to decontamination procedures should be strictly followed.

Waterproof gloves (e.g., latex, nitrile, etc.) should be worn and changed between each sample location. For further details about glove use for specific compounds see Chapter 13. Clean sampling equipment and any other objects entering the well should not be allowed to contact the ground or any other potentially contaminated surfaces (i.e., gasoline-fueled generators). If this should occur, that item should not be placed in the well or utilized for sampling.

For specific information on sampling procedures with a particular pump, or other piece of sampling equipment, refer to Chapter 5.

6.9.6.2 Sampling of Sentinel Wells

Sentinel wells are typically clean downgradient wells that are located to detect the migrating front of a contaminant plume. With no contamination detected in the well, there is uncertainty associated with the depth at which a contaminant front will arrive at the well. Impact of a sentinel well changes the status of the well and alerts responsible parties and regulators as to the presence/movement of the contaminant plume closer to the downgradient receptor. To address this concern, it is recommended by the NJDEP that the sampling of sentinel wells be performed in only two different ways, volume averaged sampling or vertically profiled. If the well is to be vertically profiled it should be performed following the procedures for vertically profiling water quality in a well intake interval outlined in this guidance document. The recommendation for vertically profiling of sentinel wells applies to all other sampling methods other than volume averaged sampling (e.g., LFPS, passive sampling, fixed depth dedicated sampling device, grab sampling, etc.).

6.9.6.3 Sampling Equipment Selection

To minimize the amount of equipment going in and out of the well, and to minimize handling of the ground water by the samplers, the NJDEP recommends purging and sampling the well using the same positive displacement variable speed pump and tubing. This procedure would eliminate use of an additional sampling device (e.g., bailer), and assure the depth in the well where the sample was collected from.

The equipment and means utilized for specific ground water sample collection can vary greatly depending on the following factors:

- Type of well (e.g., monitor well, supply well, temporary well point)
- Depth of well
- Diameter of well casing
- Depth to water
- Contaminants likely to be encountered
- Analytes of interest
- Length of open borehole (bedrock well)
- Screen length, slot size, and type
- Zones of infiltration
- Expected recharge rate of well

- Sampling objectives (e.g., field screening, remedial investigation, quarterly sampling, long term monitoring/O&M, No Further Action (NFA) closeout, Monitored Natural Attenuation (MNA) sampling, etc.)

Table 6.13 Pump Types and Uses

Category	Type	Example	Low-Flow Purging and Sampling	Volume Averaged Purging only	Volume Averaged Purging and Sampling	Temporary Wells Points or Direct Push
Bailers	Top Fill Bailer	Stainless Steel	No	Yes	No	No
	Bottom Fill Bailer	Polyethylene, Teflon, Teflon-Lined	No	Yes	Yes	Yes
Inertial-Lift Pumps	Manual Inertial Pump	Check/Foot Valve and Tubing	No	Yes	No	Yes
	Inertial Pump	Waterra	No	Yes	No	Yes
Suction-Lift Pumps	Surface Centrifugal	Grundfos	No	Yes	No	No
	Double Diaphragm Pump	Godwin Pumps	No	Yes	No	No
	Peristaltic pump[1]	GeoPump	Yes[2]	Yes	Yes	Yes
Submersible Pneumatic Pumps	Bladder pump	SamplePro	Yes	Yes	Yes	Yes
	Reciprocating Piston pump	Bennett pump	No	Yes	Yes	No
Submersible Electric Pumps	Submersible Centrifugal pump	Plastic Submersible Centrifugal Pump (e.g., Whale Pump)[3]	No	Yes	No	No
		Redi-Flo, Monsoon Pump	Yes	Yes	Yes	No
	Gear Pump	Fultz pump				
	Progressive Cavity Pump	Flowrox				
	Helical-Rotor Pump	Keck				

[1] A peristaltic pump has a depth limitation of approximately 25 feet.
[2] A peristaltic pump is not recommended for sampling volatile organic compounds and certain semi-volatile organic compounds.
[3] Plastic submersible centrifugal pumps used for purging should be adequately decontaminated.

Notes:

- Flow rates from non-variable speed pumps can be controlled with a valve; however, reducing the flow rate with a valve may cause a pressure drop to occur on the downstream side of the valve. The pressure drop may cause a loss of VOCs. The greater the restriction, the greater the potential for VOC loss. To properly assess the potential for VOC loss, the unrestricted pumping rate should be measured and recorded on the well purging report. As such, variable speed pumps are preferable.
- Pump construction material should be appropriate for analytical parameters.
- It is recommended that manufacturers' pump manuals are referenced for additional operation limitations.
- Manufacturer or model names in the Example column do not imply endorsement.

6.9.6.3.1 Use of Polyethylene Tubing for Sample Collection.

Multiple studies comparing the adsorption-desorption capacity of PTFE (i.e., Teflon®) tubing and polyethylene tubing have shown that the adsorption-desorption capacity of Teflon tubing is lower than polyethylene. The studies form the basis for the regulatory preference for the use of Teflon or Teflon-lined tubing for the collection of ground water samples. One exception to this recommendation is the use of polyethylene bladders in bladder pumps. To have enough strength to push the ground water up and out of the well, yet flexible enough to collapse and expand, most bladder pump bladders are made of LDPE. Improvements in PTFE bladders may have addressed the aforementioned issue. Please consult the manufacturer for specifics. While the NJDEP preference in bladder composition is Teflon> HDPE> LDPE, NJDEP is aware that LDPE bladders are the most common due to their mechanical advantages, and that HDPE and Teflon bladders may not available by all manufactures. To address this concern, it is requested that the composition of the bladder be recorded on the field sampling sheet.

The NJDEP is aware that the cost of polyethylene tubing is significantly less than Teflon or Teflon-lined tubing. To address the cost benefit of using polyethylene tubing, the NJDEP is allowing the use of polyethylene tubing, as an option, for ground water sampling at locations where the ground water contaminants, and their associated concentrations/exceedances have already been documented. Polyethylene tubing may be considered for use in sampling locations where the testing results will not be used to make regulatory decisions based on the absence of a ground water quality exceedance (e.g., sampling associated with a permit by rule or remedial action permit (non-closure data), O&M sampling, quarterly sampling collected for MNA assessment, assessment of remedial actions, etc.). So, within the limitations discussed earlier in this chapter, the choice of tubing composition may be based on the goal/purpose of the sampling.

Factors affecting the amount of compound removed from the water by interaction with the tubing include compound concentration in the water, temperature of the tubing, and tubing length. The percentage of compound removed from the water increases with increasing tubing temperature and tubing length. The percentage of compound removed from the water by adsorption onto the tubing decreases as contaminant concentration increases, so the negative bias imparted by the tubing increases at lower contaminant concentrations. In general, rigid tubing adsorbs less contamination than softer, more flexible tubing. Based on the above, the potential for negative sampling bias increases with:

- increasing tubing length;
- increasing tubing temperature;
- decreasing contaminant concentration; and
- increasing flexibility/softness of the tubing.

If polyethylene is used,

- it should be kept cold as tubing adsorptive capability/capacity increases with increasing tubing temperature,
- tubing length should be as short as possible when collecting the sample,
- rigid HDPE is preferred due to its lower adsorption-desorption characteristics, and
- run as much ground water through the tubing as possible before the sample is collected, this will increase the potential for the contaminants in the water to reach equilibration with the tubing.

If polyethylene tubing is going to be used in the sampling setup to collect a ground water sample, the NJDEP recommends that HDPE (see Table 6.14) be used over LDPE due to its lower adsorption-desorption characteristics.

The NJDEP recommends that Teflon or Teflon-lined tubing be used, in sampling situations where the ground water testing results may be used to make regulatory decisions. In similarity to the recommendations for the use of traditional volume averaged ground water sampling, the NJDEP recommends that Teflon or Teflon-lined tubing be used during:

- the first two rounds of permanent well sampling,
- temporary well point sampling for delineation purposes,
- temporary well point sampling of any area where the goal of the sampling is to determine if there is a ground water quality exceedance, and
- any ground water sampling used for the close-out of a well or site area.

When sampling for PFAS, the use of Teflon or Teflon-lined tubing is not recommended. The use of HDPE tubing is recommended for PFAS. This recommendation only applies to the equipment used for the collection of the PFAS sample. Sampling for PFAS compounds has its own protocol. Additional PFAS information can be found on the NJDEP emerging contaminants website available at: https://www.state.nj.us/dep/srp/emerging-contaminants/.

The issue of sampling material adsorption/desorption becomes more important the lower the contaminant concentration, and the lower the pertinent GWQS concentration. At low ground water concentrations and GWQS's, the effect of adsorption or desorption could change the interpretation of the data (i.e., exceedance vs no exceedance). This issue should be discussed in documents where HDPE or LDPE is used, and the sampling data are presented.

Table 6.14 – Ground Water Sampling Tubing		
Type	**Description**	**Preferred Use**
PTFE (polytetrafluoroethylene) (e.g., Teflon®) tubing	A transparent, chemically inert and non-toxic material that features unmatched chemical resistance and a surface that facilitates the flow.	Teflon tubing is preferred when sampling for VOCs, due to its very low absorption rate.
TLPE (Teflon Lined Polyethylene)	Polyethylene tubing with a thin internal lining of Teflon for added chemical compatibility on the inside surface where water contacts tubing.	Similar uses to PTFE, but TLPE is less expensive.
HDPE (High Density Polyethylene)	A thermoplastic made from the monomer ethylene. Molecularly structured, reducing capacity for absorption/desorption of contaminants.	HDPE is less flexible than LDPE but has better absorption/desorption properties. HDPE preferred over LDPE for sampling.
LDPE* (Low Density Polyethylene)	A thermoplastic made from the monomer ethylene. Amorphous composition facilitates absorption/desorption of contaminants.	Acceptable for purging. Not preferred for decision making sampling due to absorption/desorption issues.
Flexible Elastomer Tubing	Flexible elastomer tubing consisting of a variety of plastic compounds.	Silicone and Tygon® are common types of flexible elastomer tubing. Silicone tubing can be used in the rollers of peristaltic pumps. Tygon is sometimes used for wastewater sampling and with automatic samplers.

* Limited research suggests that linear low density polyethylene (LLDPE) may have lower adsorption/desorption properties than LDPE.

6.9.6.4 Sampling of Low-Yielding Wells

The principal focus of installing water supply wells is well-yield. In contrast, the principal focus of installing monitoring wells is water quality; well-yield is of secondary importance. In an attempt to locate and delineate ground water contamination, monitoring wells are frequently installed in low-yielding geologic media. Low-yielding wells (i.e., wells that yield less than 100 ml/min) present challenges with respect to the collection of a representative ground water sample.

Low-yielding wells can be the result of the following:

- low water storage capacity in the aquifer;

- slow well recharge rate;
- slow ground water flow velocity in the aquifer;
- improper well construction or development; and
- a compromised/damaged well.

These situations lead to wells containing water that has a long residence time in the well where the water is exposed to atmospheric conditions. Exposure of water in the well to atmospheric conditions facilitates degassing of VOCs from the water and oxidation of oxygen sensitive compounds. This action may result in the water in the well being biased low with respect to VOCs and compounds that are sensitive to exposure to oxygen.

Wells that yield less than 100 ml/min present sampling challenges as they frequently incur significant drawdown during well purging. If the drawdown occurs within the well intake interval, VOC loss may result. The greater the drawdown, the greater the potential for VOC loss, and the magnitude of VOC loss may increase. Additionally, the increased stress on a well caused by significant drawdown may also result in an increase in well water turbidity.

The removal of water by bailers may cause drawdown in the well in slug-type increments. Peristaltic pumps, which are capable of operating at very slow purge rates for extended periods of time, draw water out of the well by vacuum (negative pressure) which will result in degassing and subsequent VOC loss. The operation of variable-speed submersible pumps at very low flow rates may cause the pump to get hot. As the pump temperature increases, the ground water flowing around and through the pump will increase in temperature, which may also lead to VOC degassing and subsequent loss. Diffusion and grab samplers can easily collect the sample, but the contamination levels from these samplers may be biased low due to the long residency time of the water in the well, and a dilution effect of adding the clean water in the diffusion sampler to the well. The NJDEP recognizes that the use of LFPS methods (discussed previously) in low-yielding wells may not be practical if drawdown cannot be limited.

To facilitate the collection of a representative ground water sample from low-yielding wells, the NJDEP will allow modified sampling procedures to be used. This may include sample collection without regard to the measurement or monitoring of water quality indicator parameters.

Possible options for the sampling of low-yield wells include:

1. Collect a no purge grab sample from within the well intake interval (use only when water level is in well intake interval).
2. Collect a no purge diffusion-based sample from within the well intake interval.
3. Collect a low purge volume sample from a pump located in the well intake interval operating at a very low purge rate. The sample should be taken shortly after water reaches the surface to minimize well drawdown. When the water level is above the well intake interval, the pump should be set at the top of the well intake interval and the well purged to that point before collecting the sample. A minimum of the volume of water above the well screen + 20% of the volume of the well intake interval should be purged prior to sample collection.
4. When the depth to water is less than 25', the well can be purged and sampled very slowly with a peristatic pump. If sampling for VOCs, the sample should be collected post purge with a bailer or hydrasleeve. Insertion and retrieval of the bailer or hydrasleeve from within the water column should be done very slowly to reduce surging of the well intake interval. Where the water table is above the well intake interval, the vacuum line intake should be set just above the well intake interval and the well pumped down to that point prior to sample collection. A minimum of the volume of water above the well screen + 20% of the volume of the well intake interval should be purged prior to sample collection.

Where low-yield wells have been identified (i.e., well yield less than 100 ml/min confirmed), the well should be labelled as such in tables of well information and footnoted in tables of water quality data. If a well is sampled using a low-yield procedure, that process should be clearly explained in reports that contain data from the respective well.

Where a low-yielding well only contains several feet of water, the use of submersible pumps will likely cause unacceptable drawdown, and the low water level may hinder proper pump operation. In this situation use of a no purge sampling method is recommended.

Since sample collection may begin almost as soon as purging is initiated, it is imperative that the exact depth interval where the sample will be collected within the well intake interval be predetermined. Given the difficulties associated with sampling low-yield wells, the actual procedure to purge and sample the well may be different than common practice, or different than other wells sampled during the sampling event. It is important that the procedure used to sample low-yield wells be recorded in the field and discussed in reports containing data from the low-yield well. When ground water samples are collected from within the well intake interval the depth interval of the sampling device should be linked to the well sample (i.e., MW-1/22-24'). See Section 6.9.3.1 titled Depth of Sample Collection for more detail.

To properly assess how best to sample a low-yielding well, it is important to know the actual yield of the well. The NJDEP cannot overstate the importance of determining an accurate well yield during the installation and development of the well.

6.9.6.5 Sample Collection Procedures

The following procedures describe NJDEP recommended methods for obtaining representative ground water samples for organic, inorganic, residue, nutrient, bacteriological and other general chemical analyses. Volume-Average Purging and Sample Collection, Low-Flow Purging and Sampling, and No-Purge Sampling are the different sampling methods discussed and recommended by the Department. Ground water monitoring wells, homeowner's private supply wells, and industrial or municipal supply wells are the potential sources of these samples. Temporary well points and ground water collected via direct push technology represent additional sources. Discussions on various sample collection equipment and their operational use are presented in Chapter 5.

The procedures described herein have been developed for, and should be followed by, NJDEP personnel and anyone submitting ground water data to the NJDEP. Samples obtained in a way that does not follow these guidelines may not be considered as representative ground water samples and may not be accepted. In the case of state-approved vendors, unrepresentative sample collection may form the basis of non-payment for services rendered.

It should be noted that purge water generated during well sampling can be discharged to ground under a NJPDES permit by rule. More detailed language concerning this issue can be found in the Chapter 5 Section on Decontamination Procedures.

Submission of Well Purging Information

When sampling methods are used that require purging of the well, information on the purging of each well should be recorded, and that information submitted to NJDEP on a sampling log form or table. Information generated during the purging event should include depth to water, amount of well drawdown induced during well purging, well intake interval, and sometimes ground water chemistry (i.e., water quality indicator parameters). From a reviewer's perspective, assessing the amount drawdown in the well intake interval is critical information to evaluate the potential loss of pressure sensitive compounds. Additionally, comparing the well purge rate to well drawdown data may allude to the well recharge capacity. Changes in the water quality parameters during purging may show the difference in water quality within the well and the surrounding formation. The changes in water

quality parameters should be evaluated when considering implementing a no-purge sampling method.

Based on the above, NJDEP considers the submission of well purging information critical to a proper understanding and assessment of the sampling event and its results. As such, forms or tables of the well purging field data should be included in all reports submitted to NJDEP that contain the well sampling results. Where a report contains ground water sampling results from multiple sampling events, or provides tables of historical sampling results, well purging information should be included for all the well sampling results. The well purging information can be included in the report as an appendix.

6.9.6.5.1 Volume-Averaged Purging and Sample Collection

Overview

Volume-averaged sampling has been the traditional and preferred method of sampling monitoring wells. This procedure involves calculating, in gallons, one volume of standing water within a well, and purging three to five times that amount. As the volume-averaged sampling method produces the largest zone of influence in the aquifer, volume-averaged sampling is more likely than LFPS, grab, or passive sampling to detect contamination over the full length of the well intake interval, and contamination farther out into the surrounding formation. By sampling a larger area of the aquifer, volume-averaged sampling may also be more appropriate than LFPS, grab, or passive sampling for pre-design or remedial assessment work.

Past problems with volume-averaged sampling were frequently linked to excessive drawdown of the water-table in the well intake interval. This action resulted in the aeration of the ground water recharging into the well as the water cascaded down the interior wall of the well screen or open hole. The aeration of the ground water can lead to a loss of VOCs, higher vapor pressure SVOCs, and dissolved metals that are in a reduced valence state. Actively monitoring well drawdown during well purging, and limiting the amount of drawdown, should address the aforementioned problems. For completely submerged well intake intervals, drawdown should be limited such that the water level in the well remains above the top of the well intake interval, and preferably above the well sandpack (where applicable). Where the water table is located within the well intake interval, it is recommended drawdown be limited to 0.3'.
In contrast to the LFPS method, volume-averaged purging should be done in such a manner as to induce as much hydrologic stress on the well intake interval as possible without exposing the well intake interval (submerged well screen situation) or causing drawdown within it (water table situation). Ground-water contaminants in a heterogeneous aquifer may be restricted to thin or narrow zones of higher permeability. If this is the case, purging large volumes of water from wells with long well intake intervals may create a situation where ground water contamination being drawn from the contaminant-bearing zone may be diluted by uncontaminated water entering the well from one or more "clean" zones. See language in section 6.9.5 on vertical profiling for discussion on sampling considerations in heterogeneous/anisotropic aquifers. When ground water samples are collected from within the well intake interval, the depth interval (from ground surface) of the sampling device should be linked to the well sample (i.e., MW-1/22-24'). See Section 6.9.3.1, titled "Depth of Sample Collection," for more detail.

Where a well only contains a couple of feet of water, the use of a submersible pump may cause unacceptable drawdown, especially if the formation material surrounding the well is of a lower permeability that results in a well with a very low recharge rate. Low water levels reduce the volume of water that is available to dissipate heat generated by electric pumps, this may lead to an unacceptable increase in well water temperature, and subsequently, the temperature of the water discharged by the pump. Additionally, a low water level may result in bladder pumps not working properly due to low hydrostatic head pressure on the pump intake. Having to set the well pump intake at or near the bottom of the well may also result in a turbid sample as the pump stirs up

sediment that has accumulated on the bottom of the well. In this situation use of a different sampling method may be more appropriate.

Policy

Based on the larger zone of influence, volume-averaged sampling is NJDEP's preferred method of sample collection. **The NJDEP preferred setup for volume-averaged sampling is the use of a variable speed positive displacement pump with Teflon-lined tubing.** NJDEP prefers that the same pump and tubing be used for purging and sampling. This setup will allow the well to be purged and sampled using the same equipment, with the sample being collected from the end of the discharge tubing. This setup will reduce the potential VOC loss that may happen during sample collection using a bailer by minimizing handling of the groundwater prior to sample collection

It is recommended that the sample be collected directly from the end of the discharge tubing, and close to the well head. This may require that the tubing be cut/shortened just prior to sampling. This scenario dictates that the pump and discharge line be constructed of composition appropriate material. To achieve the maximum amount of hydrologic stress, overall, the well should be purged at the highest flow rate of the pump or the maximum sustained yield of the well, whichever is **lower.** To make this determination it is necessary to accurately know the sustained recharge rate of the well. If this information has not been previously determined, actions should be taken to determine the well recharge rate prior to performing volume average sampling.

As stated in the policy language in the beginning of Section 6.9, volume-average sampling should be performed during the installation of temporary well points (where possible), the first two rounds of permanent wells installed for investigative or delineation purposes, and for any sampling where the data will be used to justify the close-out of a site, site area, or specific well. See Figure 6.10.

Where sampling is limited to turbidity sensitive parameters (e.g., metals, PCBs, total organic carbon, pesticides, and larger molecular weight SVOC compounds), volume-averaged sampling does not need to be performed for the first two rounds of permanent wells, delineation sampling, or close-out sampling. Other sampling methods that may reduce sample turbidity (e.g., LFPS, passive, or grab samples), may be implemented at any time. If a sampling method other than volume-averaged is chosen for the first two rounds, and the well contains more than 5 feet of saturated well intake interval, vertical profiling of the well should be performed first.

Volume-Average Purging Methodology

Knowing that some monitoring wells have very low recharge capacities, and that well recharge rates may vary considerably across a site, it is incumbent on the sampling personnel to know or have accurate information on the recharge capacity of each well prior to its sampling. The differences in well recharge rate across a site may necessitate using different sampling pumps with different pumping capacities during a site multi-well sampling event. To address this issue the NJDEP recommends the use of variable speed pumps for purging and sampling when using the volume-averaged method.

If the depth to water is less than twenty-five feet, either a positive-displacement or suction-lift pump may be utilized. If a suction-lift pump is utilized for both purging and sampling, sampling is restricted to metals, pesticides, PCBs and SVOCs (no VOCs or 1,4-dioxane). If a well is purged with a suction lift device, VOC and 1,4-dioxane samples need to be collected by another means, typically a bailer.

The discharge tubing should be kept out of direct sunlight. If the tubing and flow through cell (if used) are kept out of direct sunlight, increases in water temperature due to the pump can more easily be detected. As the air temperature is frequently higher than the ground water temperature, tubing length outside the well should be kept to a minimum.

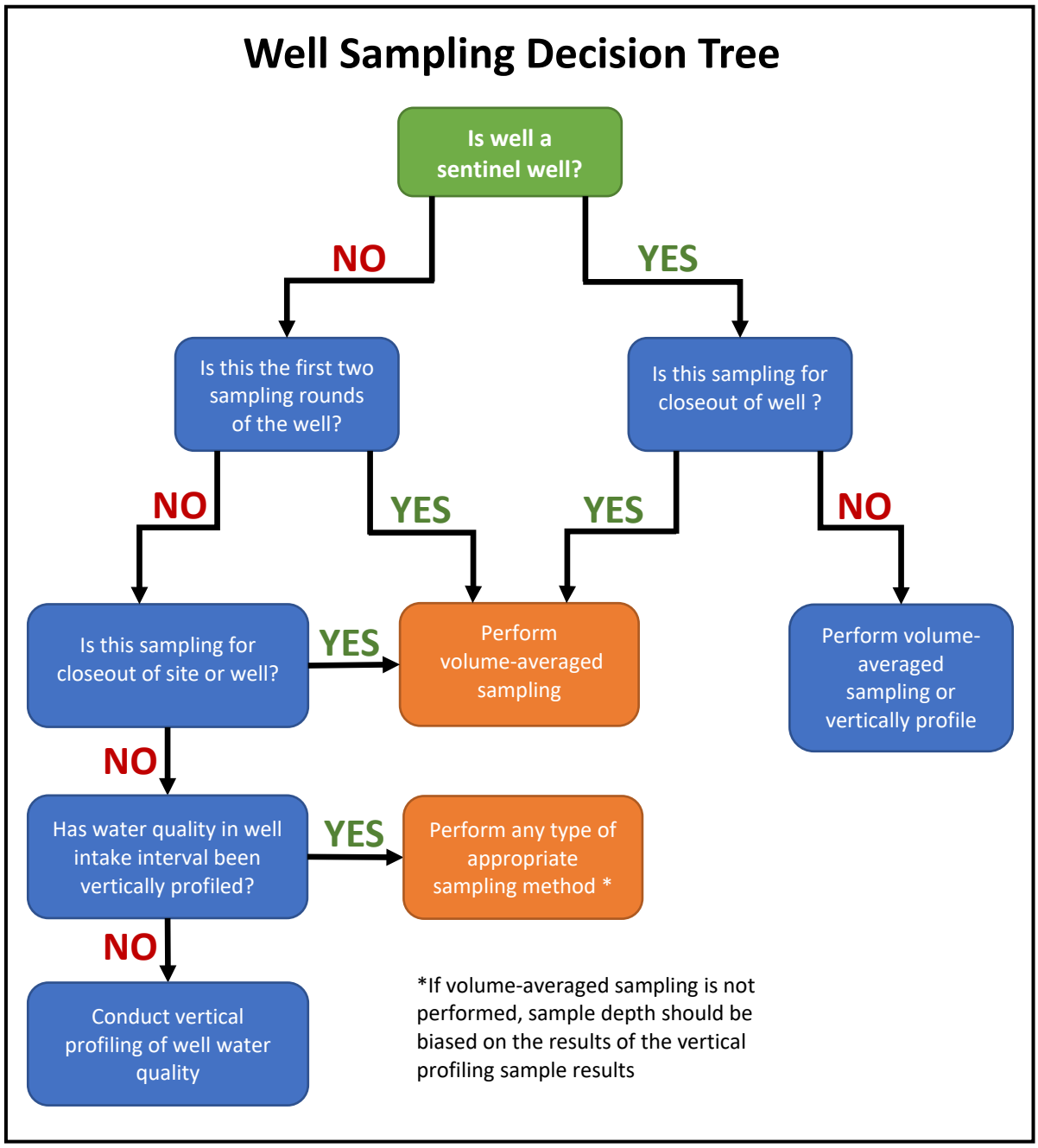


Figure 6.10 Well sampling Decision Tree

If a flow through cell is used, the interior of the cell should be clean, free of any trapped air or bubbles, and kept out of direct sunlight.

When collecting the sample directly from the discharge tubing, the sample should be collected as close to the well head as possible. At the time of sampling the tubing should be disconnected from any flow through cell used and the tubing cut back to the well head.

When possible, dedicated tubing and pumps are preferred. In many cases it may not be practical to dedicate a pump to a specific well, so it is permissible to decontaminate pumps between wells if recommended decontamination methods are used (refer to Chapter 5.2 of this manual for decontamination information). Tubing should always be dedicated to an individual well. Cleaned

equipment entering the well should not be allowed to contact the ground or be compromised by any other potentially contaminated source (i.e., gasoline-fueled generators, purged ground water, surface water, vehicle exhaust, etc.). If this should occur, the compromised item should not be placed in the well or utilized for evacuation.

In wells with very slow recovery rates, or low yields (i.e., less than 100 ml/min) evacuation of three-to-five well volumes may not be practical and the section on sampling low-yield wells should be consulted. Where a well yield of less than 100 ml/min has been confirmed, the request for volume averaged sampling may be waived, and an alternative purging and sampling method may be employed. In this situation it is recommended that the measured well yield be listed in tables of well as-built information, and tables of historical data should footnote the well as a low yielding well.

Water Table Intersects Well Intake Interval

Where the water table is in the well intake interval, the pump should be set deep enough below the water table to operate the pump and allow for monitoring water level changes. The middle of the water column may be considered a default pump placement when there is no rational to bias the pump depth. The well should be purged at a rate close to the recharge capacity of the well. The well purging rate should be gradually increased until drawdown in the well is produced. At this point the purge rate should be slightly reduced until continued drawdown stops. Where the maximum discharge rate of the pump does not produce drawdown greater than 0.3', the well should be purged at the maximum pump discharge rate. The goal of the sampling is to stress the saturated well intake interval while minimizing drawdown. To facilitate sample collection at productive wells, the discharge rate can be reduced at the time of sample collection. A maximum drawdown of 0.3' is the target, so actively monitoring the purge rate and water level drawdown during early purging is critical to preventing excessive drawdown. Changes in purging rate and water levels should be recorded, and subsequently submitted in the field sampling logs. Excessive drawdown may result in significant aeration of oxygen sensitive or volatility sensitive analytes. Where drawdown is excessive the quality/results of the sample may not be representative of the aquifer. To facilitate placement of the pump, NJDEP recommends the discharge tubing be marked with the depth to water (from top of well casing), and the base of the well.

Water Table Above Well Intake Intervals

For wells that have their entire well intake interval submerged, dealing with the issue of stagnant casing water complicates the well purging issue. This issue becomes increasingly important as either well yield or well depth increase. The stagnant casing water is not considered to be representative of the aquifer/formation and should not be included in the sample. To address this concern, efforts should be taken to purge the water above the well intake interval. Accordingly, in this situation drawdown to the top of the sandpack, or within a couple of feet of the top of the well intake interval, is allowed and recommended. At no time should the water level drop below the top of the well intake interval.

1. **Pump Capacity Greater Than Well Yield**

   Where the well purging setup has a greater discharge rate than the well recharge rate, there are two purging options.

   Option 1: Set the pump a couple of feet below the water level in the well and pump the well down to a couple of feet above the well intake interval. Implementing this procedure may result in significant amounts of discharge tubing being placed on the ground around the well. Actions should be taken to prevent the tubing from coming in direct contact with the ground. Water levels will need to be constantly monitored, and the pump and water level indicator probe repeatedly lowered as the water table drops. The discharge tubing should be marked so that the sampler will know when the pump intake reaches the top of the well intake interval.

Once the pump intake is in the top of the well intake interval, and drawdown is a couple of feet above the top of the well intake interval, stop lowering the pump and reduce the purge rate so that drawdown is stabilized. Purging should continue at a rate close to the capacity of the well until the sample is collected.

Option 2: Set the purge pump intake a couple of feet below the well casing, purge the well at a rate high enough that the water level in the casing is dewatered to a couple of feet above the well intake interval. Once the targeted drawdown has been achieved, reduce pumping rate to stabilize the drawdown and continue purging at that rate until the sample is collected.

2. Pump Capacity Below Well Yield

Where the well purge setup has a maximum discharge rate less than the well recharge rate, the pump intake should be placed at the middle depth of the well intake interval and the well purged at the highest rate the pumping setup can do. The middle of the well intake interval should be considered a default pump placement unless there is a rational to bias the pump depth. The rational should be provided in the field sampling report. The discharge tubing should be marked so that the sampler will know when the pump intake reaches the targeted depth.

Note: To reduce the volume of well water that needs to be purged in submerged well intake interval situations, NJDEP will allow the well intake interval to represent one well volume after the well casing has been dewatered. For wells that are large in diameter, or have deeply placed well take intervals, the difference in the amount of water that needs to purged can be significant. Using this option, the tracking of purge volumes for sampling purposes should not begin until the casing has been dewatered. In contrast, the field sampling logs should record all purging times, rates, volumes, and drawdowns. It should be made clear on the purge/sampling log when the volume average purging started (i.e., post casing dewatering purging). The total volume of water purged, subsequent to dewatering of the upper casing, should be clearly defined on the field sampling log.

Collection of Field Data

Because the basis for sample collection in volume-averaged sampling is principally focused on purge volume (i.e., 3 to 5 well volumes), there is no requirement to measure and record the water quality indicator parameters monitored in LFPS. While not required for volume average sampling, the NJDEP does endorse monitoring the water quality indicator parameters (pH, temperature, DO, ORP, turbidity, and conductivity) for stabilization during well purging as a secondary means of assessing whether the purged water represents fresh formation water. If the analyze immediately water quality indicator parameter data (i.e., pH, temperature and DO) will be submitted to DEP, the measurements must be collected by certified personnel.

The higher purging rates used by this method, and the higher volumes of water extracted, may result in elevated turbidities. Purging the well at a rate greater than that used to develop the well may trigger an increase in well turbidity and alter the hydrogeological properties of the aquifer in the vicinity of the well. If the sampling includes turbidity sensitive analytes, turbidity should be measured and recorded during purging and sampling.

If electrical downhole pumps are going to be used for either purging or sampling, the temperature of the discharged water should be monitored and recorded throughout the entire purging and sampling process.

Drawdown

As the amount of water level drawdown produced by this sampling method may be substantial, depth to water measurements should be collected and recorded throughout the entire purging and sampling process. Monitoring drawdown will allow the sampler to promptly adjust the purging rate as needed.

Where well yields are low, actions should be taken to keep pumping rates low enough to avoid excessive drawdown. Accordingly, it is critical that the well yield be known prior to sampling so that appropriate sampling equipment is brought to the site (e.g., tubing diameter, pump capacity, etc.). To address drawdown issues in low yielding wells, pumping rates may be adjusted, and pumping times extended to remove the necessary volume of water. Samples should be collected within two hours of purging.

When sampling for VOCs or higher volatility SVOCs, purging that results in excessive drawdown is not recommended or appropriate. It is recommended that measures be taken to limit draw-down within the well intake interval to less than 0.3'. When sampling for VOCs or higher vapor pressure SVOCs, well purging should stop if drawdown of the saturated well intake interval exceeds 20%. At that point the well should be allowed to recharge and an assessment of how to limit well drawdown made prior to re-initiating sampling of the well.

There are several reasons why the well should not be pumped below the level at which the ground water enters the well:

1. water entering the well at the top of the well screen may cascade down the side of the screen. This cascading effect may aerate the ground water to be sampled, resulting in a loss of volatile organic compounds;
2. significant drawdown in the well intake interval can lead to dewatering of the surrounding formation, where again, volatiles may be lost due to aeration within the dewatered zone; and
3. other contaminants may adsorb to formation materials where a dehydrated zone is created. As a result, samples collected upon the recharge of a well pumped to dryness or significant drawdown may not accurately characterize ground water quality due to one or more of the effects discussed above.

While drawdown in the well intake interval should be kept to a minimum, in deeper wells where the entire well intake interval is below the water table, the water level in the well riser casing may be pumped down to within a couple feet above the top of the well intake interval to speed up the sampling process, remove stagnant water from the well riser casing, and facilitate recharge into the well.

Temperature Measurement and Electric Submersible Pumps

Variable-speed electric submersible pumps, such as the Grundfos Redi Flo 2® pump, use water to cool the motor during operation. Factors such as:

1. use in a larger diameter well;
2. low purge rates;
3. long purging times;
4. use of small diameter discharge tubing; and
5. hot summer air temperatures all contribute to the potential for an increase in temperature of the discharged water.

Increases in the temperature of the water being purged and sampled may reduce the concentrations of volatile organic compounds in the ground water due to an increase in their vapor pressure. As the temperature of water increases, the kinetic energy of its molecules also increases, and the number of molecules transitioning into a vapor also increases. Accordingly, the greater the water temperature, the greater the potential for loss of VOCs.

When using an electronic pump for well purging or sampling, the temperature of the discharge water should be monitored and recorded throughout the purging and sampling operation. If the temperature of the discharge increases and does not stabilize, or stabilizes at an elevated

temperature, a field decision must be made to either discontinue or continue. If the water temperature measured/recorded increases by more than 10 degrees Fahrenheit, or 5.5 degrees Celsius, actions should be taken to reduce the temperature of the discharged water. Turning the pump off and on to control overheating is not acceptable.

If sampling with a submersible pump results in an elevated water temperature, and modifications/adjustments to the pumping setup do not eliminate the temperature issue, other sampling alternatives should be considered. If water temperatures are measured that appear to be artificially above the aquifer/formation temperature, an explanation for the anomalous temperatures should be included in the submission containing the data. Actions that can be taken to reduce the discharge temperature include:

1. using a pump shroud;
2. increasing the pumping rate;
3. using a larger diameter discharge tubing (allows for increased flow rate and reduces back pressure on the pump); and
4. covering all aboveground components of the sampling setup that convey water from direct sunlight.

When using electric submersible pumps in large-diameter wells (6" and greater), overheating of the motor, followed by mechanical shutdown and possible motor damage, may occur. This is the result of water being drawn to the pump intake in a more horizontal flow pattern which diminishes the design feature that normally moves cool water vertically across the motor (stator) housing. The use of specially designed cooling shrouds may overcome this condition.

If a flow through cell is not being used to measure the temperature of the discharge, the container used to measure the water temperature should not be left in direct sunlight, and should be kept filled with groundwater to keep the container temperature close to that of the groundwater. When taking a temperature measurement, empty the container and fill it with fresh ground water. After collecting the temperature measurement, leave the container filled with water until it is time to take another measurement. Leaving the water in the container will buffer the temperature of the container from sunlight and ambient air temperatures. The NJDEP recommends that the container used to measure water temperature be at least ½ gallon in size, or larger.

Purge Water

The NJDEP is cognizant that the cost to containerize, store and dispose of three to five well-volumes of purge water generated from a round of well sampling can be significant. To address this concern the NJDEP points out the following:

Well development and purge water may be discharged to the ground per N.J.A.C. 7:14A-7.5. This rule authorizes water generated from the installation, development, and sampling of monitoring wells to be discharged to the ground under a permit-by-rule. No written approval from NJDEP is needed for implementation of this permit-by-rule discharge. For more information about this option, consult the June 2007 "NJPDES Discharges to Ground Water Technical Manual for The Site Remediation Program" At: https://www.nj.gov/dep/srp/guidance/#njdeps_dgw_tech_manual.

The NJDEP recommends that contaminated ground water not be discharged to non-contaminated soil at concentrations that could result in the development of contaminated soil. The NJDEP also recommends that contaminated ground water from a deeper aquifer not be discharged to ground in an area where the water-table aquifer is clean without treatment to remove the contamination. Treatment could include portable units that air strip, bubble aerate, or adsorb (e.g., granular activated carbon filtration) the contaminants prior to discharge. For additional information on options to address purge water disposal, see the section on investigation derived waste (IDW) in Chapter 5.

If there is a potential for LNAPL, check the well for LNAPL prior to evacuation. The evacuation of floating product or highly contaminated water may require special collection and disposal procedures for the purge water.

6.9.6.5.2 Low-Flow Purging and Sampling

6.9.6.5.2.1 Low Flow Policy

LFPS induces less hydrologic stress to the well intake area than traditional volume averaged sampling. The low volume of water typically purged prior to sample collection using the LFPS technique make this sampling technique more like passive sampling than traditional volume average sampling in that it may only influence/sample a small area around the pump intake.

Due to the potentially limited zone of influence produced by this method, the NJDEP does not recommend this sampling method for the first two sampling rounds of any permanent well, contamination delineation sampling, and site, AOC, or well closeout sampling.

The NJDEP also recommends that LFPS not be performed on any well with a saturated screen or open borehole intake interval greater than 5 feet in length **unless:**

1. the water quality of the saturated well intake interval has been vertically profiled (see chapter section on vertical profiling for more detail). This is accomplished by collecting ground water samples from multiple depths within the saturated well intake interval,
2. the data quality objectives (DQOs) warrant sampling a specific zone (e.g., the shallow water table to investigate the potential for vapor intrusion inside a building), or
3. existing information has identified specific zones where sufficient geophysical (e.g., heat-pulse flowmeter, caliper and temperature logs, etc.), hydrogeological (e.g., tracer tests) or other information (e.g., stained soils or fractures noted on boring logs or seen on acoustic televiewers) **clearly** identify the depth(s) at which contaminants are entering the well screen or open borehole.

Once vertical profiling has been completed, an assessment of the sample results should be performed to determine at what depths future LFPS is appropriate. With respect to long term monitoring, it may be appropriate for LFPS to be conducted at multiple depth intervals, or even just one depth interval, depending on the data quality objectives of the sampling and the types of contamination present in the ground water (e.g., LNAPL, DNAPL, etc.).

Vertical profiling of the well is not necessary when a well contains an intake interval of five feet or less, or only contains five feet or less of standing water in the well intake interval. In these situations, the collection of a single LFPS sample may be appropriate.

When submitting the results of the LFPS event, the responsible party should include specific details of the LFPS event which demonstrate that they were consistent with NJDEP guidance. The responsible party should also provide adequate rationale justifying any deviations from this guidance. When ground water samples are collected from within the well intake interval the depth interval of the sampling device should be linked to the well sample (i.e., MW-1/22-24'). See section 6.9.3.1, *Depth of Sample Collection,* for more detail.

The driving force behind the development of LFPS was the reduction in sample turbidity. Where testing of a ground water sample is limited to compounds that have a high affinity for adsorption onto soil particle surfaces (see definition of turbidity or sediment sensitive compounds), samples may be collected by LFPS in lieu of volume-averaged sampling during any sampling event.

The NJDEP recommends that the rationale for the chosen sampling depths be discussed in the report that includes the respective sampling results. As the depth of sample collection may be

different between sampling events, it is recommended that the depth of sample collection be included in tables of sample results to facilitate review and interpretation of the sampling results.

Even where the use of LFPS has been shown to produce lower sampling results than volume-averaged sampling, the NJDEP is amenable to the use of the LFPS method as part of a long term or O&M sampling plan, as long as the data are not being used to make or support regulatory decisions.

6.9.6.5.2.2 Method Summary and Application

The ground water analysis for compounds that have a high affinity to adsorb onto soil particle surfaces, such as metals, PCBs, pesticides, total organic carbon, and some SVOCs (especially the larger molecular weight compounds), can be turbidity sensitive. Elevated turbidity levels in ground water samples for the aforementioned parameters can lead to ground water analytical results that are biased high when compared to filtered dissolved parameter analysis. The primary goal of developing the LFPS technique was to provide an alternative ground water sampling technique that had the potential to produce ground water samples with lower turbidities than traditional volume averaged techniques. An additional goal of the method was to eliminate the need to filter samples to remove turbidity.

The overall purpose of Low-Flow Purging and Sampling (LFPS) is to produce a ground water sample from a specific depth that is representative of ambient ground water conditions in the surrounding aquifer. This is accomplished by setting the intake velocity of the sampling pump to a low flow rate (generally 100 to 500 ml/min) that limits drawdown inside the well (generally less than 0.3'). The well is purged until the water quality indicator parameters stabilize. Stabilization parameters are provided in Table 6.15. LFPS has three primary benefits. First, it minimizes disturbance of sediment in the bottom of the well, thereby producing a sample with low turbidity. Second, LFPS should minimize aeration of the ground water during sample collection if drawdown is limited to 0.3'. Third, the volume of ground water purged from a well may be significantly less than that generated by the volume-averaged sampling method.

Where purging a well at 100 ml/min or less still results in well intake interval drawdown greater than 0.3', NJDEP recommends that LFPS not be used. In these cases, it is recommended that the low-yield well be sampled by a no-purge method.

Where a well only contains several feet of water, the use of a submersible pump may cause unacceptable drawdown, especially if the formation material surrounding the well is of a lower permeability. For electrically powered pumps the low water level reduces the volume of water that is available to dissipate heat generated by the pump, this may lead to an unacceptable increase in well water temperature, and subsequently the temperature of the water discharged by the pump. A low water level may result in bladder pumps not working properly due to low hydrostatic head pressure on the pump intake. Having to set the well pump near the bottom of the well may also result in a turbid sample as the pump stirs up sediment that has accumulated on the bottom of the well. In this situation use of a no purge sampling method may be more appropriate.

LFPS induces less hydrologic stress to the well intake area than traditional volume-averaged sampling and commonly produces sampling results that only represent the water quality of the zone immediately around the pump intake, in similarity to a grab or passively collected sample. This is likely not the case if you have vertical flow within the well.

Due largely to the lower amount of purge-water generated by the LFPS technique, use of this technique has expanded to include other parameters (e.g., VOCs) and has rapidly become the ground water sampling method of choice for general sampling. Given the expansion of LFPS for VOC sampling, the NJDEP has noticed that changing the ground water sampling method for a given well from volume-averaged purge (i.e., traditional sampling) to LFPS sometimes results in significantly different sampling result. The LFPS results can be significantly higher or lower.

The difference in the sampling results can be due to several factors: 1) the characteristics of the contaminant; 2) the hydraulic conductivity heterogeneity within the aquifer material surrounding the well screen; and 3) the depth of sample relative to the contaminant concentration distribution in the surrounding aquifer material.

Advantages:

- Ground water samples tend to be more representative of actual aquifer conditions with respect to compounds that have a high affinity for soils, such as metals, PCBs, pesticides, total organic carbon, and some SVOCs, due to the lower turbidity levels in the sample
- It causes minimal disturbance of the formation adjacent to the screened interval
- It is generally less prone to sampling variability compared to some other ground water sampling techniques (e.g., bailers) due to reduced operator variability
- Smaller purge volumes resulting in reduced handling, storage, and disposal expenses
- Increased sample consistency and reproducibility of data from dedicated systems
- Samples discrete interval in a well
- Can be deployed in series to provide a vertical contaminant profile

Limitations:

- Pump intake needs to be placed in the screened/open borehole interval. For deep wells, this will require longer sections of pump lead wire and discharge tubing, and may limit what type of pump can be used.
- May only sample a small zone.
- Assumes good hydraulic connection between sampled interval and surrounding aquifer material
- Not recommended by the NJDEP in certain situations (first two sample rounds, close-out sampling etc., see policy sections 6.9.1.4, 6.9.6.5.1, and 6.9.6.5.2.1)
- May produce biased-low samples when the contamination is not homogeneously distributed in the formation material surrounding the well
- Where more than 5 feet of saturated well screen or open borehole exist, the well will need to be vertically profiled first to assess variation in water quality

Multiple Sample Collection to Assess Contaminant Stratification (Vertical Profiling)

If contaminants are migrating through the aquifer above or below the depth where the LFPS device is positioned, the sampling device may not detect the contamination, or may not represent the maximum contaminant concentration flowing into the well. When sampling using LFPS, vertical water quality profiling of the well is recommended during the first round of LFPS to identify the presence of contaminant stratification and to document the most appropriate depth interval for future sample collection (usually the most contaminated). For details on vertical water quality profiling see the section on vertical profiling of wells presented earlier in section 6.9.

While vertical profiling is recommended for the initial LFPS sampling round, it must be recognized that for long-term monitoring applications it is also recommended that vertical profiling be conducted periodically to document that conditions have not changed, and that the sampling interval remains appropriate. The frequency of vertical profiling may be based on the length of the monitoring program, historic data trends, fluctuations in ground water elevation, contaminant distribution, or fate and transport factors.

Where vertical water quality profiling shows variation in water quality, it is recommended that

future LFPS events sample the zone showing the highest contaminant concentration, unless the sampling event is targeting a specific depth. Examples of depth specific sampling include assessing VI pathway and collection of remedial design information.

Comparison of LFPS Results with Conventional Sampling Methods

When pumping a well during sampling, conditions within the well are immediately modified. This action could result in contaminants being drawn into the well from locations that would not naturally flow into the well. For this reason, results from volume-averaged samples and LFPS samples could differ significantly.

If results from LFPS do not correlate well with results from volume averaged samples, it does not necessarily mean the LFPS sampling is inappropriate for the intended application. Poor correlation between sampling methods means that additional work may need to be conducted to identify the reason why the samples do not correlate well. Often this type of evaluation results in a better understanding of ground water flow and contaminant distribution, which ultimately helps to improve the site conceptual model. In wells where there are only minor variations in concentration data and ground water elevation data over time, comparison of LFPS and historical sampling results may provide enough information to determine whether LFPS is appropriate for the application. For wells that have demonstrated considerable variability in contaminant concentrations and ground water elevation over time, a side-by-side comparison (i.e., using both methods in the same well during the same sampling event) may be appropriate to ensure the data reflect the same sampling conditions.

Use of LFPS in Sentinel Wells

Due to the uncertainty associated with the depth at which a contaminant front will arrive at a sentinel well, the NJDEP recommends that the sampling of a sentinel well using LFPS be conducted by vertical profiling each time it is used. The sampling of sentinel wells with more than five feet of saturated well intake interval will necessitate multiple samples being collected from that well.

Laboratory Certification (N.J.A.C. 7:18) Requirements for LFPS Analyze Immediately Parameters

As the collection of "analyze immediately" field water quality indicator parameters (WQIPs), such as pH, temperature, dissolved oxygen, turbidity, and conductivity, are a critical component of the LFPS method (i.e., their stabilization is a criteria for when a sample can be collected). Per N.J.A.C. 7:18, a certification for the analyze immediately parameters is required. For more detail see the sections on laboratory certification and collection of water quality indicator parameters presented earlier in section 6.9.3.7.

Purge Water

The NJDEP is cognizant that the cost to containerize, store and dispose of purge water generated from a round of well sampling can be significant. To address this concern the NJDEP points out the following:

Well development and purge water may be discharged to the ground per N.J.A.C. 7:14A-7.5. The NJDEP requires that the discharge be to a permeable surface. This rule authorizes water generated from the installation, development, and sampling of monitoring wells to be discharged to the ground under a Permit-by-rule. No written approval from NJDEP is needed for implementation of this permit- by-rule discharge. For more information about this option, consult the June 2007 *NJPDES Discharges to Ground Water Technical Manual for The Site Remediation Program* at: https://www.nj.gov/dep/srp/guidance/#njdeps_dgw_tech_manual.

The NJDEP recommends that contaminated ground water not be discharged to non-contaminated soil at concentrations that could result in the development of contaminated soil. The NJDEP also recommends that contaminated ground water from a deeper aquifer not be discharged to ground in an area where the water-table aquifer is clean without treatment to remove the contamination. Treatment could include portable units that air strip, bubble aerate, or adsorb (e.g., granular activated carbon filtration) the contaminants prior to discharge.

Four example forms are provided at the end of this section to assist the sampler in recording low-flow stabilization data, calibration information and pump intake depth placement.

6.9.6.5.2.3 Specific LFPS Considerations

The following procedures are specific to LFPS of monitoring wells in New Jersey. These procedures were developed in consideration of the USEPA-Region I guidance document revised September 2017 (https://www.epa.gov/quality/low-stress-low-flow-purging-and-sampling-procedure-collection-groundwater-samples-monitoring) and the USEPA-Region II guidance document dated March 16, 1998 (https://www.bnl.gov/gpg/files/Misc_reports/lsgspc.pdf). In addition, the U.S. Geological Survey's (USGS) *Techniques of Water-Resources Investigations*, *Book 9, National Field Manual for the Collection of Water-Quality Data* was consulted (http://water.usgs.gov/owq/FieldManual/). The reader is encouraged to review these guidance documents prior to performing LFPS. It is recommended the procedures provided in the USEPA and USGS guidance be followed except where they differ from the information provided below.

6.9.6.5.2.3.1 Pump Intake Location

When LFPS is performed correctly, the data collected should represent a snapshot of a small zone within the well intake interval. The zone sampled is likely larger than that sampled by a passive diffusion device, but smaller than a volume average sampling device. For these reasons, it is important to place the pump intake in the zone of highest contaminant concentration or contaminant flux within the well intake interval. This is particularly important in wells constructed with more than 5 feet of well screen.

Where more than 5 feet of saturated well intake interval exists, the initial LFPS event should include vertical profiling. A discussion on the aspects of sample depth location is presented in the earlier section on vertical profiling of wells.

As the plume migrates downgradient of the source area, the importance of permeability differentials can become significant as the ground water contamination may preferentially migrate along zones of higher permeability or be vertically restricted by zones of lower permeability. Identification of these zones may be made from borehole geophysical data, (e.g., resistivity, fluid conductance, or natural gamma logging, etc.), hydraulic conductivity data, or grain-size analyses. The physical/chemical behavior of the contaminants of concern should also be considered when determining the pump intake depth. For example, gasoline-related contaminants may be present near the water table while chlorinated VOCs may be present deeper in the aquifer. If a well is contaminated by both types of contaminants, both zones may need to be sampled, each from a discrete sampling interval.

When ground water samples are collected from within the well intake interval the depth interval of the sampling device should be linked to the well sample (i.e., MW-1/22-24'). See Section 6.9.3.1 titled Depth of Sample Collection for more detail.

6.9.6.5.2.3.2 Water Quality Indicator Parameters (WQIPs) and Stabilization

With respect to LFPS, any laboratory or businesses measuring water quality indicator parameters in the field, including pH, temperature, dissolved oxygen, turbidity, and conductivity, must be certified by the Office of Quality Assurance prior to the collection of the field data.

For ground water investigations utilizing LFPS, the following parameters should be measured to determine when well stability has been achieved prior to sampling. Their respective measurements should fall within the stated range for three consecutive readings (see Table 6.15). If the anticipated "third" reading of any individual parameter does not fall within the stated range, then the process to achieve three consecutive readings for that parameter should be restarted. If, after two hours, stability has not been achieved for the parameter stabilization criteria listed below, follow the recommendations below.

Table 6.15 – Water Quality Parameters Stabilization Criteria

Parameter	Stabilization Criteria
Water Level Drawdown	< 0.3 ft*
pH	± 0.1 unit
Specific Conductance	± 3% µS/m
Temperature	± 3% ° C
Dissolved Oxygen	± 10% mg/L
Turbidity	± 10% for values greater than 1 NTU
ORP/Eh	± 10 millivolts

* During pump start-up, drawdown may exceed the 0.3-ft target and then recover as flow-rate adjustments are made. As noted in the drawdown section or when sampling for LNAPL type constituents at the water table, it is particularly important to limit the drawdown to less than 0.3 ft.

Measurements should be taken based upon the time it takes for purge water to replace one flow-through-cell volume (generally 250 ml) and the time it takes to measure and record the data. (See Chapter 5 for additional information on the flow-through-cell.) If the purge rate decreases or if the flow cell volume is increased, the time required for purge water replacement will increase. Forms at the end of this section may be used to record drawdown and the WQIPs.

WQIP measurements should be collected in a manner that will ensure integrity of the data being collected. To ensure consistency of the data, consideration of the following should be made:

- tubing diameter, length, and material of construction;
- flow-through cell design, capacity, decontamination, and "purge-train" set-up;
- pump selection and plumbing fittings;
- calibration of flow-through cell probes;
- purge rate; and,
- water-level measurement technique.

In some cases, it may take considerable time to achieve stabilization of the WQIPs. In other cases, they may never stabilize. However, as provided in USEPA guidance, the following options are available if stability has not been achieved after two hours of purging (changed to two hours per Sep. 2017 EPA Region-1 Low Flow procedure guidance):

1. continue purging until stabilization occurs, no matter how long it takes;
2. discontinue purging, do not collect a sample, and document the attempts to reach stabilization; or
3. discontinue purging, collect a sample, and document the attempts to reach stabilization.

In situations where the WQIPs do not stabilize, the sampler should document that either 1) a sample was not collected because the WQIPs would not stabilize, or 2) a sample was collected even though the WQIPs would not stabilize.

While every effort should be taken to assure that all the WQIPs stabilize prior to sample collection, one should keep in mind that the stabilization of some WQIPs may be more difficult to achieve than others. Also, achieving stabilization of some WQIPs may be more important with respect to some contaminant types (e.g., metals versus VOCs, etc.) than others. For example, total metals concentrations tend to increase with increasing turbidity due to sorption of metals on solids in the water. Similarly, VOC concentrations may be affected by dissolved oxygen (DO) concentrations (i.e., whether the ground water is aerobic or anaerobic). In addition to providing information on stabilization, collection of accurate DO data also aids in the evaluation of monitored natural attenuation (MNA) of VOC plumes. Similarly, temperature data can provide useful information regarding the sampling method. For example, temperature increases resulting from dissipation of heat generated by the submersible pump or from exposure of the tubing to excessive heat at the ground surface can have a significant negative bias on the VOC concentration of the sample. Tidal variations may affect your ability to stabilize some WQIPs, therefore it is important to determine if the site is tidally influenced.

If, for whatever reason, a WQIP is not accurately measured during the monitoring process or a certain WQIP does not stabilize, and that particular WQIP **is not** significant with respect to the type of contaminant of concern, sample collection may still proceed. For example, if DO data do not stabilize but all of the other WQIPs including drawdown and turbidity stabilize and samples will be collected for metals only, then the sample could be collected. However, any WQIPs that are affected by field conditions or instrument malfunction, should be discussed in the text of the report to alert the end-user of potential data bias.

6.9.6.5.2.3.3 Tubing

The inside diameter (ID) of tubing should be no greater than three-eighths of an inch (3/8-in). Quarter inch (1/4-in) tubing is preferred. Larger tubing diameters reduce flow velocity resulting in a corresponding increase of pump speeds to maintain flow. Increased pump speed will, in turn, elevate the potential for turbulent flow across the screened interval and this may affect the quality of the water being sampled. Conversely, any reduction in flow velocity may allow air to become trapped in the tubing, which may ultimately affect air-sensitive parameters or allow particulates to settle, which may affect turbidity values. The inner diameter of the tubing should be evaluated against the planned purge rate such that the purge rate can maintain a completely full flow in the tubing.

The length of tubing, from the top of the well casing to the flow-through chamber, should be the shortest length manageable. Attention to this detail will help ensure that: 1) exposure to ambient temperature, direct sunlight, and bubble formation are kept to a minimum, and 2) deposited solids or air bubbles will less likely be trapped in tubing bends and re-mobilized after accidental movement. Occurrence of any one or combination of these factors can cause variations in WQIP measurements, which could increase stabilization time.

If the sampling plan calls for multiple sample depths within the well screen, sampling should proceed from the top location to the bottom location. This will require that additional tubing be coiled at the surface to allow for pump relocation to the next deeper sampling location. In these instances, the coiled tubing should be protected from ambient conditions and the ground surface.

The NJDEP's preferred tubing's material is either Teflon® or Teflon®-lined polyethylene up to the flow-through cell. HDPE may be used where sample results will not be used to make regulatory decisions. This is consistent with collection of any ground water sample. See discussion on tubing quality in earlier section of 6.9. Tubing downstream of the flow cell may be constructed of a lower-quality, more flexible material. However, when sampling for metals analysis only, the tubing may be constructed of flexible polypropylene or polyethylene. Given the options presented above, it is recommended that the tubing composition be recorded and identified in reports that present the data.

Tubing "reuse" is not recommended unless the tubing is dedicated to a well. Field decontamination of tubing would not be adequate and is not recommended. If tubing is to be reused, it should undergo a rigorous laboratory decontamination procedure, which should include a hot water wash/hot air-drying process. In addition to the hot water wash/hot air drying, separate decontamination solutions of acetone and nitric acid may have to be pumped through the tubing for 15 minutes, followed by copious amounts of distilled, deionized water rinses. The cost of labor associated with decontamination, including the special handling of cleaning solvents and acid, often exceeds the cost of simply discarding the old tubing and using new tubing for each well. If a decision is made to reuse tubing, then one of the following requirements in the USGS, *Water-Quality National Field Manual,* should be considered: 1) collect additional field blanks if VOC concentrations in the last sample collected through the tubing are expected to be greater than 500 µg/L, or 2) the tubing should be replaced, rather than cleaned, if VOC concentrations in the previous sample are expected to exceed 700 µg/L.

6.9.6.5.2.3.4 Flow-Through Cell

Typical flow-through cell design is not complicated and almost all on the market today have common shared features. Cells should be transparent so that the physical condition of the purge water (e.g., turbid, containing air bubbles, etc.) passing through the system can be observed. Highly turbid or iron bacteria-laden water can be visually monitored for change as the purge progresses. The cell should be sealed against unwanted exposure to the atmosphere, thus insuring accurate measurement of air-sensitive parameters (dissolved oxygen, pH, etc.). The total capacity of the cell should be small (250- 1,000 ml) to maintain a desirable turnover rate of water coming into the cell. The volume of the flow through cell should be recorded on the sample log. To maximize water turnover rate, the smaller the flow through cell volume the better. The in-line design should allow for purge water to enter the flow cell from a bottom port and exit at the top. The discharge may be fitted with a check valve to facilitate maintaining a full flow.

Upon initial pump startup, it is good practice to not connect the pump discharge line to the flow-through cell. This will allow the sampler time to monitor drawdown, stabilize the flow rate and prevent fouling of probes by bacteria, sediment, or NAPL. Once drawdown measurements indicate that well drawdown is under control, and a few minutes (<10) have been allowed to clear any unwanted material, the pump discharge line can then be connected to the flow cell.

Flow cell decontamination is important, not only to reduce the potential for cross contamination, but also to ensure data integrity and consistent instrument performance. The cell and probes should be rinsed with distilled/deionized water between each monitoring well as accumulation of suspended material may impact probe performance. If they are exposed to

contaminants, use a mild detergent or laboratory glassware cleaning solution. Flow cell exposure to high levels of contamination may damage probes and require their repair by the manufacturer. Since LFPS is normally NOT a first-round sampling option, knowledge of contaminant levels will generally be known prior to the cell's exposure to purge water.

The location of the flow cell or cells in relation to the sample port is critical. Samples for turbidity measurement, general chemistry and laboratory analysis should be collected ahead of the flow cell. When two cells are used in series, the dissolved oxygen probe should be in the first/lead cell.

Set up the flow-through cell in a location which will cause minimal fluctuation of the flow rate due to elevation changes in the sample tubing as the tubing is disconnected from the cell prior to sample collection. It is also important to locate the flow-through cell as close as possible to the well head to minimize the length of tubing needed between the well head and flow-through cell. Actions should be taken to maintain aquifer ground water temperatures in the tubing and flow-through cell to the extent practicable. When air temperatures are greater than ground water temperatures the flow-through cell and tubing should be protected from direct sunlight. When temperatures are below freezing, actions should be taken to prevent the water from freezing. Refer to instrument manuals for suitable operating temperatures. See Figure 6.11 for a visual example of a flow-through cell.

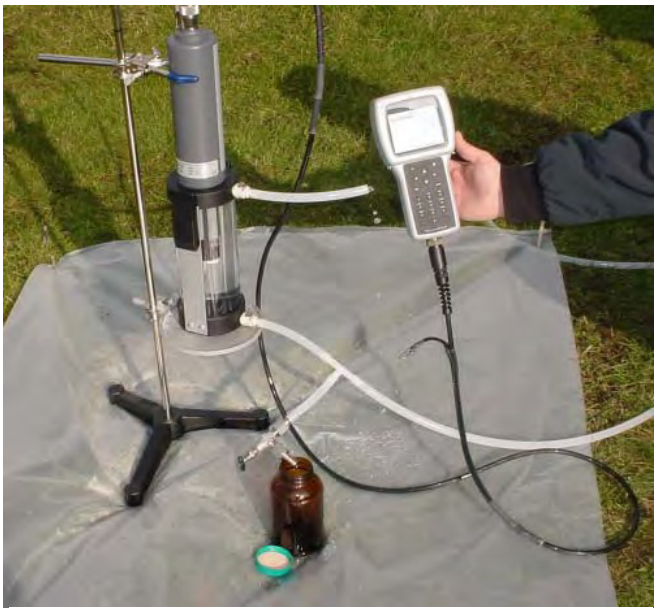


Figure 6.11 Illustration of Flow Cell with stand. (Photograph by J. Schoenleber)

6.9.6.5.2.3.5 Pump Selection

Pumps used for monitoring WQIPs should be submersible, positive-displacement pumps. Examples of acceptable positive-displacement pumps include bladder, variable-speed submersible-centrifugal, reciprocating-piston, progressive-cavity, and gear pumps. The pump discharge should be fitted appropriately to receive either 1/4 or 3/8-inch inside-diameter (ID) tubing.

Peristaltic pumps are suction-lift pumps that operate by causing a negative pressure gradient (i.e., a vacuum). Therefore, their use is not appropriate when collecting ground water samples for analysis of pressure sensitive (i.e., volatile) compounds. However, peristaltic pumps may be used for the collection of ground water samples for analysis of inorganic compounds. It should be kept in mind, however, that sampling with peristaltic pumps may affect the accuracy of some WQIPs including dissolved oxygen, pH, and redox potential. Since these WQIPs can be affected by the peristaltic pump, this pump should not be used when the WQIP results are going to be used to evaluate Monitored Natural Attenuation.

Two basic collection scenarios have a bearing on pump selection. These include: 1) a permanently installed pump system, or 2) a portable (well-to-well) pump installation. Bladder pumps can be used for either scenario, however, only those with disposable bladders and easily cleaned parts are suitable when sampling on a well-to-well basis.

Variable-speed submersible-centrifugal pumps, gear or progressive-cavity pumps can be used for either scenario as long as they are constructed of easy to clean stainless steel/Teflon® parts. Pumps constructed with impellers, helicoils, or gears, which are difficult to clean, or are constructed of plastics that have not been recommended should be considered not suitable for sampling. In addition, when conducting LFPS on a portable basis, the power or gas supply line should be isolated from the sample tubing. Power supply and sample tubing lines that form a single unit do not allow for easy decontamination and are not recommended.

6.9.6.5.2.3.6 Plumbing Fittings

A check valve should be incorporated into the tubing train or flow cell discharge to eliminate accidental drainage and subsequent aeration of the flow cell. More importantly, a check valve will prevent a back-surge of purged water being reintroduced at the screen interval of the well should the power source or pump experience mechanical failure. A back-surge of purge water into the screened interval of the well may result in variability of the WQIPs and create analytical bias. To avoid the need to decontaminate the check valve, it may be placed on the discharge side of the flow cell or installed immediately above the pump discharge. Some flow-through cells have check valves built into the unit. By design, bladder pumps also have a check valve built into their construction.

A ¼- or 3/8-inch ID barbed "T" or "Y" fitting, placed ahead of the flow cell, may be used to establish the line which will receive a needle valve for turbidity, general chemistry and analytical sample collection. The "T" or "Y" fitting used should be constructed of Teflon® or stainless steel and decontaminated between each use, if used for analytical samples. The fitting may be constructed of polyethylene and decontaminated between each use if it is only used to sample for turbidity and general chemistry parameters. If analytical samples are collected through the "T" or "Y" fitting and needle valve, then those parts should be incorporated into the field blank collection technique.

When collecting a sample at the port ahead of the flow cell, a flow control valve (stainless-steel needle valve [preferred] or stainless steel/Teflon ball valve [optional]) could be used to prevent backpressure and air bubbles from forming in the tubing (see http://water.usgs.gov/owq/FieldManual/chap4_rpt.pdf, page 84). The "needle valve" offers versatility as it can be used for collection of turbidity, general chemistry, **and** analytical samples. It can be used with Teflon® tubing and can be used to control sample flow rate because the design significantly reduces any backpressure gradient. Like all other sampling equipment, the "needle valve" should be decontaminated before use at any well. See Figure 6.12. However if a needle valve is not used, the sample should be collected before the flow through cell.

Figure 6.12 Closeup of Needle Valve. (Photograph by D. Dibblee)

6.9.6.5.2.3.7 Calibration of Probes

Probe calibration is critical to the accurate and precise measurement of WQIPs.

The manufacturers' instructions for proper care should be followed. Solutions for probe calibration should be held to the temperature of the liquid (ground water) being measured as temperature correlation is critical in calculating conductivity, dissolved oxygen, and pH. Tables and equations to compensate for the difference between ambient ground water and calibration solution temperature are sometimes provided in the operating manuals or with the calibration solutions. **Some instruments are designed with internal features to compensate for this difference in temperature.** The respective difference between calibration of conductivity and specific conductivity requires compensation for ground water temperature at the time of calibration vs. solution temperature adjusted to 25°C at the time of calibration. For dissolved oxygen, the flow cell itself should be maintained at the temperature of the ground water during calibration. All efforts made to account for proper temperature control of solutions during calibration should be recorded and reported. All steps should be recorded in the field notes. It is recommended that sampling not commence until all instruments are calibrated and operating properly.

> Calibration of the probes used to monitor water quality indicator parameters should take place **in the field prior** to the day's events. The Office of Quality Assurance must certify the environmental laboratory (see Section 6.9.3.7 *Laboratory Certification Requirements for Water Quality Indicator Parameters*) using probes for pH, dissolved oxygen and temperature measurement.

6.9.6.5.2.3.8 Temperature of Calibration Solutions

Correct field measurement of dissolved oxygen, conductivity and pH requires tight control over calibration solution temperature. Proper equipment calibration calls for the calibration solution to be the same temperature as the ground water being measured (https://water.usgs.gov/owq/FieldManual/). This may be difficult to achieve as ground water temperature can vary between wells based on depth, local setting (asphalt vs. open field) and other atmospheric and hydrogeological factors. In addition, it is logistically difficult to bring the solutions to ground water temperature, at the point of the pump intake, without first installing the pump, collecting purge water, and allowing sufficient time to bring calibration solutions to appropriate temperatures.

To approximate ground water temperatures in New Jersey, it is recommended that calibration solutions and the flow-through cell itself be maintained at approximately 54° F (12° C ± 2° C) during calibration. When ambient conditions warrant, this may require the suspension of the solutions and flow-through cell in a container/bucket of water at the aforementioned temperature. When calibrating for dissolved oxygen, always make sure the cell is vented to the atmosphere by attaching short pieces of tubing to the inlet and outlet fittings while the cell is submerged.

During the purge phase, record the difference between the stabilized temperature and the temperature of the calibration solutions. This information should be included in the report. If the sampling event is extended for two or more days, appropriate adjustments can then be made to reflect the ground water temperature more accurately during calibration.

6.9.6.5.2.3.9 pH

Monitoring for stabilization of pH in ground water is relatively straightforward and rarely requires serious troubleshooting. When calibrating for pH, a three-point calibration (e.g., 4 pH, 7 pH, and 10 pH) should be performed. The calibration range should bracket the anticipated pH of the ground water. The temperature of the buffer solutions should be as close to the temperature of the ground water as possible. As with preventative maintenance of any probe, make sure that the pH probe is rinsed with distilled/deionized water between use and cleaned periodically per the manufacturer's specifications.

6.9.6.5.2.3.10 Water Level Measurements

The depth to the top of the water column should be recorded prior to pump installation and/or prior to purging. If the **total** depth of the well needs to be determined (e.g., to verify the correct well designation and/or to determine if silt has accumulated in the bottom of a well), it should be measured at least 48 hours prior to sample collection or after the sample has been collected and the pump removed. Total depth measurements should not be taken immediately before purging as this may cause the re-suspension of solids in the well and prolong the purge time.

Once the initial water-level measurement has been recorded and the pump installed, suspend the water-level probe in the well to the point at which drawdown is equivalent to a 0.3-foot drop. Record water levels simultaneously with WQIP measurements, approximately once every five minutes.

Water-level measurement devices, which may impart some disturbance to the water column (i.e., stainless steel "popper" or coated tape), are not recommended.

6.9.6.5.2.3.11 Pump Installation

LFPS pump installation can be divided into two general collection scenarios: permanent and portable (well to well). Permanent pump installation is the most desirable. Among other advantages are improved consistency in data acquisition and reduced long-term labor, preparation, and material costs. However, permanent installation is more typically associated with long-term monitoring due to the high initial capital investment required.

The more common practice is to use a portable pump on multiple wells. While initial capital investment is comparatively less than that of a permanent installation, this practice requires close attention to quality control aspects of pump selection, preparation, and decontamination.

Once pumps have been properly decontaminated and fitted with appropriate tubing, installation of the pump can begin. Ideally, pumps should be installed 24 to 48 hours prior to initiation of purging. However, this is rarely practical, especially when site security cannot be guaranteed. In addition, wells constructed with flush-mount casing are difficult to protect from storm water or infiltration of other contaminants during the extended period the monitoring wells are open.

The pump should be placed in the well in such a manner as to ensure any disturbance in the well is kept to an absolute minimum. Once pumps reach the top of the water column, their descent should proceed very slowly through the water column. The actual level where the pump intake is to be suspended should be predetermined. The pump should not be allowed to make contact with, or be "bounced" off, the bottom of the well because doing so is likely to stir up sediment settled at the bottom of the well, which would result in high turbidity readings and prolong purge time.

6.9.6.5.2.3.12 Purge Rates

Control over the purge rate is one of the most critical aspects of this technique. Once the pump is set within the screened interval at the desired depth, a clean electronic water-level monitoring device is lowered approximately 0.3 ft into the water column. Start the pump at a speed that results in a flow rate up to 500 ml/min. Pump the initial purge water to waste to prevent any fouling of the flow-through cell. With the pump running, connect the tubing to the cell. Make sure that all air is purged from the tubing and flow cell as the system fills with purge water.

For LFPS the flow rate should not exceed 500 ml/min. If drawdown exceeds 0.3 ft., reduce the pump speed until the drawdown has stabilized. At no time should the well be pumped to dryness. For wells screened below the water table, at no time should purging/evacuation allow any portion of the well screen to be exposed. For wells that screen the water-table, monitoring drawdown in the well is critical. If drawdown in the well intake interval goes beyond 0.3ft., actions should be taken to limit drawdown, such as reducing the purge rate. Ideally the well should be allowed to recover and the well purged at a lower rate. The well sampler should know, or have an approximation of, the well yield (e.g., brining past low flow groundwater sampling logs) prior to sampling of the well. Once stabilized, changing the flow rate may trigger an increase in well turbidity.

Adjustments to pump speed are best made during the first 15 minutes. Once a "feel" for the purge rate is obtained, begin recording well stabilization indicators. Any significant change to purge rates after this time may negatively impact well stabilization measurements.

Purge rates are best monitored by measuring the flow from the discharge side of the flow cell with a graduated cylinder. Record all of the required WQIPs. Once stability has been attained and recorded, begin sample collection (refer to WQIP stabilization criteria in Table 6.15).

6.9.6.5.2.3.13 Temperature Measurement and Submersible Pumps

Variable-speed electric submersible pumps such as the Grundfos Redi Flo 2® pump use water to cool the motor during operation. Sometimes, reduced flow rates may result in insufficient cooling of the motor and may elevate the temperature of the water to a point where it may begin to affect sample integrity. If the pump is used in low-yielding 2" or 4" diameter wells, temperature increases that do not stabilize may result. If this is observed, a field decision must be made to either discontinue or continue with LFPS. If all other WQIPs have stabilized, then collecting the sample and qualifying the water-quality data accordingly may be acceptable. If the temperature increase continues and other WQIPs have not stabilized, sampling should be discontinued. Turning the pump off and on to control overheating is not acceptable. Always keep in mind that elevated temperature has a direct relationship with dissolved oxygen, specific conductance and, to a lesser degree, pH measurement. Increasing the temperature of the water being purged and sampled may also reduce the concentrations of volatile organic compounds in ground water due to their higher vapor pressure and Henry's Law constants. Variables such as low purge rates, long well purging times, small diameter tubing, and hot summer air temperatures all contribute to the potential for an increase in water temperature and VOC loss. If sampling with submersible pumps continues to result in an elevated water temperature, other sampling alternatives should be considered. Excessive temperature change during ground water sampling should be monitored, recorded, and explained in the submission containing the data.

When using some submersible pumps in large-diameter wells (6" and greater), overheating of the motor, followed by mechanical shutdown and possible motor damage, may occur. This is the result of water being drawn to the pump intake in a more horizontal flow pattern which diminishes the design feature that normally moves cool water vertically across the motor (stator) housing. The use of specially designed cooling shrouds may overcome this condition.

6.9.6.5.2.3.14 Control of Pump Speed

To achieve the high turning speeds, low-speed startup torque is generally lacking in some submersible pumps including the Grundfos Redi Flo 2® pump.

When attempting to control initial drawdown and/or sample flow rates, it is possible for the pump to cease pumping. If a check valve has been installed just above the pump, the pump may not have enough torque to overcome the head pressure when attempting to restart it. Sometimes, turning the pump to the highest speeds will overcome this situation or sometimes the pump may have to be pulled from the well and reinstalled. Neither of these corrective measures is conducive to LFPS. To avoid this scenario, make sure the control box comes equipped with a "ten turn pot" frequency adjustment knob. This will allow significantly greater control over pump speeds and the risk of losing pump flow will be reduced.

6.9.6.5.2.3.15 Pump Decontamination

The pump forms one of the two key elements of sampling equipment (tubing is the other). The importance of proper pump decontamination is especially true when pumps are rented and utilized on a well-to-well basis. Never assume that rented pumps have been thoroughly cleaned. **Pumps constructed with plastic parts or sealed inner workings that are inaccessible to direct handling are not recommended for LFPS well-to-well consideration because of their limited ability to be decontaminated thoroughly**.

Most bladder pumps cannot be easily decontaminated in the field due to their unique construction. For that reason, bladder pumps are not employed on a well-to-well basis **unless** they are constructed with easy to clean parts and *disposable* bladders. Bladder pumps are best suited for dedicated (permanently installed) scenarios. Another popular pump, the variable-speed, 2-inch diameter submersible, is more adaptable for well-to-well sampling; however,

Figure 6.13 Grundfos® Pump being prepared for decontamination (Photograph by J. Schoenleber)

close attention to decontamination is warranted. One manufacturer, Grundfos®, clearly states in the operational handbook that the pump must be completely disassembled, including removal of the motor shaft from the stator housing, and all components within the impeller housing. See Figure 6.13. Care must be taken upon reassembly to ensure that the cavity housing the motor shaft is **completely** refilled with distilled/deionized water. Care must also be taken with this pump during periods of cold weather to avoid freezing of the coolant water. Proper decontamination not only helps to ensure more reliable data; it also prolongs the life of any pump.

6.9.6.5.2.3.16 Sampling

Once WQIPs have stabilized (see Table 6.15 for stabilization criteria), or 2-hours of pumping has been performed, sampling can proceed. Do not adjust the flow rate; maintain the same pumping rate during sampling that was used to purge the well. One option for sample collection is to collect the sample directly from the needle valve at the sample port. The needle valve allows for sample collection with significantly reduced backpressure and turbulence and offers the best means for sample collection without affecting water quality. It also allows for monitoring using the flow-through cell during sample collection, thereby allowing a final WQIP measurement to be recorded immediately after sample collection. This is the preferred method, especially if volatile organic compounds are the parameters of concern. An alternative option is to cut the sampling hose just outside of the well (to minimize the length of tubing the water flows through outside of the well) and to collect the sample from the end of the tubing.

If higher than expected water temperatures are being observed, evaluate whether the submersible pump is overheating. If the pump motor is not suspected, check the system for any exposure to direct sunlight, especially during warmer periods of the year.

6.9.6.5.2.3.17 Field Blank Collection

When employing LFPS techniques, collection of the field blank should follow the same general rules for all ground water sampling equipment. This includes the requirement that "all" reusable sampling equipment, which comes in contact with the sample, should also come into contact with the field blank water. To overcome the difficulty of collecting a manual field blank through the inside of a pumping system, the following procedure is strongly recommended. Fill a 1000- ml decontaminated, glass graduated cylinder with field blank water supplied by the laboratory performing the analysis. Place a properly decontaminated pump into the graduated cylinder with sample tubing and plumbing fittings attached. Activate the pump and collect the required field blank samples. As the water is removed from the cylinder, replace it with additional field blank water. This procedure will require that the laboratory supply larger volumes of field blank water i.e., bulk water in liter or 4-liter containers. The traditional requirement that field blank water be supplied in the same identical containers as the sample being collected cannot be practically satisfied when using LFSP. The identical bottle-to-bottle field blank requirement is waived for this sampling technique procedure only.

> The forms below are examples provided to assist the sampler in recording calibration information, low-flow stabilization data, pump intake depth placement, and volume averaged purge data. These specific forms are not required by the NJDEP, they are examples and can be modified or substituted.

DAILY CALIBRATION SHEET FOR FIELD ANALYSIS

Site: _____

Date:_____ Time:_____ Barometric Pressure:_____ mmHg

Field Personnel: _____

CONDUCTIVITY

Instrument Model/ Serial Number:

Standard	Initial Reading	Reset To	Temperature (°)	Lot	Expiration Date

Calibration Check: Standard: Reading: Within ±1% of Standard? Yes / No-Recalibrate

pH

Instrument Model/ Serial Number:

Buffer	Initial Reading	Reset To:	Temperature (°)	Lot	Expiration Date

Calibration: All reset readings within 0.05 pH units of Buffer? Yes; No-Recalibrate

Calibration Check: Buffer: Reading: Within 0.1 pH units of Buffer? Yes; No-Recalibrate

3-Hour Calibration Check

Time	Buffer	Reading	Temperature (°)	Reading within ±0.2 pH Units
				Yes / No-Recalibrate
				Yes / No-Recalibrate
				Yes / No-Recalibrate

DISSOLVED OXYGEN

Instrument Model/ Serial Number:

O_2 Concentration	Temperature (°)	Air Concentration	Reading	Reset To:
Zero				
Saturated Air		100 %		

Calibration Check: Saturated Air Value: Reading: Within 0.3 mg/l? Yes / No-Recalibrate

TURBIDITY

Instrument Model/ Serial Number:

Primary Standard Calibration: Number of Standards: List Standards:

Secondary Standard Value	Reading	Within 10% of True Value?	Lot#	Expiration Date
		Yes / No-Recalibrate		
		Yes / No-Recalibrate		
		Yes / No-Recalibrate		
		Yes / No-Recalibrate		

Calibration Check: Standard: Reading: Within ±10 % of Standard? Yes / No-Recalibrate

Secondary Cal. Check: Standard: Reading: Within ±10 % of Standard? Yes / No-Recalibrate

Calibration Technician: _____ _____

Print Name Signature

- Please calibrate to manufacturer specifications
- Attach additional pages for duplicate readings

LOW FLOW GROUND WATER SAMPLING LOG

Site: _____ Date: _____
Project ID: _____ Weather: _____
Sampling Personnel: _____

Well ID: _____ Well Permit Number: _____

WELL INFORMATION

Well Depth from Well Log: _____ Well Material and Diameter: _____
Measured Total Depth: _____ Screen/Open Borehole Interval: _____
Static Depth to Water: _____ Pump Intake Depth: _____
Head Space (PPM): _____

PURGE INFORMATION

Time Purge Start/Stop: _____/_____ Flow-through Cell Volume: _____
Pump Type and ID: _____ Purge Rate: _____
Tubing Material: _____ Cell volume / purge rate =
Tubing Diameter (Inner): _____ Flow-through Cell Turnover Time: _____
Total Purge Volume: _____ (Calculated reading collection interval)
Water Quality Meter(s) type and serial number:_____

SAMPLING INFORMATION

Sample ID: _____ Sample Time: _____ # of Bottles Collected: _____
Bottle Preservatives: _____ Analysis: _____
QAQC Samples: _____

Time	Depth to Water (ft/bmp)	Purge Rate (ml/min)	Temperature (ºC)	pH (standard units)	ORP/Redox	Specific Conductivity (µS/cm)	DO (mg/L)	Turbidity (NTU)
Stabilization Criteria			±3%	±0.1	±10 mV	±3%	±10%	±10% if >1

Indicator parameters have stabilized when 3 consecutive readings are with: ±0.1 for pH; ±3% for Specific Conductivity and Temperature; ± 10 mv for Redox Potential; and ± 10% for Dissolved Oxygen and Turbidity.

ADDITIONAL INFORMATION: (notes, problems encountered, maintenance required, unusual color/odor, etc.)

_____

Monitoring Well Information in Support of Pump Intake Depth Placement

SHEET _____ OF _____

Monitor Well	Screened/Open Interval			Intake Depth(s) (ft TOC)	Rationale for Pump Intake Depth(s)*
	Top (ft TOC)	Bottom (ft TOC)	Length (ft)		

ft = feet

ft TOC = feet below top of casing

Note: this form should be prepopulated and given to the field sampler to enable proper pump placement.

* If necessary, attach supporting documentation (e.g., boring logs, construction diagrams, soil sampling data, etc.).

Volume-Averaged Sampling Field Sheet

Well ID: _____ Well Permit Number: _____

Site: _____ Date: _____

Sampling Personnel: _____ Weather: _____

Total Volume to be purged: _____ Head Space (PPM): _____

Well Diameter: _____ Well Depth: _____ Screen/Open Borehole Interval: _____

Static Water Level: _____ Pump Intake Depth: _____ Sample Equipment: _____

Tubing Type/Size: _____ Well Construction: _____

Sample ID: _____ Sample Time: _____

QA/QC Sample ID (If applicable): _____ QA/QC Sample Time: _____

Sample ID: _____ Sample Time: _____

QA/QC Sample ID (If applicable): _____ QA/QC Sample Time: _____

Time	Purge Rate _____	Volume Purged Gal or L	Depth to Water (x.xx feet)	pH STD Units	Temp ºC	DO (x.xx mg/L)	Specific Conductivity _____	ORP/Redox mV	Turbidity _____	Notes

Analytical Parameters: _____

Comments: _____

Well Volume Coefficients: 1" = 0.15 ml/ft (0.041 gal/ft) **2"** = 617 ml/ft (0.163 gal/ft) **4"** = 2,470 ml/ft (0.653 gal/ft) **6"** = 5,561 ml/ft (1.469 gal/ft) **8"** = 9,883 ml/ft (2.611 gal/ft)

6.9.6.5.3 No-Purge Sampling

No-purge sampling, sometimes referenced as point source or passive sampling, is a technique that utilizes a device specifically designed to obtain a sample of limited volume within the well intake interval without well purging prior to sample collection. No-purge samplers commonly used for ground water sampling can be divided up into two general types: diffusion and grab. These devices should only be used once the contaminants of concern have been identified and the specific zone(s) of contaminant flow in the well intake interval has also been identified. Based on the above guidance, it is more appropriate, and more likely, that these devices be used for long term, or operation and maintenance sampling. There may, however, be instances where deployment of multiple point source samplers in one well may be instrumental in determining the zone of contaminant flow into the well by vertical profiling the water quality in the well intake interval. See the previous section on vertical profiling of water quality for more detail.

When ground water samples are collected from within the well intake interval the depth interval of the sampling device should be linked to the well sample (i.e., MW-1/22-24'). See Section 6.9.3.1 titled Depth of Sample Collection for more detail.

See below for a description of some devices using this technique and their associated advantages and disadvantages. For additional details on passive sampling devices see Chapter 5 of the FSPM, the USGS publications https://pubs.er.usgs.gov/publication/tm1D8 and https://itrcweb.org/GuidanceDocuments/DSP-1a.pdf, and the ITRC publication https://www.itrcweb.org/GuidanceDocuments/DSP-5.pdf.

Well Construction Considerations

No-purge sampling devices work best when there is horizontal movement of ground water through the well intake interval. As such, no purge sampling devices critically rely on a good hydrologic connection between the well and the surrounding formation. Well construction may have a significant effect on the ability of the well to provide a representative sample. If the well has been constructed with a filter pack that is less permeable than the surrounding formation, ground water flow lines may be diverted around the well, resulting in stagnant water in the well that may not be representative of the surrounding formation water. Inadequate or inappropriate well development could also create a similar condition. The aforementioned examples may diminish the ability of no-purge sampling devices to operate as intended. Under these circumstances, it may be necessary to use a pump to draw formation water into the well. Well construction specifications (i.e., construction material, well diameter, total well depth, screen length and depth interval, screen slot size, and filter pack, etc.) from "as- built" well diagrams should be considered when evaluating the appropriateness of using no-purge sampling devices in a well. Occasionally wells are constructed with a "sediment trap" or "sump", which is an added length of blank casing attached to the bottom of a well screen. Sumps are intended to provide an area where sediment can accumulate without obscuring the well screen. For wells that have sumps below the well screen, care must be taken to account for the added depth when determining the sampling device position in the well. No-purge sampling devices should not be placed in well sumps.

Assessing Contaminant Stratification by Multiple Sampler Deployment (Vertical Profiling)

The NJDEP recommends that no-purge sampling devices not be used in a well until the water quality in the well intake interval has been vertically profiled. See the detailed section on vertical profiling and vertical flow presented earlier in section 6.9.5.

Policy

No-purge sampling equipment by its nature does not create a zone of enhanced capture/influence within or around the well, and is only sensitive to the water quality in the area immediately around the sampling device. As such, no purge sampling induces less hydrologic stress to the well intake

area than traditional volume averaged sampling or LFPS. Because of this limitation it is important to understand how the ground water contamination is migrating within the surrounding aquifer, as aquifer heterogeneity may affect contaminant distribution within the aquifer. Given the small interval of the well intake interval that may be sampled by this technique, it may not provide worst case results.

Due to the limited zone of influence produced by this method, the NJDEP does not recommend this sampling method for the first two sampling rounds of any permanent well, contamination delineation sampling, and site, AOC, or well closeout sampling.

The NJDEP also recommends that no purge sampling not be performed on any well with a saturated screen or open borehole intake interval greater than 5 feet in length **unless:**

1. the water quality of the saturated well intake interval has been vertically profiled (see the vertical profiling section in 6.9.5 for more detail). This is accomplished by collecting ground water samples from multiple depths within the saturated well intake interval;
2. the data quality objectives (DQOs) warrant sampling a specific zone (e.g., the shallow water table to investigate the potential for vapor intrusion inside a building, or remedial design work that is targeting a specific depth zone); or
3. existing information has identified specific zones where sufficient geophysical (e.g., heat-pulse flowmeter, caliper, and temperature logs, etc.), hydrogeological (e.g., tracer tests) or other information (e.g., stained soils or fractures noted on boring logs or seen on acoustic televiewers) **clearly** identify the depth(s) at which contaminants are entering the well screen or open borehole.

Once vertical profiling has been completed, an assessment of the sample results should be performed to determine at what depths future no purge sampling is appropriate. With respect to long term monitoring, it may be appropriate for no purge sampling to be conducted at multiple depth intervals, or even just one depth interval, depending on the data quality objectives of the sampling and the types of contamination present in the ground water (e.g., LNAPL, DNAPL, etc.).

When submitting the results of a no purge sampling event, the responsible party should include specific details of the no purge sampling event which demonstrate that they were consistent with NJDEP guidance. The responsible party should also provide adequate rationale justifying any deviations from this guidance.

The use of diffusion-based no-purge sampling for temporary well points is generally inappropriate given the 72-hour time limit for temporary wells installed in New Jersey.

The NJDEP recommends that the rationale for the chosen sampling depths be discussed in the report that includes the respective sampling results. As the depth of sample collection may be different between sampling events, it is recommended that the depth of sample collection be included in tables of sample results to facilitate review and interpretation of the sampling results (e.g., MW-1/ 22-24'). When the most impacted depth interval identified by vertical profiling is not sampled, that point should be clearly stated every time it occurs.

Even where the use of no purge sampling has been shown to produce lower sampling results than volume-averaged sampling, the NJDEP is amenable to the use of the LFPS method as part of a long term or O&M sampling plan, as long as the data are not being used to make or support regulatory decisions. When the sample results from no-purge sampling are found to be significantly less than that produced from volume average sampling, the presentation of subsequent no-purge sample results should be footnoted to present that finding.

Use of No-Purge Sampling Devices in Sentinel Wells

No-purge sampling devices are not recommended for monitoring sentinel wells if the saturated

length of the well intake interval exceeds five feet, unless multiple depth discrete samplers are used every sampling round. This is due to the uncertainty associated with the depth at which a contaminant front will arrive at a sentinel well. If the device is positioned above or below a discrete zone where the contaminants are migrating, the contaminant concentration would be biased low, or may not be detected at all. To avoid missing the contaminant, the well should be vertically profiled every sampling round when no-purge devices are used in sentinel wells with saturated screens/open boreholes in excess of five feet (see the vertical profiling section in 6.9.5 for more detail).

Diffusion-Based Samplers

The composition of different types of diffusion sampling devices varies. The difference in composition results in different types of diffusive samplers having different compound detection capabilities. Diffusion samplers should not be used to detect compounds for which there is not supporting documentation confirming that the diffusion device has a high detection correlation for the compound(s) of interest.

The NJDEP recommends that diffusion-based sampling devices reside in the well intake interval depth for a minimum of two weeks prior to retrieval.

When diffusion-based sampling devices are used, the NJDEP recommends that the type of diffusion sampler be identified in reports presenting the data. A reference supporting the use of the diffusion sampler for the site-related compounds should be provided where the data are presented.

The use of diffusion-based samplers in very low-yielding wells represents a special application of this type of sampling device. In this situation, the rate of contaminant diffusion from the well into the diffusion-based sampler may be faster than the rate of ground water flow through the well. The result is an overall lowering of the contaminant concentration in the well due to dilution. Accordingly, the equilibration concentration in the diffusion-based sampler may be biased low with respect the actual contaminant concentration in the surrounding formation. The smaller the well diameter, the greater the potential negative bias, due to a smaller volume of water in the well. In this situation it may be concluded that a non-diffusion based grab sample may be more representative.

6.9.6.5.3.1 Passive Diffusion Bag Samplers (PDBs)

Introduction

For the purposes of this guidance, the intended application of Passive Diffusion Bag Samplers (PDBs) is for long term monitoring of volatile organic compounds (VOCs) in ground water at well-characterized sites. This section of the Field Sampling Procedures Manual was prepared using guidance from the following documents:

- "*User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells"*, United States Geological Survey (U.S.G.S.) Water Resources Investigations Report 01-4060, March 2001. https://itrcweb.org/GuidanceDocuments/DSP-1a.pdf
- "*Technical and Regulatory Guidance for Using Polyethylene Diffusion Bag Samplers to Monitor Volatile Organic Compounds in Groundwater*", Interstate Technology and Regulatory Council (ITRC) 2004 Publication (issued by the ITRC Diffusion Sampler Team) https://www.itrcweb.org/GuidanceDocuments/DSP-3.pdf

It is recommended that anyone considering using PDBs in the State of New Jersey review both documents referenced above to obtain additional detail on theory, construction, deployment, and data considerations. These documents can be accessed via the Internet at the *Interstate Technology and Regulatory Council* (ITRC) *Diffusion Sampler Information Center* Website at http://diffusionsampler.itrcweb.org.

Advantages:

- No purging (purge water associated with conventional sampling is eliminated).
- The devices are relatively inexpensive and disposable.
- PDBs are easy to deploy and recover, which reduces both sampling costs and operator error.
- Purging stabilization criteria do not need to be measured which reduces time and associated cost.
- The stainless-steel weights and Teflon® coated wire rope (if used) are the only equipment to be decontaminated. Based on site conditions and sampling frequencies, equipment may be dedicated to a well, which reduces the need to decontaminate equipment between sampling events.
- Quick deployment and recovery are a benefit when sampling around high-profile areas such as business establishments and schools, and in dangerous areas like roadways and parking lots.
- Multiple PDBs can be deployed along the screened interval or open borehole to detect the presence of VOC contaminant stratification.
- PDBs can provide samples for accurate Dissolved Oxygen measurement.
- Since alkalinity conditions in the well are not transferred across the membrane, effervescence associated with HCl preservation is avoided.

Limitations:

- PDBs provide a time-weighted VOC concentration that is based on the equilibration time of the particular compounds, usually 1 to 4 days. A two-week residency time in the well is considered the standard minimum time to allow for equilibration with the water in the well. Accordingly, the NJDEP recommends that PDBS reside at the target depth in the well intake interval for a minimum of two weeks prior to retrieval. In a low-yielding well, two-weeks might not be sufficient time for equilibration to occur. This is a limitation if the sampling objective is to obtain a grab sample representative of contaminant concentrations in the well at the exact time of sample collection.
- At this point the detection capability of PDBs is limited to select VOC parameters.
- PDBs represent a point sample within the well intake interval. Contamination migrating horizontally above or below the targeted depth interval may not be detected by the sampler.
- Water from within the sampler should not be used for measurement of water quality parameters.
- In some cases, biofouling of the bag could inhibit sampler performance. However, biofouling of the membrane has not been observed during field testing of PDBS for in-well deployment timeframes of up to three months in duration.
- The PDB needs to stay submerged in the well. If the water level drops and exposes the bag to the atmosphere, VOCs in the PDB will degas to the atmosphere and bias the sample low.

Theory

PDBs have proven effective in detecting select VOCs in ground water. The function of the sampler is based on the *Law of Diffusion,* which states that compounds tend to migrate from areas of higher concentration to areas of lower concentration. PDBs are suspended within the screened interval or open borehole of a ground water monitoring well. VOCs in the well water will diffuse

across the semi-permeable polyethylene membrane into the distilled water of the sampler until the concentration inside and outside of the bag reach equilibrium.

It is necessary to consider several factors that affect the ability of PDBs to obtain a representative sample. These factors include well construction, lithology, contaminants of concern, the potential for contaminant stratification, and vertical flow within the well. By the nature of how PDBs work, they may produce sample results that differ from other sampling methods.

PDB Construction

PDBs are typically made of 4-mil. low-density polyethylene (LDPE) flat tubing that is filled with laboratory reagent grade (ASTM Type I or Type II) water and sealed at the ends.

The samplers can be outfitted with a protective polyethylene mesh sleeve to protect the bags against abrasion and tears during deployment and recovery. The addition of this outer protective mesh covering does not affect sampler performance (i.e., does not enhance or inhibit the transfer of VOCs across the polyethylene membrane). While use of the protective cover may be beneficial, it is not specifically required.

Currently, there are two variations of PDB available. One sampler is **prefilled** by the vendor and shipped to the sampling location for deployment. The second type is shipped **unfilled** to the sampling location and should be filled in the field with ASTM Type I or II reagent grade water prior to deployment. Vendors can usually modify the length and width of a sampler to meet specific sampling requirements.

The PDBS are suspended in the well intake interval at a predetermined depth via low-stretch braided, polyester rope (preferred), Teflon®-coated stainless steel wire cable, or stainless steel wire cable (please see "Deployment" section for additional requirements regarding deployment line/tether materials). In most cases, the samplers are neutrally buoyant. Sufficient weight must be attached to the bottom of the deployment line to keep the samplers positioned at the desired location within the screened interval/open borehole of the well. Equipment vendors can supply stainless steel weights that can be easily decontaminated and reused.

Contaminant Detection Capabilities

PDBs are capable of collecting most VOCs in ground water, however, some highly water-soluble VOCs such as methyl-tert-butyl ether (MTBE), and acetone have shown poor correlation in laboratory tests (i.e., greater than 11% difference between concentrations inside and outside the PDB). For that reason, use of PDBs is not recommended for sampling the aforementioned parameters. Parameters showing good correlation in lab tests and recommended for sampling with PDBs are identified in Table 6.16. Since PDBs have a limited detection capability (i.e., VOCs), they are not recommended for initial investigations where there is not a thorough understanding of the contaminants present. PDBs should generally not be used at a site **until** the contaminants of concern have been thoroughly documented and are determined to be compatible with their use.

Table 6-16.
Parameters Suitable for Passive Diffusion Bag (PDB) Samplers

Laboratory Tested VOCs that Displayed Good Correlation (i.e., less than 11% difference between concentrations inside and outside the PDB)		
Benzene	BDC Methane	Bromoform
Chlorobenzene	Carbon Tetrachloride	Chloroethane
Chloroform	Chloromethane	2-Chlorovinylether
Dibromochloromethane	Dibromoethane	1,2-DiChlorobenzene
1,3-Dichlorobenzene	1,4-DiChlorobenzene	Dichlorofluoromethane
1,2-Dichloroethane	1,1-Dichlororethene	cis-1,2-Dichlororethene
trans-1,2-Dichloroethene	1,2-Dichloropropane	cis-Dichloropropane
Ethyl dibromide	trans-1,3-DCPE	Ethylbenzene
Naphthalene	Toluene	1,1,1-Trichloroethane
1,1,2-Trichloroethane	Trichloroethene	Trichlorofluoromethane
1,2,3-TCPA	1,1,2,2-PCA	Tetrachloroethene
Vinyl Chloride	Xylene	

PDBs are deployed at specific depth intervals, and therefore, it is necessary to know what contaminants are present at the sample depth of the deployment location. Depth can be biased based on contaminants and geology (e.g., bedrock fractures). Midpoint is a default when there is no information to bias the placement depth. See the Section 6.9.5 *Vertical Profiling*, for more detail about device placement.

Note: Compounds that displayed poor correlation in testing and are not recommended for sampling with PDBs include MTBE, Acetone, Styrene and MIBK (i.e., compounds with high water solubilities). Due to its high water solubility, it is likely that the testing of 1,4-dioxane by PDBs may not be appropriate. The use of PDBs for the sampling for compounds outside the list below needs to be supported by testing documentation. The supporting documentation should be included in the report where the data are presented.

Procedures for PDB Use (Deployment/Retrieval)

PDBs can be obtained pre-filled from a vendor, or they can be obtained empty and filled in the field prior to deployment. In both cases, the PDB must be filled with laboratory reagent grade ASTM Type I or II water. As with all ground water sampling approaches, plastic sheeting should be laid out on the ground surface at the sampling location to provide a contaminant free surface to assemble and prepare the samplers for deployment. PDBs can be placed inside a protective polyethylene mesh sleeve (available from current vendors) to protect the bags against abrasion and tears during deployment and recovery. The use of the outer protective mesh covering is not required, however, if a sampler tears during retrieval, another PDB should be prepared and deployed for an additional 2-week equilibration period.

Weights and Deployment Lines

Since PDBs are neutrally buoyant, they must be attached to a weighted line to keep them positioned at the desired sampling depth over time. The weight should be constructed of stainless steel, which can be reused after thorough decontamination per acceptable decontamination procedures (See Chapter 5. 2 *Decontamination Procedures*,). If the weight is to be placed back into the same well, it does not necessarily need to be decontaminated.

Low-stretch synthetic rope is preferable for deploying the samplers in the well. Deployment lines/tethers should be dedicated to a single well. The only acceptable material for use in multiple wells with proper decontamination between wells is Teflon® coated stainless-steel wire; however, it is not recommended to use the same deployment line in more than one well. Stainless steel cables may be used as the deployment line for dedicated well use. Rope should be low stretch, non-buoyant, and sufficiently strong to support the weight of the sampler(s). An example of acceptable rope would be uncolored (white) 90- pound, 3/16-inch braided polyester. Extreme care must be exercised when using rope as a deployment line in deep wells due to the potential for the deployment line to stretch, which may result in improper location of the PDB within the well. Deployment lines consisting of material other than Teflon® coated stainless steel wire should not be used in another well. Deployment lines can be used A) one time and discarded, B) removed from wells between deployments if properly labeled with well ID and stored, or C) remain in the well between sampling rounds. The deployment line and PDB should not contact non-aqueous phase liquid (NAPL) during deployment or retrieval, which could lead to carry-over of contamination and degradation of the polyethylene membrane. Therefore, the use of PDBs in wells with floating LNAPL may be inappropriate unless actions are taken to prevent the PDBs from contacting the product. Under no circumstances should PDBs be reused.

The preferred deployment method is to have the weight attached to the end of the deployment line and position the line so that the weight rests on the bottom of the well with the line taut above it. The PDBs are attached directly to the deployment line at a depth interval corresponding to the targeted sample depth within the screened interval. As previously mentioned, sufficient weight must be added to the PDB deployment line to counterbalance the buoyancy of the PDBs. This is particularly important when deploying multiple PDBs.

Measuring and Attaching the PDBS to the Deployment Line

Before sampler deployment, measure the total well depth and compare it with the reported depth to the bottom of the well from **as-built** well construction diagrams or tables to evaluate whether sediment has accumulated in the bottom of the well. In some cases, wells are constructed with sediment traps or sumps. It is important to identify and account for the presence of these structures when measuring the placement location of the sampler on the deployment line. Wells with depths or construction details vastly different from the as-built diagrams may indicate that there is a problem with the well or that the well is misidentified. In these cases, the well designation and location should be verified to find the source of the error. If there is uncertainty regarding the length or depth of the well intake interval, an independent method of well construction confirmation should be employed, such as video imaging.

It is usually easier to measure the placement of the PDB on the deployment line from the bottom of the well. Provide attachment points in the deployment line using loops at appropriate points, or movable clamps with rings. Attach the PDB to the deployment line with cable ties, stainless steel clamps, or simply tie in a way that prevents slipping of the sampler bag along the wire/rope. Care should be taken to eliminate sharp points or ends of clamps or cable ties to decrease the potential for puncture or tear of the PDB.

For wells that are screened across the water table PDBs should be placed at least 2 feet below the water table in the well. Extreme care should be taken to ensure that no part of the sampler bag will be exposed above the water table during the equilibration period. Since VOCs can diffuse into and out of the PDB, VOCs from ground water that

At locations where changes in ground water elevation are expected, or the PDB is being used to sample contamination that is concentrated near the water table (e.g., samples for vapor intrusion assessment, or evaluation of LNAPL type contamination), a float could be attached to the line so that the PDBs maintains a fixed depth below the water table in the well.

diffuse into the bag can diffuse out of the top of the bag into ambient air if the PDB is exposed. If this condition was observed prior to retrieval of the PDB, it would be necessary to resuspend the sampler at least 2 feet below the water table and wait for an additional 2-week equilibration period. For areas where there are large tidal influences or significant fluctuations in ground water elevations, historic ground water elevation data should be reviewed to determine the appropriate depth to set the PDB so it will not be exposed to ambient air during the equilibration period. In this situation, using a float and weight combination may be appropriate as suspending the PDB from the float would allow it to adjust to the tidal water level changes.

Equilibration Time

The sampler is positioned at the desired depth interval in the well by attachment to a weighted deployment line and left to equilibrate with the water in the well. While some VOCs equilibrate within 48 to 72 hours, the minimum recommended equilibration period for PDBs is 2 weeks. This is to allow the formation water and well water to re-stabilize after deployment of the samplers, and to allow diffusion between the stabilized well water and the PDB to occur. In low-yielding formations, additional time may be required for the well to re-stabilize. If quarterly sampling is being conducted, it is acceptable to leave PDB in the well for up to three months so that samplers can be retrieved and deployed for the next monitoring round during the same mobilization. Longer deployment periods (i.e., semi-annual or annual) are generally acceptable; however, individual well conditions should be considered when determining appropriate maximum deployment time. As the manufactures of PDBS have not provided time limits for how long a PDBS can be kept in a well without compromising the integrity of the device, the retrieval of a PDB that shows any signs of structural integrity issues or fouling (e.g., iron or biological) should be promptly reported to NJDEP and clearly discussed in documents presenting data from that PDB.

If it is decided to use a PDB in a low yield well, the PDB should be left in the well for a significantly longer time period for the water quality in the PDB to be similar to the surrounding formation.

Sample Retrieval

After the appropriate equilibration period (discussed above), the PDB is removed upward and out of the well using the deployment line. If multiple samplers are being retrieved from a single well, care must be taken to ensure the vertical placement of the sample within the well is accurately recorded on each sample vial and in the fieldnotes. When retrieving multiple samplers from a single well, only one PDB should be removed and processed at a time. The remaining samplers should be suspended in the well until they can be processed to isolate them from exposure to ambient weather conditions and direct sunlight.

Once a sampler is removed from the deployment line, the sample water should be immediately transferred into appropriate pre-labeled, VOC vials. It is not acceptable to remove more than one PDB from a well at a time prior to sampling (i.e., multiple PDBS should not be collected and then sampled at one location). Sampling information (e.g., sample ID, date and time of collection, depth interval, etc.) must be recorded before removing the next PDB from the deployment line.

PDB water can be transferred to VOC sample vials using a small lab-clean one-time-use straw that has a sharpened end. The straw is used to pierce the bag at the bottom and the sample is decanted though the straw into sample vials. In all cases, care must be taken when transferring the sample since the bags themselves are not rigid and can bend or collapse during handling.

Collected samples must be placed immediately in a sample cooler that is **already** full of ice so that samples are **immediately** chilled and stored at a temperature of 4°C, in accordance with existing NJDEP ground water sampling protocols.

Quality Assurance/Quality Control Samples

"Duplicate/blind duplicate" samples should be collected at a rate of 10 percent of the total number of samples collected. A duplicate/blind duplicate sample must be obtained from the same bag as the original sample. Sample volume consideration must be accounted for when collecting matrix spike and matrix spike duplicate (MS/MSD) samples. If the laboratory requires three 40-ml vials for each sample location, then a total of nine 40-ml vials will be required to cover the sample plus MS/MSD requirement. That means a minimum (no spillage) of 360 ml must be obtained from the targeted location. Deployment of two bags at the same sampling interval may be necessary to obtain these required QA/QC samples. If the well is 2 inches in diameter, two bags placed side-by-side at the same sampling interval may not fit down the well. In this case, a larger bag (capable of holding more than 360 ml of water) may need to be ordered from the vendor and deployed to provide sufficient sample volume to meet QA/QC requirements. Another option is to speak with the laboratory to identify the minimum sample volume they need to conduct the required analysis. Often, labs will require more water than necessary to be collected for analyses. This is typically to account for potential loss of sample volume due to spills or vial breakage during shipment and/or during sample preparation in the lab. (Note: The ITRC Diffusion Sampler Team has worked with Columbia Analytical Labs and USEPA Laboratory representatives to generate a *Minimal Volume Document* that identifies the least amount of sample volume required to do conventional sample analysis. Although this document uses standard analytical protocols, labs should be contacted to ensure they are comfortable with the approach.) In addition, contact the laboratory if there are any additional QA/QC requirements for the sampling methodology.

Blanks for Lab-filled PDBs

For PDBs that are filled in a laboratory and shipped to the site, a modified PDB trip/equipment blank should be taken during deployment of the samplers. The purpose of this blank is to identify potential biases in sample quality resulting from water used by the lab to fill the samplers, sampler materials, and environmental conditions that the samplers were exposed to during storage, shipment, and deployment.

This blank is obtained by ordering an *extra* PDB which is shipped to the site in the same container and handled in the same manner as all of the other PDBs that will be deployed during the sampling event. If offered by the manufacturer, it is acceptable to use a pre-filled "travel blank", which is a miniature passive diffusion bag without protective mesh, for the trip blank sample, if it is ordered at the same time, remains with the shipment of PDBs at all times prior to sampling it, made from the same material, and is filled with the same lot of water. This type of blank should be collected at a rate of one per sample shipment. If there is more than one sampling crew, and samplers are being transported in separate containers, one modified trip blank (i.e., *extra* PDB) should be taken for each sampler container.

Throughout the deployment event, the "extra" PDB must travel in the same container as the other samplers that are being deployed. Once all samplers have been deployed, a sample should then be taken from the *extra* PDB. Open this PDB and transfer a sample into a VOC vial in the same manner as will be used to obtain samples from all of the other PDBS when they are retrieved after the equilibration period.

This sample should be processed (i.e., if appropriate, preserved, and properly labeled) and immediately chilled/stored in a sample cooler at 4º Celsius and sent to a NJ-certified laboratory for analysis. Once the sample water is transferred to the 40-ml VOC vials, the regularly required complement of QC samples and chain-of-custody requirements that applies to all ground water sampling protocols is followed.

Blanks for Field-filled PDBs

Some samplers available from equipment vendors are designed to be filled in the field prior to deployment. If PDBs are field-filled, they should be filled with laboratory reagent grade water that meets the specifications of Type I or Type II of ASTM D1193 - 06(2011) Standard Specification for Reagent Water. It is also necessary to take a **modified trip/equipment blank** for this type of sampler. This type of blank should be collected at a rate of one per sample shipment. If there is more than one sampling crew, and samplers are being transported in separate containers, one modified trip blank (i.e., **extra** PDB) should be taken for each sample container. This blank is intended to detect any sample bias due to the quality of the fill water, PDB material or, if applicable, the environmental conditions they may potentially be exposed to during transport to the deployment location.

If these types of samplers are filled at a location other than the wellhead where they will be deployed, the blank should be taken in the same manner as the one described above for lab-filled PDBs. While the lab-filled blank comes pre-filled, the field-filled blank is initially empty and should be filled by the sampling crew using the same procedure that will be used to fill all of the other samplers that are deployed at the site (e.g., if other samplers are filled using a funnel, follow the same procedure to fill the trip/equipment blank sampler).

After filling the sampler, seal it as you would all other samplers and place it in the same container as the other samplers for transport to the deployment location. As discussed above, once all samplers have been deployed, a sample should then be taken from the **extra** PDBS. Open this PDB and transfer a sample into a VOC vial in the same manner as will be used to obtain samples from all of the other PDBs when they are retrieved after the equilibration period.

This sample should be processed (i.e., if appropriate, preserved, and properly labeled) and immediately chilled/stored in a sample cooler at 4º Celsius and sent to a NJ-certified laboratory for analysis. Once the sample water is transferred to the 40-ml VOC vials, the regularly required complement of QC samples and chain-of-custody requirements that applies to all ground water sampling protocols is followed.

Data Reporting Requirements

To use PDBs as a replacement sampling technology for long term monitoring, it is necessary to demonstrate that the use of PDBs is appropriate at each well. In addition, it is important to document that the sampling method was performed in accordance with NJDEP guidance. To meet these objectives, a PDB Data Checklist (see page 126) should be completed for each well where PDBs are deployed. This checklist should be submitted with the analytical results for each sampling round. In addition, a narrative should accompany the checklist and analytical data that describes the site, the well, and procedures that were used to deploy and retrieve the PDB. The narrative should also include any problems encountered during PDB deployment and retrieval and the steps taken to address the problems.

Other Diffusion Based Samplers

Several other diffusion-based samplers exist but are not specifically discussed in this manual (e.g., Regenerated Cellulose Dialysis Membrane (RCDM), Rigid Porous Polyethylene (RPP), etc.). The reader is referred to documents published by ITRC and the USGS for additional discussions on these sampling devices. Some of the devices are commercially available for purchase and use, others may not be available and may only exist in the research and development stage. See below for considerations when sampling with PDBs or other diffusion-based sampling devices:

1. The devices should only be used for the collection of compounds for which available documentation exists showing a high correlation between the contaminant concentration

in the device and the concentration in the surrounding water. For passive diffusion devices other than PDBs, that documentation should be included in the report that includes the ground water sampling results from the device in question.

2. The sampling devices must remain submerged in the well during the entire time that the devices are in the well.
3. The devices are only to be used in the well intake interval.
4. A depth of deployment in the well intake interval should be proposed prior to field mobilization.
5. The depth to water should be measured and recorded just prior to deployment and just prior to retrieval.
6. Where multiple devices are deployed in a single well, only one device shall be removed for sample collection at a time.
7. The devices should not be used for the initial sampling of an AOC or well, or the close-out sampling of a well, AOC, or site.
8. If used for the sampling of a sentinel well, the well should be vertically profiled using the device each time it is used.
9. The sample designation should link the well and the sampling interval (i.e., MW-1/22-24').
10. The NJDEP considers two weeks to be a minimum equilibration time for diffusion-based samplers. Where the manufacture recommends a longer equilibration time, the manufacturer's time becomes the minimum time for the device to be in the well prior to removal.

New Jersey Department of Environmental Protection

Checklist for the Submission of Sampling Data for Passive Diffusion Bag Samplers (PDBs)

1. Site: _____
2. Location: _____
3. Well Designation: _____
4. Well Permit Number: _____

5. Type of Well: ☐ Monitoring ☐ Extraction ☐ Residential ☐ Public Supply ☐ Irrigation ☐ Other
6. Well Surface Finish: ☐ Stick up ☐ Flush Mount
7. Location of Measuring Point: ☐ Top of Casing ☐ Other (specify)
8. **Note:** PDBs represent a point sample within the screened interval or open hole of the well. It is critical to know the exact depth within the well where the PDB is deployed. Well construction specifications, which are typically used to determine where to set the PDB in the well, are measured in feet below ground surface (ft bgs). If the depth interval for PDB deployment is measured from the reference point identified above, the difference between this reference point and the ground surface must be measured and accounted for to determine the proper depth interval to set the PDBS. Please identify below, any differences between the measuring point identified above and actual ground surface at the well head.

   Distance between measuring point and ground surface (ft.) _____
9. Total Well Depth (ft bgs): _____
10. Screened interval/open hole (ft bgs): _____
11. Well Casing: Diameter: _____ Material: ☐ PVC ☐ Carbon Steel ☐ Stainless Steel
12. Well Screen (or open hole diameter): Diameter: _____ Material: ☐ PVC ☐ Carbon Steel ☐ Stainless Steel
13. Screen Size (slot) Screen Slot Size _____

14. Date and Time of Deployment Date: _____ Time: _____
15. Depth to Ground Water Depth to ground water at time of deployment _____
16. Date and Time of Retrieval Date: _____ Time: _____
17. Depth to Ground Water Depth to ground water at time of retrieval _____
18. Type of Deployment Line Used Diameter: _____ Material: _____

19. Material and Mass (oz.) of PDBS Weight _____ (stainless steel recommended)
20. Type of PDBS Used
    - ☐ Laboratory Filled (Modified Trip Blank must be taken at time of deployment)
    - ☐ Field Filled (Modified equipment blank of fill water must be taken at time of deployment. If PDBS isn't filled at well head, blank must travel with samplers until last sampler is deployed. Blank is then taken.)
21. Dimensions of PDB Length (in.) _____ Diameter (in.) _____ Filled _____
22. Position of PDB Weight
    - ☐ Attached to bottom of PDBS and suspended in well
    - ☐ Attached to bottom of deployment line and suspended in well
    - ☐ Attached to bottom of deployment line and resting on bottom of well (preferred)
23. Position of PDBs in Well Screen (ft. from measuring point to top of PDBS)

1st PDB	2ND PDB	3RD PDB	4TH PDB
_____	_____	_____	_____
5TH PDB	**6TH PDB**	**7TH PDB**	**8TH PDB**
_____	_____	_____	_____

24. If the saturated portion of the well screen or open hole is greater than 5 feet, has the well been vertically profiled to assess the potential for contaminant stratification?
    - ☐ **No**, this well is being profiled during this sampling round
    - ☐ **Yes**, this well was profiled already. Date when well was profiled:
25. If the saturated portion of the well screen or open hole is greater than 10 feet, has the well been flow tested to assess the potential for vertical flow to be present within the well?
    - ☐ **No**, flow testing has not been conducted in this well
    - ☐ **Yes**, flow testing of this well was conducted. Date of testing:

      Type of flow meter used: _____

      Measurements taken every _____ feet **[Please attach Results]**
26. Weather Conditions During Deployment Temp. _____ Wind _____ ☐ Sunny ☐ Overcast ☐ Raining ☐ Snowing
27. Weather Conditions During Retrieval Temp. _____ Wind _____ ☐ Sunny ☐ Overcast ☐ Raining ☐ Snowing

28. Field Sampling Technician: Name(s) and Company (please print clearly)

Name	Company

6.9.6.6 Temporary Wellpoints and Direct Push Technology

The 1994 Alternative Ground Water Sampling Techniques (AGWST) Guide outlined several temporary well point constructions. Advances in small diameter positive displacement pumps and expanded direct push tooling has rendered this guidance obsolete. Accordingly, the NJDEP no longer supports the temporary well construction methods outlined in the aforementioned document. Guidance on the use of temporary well points should be taken from the Field Sampling & Procedures Manual and the well construction regulations at N.J.A.C. 7:9D.

Since direct push methods do not agitate ground water like air rotary or auger methods, ground water samples collected from direct push methods can be collected immediately upon installation of the well point. While not required, NJDEP recommends that the drive point be developed before the ground water sample is collected. For situations where the water table is less than 25 feet, development of the well point using a peristaltic pump is possible. Temporary wells are typically narrow-diameter wells with short screens (one to ten feet) installed by hand (shallow), drill rig, or hydraulic direct push. Ground water samples collected from temporary well points using shorter screens may only represent the water quality of a small vertical interval of the aquifer. Similar to sampling permanent wells, measures should be taken to limit well drawdown in the well intake interval. When sampling below the water table (completely submerged well screen), drawdown to the top of the well screen is acceptable. When sampling at the water table, the sample should be collected during a period of minimal drawdown in the well intake.

Pursuant to N.J.A.C. 7:9D-2.1(a)4, if the casing and screen are removed and the borehole properly decommissioned within 72 hours of their installation, they are considered to be a Category 4 well. Any well remaining in the ground for more than 72 hours will be classified as a permanent well and will be subject to all the regulations regarding monitoring well construction and decommissioning found in the "Subsurface and Percolating Water Act", N.J.S.A. 58:4A-4.1 et seq., and their implementing regulations (N.J.A.C. 7:9D-1.1 et seq.).

The 72-hour limit allows for temporary wells to be developed and surveyed. Development of a temporary well may:

1. increase the hydrologic connection between the well and the surrounding formation;
2. reduce well water turbidity; and
3. increase well yield.

Surveying a temporary well would allow depth to water measurements collected from the well to be used in the construction of ground water contour maps.

Situations may arise where there is a need to leave a temporary well point in the ground for greater than 72 hours. NJDEP does provide a mechanism for addressing this situation. Under N.J.A.C. 7:9D-2.8 one can request a "Deviation" from the well construction standards. All deviation from construction standards requests shall be in writing and must be approved prior to performing the pertinent work. N.J.A.C. 7:9D-2.8 outlines the informational requirements that need to be submitted for such a deviation request. The information must be submitted with an accompanying well permit to the Division of Water Supply and Geoscience, Bureau of Water Allocation and Well Permitting, by a licensed well driller via the NJDEP portal. The approval of any deviation from construction standards request must be through the issuance of a well permit.

It should be noted that within the March 1, 2018, edition of 7:9D, soil borings and Category- 4 wells that are 50' or less in depth, and 8.5" in diameter or less, are considered a general Permit-by-rule condition where individual permits are not issued by the NJDEP. If the proposed work meets the Permit-by-rule conditions, and a deviation from the construction standards is needed, the submittal of a well permit will be required as part of the deviation request.

Sample results from ground water samples collected from temporary well points using a method and

equipment acceptable for collecting a similar sample from a permanent monitoring well (that is contaminant appropriate) would carry the same weight as the permanent well results and could be used for any purpose (e.g., determination of an exceedance, delineation, area closeout, etc.). Ground water samples collected from temporary well points using methods or devices "not recommended" by NJDEP, with respect to the contaminant(s) of concern will be viewed by NJDEP as screening quality, and should not be the sole data used for regulatory decisions (e.g., determination of exceedances, delineation determination, clean area determination/close out sampling, etc.).

In similarity to the issues discussed for vertical profiling, temporary well point samples should be vertically biased based on-site information (e.g., are the contaminants LNAPL or DNAPL, is there a downward gradient in the aquifer, does the ground water contamination appear to be stratigraphically constrained, is there existing site information that shows specific vertical presence of the contamination, etc.).

Where temporary well points are being used to delineate ground water contamination, the small well intake interval dictates that the temporary well point sampling be implemented in similarity to vertical profiling such that one sample is collected in each 5-foot interval of the saturated aquifer.

Temporary wellpoints can be used to characterize a ground water contaminant plume through vertical profiling. They can also be used to construct "transects" whereby temporary well points are placed at selected intervals perpendicular to the direction of plume movement. This focused approach allows for refined decision making when placing permanent monitoring wells for plume delineation. In addition, advancement in direct push technology now allows for the generation of geophysical and hydrogeological data once strictly associated with permanent monitoring well installation and observation.

Direct push methods frequently produce turbid samples since there is usually no filter pack and the screened interval is usually not fully developed. Therefore, analytical results for total metals may be biased high. Application of sampling devices with pre-attached filter packs offers a means to reduce turbidity, however, there is no guarantee turbidity will be completely eliminated. If the temporary well point is to be sampled for sediment sensitive compounds, small diameter bladder pumps or peristatic pumps can be used in an attempt to develop the well. As volatile organic contaminant concentrations are typically not influenced by the presence of suspended material, the VOC results derived from temporary well points may yield representative data.

Where ground water contamination is detected with temporary wells, the NJDEP recommends that permanent wells be installed so that the contamination can be monitored and ground water flow direction for the area can be assessed.

It should be noted that monitoring under a Ground Water Remedial Action Permit will require the sampling of downgradient sentinel wells that show no site related GWQC exceedances. While usually addressed through the installation of permanent wells, the use of temporary wells for sentinel monitoring can be proposed via a deviation request to the BRAP program and approved on a case-by-case situation. The issues concerning temporary well use are generally related to sample depth and length of screen used. If using temporary wells for sentinel monitoring, the collection of multiple drive point samples at a single location may be required. For additional information on Remedial Action Permit (RAP) requirements please see the RAP Guidance at: https://www.nj.gov/dep/srp/guidance/#rap_gw.

There are several technologies where direct push downhole equipment is used to generate qualitative sampling results. These technologies include, but are not limited to, the membrane interface probe (MIP) and light induced fluorescence (LIF). These technologies are limited to field screening data and are further discussed in Chapter 7.

The American Society for Testing Materials discusses general technique issues in ASTM D6001-05, *Standard Guide for Direct Push Groundwater Sampling for Environmental Site Characterization (2012)*. Additional information can be found on the Internet at the following USEPA and vendor URLs:

https://clu-in.org/s.focus/c/pub/i/1207/

http://www.epa.gov/swerust1/pubs/esa-ch5.pdf

http://www.geoprobe.com/products/tools/tools_menu.htm

https://www.hydrasleeve.com/images/stories/Studies/mcclellan_final_results_report.pdf

http://www.ams-samplers.com

6.9.7 Sampling for Non-Aqueous Phase Liquids

6.9.7.1 Sampling for Light, Non-Aqueous Phase Liquids (LNAPLs)

LNAPLS are generally considered to be low density, immiscible organics including gasoline, petrochemicals and other chemicals that have specific gravities less than water. They are likely to be present in aquifers as a separate phase because of their low solubility in water. These chemicals tend to float on the water surface in a water table environment and commonly occupy the capillary fringe zone above the water table. For this reason, if LNAPL product is suspected to be floating on the water table, all shallow wells installed in the area under investigation should be screened across the water table.

In a confined aquifer, these chemicals are found along the upper surface of the permeable material and also within the overlying confining layer. When immiscible organics with a specific gravity less than water are the contaminants of concern or if contaminants are suspected in more than one stratified layer in the well column, sampling procedures should be modified. It may be necessary to lower the bailer used for sample collection to a particular depth in the well, or to utilize a double check valve bailer.

Sampling procedures for LNAPL differ substantially from those for other pollutants. If more than one distinct LNAPL layer is present in a well, each layer should be sampled. Samples should be analyzed for chemical composition (i.e., for VOCs and base-neutral extractable compounds, etc.) and physical parameters (e.g., specific gravity, water solubility, vapor pressure of the liquid, and Henry's Law Constant, etc.). Gas-chromatography (GC) fingerprinting may also be used to characterize the LNAPL as gasoline or diesel fuel, etc.

After the well is initially constructed it should be developed and pumped to remove stagnant water, then it should sit idle for at least two weeks to allow the water-level to fully stabilize and the floating layer to stabilize.

Measurement of the thickness of the floating layer may be accomplished by using an interface probe. The difference between these two readings is the thickness of the floating layer. Measurement of the thickness of the floating layer may also be accomplished by using an interface probe or clear Teflon bailer, if the product thickness is less than the length of the bailer. Electric water-level sounders will not work properly for these determinations.

Prior to purging ground water from the well, a sample of the floating layer may be obtained using a bailer that fills from the bottom. Care should be taken to lower the bailer just through the floating layer but not significantly down into the underlying ground water. After following typical evacuation procedures discussed previously in this section, a sample of formation water may be obtained from the well.

6.9.7.2 Sampling for Dense, Non-Aqueous Phase Liquids (DNAPLs)

DNAPLs include chlorinated solvents and other chemicals that have specific gravities greater than water. They are likely to be present in aquifers as a separate phase because of their low solubility in water. DNAPL chemicals tend to migrate downward through the unsaturated zone and the saturated zone due to their high density. If the volume of DNAPL chemical introduced into the subsurface is larger than the retention capacity of the vadose and saturated zones, a portion of the DNAPL will spread out as a layer of free liquid on the bottom of the aquifer or on lower permeability beds within the aquifer.

Measurement of the thickness of DNAPLs (and LNAPLs) should be performed prior to purging (evacuating) the well. Measurement of the DNAPL may be accomplished by using an interface probe (if no LNAPL is present) to determine the depth of the top of the DNAPL and the bottom of the well. The difference between these two measurements is the thickness of the DNAPL in the well. An interface probe may also be used to measure DNAPL thickness in the well.

Prior to purging a monitoring well, a sample of the DNAPL may be obtained using a dual check valve bailer or a bladder pump. If both LNAPLs and DNAPLs are present in a well it may be necessary to purge the well of one casing volume of water prior to sampling the DNAPL provided that efforts are made not to disturb the DNAPL in the bottom of the well. This can be accomplished by setting the pump intake of the submersible or suction-lift pump several feet above the DNAPL.

Samples should be analyzed to determine the chemical composition of the DNAPL and its physical properties (e.g., specific gravity, water solubility, equilibrium vapor pressure of the liquid and Henry's Law Constant, etc.). Gas-chromatography (GC) fingerprinting may also be used to characterize the DNAPL as TCE or coal tar, etc.

6.9.8 Sampling Private Homeowner Wells (a.k.a. Private, Non-Public/Potable Wells)

Site Remediation potable well requirements may be different from the Private Well Testing Act (PWTA) requirements. Potable well samples should be collected based on the specific program requirements. For additional information on the PWTA please see the website: https://www.nj.gov/dep/dsr/pwta/.

Potable wells usually provide only limited useful information for ground water investigations. This is because adequate geological information relative to the well's placement and construction is not available. Also, potable wells usually have long well screens, which may cause dilution of the contaminants being investigated (volume-averaged sample). However, potable wells do provide useful information regarding contaminant identification and exposure levels to those using the well water.

When sampling these types of supplies, conduct an initial survey to get a general overview of the water system and its operation. Note how the configuration of the system relates to the type of sample that you want to collect (raw water, finished/treated water, or an intermediate sampling point). Inquire as to whether any treatment units are installed on the system. Softening (pH adjustment), iron removal, turbidity removal, chlorination, are often used; these may give misleading analyses depending upon the parameters of interest. Home carbon filters used for the removal of organics are increasingly popular. Basement and outside faucets may bypass such treatment systems. Always collect finished water samples from the cold-water faucet with the aerator removed. Should a raw water sample be desired, sample from the raw water sample tap at the well head. If a raw water sampling tap cannot be located, sample as close to the well head as possible and upstream of the storage tank or any treatment system.

Important considerations to record are:

- Well driller and date drilled
- Construction of well and casing depth
- Well and pump location

- Well depth and pump capacity (if available)
- Storage tank capacity
- Treatment or conditioning unit (if any)
- Plumbing arrangement
- Possible sample collection points
- Distance of well to any septic systems or underground storage tanks
- Aesthetic information (color, odor, observed suspended material)

Well construction information should be verified, if possible, by obtaining drilling logs that were submitted to the NJDEP with the Monitoring well Record which are maintained by the Bureau of Water Allocation.

When collecting a sample from an operating domestic well, it is essential to evacuate standing water in all plumbing lines and water storage tanks. Running the water for a minimum of fifteen minutes before collection is a good rule of thumb (unless a first-draw *System Sample* is desired), however, a longer period of time may be desirable. Listen for the pump to turn on. This is a good indicator that the tank and plumbing are being evacuated.

Home faucets, particularly kitchen faucets, usually have a screen (aerator) installed on the discharge. The screen must be removed prior to sampling for bacteria, or for volatile organics, since the screen tends to aerate the water and some organics may be lost. Also, when sampling for bacteria, do not take a sample from a swivel faucet since the joint may harbor a significant bacterial population.

Note: Homeowners' plumbing systems should not be tampered with in any way, except for removal of the faucet screen (aerator) with permission of the homeowner. Under no circumstances shall a pump be pulled from a homeowner's well unless the removal is authorized by the home- owner and is carried out by a licensed pump installer. Pump installers are trained professionals with experience in the electrical and plumbing aspects of well pumps. In addition, pump installers are trained in the proper chlorination of wells after work is completed and will advise homeowners of any precautions to take to avoid excess rust from entering their system.

For long term monitoring projects, which include sample collection from domestic wells, a specific tap or faucet should be designated as the target sample access point for consistency and data comparability of future samples.

6.9.9 Sampling Point of Entry Treatment (POET) Systems

Treatment systems are typically installed either on a temporary or permanent basis in residential homes, schools, and businesses where contamination has been positively identified at levels exceeding Safe Drinking Water Standards. These Point of Entry Treatment (POET) systems are designed to remove contaminants via filtration through carbon or other media and subsequently the water quality must be monitored on a routine basis to ensure the treatment system is functioning properly.

POET systems are generally installed with multiple sampling locations to provide the information necessary to determine operating efficiency and to decide when the filtering media must be replaced. The same purging/sampling considerations apply to private homeowner wells discussed above as to POET systems.

However, since POET systems are normally installed after home construction, there is an opportunity to control the type of sampling port. Standard gate valves (commonly termed garden faucets) have a tendency to aerate the sample, especially when the valve is only slightly opened to control flow rates. For analyses measured at the parts per trillion level, this aeration may bias the results. To control sample flow rates and assist in reducing aeration bias, install ball valves at sample ports. Select ball valves with Teflon™ or PVC internal components and non-toxic lubrication. Depending on plumbing dimensions (1/2

or 3/4-inch diameter pipe), valves should be fitted with an outlet of smaller dimension to further control flow.

6.9.10 Sampling Industrial Wells

When sampling industrial wells, it is desirable to sample as close to the well source as possible. Samples should be taken directly from the well head whenever possible. This will eliminate treatment interference, possible changes in quality within the lines, and mixing of water from other wells, etc.

Large capacity wells, which are **on-line** during the visit, can be sampled immediately. Wells, which are **off-line**, must be pumped to waste prior to sampling. Pumping fifteen minutes or more is suggested. Access to municipal well systems and well houses, etc. requires the assistance of a water department employee. Prior notification is essential.

6.9.11 Public Water Systems

Sampling Definition: Systems for provision to the public of piped water for human consumption, if such system has at least 15 service connections or regularly serve at least 25 individuals at least 60 days out of the year.

6.9.11.1 Source Sample (Raw Water)

6.9.11.1.1 Ground Water

Samples from a well supply should be collected as close to the well head as possible (before any treatment) preferably from a designated raw water sample tap. The sampler is cautioned to remember that well pumps and casings can contribute to sample contamination. If a well pump has not run for an extended period of time prior to sampling, the water collected may not be representative of actual water quality. The sample may be collected immediately (after flushing the sample tap) if the well has been running continuously. If the pump has turned off or is running intermittently, run the pump for a minimum of 30 minutes.

6.9.11.1.2 Surface Water

Samples collected from a surface water supply are to be collected before the water receives any treatment and should be representative of the water entering the intake structure. The actual sampling location may be downstream of the low lift pumps or at the intake structure. This sample is NOT to be collected along the banks of a river, lake, or reservoir.

6.9.11.2 Plant Delivered Sample (Finished Water)

This sample is to be collected at a location downstream of all water treatment and must be representative of the finished product leaving the treatment facility. Only proper spigots are to be used and they must be flushed prior to sampling.

6.9.11.3 Point of Entry Sample

This sample is to be collected at a point of entry into the water distribution system representative of a particular source after the application of any treatment.

In many cases this may be a plant-delivered sample (if no other sample tap is available) or a meter pit sample tap where water purchased in bulk from another water supply enters a distribution system.

6.9.11.4 System Sample

A system sample is a sample collected from the water distribution system. A **First draw** sample is water that immediately comes out when a tap is first opened after a period of stagnation. This type of

sample is useful when evaluating whether plumbing materials are contributing lead or other contaminants to the water supply. A **Flushed sample** is collected after the piping has been evacuated and should be representative of the water flowing in the public water main.

When collecting a **Flushed sample**, allow the spigot to run long enough to obtain a representative sample. A good rule of thumb is to allow the water to flow until the water in the service line (the pipe that carries tap water from the public water main to a home or building) has been replaced at least twice. A convenient flow for sampling is usually about a half-gallon per minute. (To estimate flow, use a gallon jug and time the fill rate.) For a flow of a half-gallon per minute, the jug should be half full in one minute or completely full in two minutes). Since 50 feet of 3/4-inch service line pipe contains over one gallon (3.8 liters), 4 or 5 minutes of running time would be necessary to replace the water in the line twice.

Samples should not normally be collected from fire hydrants, drinking fountains, or from spigots that contain aerators or screens. If aerators or screens are present, they should be removed with care. Do not sample from taps that are surrounded by excessive foliage (leaves, flowers) or taps that are dirty, corroded, or are leaking. Never collect a sample from a hose or any other attachment to a faucet. Be sure that the sample container does not touch the faucet.

6.9.12 Sampling Municipal and Industrial Wastewater

Sampling of municipal and industrial wastewater is performed for a number of reasons:

- to determine compliance with Federal, State or local standards;
- to verify reported self-monitoring data;
- to assist in determining discharge or user fees based upon wastewater strength;
- to verify the sampling technique and monitoring points of regulated parties; and
- to aid in determining the sources of prohibited or unwanted wastes.

The most difficult type of sampling to perform is the collection of background information for future use; sometimes the correct information will be obtained and sometimes it will be missed. The collection of background information is critical. Information that may be gathered includes flow rate and totalizer readings, pH, TSS, treatment plant configuration and operating status.

When sampling wastewater, one must take into consideration that good sample results depend on several factors, including sample representativeness, proper sampling technique and proper preservation. A location for sample collection should be chosen where uniform wastewater quality and thorough mixing exist. Wastewater influent samples should be collected at a point upstream of any recycle, supernatant or return lines; wastewater effluent samples should be collected after the final treatment process.

Take into consideration that the representativeness of samples may depend on timing; for example, influent samples collected at a municipal treatment plant with a substantial collection system may represent discharges into the system that occurred hours ago. This type of sampling requires a knowledge of the detention time of each unit operation in the wastewater treatment train to ensure that the effluent is representative of the influent wastewater. In addition, be cognizant that many sampling locations present safety hazards, ranging from confined spaces, elevated platforms, unsteady equipment or surroundings, airborne pollutants, and biological hazards that may include infectious disease agents, ticks, poison ivy and snakes to chemical hazards such as corrosive liquids, heavy metals, and potentially explosive atmospheres. Wastewater sampling, especially in manholes and enclosed spaces, may involve exposures to vapors of oxygen-depleted atmosphere, requiring suitable precautions.

Samples may be collected as grabs or composites, depending on the purpose of the sampling, regulatory requirements, or site conditions. Grab samples are single samples collected at neither a set time nor flow rate. It may be advantageous to collect grab samples if wastewater flow is not continuous, if the wastewater's character varies or is not consistent, or if there is a need or desire to determine if a

composite sample of the wastewater would obscure extreme conditions of the waste. In addition, some parameters, specifically dissolved oxygen or other dissolved gases, total and fecal coliform and other bacteria, pH, temperature, oil and grease and petroleum hydrocarbons, purgeable organics, and available and residual chlorine sulfite may only be collected as grab samples.

Composite samples may be collected in six different ways depending on sample volumes collected and at what frequency sample collection occurs. Composite samples may be collected as follows:

- constant sample volume/consistent time intervals;
- constant sample volume/time interval between samples is proportional to wastewater flow;
- constant time intervals/sample volume is proportional to the wastewater flow rate at the time of sample collection;
- constant time interval/sample volume is proportional to total wastewater flow since the last sample was collected;
- continuous sample collection or pumping rate; and
- continuous sample rate is proportional to wastewater flow.

If flow rates at the time of sample collection are within (+/-) fifteen percent of the average flow, sample compositing based on constant sample volumes and constant time intervals is generally representative, however, the method is not considered to be the most representative for highly variable flow or concentration conditions. During sample compositing, a minimum of eight individual samples should be collected, if possible, and each individual aliquot should be a minimum of 100 milliliters. During six-hour composites, a facility should collect an aliquot at least once each half-hour.

Composite sampling may be conducted manually or using an automatic sampler. The most common automatic samplers use either a vacuum pump or a peristaltic pump to draw the sample into the unit. A unit with a vacuum pump may be able to draw the sample at a higher velocity and from a cross-section of the wastestream. However, it may also bias the solids concentration in the collected sample if the unit operates first by filling a reservoir, then by wasting excess sample material before draining the remainder into the sample container. A unit with a peristaltic pump discharges a measured sample volume into the sample container, so less solids separation and associated sample bias should occur. However, peristaltic pump units generally sample from only one point in the wastestream. Automatic samplers operating with a suction-lift and without a detachable gathering system are practically limited to operation at heads at or under 25 feet due to internal friction losses and atmospheric pressure.

Automatic samplers should be capable of rapidly purging the intake system prior to and immediately after collection of an aliquot. The transport lines for the units should also be at least 0.64 centimeters (0.25 inches) in diameter to prevent clogging. It should be recognized that the transport lines might build up growths, which may periodically slough off and contaminate sample material if left uncleaned or unnoticed. Samplers should have an intake velocity of between two and five feet (0.6 to 1.5 meters) per second. Units with an intake velocity under two feet per second may leave solids behind in the tubing, while those with intake velocities over this range may draw in large pieces of suspended material; either case may yield erratic analytical results. One reference consulted recommended determining the suspended solids concentrations obtained from an automatic sampler and comparing it with a mean of a minimum of six simultaneously collected manual grab samples. The obtained ratio (automatic: grab) for a municipal treatment plant influent should be 1.6 to 2.0 and, for a municipal treatment plant effluent, the ratio should be 0.9 to 1.3.

Samples should be kept near 4°C during compositing; if the sampler does not have an integrated refrigeration unit or ice compartment, it may be placed on ice in an ice chest that has been laid on its end. *Standard Methods for the Examination of Water and Wastewater* recommends the addition of chemical preservatives at the start of composite sample collection, so that all sample portions are preserved as soon as they are collected.

Units to be used for collecting samples to be analyzed for trace organics must be free of Tygon tubing, which may be a source of phthalate ester contamination, and of other sources of contamination such as plastic or rubber compounds. The collection of a field blank must include the automatic sampling equipment.

When sampling wastewater, any equipment coming in contact with the sample material must be clean (see Chapter 5.2, *Decontamination Procedures*). It is preferable to collect samples directly into the containers in which they will be submitted for analysis, if possible. If a bucket or sampling device is to be used for collecting samples that will be analyzed for metals, do not use a metal device. Some parameters, such as oil and grease, petroleum hydrocarbons, volatile organics, and base neutral/acid extractable organics should not be collected except in the final sample container, if possible. Any device or bottle coming into contact with the sample material should be rinsed with the liquid two or three times, unless the bottle is pre-preserved, contains a dechlorinating agent, has been rinsed with acid, acetone, or hexane, or the sample is to be analyzed for oil and grease, petroleum hydrocarbons or microbiological parameters.

Sampling devices should face upstream, and samples should be collected centrally (at a 0.4 to 0.6 times the depth from the bottom of the wastestream and in the center of the channel). Collecting samples at this depth avoids skimming the surface of the wastestream, where the concentration of lighter-than-water materials will be highest, and lowers the possibility of sampling bed loads in situations where solids separation is a concern.

When sampling from a valve or a faucet, flush the sampling line first, taking into consideration the line diameter, length of pipe to be flushed and velocity of flow. When sampling wastestreams that are under pressure, regulate the flow rate in the sampling line to not less than 500 milliliters per minute after first flushing the line at a rate high enough to remove sediment and gas pockets. If it is believed that dissolved gases will be released from solution due to the drop in pressure, a notation should be made. If samples are to be collected from a wastestream that is at an elevated temperature, they must be collected through a cooling coil.

The importance of the use of proper containers and proper sampling and preservation techniques cannot be overly stressed. A material with a pH of 6.5 or less, and a low buffer capacity, may experience a significant pH change if shaken. In addition, samples stored in plastic containers may experience a change in pH due to the permeability of the container walls to gases like carbon dioxide. With a change in the carbon dioxide, pH, and alkalinity balance, calcium carbonate may precipitate out and the concentrations of total hardness and calcium may drop. A change in the concentrations of carbon dioxide and dissolved oxygen and changes in pH and temperature may change the concentrations of inorganic parameters such as manganese, iron, alkalinity, and hardness. If air contact will change the concentration or characteristics of a constituent, it is recommended that the sample bottle be completely filled and secured from air contact. If the sample will require mixing, if the sample will be completely consumed during analysis (such as oil and grease and petroleum hydrocarbons), or if microbiological parameters are to be analyzed, the bottle will not be able to be completely filled. If a preservative has already been added to the bottle, do not overfill the container.

Containers should be completely filled for the following analyses: purgeable organics, hydrogen sulfide, free and residual chlorine, pH, hardness, ammonia, dissolved oxygen and oxygen demands, sulfite, acidity, alkalinity, ferrous iron, and for most organics. For samples requiring shipment, allow a one to ten-percent airspace for thermal expansion except for VOC, BOS and DO samples. This airspace will most likely not compensate for accidental sample freezing; however, microbiological activity may be responsible for changes in the nitrate/nitrite/ammonia concentrations of a wastewater, may reduce phenol concentration, may cause the reduction of sulfate to sulfide, reduce biochemical oxygen demand, and reduce residual chlorine to chloride. Due to oxidation, sulfite, sulfide, iodide, cyanide, and ferrous iron concentrations may decrease. Hexavalent chromium may be reduced to chromic ion. Color, odor, and turbidity may change in quality. Silica, sodium, and boron may be leached out of glass containers. Some

cations may be lost by adsorption onto, or in ion exchange with, the glass walls of sample containers.

Individuals, who are required to choose dilutions for biochemical oxygen demand or coliform bacteria analyses, may find Table 6.17 to be helpful:

Table 6.17 Suggested Biochemical Oxygen Demand Dilutions

Sample Type	Dilutions
Raw Sewage	1 - 2 - 5%
Secondary Effluent	5 -10 - 25%
	or 2 - 5 - 10%
Tertiary Effluent	5 -10 - 25%

Suggested Coliform Dilutions

Sample Type	Dilutions
Raw Sewage	10-4, 10-5, 10-6
Disinfected Effluent	1, 10-1, 10-2

Dilutions	MPN Range	
10, 1, 10-1	2.0	1,600
1, 10-1, 10-2	20	16,000
10-1, 10-2, 10-3	200	160,000
10-2, 10-3 10-4	2,000	1,600,000
10-3, 10-4, 10-5	20,000	16,000,000
10-4, 10-5, 10-6	200,000	160,000,000

6.10 Biological Sampling Procedures

Biological sampling is performed for a variety of objectives including but not limited to: community surveys, biological impairment assessments, and tissue studies. This section in intended for the collection procedures only. Analysis and assessment of the biological communities or tissue should refer to the method(s) employed and objectives of the specific project. Biological sample processing and analysis methods should be outlined in the QAPP. Habitat assessments are a useful tool in identifying potential impacts to biological communities, see the EPA website for additional information.

6.10.1 Phytoplankton. Pigment, and Harmful Algal Bloom (HAB)Sampling

6.10.1.1 Sample Site Location

Locate sampling stations as near as possible to those selected for chemical and bacteriological sampling to ensure maximum correlation of findings. These locations will depend upon the physical nature of the water body. In streams or rivers, stations should be established both upstream and downstream of a suspected pollution source or major tributary. Stations should also be set up on either side of the river to account for unequal lateral mixing. Slow moving sections of streams generally contain more phytoplankton than faster moving segments. If there are any lakes, reservoirs, or backwater areas (i.e., potential phytoplankton sources) upstream of sampling stations, notes on their nature and location should be included in the sampling log.

Sampling stations in lakes, reservoirs, estuaries, and the ocean should be located along grid networks or transect lines, aligned to provide the most representative sampling. Points of interest should include intake and discharge areas, constrictions within the water body, and major bays and tributaries off the main basin. In tidal areas, the effects of tidal oscillation should also be considered when determining sampling frequency, with samples collected at both high and low tide. In tidal areas, it is also important to collect reference or background samples from outside the influence of a potential pollution source (see NJDEP's *Ecological Evaluation Technical Guidance* available at: https://www.nj.gov/dep/srp/guidance/#eco_eval). When locating stations for a red tide survey in estuarine or coastal waters, note where and when the blooms tend to occur.

When sampling a Harmful Algal Bloom (HAB), samples are collected at areas where the HAB is visible. These samples are used for identification, enumeration, pigment, and cyanotoxin analysis.

6.10.1.2 Sampling Depth

Rivers, streams, shallow bays, and coastal waters are usually well mixed so that only subsurface sampling is necessary. In lakes, reservoirs, as well as some coastal waters, plankton composition and density may vary with depth; thus, sampling should be done at several depths determined by the depth of the thermocline, the presence of a halocline, the euphotic zone if applicable, and overall, the depth at the station. In shallow areas (1-2 meters) subsurface samples (to a depth of 1M) are usually sufficient. In deeper lakes and reservoirs, samples should be taken at intervals of 5M or less to the thermocline. In estuarine and coastal waters 2-10M deep, subsurface, mid-depth and near bottom samples are recommended. Offshore samples should be collected at intervals of 5M or less to the bottom of the thermocline, and near the bottom where depletion of oxygen by decaying blooms is critical; Please note that in waters of lower productivity larger sample volumes are needed.

When sampling a HAB, samples are collected at areas where the HAB is visible at the surface (approximately 6 inches in depth) and/or at depths where the bloom is most concentrated.

6.10.1.3 Sampling Procedure

Sample size, preservation and storage are dependent upon certain variables. Refer to Chapter 2, *Appendix 2.1* for details and discuss with the laboratory.

If analysis is limited to species composition, clear polyethylene or glass bottles may be used. If chlorophyll, phycocyanin, or cyanotoxin analyses are requested, amber bottles are recommended. Plastic bottles made of polyethylene terephthalate glycol (PETG) or High-Density Polyethylene (HDPE), wrapped in foil may be used as an alternative to glass.

Samples collected for chlorophyll, phycocyanin, or cyanotoxin analyses shall not be fixed (chemically preserved). These samples shall be preserved by chilling to 4°C. Specific preservation may be required for cyanotoxins therefore preservation and handling should be confirmed with the laboratory before sampling. If species composition analysis is necessary, then it shall be collected in a separate sample bottle, or fixed preserved by laboratory staff after the aliquot for chlorophyll analysis is removed from the sample container.

When deeper samples are needed, use of a Kemmerer, Water Bottle, Van Dorn or Juday samplers are standard. All of these devices basically consist of a metal or plastic hollow cylinder with remotely activated stoppers at either end. The sampler is lowered to a desired depth with a graduated line. Once at the desired depth, a weighted messenger, attached to the line, is released. It slides down the line, strikes the release mechanism on the sampler which pulls the stoppers tight against the open ends of the cylinder, trapping the specific-depth sample of water inside.

The sampler is then withdrawn, and the water emptied into the sample container via a small spigot or tube in one of the stoppers. Use only non-metallic samplers when metal analysis, algal assays, or primary productivity measurements will be performed on the sample.

Sample bottle labels should identify the body of water sampled, the sample location, and list the date and time of collection, collectors name, preservative if present, and the type of biological analysis desired (determination of dominant or bloom species, total cell count, etc.). It is important that labels clearly identify live plankton samples as being unpreserved.

Freshwater samples for species composition analysis should be preserved with a solution of neutralized formalin (5 ml neutralized buffer with formalin/100 ml of sample). Estuarine and marine samples are to be preserved with Lugol's solution (60 g KI + 40 g iodine crystals in 1,000 ml distilled water) at a rate of one (1) drop Lugol's solution to 100 ml of sample. In special studies, glutaraldehyde may be used (6-drops/25 ml of sample). All preserved samples should be stored in the dark immediately to prevent the degradation of the phytoplankton, or the preservative if Lugol's solution is used.

All species composition phytoplankton samples should be fixed except where primary productivity and phytoplankton populations must be studied in extensive detail. When collecting live samples, leave at least a four-cm air space in the bottle and chill to 4 ºC (e.g., in a cooler with ice) during transit storage. For delicate flagellated species, do not refrigerate sample bottles. Maintain in-situ temperature by storing them in a sealed sample container, out of direct sunlight, in a cooler partially filled with some of the ambient water, replace the ambient water periodically to maintain original temperature. Surface samples in streams, rivers, shallow estuaries and coastal water can be collected simply by inverting the sample bottle, immersing it up to one (1) meter below the water surface and slowly filling it as it is removed from the water. A Kemmerer sampler may also be used, holding it in a horizontal position and closing it manually.

6.10.2 Zooplankton Sampling

6.10.2.1 Sample Site Location

The procedures outlined for phytoplankton sampling can be applied.

6.10.2.2 Sample Depth

The same procedure as phytoplankton for rivers and streams but in lentic environments sample at one

(1) meter intervals from the surface to the lake bottom, since these organisms are not confined to the euphotic zone.

6.10.2.3 Sampling Procedure

Zooplankton analysis requires larger volume samples than phytoplankton, at least six (6) liters in moderately and highly productive waters. For appropriate preservation requirements refer to Appendix-A.

6.10.3 Macrophyte Sampling

Field observations are very important when analyzing macrophyte populations. The sampling person must estimate the percentage of the lake's surface area, and bottom area, if possible, over which macrophyte growth occurs and the dominant form or forms for any samples taken.

When taking a macrophyte sample, an entire plant of each kind encountered should be collected if possible. If this is not possible, as much of the plant as can be collected should be taken, and care should be taken to include any reproductive structures present, complete leaves, and a section of stem showing branching pattern, if any. Specimens can be placed in plastic bags or containers without special preservatives, although completely aquatic species should be kept moist; refrigeration is recommended unless otherwise specified. If the samples cannot be examined within 3 days, it is recommended that they be preserved with a 5% solution of formalin.

6.10.4 Macroinvertebrates

6.10.4.1 Hester-Dendy Artificial Substrates

6.10.4.1.1 Sampler Placement

These multiple-plate samplers consist of eight large tempered plates separated by seven small plates, exposing one square foot of surface area. A hole is bored through the center of each plate. Plates placed alternatively on a galvanized eyebolt, threaded rod or nylon cord and secured. Samplers may have a brick attached to one end to anchor the sampler to the bottom for use in shallow streams, or they may be suspended from anchored floats in lakes and deep rivers. Used throughout, artificial substrates provide consistency of habitat to facilitate comparison among stations. Samplers are usually placed at equal intervals across a stream. However, species colonization is greatly affected by current velocity. When conducting a survey, care should be taken to place substrates at locations having similar flow characteristics. Three samplers are routinely placed at each sample site, although more samples may be necessary to satisfy particular statistical criteria. When using brick-anchored samplers, additional rocks are often necessary to secure the sampler in an upright position. Care should be taken not to block the plates with the rocks and thus limit colonization. Sampling devices should be placed as inconspicuously as possible, since they are prone to removal by the public. They should be secured with strong nylon line (not attached to the anchor line itself). In deeper waters, suspended samplers should be placed within the euphotic zone (i.e., shallower depths where light penetrates) usually less than 2 meters.

6.10.4.1.2 Sampler Retrieval

The samplers should be removed after a six-week colonization period. Gently remove the sampler from the water in order not to dislodge the organisms, and immediately place the sampler in a plastic tub or bucket. Anchors attached to the substrate should not be placed in the tub until any organisms on the anchor are removed and discarded. Add a small amount of water to the tub and wash the easily removable material from the plates. Then gently scrape the top and bottom of each plate into the tub removing the plates as cleaned. Scalpel, spatula, or soft toothbrushes are useful cleaning tools. Pour the sample slurry through an U.S. Standard No. 30 sieve. Additional water

may be used to completely clean the tub. Pass this through the sieve as previously described. Transfer the sample material from the sieve to the sample jar(s) using forceps or a stream of water from a wash bottle. Fill each jar no more than half full. Work directly over the tub so that any spilled materials can be recovered. Finally, inspect the tub for any remaining organisms and transfer them to the sample jar(s).

Water-resistant paper should be used for sample labels and all information written with a soft lead pencil. Include sample (log) number, water body, station, sample number, sample device, and other pertinent information. Record the sample number in a bound notebook together with other environmental information. Place the label inside the sample jar. An external label is helpful in identifying the sample in the laboratory. See below for preservation. Any samplers thought to be contaminated by oil, grease, toxins, etc. should not be reused. All other samplers are to be washed thoroughly in the laboratory before reuse.

6.10.4.2 Surber or Square Foot Bottom Sampler

6.10.4.2.1 Sampler Placement

This sampler consists of a strong close-woven fabric (0.595-mm opening) approximately 69-cm (27 in.) long held open by a square foot metal frame hinged at one side to another frame of equal size. The sampler is generally used in procuring samples in fast-flowing streams less than 1m deep. It can also be used in pools where the water depth is wadeable. Three replicate samples are usually obtained at each sampling station.

Carefully place the sampler in position with the net opening facing upstream, using the current to hold the net open, while standing downstream and to the side of the sampling area. By imbedding the separate 2 or 4-inch extensions of the horizontal frame, the sampled area will be more effectively isolated. When taking replicate samples, always work across or in an upstream direction. Dislodge the rocks, stones, and other bottom material within the frame to a depth of at least 2 inches and collect them in the net.

6.10.4.2.2 Sampler Retrieval

Remove the sampler and empty the contents into a plastic tub. Carefully inspect the larger rocks and stones removing any organisms clinging to them and discard the stones when cleaned. Also, carefully inspect the net and remove any organisms remaining. After the larger materials have been inspected and removed, add a small amount of water to the tub and pour the slurry through an U.S. Standard No. 30 sieve. This may have to be repeated several times to completely empty the tub.

Follow the same techniques described under Hester-Dendy retrievals in transferring the sample to the sample jars and in labeling. See below for preservation.

6.10.5 Grab Samplers

The Ponar, Peterson, and Ekman grab are the most commonly used grab samplers. The Ponar is similar to the Peterson, except that it has side plates and a screened top to prevent sampling loss. The Ekman grab is useful in sampling silt and muck in water with little current. Extreme care must be employed when locking open the jaws of the samplers, as premature tripping will squash or sever fingers or hands. Handling by the attached line is recommended with an open sampler. Carefully lower the grab to the bottom so as not to agitate the substrate prior to sampling. Slacken the rope to trip jaws (the Ekman grab employs a messenger, which is released by the operator) and retrieve the sampler. Place it in a plastic tub or large screened bin and carefully open the sampler jaws to release the sample. The sample should be discarded if sticks or stones have obstructed the jaws or if there is incomplete closure for any other reason. Inspect the larger debris for organisms and discard the debris when cleaned. Filter sample through a #30 sieve to remove smaller particles. Then transfer, label, and preserve the sample as

described in Chapter 2, *Appendix 2.1*.

A Mason jar, or any glass or plastic wide mouth container can be used for macroinvertebrate samples. All macroinvertebrates are preserved in 5% formalin (5 ml formalin/100 ml of water from which the organism was taken), with 95 % ethanol, or isopropyl alcohol.

Equipment List for Macroinvertebrate Sampling Using Surber, Square-Foot, Hester-Dendy or Grab Samplers:

- U.S. Standard No. 30 Sieve
- Plastic trays
- Brush
- Forceps
- Gloves
- Sample containers
- Boots
- Formalin
- Labels
- Squeeze bottle

6.10.6 Periphyton Sampling

6.10.6.1 Artificial Substrates

6.10.6.1.1 Sampler Placement

Samples are collected using standard 25 x 75 mm (1 x 3in) unfrosted glass microscope slides as artificial substrates mounted in a floating rack. Eight slides are to be placed at equal intervals in the sampler and secured with monofilament fishing line. The sampler is then attached several feet downstream of a large anchored float. The sampler should be secured so that the slides are parallel with the current. The large float helps to deflect floating materials, which would otherwise cover the slides and reduce photosynthesis. It also forms an eddy, which may be more conducive for periphyton colonization than a faster current. In shallow streams, the sampler may be tied directly to a brick and placed directly on the stream bottom. This is especially advantageous in areas where floating samples may be disturbed or removed by the curious. Care should also be taken to place the samples in well lighted stream segments so that light intensity will be similar at all stations in a survey.

6.10.6.1.2 Sampler Retrieval

A two-week exposure period constitutes the optimum exposure period. Upon retrieval, three slides should be immediately processed for chlorophyll A determinations. If it is impossible to begin immediately (while rowing a boat for example) place the sampler in a bucket or tub and cover, since exposing the slides to direct sunlight will result in a rapid deterioration of chlorophyll.

To process chlorophyll, scrape three slides clean as soon as possible with a razor blade or rubber policeman, being careful not to touch the surfaces with your fingers. Place the scrapings from each slide into separate 120 ml amber jars (with polyseal caps) and then, using an eyedropper, rinse each slide with a small amount of 90% acetone. Twenty to thirty milliliters to a maximum of fifty milliliters should suffice. The remaining slides, to be used for species composition determination, should be placed in separate clear glass jars filled with 5% formalin.

Seal jars tightly and label appropriately including station, sample number, date, and collector's

name. Place samples in an ice chest for transport to the laboratory.

Process the slides used for chlorophyll analysis (and later, ash-free weight) first since chlorophyll degrades rapidly and, if a slide is broken or contaminated the extra slide can be substituted.

Equipment List for Placement and Retrieval of Diatometers for Periphyton Sampling:

- Boots
- Knife
- Labels
- Gloves
- Bricks
- String
- Diatometers
- Plain glass slides
- Nylon monofilament
- Wide mouth amber bottles
- Razor blades or rubber policemen
- 90% acetone (for chlorophyll A samples)
- 5% formalin (for taxonomic ID samples)

6.10.6.2 Natural Substrates

If differences between substrates at the various study stations are not great, it is often advantageous to sample the natural substrates available. To do this a rubber sheet with a 10-cm^2 space cut out of its center is placed on a rock, piece of wood or large plant stem or leaf taken from the water. A small amount (about 1 ml) of acetone solution (90% acetone, 10% distilled water) is sprayed on the area exposed by the cut-out section of the rubber sheet. This area is then scrubbed with a toothbrush, which is repeatedly rinsed off with the acetone solution into an amber jar. The scrubbing and rinsing continue until the exposed area of substrate and toothbrush are clean. Approximately 20-30 ml of reagent grade acetone solution is needed per sample.

For chlorophyll and ash-free weight determinations, 3 replicates per station are required, each taken from a separate substrate unit (e.g., 3 separate rocks or logs). For species composition analysis, substitute water for acetone and add enough formalin to the sample jar to make a 5% solution. One composite sample should be sufficient, made from scrapings from each of the substrates used for chlorophyll sampling. Label all jars with the station designation, date, preservative used, area of substrate cleaned, and operation to be performed.

6.10.7 Rapid Bioassessment Protocol (RBP) Techniques

Rapid bioassessment provides an efficient tool for screening, site ranking and trend monitoring regarding quality of the State's waters. The methods currently in use pertain to rapidly moving fresh water (i.e., streams and rivers). Guidance on sampling and developing impairment indices can be found in the USEPA RBP manual: *Rapid Bioassessment Protocols for Use in Streams and Wadeable Rivers: Periphyton, Benthic Macroinvertebrates, and Fish, Second Edition*, EPA 841-B-99-002, 1999 EPA Office of Water.

6.10.7.1 Benthic Macroinvertebrates

Benthic RBPs usually employ direct sampling of natural substrates, as do Surbers and grab samplers; under certain conditions, however, such as in large rivers, the use of artificial substrates may be more appropriate for RBP analysis. The collection procedure should provide representative samples of the macroinvertebrate fauna from comparable habitat (substrate) types at all stations in a particular survey. Either single or multiple habitat samples can be employed depending on which is more suitable for a particular survey. A riffle/run habitat, with rock substrate, will generally provide the most diverse community of major macroinvertebrate groups. If the stream or river is non-wadeable or has an unstable substrate, fixed structures (e.g., submerged boulders, logs, bridges, and pilings) can provide suitable habitat.

D-framed or rectangular framed, 500 – 900 mm mesh "kick" nets can be employed as either single or multiple habitat samplers. See Figure 6.14.

Figure 6.14. D-Frame Net. The bottom of the net is flat to facilitate getting the net close the bottom.

6.10.7.2 Single Habitat Sampling

A 100 m reach representative of the characteristics of the stream is chosen, and whenever possible, upstream of road or bridge crossing.

A composite sample is taken from individual sampling spots in the riffles and runs in the stream reach. A minimum of $2m^2$ composited area is sampled.

Sampling begins at the downstream end of the reach and proceeds upstream. 2 to 3 *kicks* are sampled at various velocities in the reach. A *kick* is a stationary sampling accomplished by positioning the net on the bottom of the stream and disturbing one square meter upstream of the net. The substrate can be disturbed using the heel and toe of the boot or rubbed by hand for larger substrate particles. Several kicks will make up the composite sample.

Empty the composite sample into a sieve or sieve bucket and mix to ensure a homogeneous composite. Place the sample into a sample jar of at least one liter, and label with the site name, location, date, and sampler(s) name. Preserve the sample with 95 % ethanol, or isopropyl alcohol, or 5 % formaldehyde.

6.10.7.3 Multi-habitat Sampling

For sampling low gradient streams or streams with variable habitats, a multi-habitat sampling approach is required.

A 100 m reach representative of the characteristics of the stream is chosen, and whenever possible, upstream of road or bridge crossing.

Sampling begins at the downstream end of the reach and proceeds upstream. Habitats are sampled in their approximate proportion to their representation of surface area in the reach. In low gradient

streams, snags, vegetated banks, submerged macrophytes, and gravel/ sand are habitats that support fauna. A total of 20 *jabs* or *kicks* should be sampled over the length of the reach. A *kick* is a stationary sampling accomplished by positioning the net on the bottom of the stream and disturbing one square meter upstream of the net. The substrate can be disturbed using the heel and toe of the boot, or rubbed by hand for larger substrate particles. A *jab* consists of forcefully thrusting the net into a productive habitat for a linear distance of 0.5 m. Then, sweep the area with a net to ensure macroinvertebrates, that have disengaged from the substrate, are collected. A minimum of 2 m^2 composited area is sampled.

Empty the composite sample into a sieve or sieve bucket and mix to ensure a homogeneous composite. Place the sample into a sample jar of at least one liter, and label with the site name, location, date, and sampler(s) name. Preserve the sample with reagent grade 95 % ethanol, or isopropyl alcohol, or 5 % formaldehyde.

6.10.7.4 Periphyton

Benthic algae (periphyton) are primary producers and important foundation of many stream food webs. Periphyton also stabilize substrata and serve as habitat for many other organisms. Their characteristics are affected by physical, chemical, and biological disturbances that may occur in the stream reach.

Equipment:

- Stainless steel teaspoon, toothbrush, or similar brushing and scraping tools
- Section of 3" diameter or larger PVC pipe fitted with a rubber collar at one end
- White plastic or enamel pan
- Petri dish and spatula
- Forceps, suction bulb, and disposable pipets
- DI water
- 125 ml wide mouth sample jars
- Labels
- Preservative (Lugol's solution, 4% buffered formalin, "M3" fixative, or 2% glutaraldehyde)
- Cooler with ice

Establish the sampling reach as per benthic macroinvertebrates above. Collect samples using techniques for specific substrate types:

Removable substrates (hard): gravel, pebbles, cobble, and woody debris. – Remove representative substrates form the water; brush or scrape a representative area of algae from the surface and rinse into sample jar.

Removable substrates (soft): mosses, macroalgae, vascular plants, root masses. – Place a portion of the plant in a sample container with some water. Shake it vigorously and rub gently to remove algae. Remove plant form sample container.

Large substrates (not removable): boulders, bedrock, logs, trees, and roots. - Place PVC pipe with a neoprene collar at one end on the substrate so that the collar is sealed against the substrate. Dislodge algae in the pipe with a toothbrush, or scraper. Remove algae from pipe with pipette.

Loose sediments: sand, silt, fine particulate organic matter, clay. – Invert petri dish over sediments. Trap sediments in petri dish by inserting spatula under dish. Remove sediments from stream and rinse into sampling container. Algal samples from depositional habitats can also be collected with spoons, forceps, or pipet.

Place samples collected from all substrate types into a single watertight, unbreakable, wide mouth container. If a single habitat is sampled, collect from several areas. A composite sample measuring four ounces (125 ml) is sufficient. Add preservative, and place label on outside of container with pertinent information.

Transport samples on ice and in the dark.

6.10.7.4.1 Sediment Core Periphyton/Diatom Sampling

Diatoms are unicellular algae with a species-specific ornamented silica shell. These morphologically diverse glass shells, together with other aquatic organisms and material from the watershed, build up in lake sediments. Collecting and analyzing diatoms throughout a sediment core can provide past and present water quality and biological conditions in a water body.

Mini-Glew Corer - Operating Instructions[1]

Step 1: Corer Preparation

Ensure top of core tube (flat end, not tapered) and inside of housing have been lubricated with vacuum grease (needs to be done once per coring day). Attach core tube to corer and tighten band clamp on tube housing using screwdriver. Core tube should not move within housing. Make sure rubber band is properly positioned and add weight to core tube to aid in sediment penetration. Raise plunger of corer to "loaded" position.

Step 2: Testing Corer for Proper Seal

Test to see if corer is properly sealed. Completely lower the corer into the water, trigger the corer, and lift it out of the water ensure the tube is filled with water and holds it. (If not, recheck seals, vacuum grease and ensure band clamp is tight). Release water and reset corer to "loaded" position.

Step 3: Lowering of Corer

Extend arm and lower corer at a *constant rate* until corer penetrates into sediment. Send messenger down line to trigger corer. After plunger on corer is triggered, raise *slowly* to surface.

Do not allow top of core tube to break surface of water!

Step 4: Retrieval of Corer

Keep corer vertical and while core tube is still submerged at least six inches, insert rubber stopper into bottom of tube to form a lower seal.

Step 5: Retrieval of Corer II

While holding rubber stopper into bottom of core tube, lift corer slowly out of water while keeping it vertical. *Be careful not to disturb the sediment-water interface.* Check for clarity of water directly above sediment and presence of chironomids or green algal mats. At this point, measure the length of the sediment core (in centimeters) and take a digital picture of the core sample. If the sample does not contain a clear sediment-water interface or is very cloudy, discard the sample into a plastic bin for disposal upon the return to shore.

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[1] Modified version of instructions prepared by Brian Ginn, Paleoecologically Environmental Assessment and Research Laboratory, Dept. of Biology, Queen's University

Step 6: Separating Core Tube from Corer

Set bottom of core tube onto a stable surface. Firmly holding onto the corer, use the screwdriver to loosen the band clamp on the tube housing. Rotate corer slightly to ensure band clamp is loosened sufficiently.

Step 7: Separating Core Tube from Corer II

Holding onto the core tube with one hand, use the other hand to slowly remove the corer from the top of the tube. Some back and forth rotation of the corer may be necessary. *Be careful not to disturb the sediment-water interface.*

Step 8: Removal of Excess Water

Place core tube in the wooden frame. Use the turkey baster to begin removing water above the sediment. If quick removal of water is necessary, push the core tube firmly but slowly against the wooden dowel. This will raise the sediment toward the top of the core tube. When sediment approaches top of the core tube, remove last bit of water using only the turkey baster.

Step 9: Sediment Collection

If a small bit of water remains, it may be removed using the turkey baster. Holding turkey baster on an approximate 30° angle from horizontal, remove first 0.5cm layer of sediment. Rotate core tube slightly to ensure a collection of all the top sediment layers. Collect about 10ml (1/4 oz. of watery sediment). Open a Whirl-Pak bag and hold close to top of core tube.

Step 10: Sediment Collection II

Empty the sediment collected in the turkey baster into a Whirl-Pak bag. Label bag accordingly (if not already done) and ensure label on bag is correct. Close top of bag, push out excess air, and spin a few times around top twist tie. Tie off bag.

Step 11: Sediment Collection III

Push the core tube down on the wooden dowel to bring the sediment to the top of the tube. Repeat Steps 8 and 9 for the next 0.5cm layer of sediment.

Step 12: Sediment Collection IV

Push the core tube down on the wooden dowel and remove all sediment until there is 1cm of sediment left in the tube. This will be the deepest layer of sediment obtained in the sample. Collect the 1cm layer (with spatula or butter knife) and place into a Whirl-Pak bag. Retain the unsampled sediment in the plastic bin for disposal upon return to shore.

Step 13: Rinsing Equipment

Place the collected samples in a cooler. Upon return to shore, discard unsampled sediments on shoreline.

6.10.8 Fish Collection

The sampling objective is to obtain a representative sample of the fish assemblage in a 150-meter stream reach. Fish will be captured using electrofishing equipment (either backpack units or barge mounted unit), identified to species level, and then released. Electrofishing is inherently dangerous and, therefore, team leaders must be trained in safe electrofishing techniques and practices to ensure safe working conditions for themselves and the field staff (AFS Professional Safety Committee 2008). Exposure to low electrical current (like that used in electrofishing) may cause death due to respiratory arrest or cardiac fibrillation (AFS Professional Safety Committee 2008). Due to these dangers, the field team leader and at least one other crew member must be trained in CPR and AED procedures. All crew members are required to wear chest waders with non-slip soles and electrician gloves rated at 7,500 watts. Sampling

gear and crew size is directly related to stream width, but is at the discretion of the field team leader. Specific fish sampling methodology may be found in the Ecological Evaluation Technical Guidance.

Fish collection should be performed with the appropriate equipment depending on species sought. The target species should be selected based on their potential presence in the study area, their potential for exposure to contaminants of concern, their potential to serve as food for humans, and/or for their potential to serve as ecological receptors. To address the different types of fish potentially impacted, investigators may target a single sentinel species, or collect fish from multiple different trophic levels (e.g., forage fish, bottom fish, predatory fish). The collection methods may include: electrofishing, trawls, gill nets, seines, cast nets, fyke nets, baited traps, spearfishing, and/or angling. Other appropriate methods may also be useful depending on the habitat (e.g., stream, pond, lake, estuary, ocean) and the target species.

Before using any fish collection method, investigators must obtain the appropriate scientific collecting permit from the NJDEP Division of Fish &Wildlife (https://www.njfishandwildlife.com/scicolperm.htm). The Division also has guidance on seasonal exclusions for certain types of collecting equipment, and limitations on the types of collecting equipment that can be used in NJ. Though scientific collection may require collection of a large number of fish of varying sizes, investigators should also be familiar with current minimum/maximum size limits and catch limits (https://www.state.nj.us/dep/fgw/).

6.10.8.1 Fish Collection Methods:

Specific procedures used to process fish will depend on the project objectives. Regardless of the objectives, data which should always be collected on fish in the field include length, weight, species, and information on any parasites or gross external abnormalities. For a guide to common fish abnormalities see the USGS Illustrated Field Guide for Assessing External and Internal Abnormalities in Fish (https://www.cerc.usgs.gov/pubs/center/pdfdocs/itr_2002_0007.pdf). Length measurements can include standard length (tip of the snout to the base of the tail [caudal peduncle]), fork length (tip of the snout to end of the tail fork), or total length (maximum length with the mouth closed and the tail pinched together). Freshwater guidelines generally are based on total length, while some saltwater regulations are based on fork length. Scales, otoliths (ear bones), or fin rays should also be collected for aging fish as required by the study design. When possible, sex and stage of maturity should also be noted.

At each target station, the station location (e.g., GPS coordinates) should be recorded, along with water depth, and tide stage (if sampling in a tidally influenced water body). Investigators should also collect surface water quality data (e.g., temperature, dissolved oxygen, pH, salinity, specific conductance, turbidity), and collect any required surface water samples.

6.10.8.1.1 Electrofishing:

Electrofishing is a common non-lethal method for the scientific collection of fish. The boat-mounted (or backpack-mounted or barge-mounted) electrodes create a voltage potential in the water that causes galvanotaxis, an involuntary muscular contraction that results in the fish swimming toward the electrodes, becoming briefly stunned. The stunned fish can then be collected with a dip net. Stunned fish can recover completely within a few minutes (depending on the size of the fish, species, water temperature, and the electrical conductivity of the water). Therefore, fish that are not retained for study can be released unharmed, and those that were not netted are able to swim away. If the study includes a species assemblage aspect, all specimens may be collected and recorded before release. If the study purpose is tissue collection, only the target species should be retained.

Use of electrofishing requires training and an array of safety procedures to ensure live captures and the safety of the field sampling crew. The object of this manual is not to train investigators to use electrofishing equipment, but to give a brief introduction. Knowledge of water conductivity is also critical to set the voltage of the electrical generator used to create the voltage potential between the

anode and cathode. Using too much power can yield galvanotaxis contractions strong enough to damage vertebrae.

Electrofishing is a viable method only in freshwater, as the electrical conductivity of saltwater is greater than the conductivity of the fish (meaning the voltage potential will dissipate around the fish instead of going through it). In freshwater, the necessary power output, the size of the electrodes, and the size and shape of the electrical field should be known prior to shocking. The direct current (DC) pulse rate and the intensity of the electric field will selectively bias the catch to fish size and species composition.

Electrofishing is typically performed by a crew of three or more. When using a boat-mounted electrofishing system, a purpose-built boat is typically employed. The boat will likely be a shallow-draft aluminum hulled vessel with mounting poles for electrodes, and railings to allow investigators to safely stand and lean over to net fish. One technician typically drives the boat and maintains the generator and the catch basin (into which collected fish are deposited), one technician operates the electrodes (with a foot switch) and nets fish, and the third collects fish. After a suitable time period, at the end of a predetermined reach, or when enough fish have been collected, the boat returns to the staging area to process the fish.

When using a backpack-mounted generator, one technician wades while carrying the generator and the electrodes, and the others net the fish into appropriate collection containers. A barge-mounted generator is typically on a small float, towed by the wading crew. The advantage of the barge-mounted generator is that it doesn't have to be carried while wading over rocks and other potential obstructions. All field team members require rubber waders, rubber safety gloves, and non-conducting dip-nets to avoid electrical shock.

Electrofishing is useful for collecting large numbers of fish in relatively shallow water, or in water with uneven bottom profile, aquatic vegetation (submerged or emergent), or numerous snags (e.g., fallen branches, debris), where other methods (e.g., trawls, seines, cast nets) may not be feasible.

6.10.8.1.2 Trawls:

Trawls are large nets designed to be towed behind a boat to catch fish. Trawls can generally be divided into bottom trawls and midwater trawls. Bottom trawls can be towed along the bottom (benthic trawling for bottom fish) or close to the bottom (demersal fish that live above the bottom). Midwater (pelagic) trawls are towed above the bottom to collect pelagic fish.

The trawl net uses a "float line" to keep the upper edge of the net floating, and a weighted rope on the lower edge of the net to keep it down. To prevent the net from collapsing during trawling, trawl boards (sometimes called otter boards) that are designed to act as wings are used to keep the net open. The net design, trawl boards, tow line length, and tow speed are used to keep the net at the desired depth, either in contact with the bottom or elevated in the water column.

Trawl nets are typically conical, with a closed off "cod end" where fish are collected. Modifications of trawl nets can include the opening size, net length, and mesh size, depending on the size of the vessel, the habitat to be trawled, and the target species. Depending on the size of the trawl used and nature of target specimens it may be necessary to invert the cod end of the net to remove entangled specimens which are often not dislodged by shaking alone.

The starting and ending position of the trawl should be recorded using GPS, along with the trawl time, vessel speed-over-bottom (travel speed taking current into account), water depth, and depth of tow. When the tow is complete (typically a timed tow), the vessel is stopped, and the net is retrieved (depending on the size of the vessel, either over the transom or from one side of the boat). When the net is aboard, the cod end of the trawl is opened, and the contents of the net are emptied into a suitable container from which the fish are processed. If the study includes a species

assemblage aspect, all specimens may be collected and recorded before release. If the study purpose is tissue collection, only the target species should be retained.

Trawling is not selective and will often result in significant bycatch (collection of non-target species), much of which may be dead or severely injured. Bycatch, and the death of bycatch, can sometimes be reduced by limiting the trawl time and the vessel speed to cut down on the amount of time fish are in the net and the force at which they are pushed into the cod end of the net. Bottom trawling also causes destruction of the bottom substrate (e.g., uprooting submerged vegetation, overturning large rocks, damaging oyster reefs). It is also not feasible to trawl in water bodies with snags (e.g., tree limbs) or debris that may impede or damage the nets. These concerns should be addressed in the field sampling plan.

6.10.8.1.3 Gill Nets:

Gill nets are passive entanglement type mesh nets (typically made of monofilament) that a fish's head fits through, but the body does not. Fish can get wedged in the mesh, fish can try to back out and get caught by their gill covers (the opercula), or a fish can get tangled by its fins/spines/mouth.

Gill nets come in many sizes and can be more size-selective than trawls, depending on the mesh size; when targeting larger fish, larger mesh is used, allowing smaller fish to pass. A common type of gill net used for scientific collection is a "set net", which is designed to be set perpendicular to shore (in a riverine system), with a weighted "lead line" (or foot rope) on the bottom and a floating top line (or headline) with additional floats to keep the net upright in the water column. Gill nets can be set from bottom to surface, or they can be set in open water, at any desired depth by reconfiguring the weighting and floats. While commercial open-water nets can be a mile long, the gill nets used for scientific collection are typically much smaller (e.g., 50 to 300 feet long), and are commercially available in heights from six feet to 30 feet. Gill nets can be a single mesh size or can be made in a series of panels with varying mesh sizes (e.g., 1, 2, 3, and 4-inch mesh).

The starting and ending position of the gill net should be recorded using GPS, along with the deployment time, water depth, and tide stage (in tidally impacted areas). When the soak time is complete, the net is retrieved (depending on the size of the vessel, either over the transom or from one side of the boat) from the downwind or down-current side to prevent backing over the net. To prevent tangling, and to allow for redeployment, the net should be immediately stacked in its container as fish are removed. As the net is brought aboard, fish are removed from the net as quickly as possible and placed into a suitable container from which the fish are processed. It is important that the crew work quickly to minimize the death of or damage to bycatch.

Gill netting is not selective and will often result in significant bycatch, some of which may be dead or injured. Bycatch, and the death of bycatch, can sometimes be reduced by limiting the soak time. Concerns about bycatch should be addressed in the field sampling plan.

6.10.8.1.4 Seines:

Seines are similar in design to gill nets, except the net is a barrier as opposed to a passive entanglement net. Seines use the same type of float lines and lead lines to keep the net upright in the water column, but the monofilament or nylon mesh is typically smaller (¼ -inch to 1¼ -inch), preventing all but the smallest fish from passing through. Commercially available seines designed for wading will also usually be four to ten feet tall and 20 to 100+ feet long and have poles at both ends for field technicians to maneuver the net through the water. While a ten-foot tall seine is deeper than wading depth, the taller the net, the larger the pocket that is formed while dragging the net through the water. The seine is usually dragged through the water in an arc from an anchor point on the shore against the current.

There are also larger boat-deployed commercial seine nets (e.g., purse seines) which are better suited for commercial harvest than scientific collection and won't be discussed here.

A typical wading seine event starts with the net stretched out along the shore, and then one technician holds the anchor end of the seine on or close to the shore while another technician walks the other end of the seine out into the water, keeping the lead line on the bottom, in a 180-degree arc around the anchor end back to the shore. It is important to keep the end poles angled so that the lead line stays ahead of the float line so that fish cannot swim under the net. The net is then checked for fish, either by dragging it onto the shore or keeping it just at the water's edge to prevent damage to the collected fish. Fish can be picked from the net by hand or using small hand nets to scoop the collected fish into appropriate containers from which they can be processed. If the study includes a species assemblage aspect, all specimens may be collected and recorded before release. If the study purpose is tissue collection, only the target species should be retained.

The seining arc described above can be modified to meet study requirements, habitat type, and water depth. When using a longer net, one or more technicians may be useful to assist dragging the end or the middle portion of the seine through the water. If the water is too deep in which to wade, the net can be dragged through its arc using a boat. Alternately, the net can be dragged by both ends along a beach or a stream reach, keeping the lead line on the bottom, for a predetermined time or distance before angling toward the shore.

In tidal areas, seining can be performed at any time during the tide cycle, but it is usually most productive during incoming and outgoing tides when fish are moving. Seine nets do not work well in areas with obstructions, snags, or debris on the bottom. Seining is not selective and will often result in significant bycatch. The advantage of using a seine over gill is that there is low potential for damaging the bycatch.

6.10.8.1.5 Cast Nets:

Cast nets (also called throw nets) are useful tools for collecting bait fish (forage fish) that tend to travel in schools. A cast net is a circular monofilament net typically between four and 12 feet in diameter with small weights attached to the outer edge, and a central handline for retrieval. The net is thrown (cast) form a boat, dock, or shore to the location at which fish are observed in a manner that causes the net to open to its full diameter as it lands in the water. The weighted outer edge pulls the net down around the school of fish, and the handline is pulled in to catch the fish. The central handline is attached by multiple smaller lines to the outer edge, so that when the net is retrieved by pulling the handline, the outer edge is pulled inward and closes around the school of fish. The net can then be placed into an appropriate container and opened to release the captured fish. If the study includes a species assemblage aspect, all specimens may be collected and recorded before release. If the study purpose is tissue collection, only the target species should be retained.

A cast net is typically thrown by draping the net over one arm so that the weights swing freely, holding the upper part of the net in that same hand, with the handline in the other hand. The net is thrown using a circular motion designed to spread the net to its full diameter as it hits the water. Casting a net properly takes practice, but there are many online tutorial videos to demonstrate proper technique.

Cast nets work best in water with no obstructions (e.g., snags, vegetation, debris) which may cause tangles or tear the net. Cast nets also work best in shallow water which doesn't allow the fish to swim downward to escape the sinking net. Cast netting does not usually include much bycatch, but if handled carefully, harm to bycatch can be minimized.

6.10.8.1.6 Fyke and Hoop Nets:

Fyke nets and hoop nets are fish traps consisting of a cylindrical or cone shaped net, held open by a series of rigid frames (e.g., rings or squares), and staked or anchored to the bottom of a shallow water body. At each of the rings, another cone of netting (a "throat") is used which allows fish to

enter but makes it difficult for them to leave. In a fyke net, the main opening of the net is framed by long panels (25 to 50-foot), also called wings, of netting to guide fish into the net. The wings themselves are very similar to seine nets. The end of the fyke or hoop net can be simply the end of a cone tied shut, or it may be a box chamber, or it may have a zipper opening to allow fish to be removed with a dip net into a suitable container for processing. If the study includes a species assemblage aspect, all specimens may be collected and recorded before release. If the study purpose is tissue collection, only the target species should be retained.

Fyke and hoop nets are typically made from nylon but can be made using monofilament. Fyke and hoop nets are designed to be deployed one day and checked on successive days (or on tide cycles). When deployed in tidal areas, it is critical that the net is not completely out of the water at low tide. The net should be placed at low tide, so that there is sufficient water depth that any trapped fish can remain alive. Fyke and hoop nets should also be set so that the net is not completely submerged at high tide, to ensure that any turtles, mammals, or birds that enter the net do not drown. If placed in navigable waters, the nets should not be placed in navigation channels, and should be visible to boaters.

6.10.8.1.7 Baited traps:

Minnow traps include the small galvanized mesh (sometimes plastic, or plastic-coated) cylindrical minnow traps with inverted cones at each end that are available online or at most bait shops. They often have an optional cylindrical extender to make the trap long enough to accommodate eels. The traps are meant to be baited and deployed in the target sample location. The traps can either be tethered to shore or to a boat, or they can be left in place marked with a buoy. Such traps are generally only useful for calm areas with low flow velocity because they are easily rolled around or swept away in a current. To retrieve the traps, simply pull the tether line in, open the trap, and place the fish in an appropriate container from which they can be processed.

Larger fish and eel traps are sturdier, multi-compartment galvanized mesh boxes (often plastic-coated) that can be adapted with weights to hold position in a current. The rectangular shape, along with the addition of weights (purpose made weights, or bricks) makes them resistant to rolling around or being swept along the bottom. Such traps typically have a hatch which can be opened to place bait in the trap or remove fish from the trap. The hatch will generally have some degradable part (the latch or the entire door) that will rot away if a trap is lost, so that it does not continue to catch fish.

Fish traps can be baited with a wide variety of baits (e.g., fish parts, chicken, or a partially opened can of cat food), while eels tend to prefer crab (particularly horseshoe crabs). The bait should be sturdy enough to last for the entire soaking period without being depleted. The traps are easy for fish to get into, but difficult but not impossible for them to get out of. When there is bait in the trap, there is reason to stay, when the bait is gone, the fish will try to leave, and the catch will be low. It is also important that if collected fish are to be analyzed as whole-body tissue samples, an aliquot of the bait should also be analyzed for the same contaminants of concern, since the fish will have consumed a portion of the bait.

When deploying traps, each trap location should be marked using GPS, and the time of deployment, depth, tide phase, weather, and any water quality information should be recorded. Because minnows and forage fish tend to travel in schools, minnow traps can often be checked in as little as an hour to obtain a sufficient amount of tissue mass. However, it is common to deploy traps early in the day and check them toward the end of the day. Traps can be left overnight, especially when trying to collect eels, which are nocturnal feeders.

When used in tidal systems, especially in deeper water bodies, it is also important to account for the drag from the buoy line and buoy when weighting the traps. Though the trap itself may stay in place in a strong current, the force of the water pulling the buoy line can drag the trap a long way

from its intended position. For deeper deployments or deployments in areas with large tidal range, it is also advisable to use a section of floating line to attach to the trap (which will tend to stay off the bottom and be less likely to get snagged), spliced to a section of sinking line to attach to the buoy (which will tend to sink and not be a hazard to navigation). When trapping in navigable waterways, investigators must follow NJDEP Division of Fish & Wildlife guidance for marking traps and buoys (https://www.njfishandwildlife.com/njregs.htm#fishing).

The presence of many fish species is seasonal, particularly in estuarine or coastal areas, and this should be addressed in the sampling plan. Fish traps are non-selective and may have bycatch, though there will not likely be any harm to the bycatch. If the study includes a species assemblage aspect, all specimens may be collected and recorded before release. If the study purpose is tissue collection, only the target species should be retained.

6.10.8.1.8 Spearfishing and Angling:

Both spearfishing and angling are suitable fish collection methods. However, angling is very time-consuming and is not an optimal method to collect large numbers of fish in a reasonable amount of time. Experienced anglers can use different bait (live or artificial) to collect some target species (e.g., largemouth bass and catfish), but some fish are harder to collect using hook and line. Additionally, fish collection plans for tissue analysis should include sufficient numbers of fish to be able to compare the tissues from one location to the tissues collected at another location. That typically requires ten or more fish of the same species and size range from each location.

Trotlines are fishing lines with a series of baited hooks at regular intervals with stakes or anchors/buoys at either end. NJDEP Division of Fish and Wildlife Bureau of Marine Fisheries posts recreational trot line regulations stating that non-commercial trotlines should not exceed 150 feet in length with a maximum of 25 baits attached (https://www.njfishandwildlife.com/pdf/non-comm_crabpot_regs.pdf).

With suitable underwater visibility, divers or snorkelers can be very selective in the species and size ranges collected, and the incidence of bycatch is eliminated. Spearfishing is also very time-consuming and is not an optimal method to collect large numbers of fish in a reasonable amount of time. However, when collecting fish from potentially contaminated sites, only divers that have been properly trained and equipped to dive in contaminated water should be employed (https://www.epa.gov/diving/epas-diving-safety-program).

6.10.8.2 Fish Sample Processing

When fish are collected for community assemblage survey purposes, the fish should be identified to the lowest practical taxa (usually species), and any desired metrics (e.g., length, weight, sex, gross external abnormalities) should be collected as quickly as possible before releasing the fish at, or close to the point of capture.

When fish are collected for tissue residue analysis, all collected fish should be held until a sufficient number of appropriately sized fish have been collected to meet the project data quality objectives. If fish are not processed immediately, they should be placed in individual sealed plastic bags with unique markings to identify the location and time of collection, on wet ice, until they are ready for processing.

A biota collection data sheet should be completed for each specimen (or composite of specimens) processed. Sample collection, date, time, species, and desired biological metrics should be recorded. All biological metrics should be measured in a consistent manner as described in the following subsections.

When compositing fish, EPA's *Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories* (USEPA 2000; https://www.epa.gov/sites/production/files/2015-

06/documents/volume1.pdf) states that the smallest fish in a composite should be no less than 75% the length of the largest fish. Biota compositing schemes should be explicitly described in the project work plan to ensure that a statistically robust data set can be developed.

6.10.8.2.1 Length

Fish length should be measured using a measuring board (a board with a stop at one end, with a tape measure running the length of the board) with the head placed against the stop. The fish should be measured with mouth closed and with the body positioned on its side (the same side for all fish measured). Fish specimens are measured in total length from the tip of the snout to the end of the longest tail lobe. Measurements are recorded in millimeters. Three different length measurements can be taken (though not all projects require all three): total length, fork length, or standard length. Total length is the greatest length from the snout to the end of the tail fin. For fish with forked tails, the two lobes should be pressed together, and the length of the longest lobe should be taken. Fork length is measured from the snout to the tip of the middle rays of the tail. Standard length is from the snout to where the base of the median tail fin rays joins the caudal peduncle. Because standard length is difficult to measure on some species, the total or fork length are most often used.

6.10.8.2.2 Weight

Spring scales or digital scales are typically used to weigh individual fish and are weighed in grams or kilograms. Spring scales often have a hook which can be run through the fish's lip or gills, or a vice-like grip to hold the fish's lower jaw. Fish can be weighed by themselves, or by placing them in a tared basket or a container of water (weighing in water reduces error due to fish movement but is not practical for large fish). Even if fish are to be composited, each individual fish should be weighed. Scales should be appropriate for the size of the fish being weighed (e.g., some scales are designed for large fish and won't be as accurate for small fish). All scales and balances used for measuring biota samples should be appropriately calibrated, and when using benchtop scales, they should be on a stable, level surface (not on a boat).

6.10.8.2.3 Species Identification

Fish should be identified to the lowest practical taxon, typically species, using appropriate taxonomic references.

6.10.8.2.4 Aging

Because it is not possible to determine the age of fish by their size, investigators can collect scales, otoliths (ear bones), spines, or fin rays. A literature search should be conducted to determine the best aging method for the target species.

Scales are the easiest hard structure to collect, and scales can be collected from live fish without significant health impacts. However, not all of the scales on a fish can be used for aging. The most appropriate spot from which to collect scales for aging is different on different species of fish, so a literature search should be conducted to determine the most appropriate location from which to remove scales on the target species. Scales can be removed by first gently scraping away the mucus layer, then by scraping toward the head (to remove multiple scales), or by firmly pressing the point of a knife on a single scale and pushing toward the tail. When aging fish using scales, multiple scales (e.g., 10) should be measured. The cleaned scales should then be placed in a small, labeled bag or envelope for shipment to the lab.

Otoliths are the most accurate method of determining age, but collection and reading otoliths requires more time and experience than collecting scales. To collect otoliths, the top of the head should be cut and pulled back from just behind the eyes to the upper edge of the operculum. The

otoliths should be exposed for removal with forceps. The cleaned otoliths should then be placed in a small, labeled bag or envelope for shipment to the lab. Otoliths can be used in two ways: the rings can be counted for aging; and the otolith itself can be analyzed for calcium and strontium isotopes to determine what portion of the fish's life was spent in fresh or saltwater.

Some fish (e.g., catfish, eels) have no scales, and otoliths are the best method of aging. However, some fish, like catfish, can be aged by examining the rings at the base of one of its pectoral fin spines. The spine can be removed, cleaned, and placed in a labeled bag or envelope for shipment to the lab.

6.10.8.2.5 External Examination

While processing fish samples, investigators should note the sex (if possible), and any gross external abnormalities (e.g., lesions, neoplasms, abrasions, missing/deformed fins, infections) and/or parasites. Fish abnormalities should be recorded and classified in accordance with the United States Geological Survey (USGS) Illustrated Field Guide for Assessing External and Internal Anomalies in Fish (USGS 2002; https://www.cerc.usgs.gov/pubs/center/pdfDocs/ITR_2002_0007.pdf). Fish abnormalities should also be photographed for the report record.

6.10.8.2.6 Dissection and Filleting

Investigators will often ship whole-body fish tissue samples to a laboratory for processing to avoid potential field contamination from cleaning fish on a boat or on an outside table near a water body. It is especially important when analyzing for low level parameters that fish processing is performed in an environment free of ambient contaminants. If such an area is not accessible for the samples to be processed, then processing should be performed by the analytical laboratory. For ecological risk assessment, the desired tissue sample is typically whole-body fish, but for human health risk assessment, the desired tissue may instead by fillets. For samples that will be used in both ecological and human health risk assessments, the fish may be filleted, and the laboratory may analyze both the fillet and the remainder (the carcass and offal). Analyzing both portions can allow for mathematical calculation of both the fillet and the whole-body tissue concentrations.

To fillet a fish, the entire fillet from each side of the fish should be carefully cut away from the skeleton, taking care not to damage the intestines (which may contaminate the fillet). Depending on the species and on the project objectives, the skin may be left on the fillet (e.g., for bass) or it may be removed (e.g., for eel). Many fish have a fatty belly flap (e.g., striped bass) that is a sink for bioaccumulative contaminants, and it is usually included with a fillet.

After filleting fish samples, investigators should continue dissection (if included in the project plan) by opening the abdominal cavity. Any gross abnormalities or parasites noted in the body cavity should be noted. The sex and state of maturity should also be noted.

The liver, kidney, and/or gill tissue may be collected for histopathology or residue analysis. When organs are collected, they should be individually weighed and checked for abnormalities. Additionally, the digestive tract may be opened to determine the fish's nutritional status and to get an estimate of its diet. A complete internal examination should be performed in accordance with the USGS 2002 guidance.

6.10.8.2.7 Shipment for Analysis

Fish should be shipped in sealed plastic bags, though for analysis of some organic compounds the fish should be wrapped in hexane-rinsed aluminum foil prior to placing it into the plastic bag (consult the analytical laboratory). The sample bags should have waterproof identification labels. Samples should be frozen and shipped to the laboratory on dry ice to ensure they stay frozen during

transport, and a temperature blank should be included in the cooler. All appropriate chain-of-custody procedures should be followed.

6.10.9 Small Mammal Collection

Due to their trophic position as consumers, small mammals can act as indicators of the effects of contamination on terrestrial and wetland communities (McBee and Bickham 1990, EPA 1997). Small mammals may be used to determine: 1) tissue contaminant concentrations; 2) histopathological effects of contaminants; 3) effects of contaminants on general health, growth, and reproduction; 4) potential impacts of contaminants on population density and demographics; and 5) site-related risks to upper level trophic receptors consuming small mammals.

These data may be incorporated into an ecological risk assessment to predict risk to small mammal populations and populations of endangered or protected species, or species that may not be practical to sample (e.g., carnivorous birds and mammals). Some small mammal tissue (e.g., squirrels and rabbits) may also be incorporated into human health risk assessments. This section also includes information about personal protective measures that should be taken to reduce the risk of infection by hantavirus and other diseases that can be transmitted to humans when trapping, handling, or processing small mammals.

6.10.10 Small Mammal Health and Safety Concerns

According to the Centers for Disease Control and Prevention (CDC), several species of small mammals (e.g., deer mouse [*Peromyscus maniculatus*], cotton rat [*Sigmodon hispidus*], rice rat [*Oryzomys palustris*], and white-footed mouse [*Microtus pennsylvanicus*]) have been found to carry and potentially transmit a hantavirus to humans (CDC 2018). Field biologists and other personnel who are exposed to small mammal body fluids and excreta are at risk of hantavirus infection (Kelt et al. 2010; Mills *et al.* 1995). This virus can cause hantavirus pulmonary syndrome (HPS), which has been fatal to a high percentage of exposed individuals. Investigators who plan to trap, handle, process, or otherwise be involved in any activities related to small mammals should be educated about the inherent risks of such activities, as well as ways to minimize those risks.

During summer months, small mammals may also carry external parasites such as ticks and fleas, which may transmit diseases such as Lyme disease, Rocky Mountain Spotted Fever, or Plague. When pesticide residue analyses are being performed on the specimens being collected, insect repellant may not be used, as it may interfere with analytical results. Personnel should carefully inspect their clothing and wear disposable full body coveralls (preferably white) when appropriate to avoid the possibility of infection by insect bites. In addition, personnel working with live animals should have a tetanus vaccination. If the potential exists for trapping animals that may be carriers of the rabies virus, the appropriate precautions should be taken, including vaccination against this virus. Because both hantavirus and rabies have the potential to be fatal to individuals exposed to them, the appropriate risk reduction/elimination measures should be included in the site-specific health and safety plan.

A limited number of people should be assigned to trap, handle, and process small mammals. An area away from and downwind of human traffic, vehicles, equipment, and any domestic animals (including livestock) should be designated as a small mammal processing area. This area should only be entered by the personnel assigned to trap and handle small mammals. Food and drinking water should not be allowed in the small mammal processing area.

When setting and checking traps, personnel should wear surgical gloves underneath an exterior pair of leather or thick rubber gloves to prevent the interior gloves from getting torn on the sharp surfaces of the traps. Care should be taken when handling the traps to avoid injury. When checking traps and disinfecting equipment, safety precautions should include wearing half-face respirators with HEPA filters. In dry or dusty conditions, disposable coveralls and appropriate eye protection should be worn as well. During processing of small mammals in the field, full face respirators fitted with HEPA filters (or half

face respirators along with appropriate eye protection) should be worn, along with two layers of chemical resistant surgical gloves or one layer of surgical gloves and one layer of thick nitrile gloves.

When handling dry ice for tissue shipping, cotton or leather gloves should be worn because it can burn unprotected skin. The quantity of dry ice used in the shipping cooler must be listed on the air bill and on a dry ice warning placard. It is also important to vent the cooler to allow for dry ice sublimation, otherwise the cooler may burst open as pressure builds. Also, important when transporting coolers with dry ice inside a vehicle is to, at least partially, open the vehicle's windows to prevent CO_2 buildup which can displace the air inside the vehicle and cause the occupants to pass out.

6.10.10.1 Preliminary Information Collection

If the target species are known prior to the field investigation, information should be assembled on their life histories, appropriate aging techniques, and trapping methods. If the target species are not known, a literature review of distribution patterns, habitat requirements, and general abundance of species inhabiting the region of the site should be conducted. This information may be used in conjunction with site data to predict the species most likely to be encountered and trapped on the site.

As directed in the NJDEP's *Ecological Evaluation Technical Guidance* (https://www.nj.gov/dep/srp/guidance/#eco_eval), investigators should determine whether threatened or endangered (T&E) species have been recorded on or near the area of concern. The NJDEP Division of Fish & Wildlife (https://www.nj.gov/dep/fgw/tandespp.htm), the NJDEP's GeoWeb (https://www.nj.gov/dep/gis/geowebsplash.htm) interactive mapping service, and the NJDEP's Natural Heritage Program (https://www.nj.gov/dep/parksandforests/natural/heritage/#datarequest) can provide the necessary information. If there is potential for T&E small mammals to be within the collection area, only live trapping methods should be used to collect small mammals.

Pertinent background information such as topographic maps, soil survey maps, previous site reports, and aerial photographs should be reviewed during the development of the sampling plan. Analytical requirements, including tissue mass requirements, sample holding times, and method detection limits for each analysis should be determined before the sampling plan is prepared. A preliminary site visit should be conducted prior to initiation of sampling. A statistically designed sampling plan should be developed, depending on the nature of the investigation, to ensure that the data collected are unbiased and that a sufficient number of samples are collected from each area of concern to determine whether statistically significant differences exist. Consultation with a statistician is highly recommended.

6.10.10.2 Preliminary Site Visit and Field Preparation

A general site survey should be conducted in accordance with work plan requirements. On-site sampling areas and a suitable reference area should be identified. The habitat within the chosen reference area should be similar to the site, yet outside of site influences. For example, if on-site trapping takes place in a red maple wetland, then a nearby red maple wetland should be selected as a reference area. If no identical habitat type can be located for a reference area, the investigator's experience and scientific judgement should be used to locate a suitable reference location.

Property access agreements should be obtained prior to any collection activities, and a scientific collection permit should be obtained from the NJDEP Division of Fish & Wildlife (https://www.njfishandwildlife.com/scicolperm.htm). The permit application can take more than a month, so it should be submitted well before planned field activities.

A preliminary site visit should be conducted, if feasible, before the actual fieldwork begins to obtain data on potential target species. Target species and sample design, including the level of sampling effort, should be based on the results of the preliminary site visit. During the visit, a variety of traps should be utilized to determine the species present and most effective trapping technique. The area of the site, the diversity of habitat, and the trapping success should determine the number of trap-nights (overnight periods during which the trap is set) to use during the actual sampling period. It is

important to note that during the preliminary site visit, a trapping effort that is too extensive or performed too close in time to the actual study may potentially deplete small populations and affect the study. In areas of lesser habitat quality, sampling could deplete local populations. Therefore, live traps should be used whenever possible. As an alternative, traps can be set in areas outside the primary focus of the study, such as the site periphery, to minimize the level of disturbance to vegetation in the area.

6.10.10.3 Collection of Specimens

6.10.10.3.1 Determination of Trapping Method

The number and type of traps and the number of trap nights should be determined according to the study objectives. If those objectives include histopathological analysis, live trapping should be conducted because tissue characteristics are less likely to change in a live animal than in a specimen that has been dead for several hours before collection. Alternative trapping methods such as snap trapping may be used for studies that do not require histopathological analysis or as a supplement to live trapping, especially if live trapping success is low.

The types of traps used should be appropriate for the target species. This can be determined by a literature review and previous experience. Several trapping techniques may be employed together if a variety of species are to be investigated, or if information on species diversity or community composition is required.

Once the trap types and target species are selected, the method of trap placement should be determined. The habitat present, the selected target species, and the study objectives may affect the determination of the trapping method to be used. Typically, a grid, pace line, or sign method is used (DeBlase and Martin 1981). However, depending on study needs other trap placement designs may be used.

Grid Method

Grids consist of a series of parallel trap lines spaced at a predetermined distance apart, with each line having the same number of traps. Traps are typically placed 10 meters (m) apart along the line but the distance between trap lines and traps may vary considerably (from three to 20-m between grid lines and traps) depending upon the size of the area of concern, the species present, the habitat, and the type of study. Traps are placed in the best available spot (e.g., under a bush) within about a 2-m distance of the grid node. Each grid line and each trap should be marked with a pin flag, survey tape, and/or Global Positioning System (GPS) coordinates. Grids are best suited for mark and recapture studies (e.g., population studies) or where unbiased sampling is required.

Pace line Method

The pace line method places traps at set distances along a single trap line. The beginning and end of the trap line and every trap should be marked with flagging and/or GPS. This method is most useful for trapping along edge habitat or on sites with fragmented habitat where a grid cannot be established.

Sign Method

This method places traps at locations most likely to catch animals based on animal sign and microhabitat. It is biased towards trapping species that have conspicuous sign (e.g., burrows and runways) compared to species that do not have conspicuous sign. It therefore should be used mainly when targeting specific species as opposed to taking an unbiased sample for determining community composition. The sign method typically provides the greatest trap success, but it is also the most time consuming to set. Since the traps are not placed at consistent distances apart, it is

important to mark the location of each trap with a flag or survey tape and GPS. Depending on the habitat, additional notations in a field notebook may be necessary.

6.10.10.3.2 Sampling Effort

The sampling effort should be based on the size of the site and the number of animals required to meet the study objectives. For most small mammal investigations, three trap-nights are sufficient to capture the required number of animals. However, the effort may be adjusted during the study as needed. When comparing areas (e.g., the on-site area compared to a reference area), an attempt should be made for equal trap success among areas to facilitate data analysis and interpretation. If the areas compared are of similar, relatively homogenous habitat, this may be achieved by expending equal trap effort per area. Additional trapping effort may be required in areas containing less than optimal habitats. Trap effort will need to be considered as a variable if community composition is being compared among areas.

6.10.10.3.3 Trap Placement and Marking

Upon arrival at the site, the traps should be counted and placed in a container (e.g., 5-gallon pail). This is important for maintaining a trap inventory and ensuring that the correct number of traps are set and retrieved.

Trap areas should be established in habitat suitable for the target species. Depending on the accuracy required, a measuring tape may be used, or points can be marked using surveying equipment or GPS.

The start and end of each grid line or trap line should be marked with a survey flag and/or length of flagging tape tied to a branch at eye level. The flag should be labeled with the trap area, trap line, and trap number, using a waterproof marker. In heavily vegetated areas, individual trap locations may also be marked with a labeled survey flag. This simplifies trap relocation and reduces habitat destruction during subsequent trap checks. At locations where a survey flag is used, the flag should be placed at the grid node. Traps should be set at the most appropriate location within about 2-m of the grid node. Flags should be placed so that they do not impede an animal's progress toward the trap.

At the beginning of each trap line, a labeled flag and baited trap should be placed. Thereafter a distance of 10-m (or the distance necessary to meet the site objectives) should be paced or measured in a straight line, set the next trap, and place a survey flag (if required based on the habitat). This procedure should be repeated until all the traps are set. Alternately, all traps can be placed on the first pass, and then baited on a second pass. Investigators should take care to minimize habitat disturbance and destruction during trapping.

Each trap area should be given a unique identification (e.g., Area 1, Area 2, Reference Area). Each trap line should be assigned its own unique number or letter, and lines should be numbered/lettered sequentially. Each individual trap along the trap line should also be assigned a sequential number, based on its position along the line. Traps should be numbered so that low numbers are consistently located toward one end of the trap grid. The location and orientation of each trap grid should be sketched in field notes and on a single "master copy" of a map or aerial photo of the site. The simpler the sampling design, the easier it is to locate and document successful captures and to pick up traps at the end of the study. If the number of traps differs among grids, this should be noted in field notes and on the map as well. Recording the trap locations at which animals are collected will allow investigators to collect soil samples most closely associated with the actual area in which the animal was exposed.

6.10.10.3.4 Types and Trap Setting

No single trap type captures all species, sexes, or age classes within a community with equal probability (Smith *et al.* 1975). Based on the objectives of the study, it is important to use the most appropriate trap type. For example, Longworth traps are considered best for voles, and pitfall traps are best for soricid shrews (DeBlase and Martin 1981). If the target species is known before the initiation of the study, a trap type that would optimize trapping efficiency of the target species while satisfying the project objectives (e.g., live traps for histopathology) should be selected. Trap size should be appropriate for the target species. If fossorial (burrowing) species are being trapped, the diameter of the trap should be approximately the same as the burrow opening size. If non-fossorial species are being trapped, the traps should allow enough space for animals to move around (Sikes et al. 2016). If the target species is not known prior to the initiation of the study or if the project objectives dictate a small mammal community census, multiple trap types and sizes should be used. Several traps of different types can be placed at each grid node. If multiple trap types are used, the same proportion of each trap type and size should be used at on-site areas and reference areas. Additionally, NJDEP Division of Fish and Wildlife publishes an annual Game Code, specifying certain trap types/styles that are not legal in the State (https://www.njfishandwildlife.com/njregs.htm#hunting), investigators should be familiar with all appropriate guidance.

The time of day traps are set depends upon the species being trapped. If only nocturnal species are being sought, traps should be set in the late afternoon/early evening and checked before or immediately after sunrise. Traps should then be kept closed during the day to avoid capturing diurnal species.

Wooden snap traps, such as Museum Specials, rat traps, and mouse traps are prone to warping when they wick moisture from soil, absorb morning dew, or become wet from rain. When traps warp, they may trigger on their own, or they may not trigger at all. To prevent this, wooden traps can be waterproofed with paraffin wax.

Paraffin should be melted in a suitable container (e.g., an aluminum pan), using a suitable heat source (e.g., a hot plate), with suitable ventilation (e.g., a fume hood). Since paraffin is flammable, an open flame must not be used, and the paraffin must never be left on the burner unattended. When the paraffin is completely melted, traps should be dipped briefly, and allowed to drip back into the paraffin. If the wax is not hot enough, the trap will get a thick coat of wax which will not penetrate the wood and it may flake off during use. When the paraffin is hot enough, the wood will be infused with wax, with very little wax coating the trap. The traps should be hung up to cool and dry overnight.

Traps should be baited when they are set. The bait types/mixtures listed below are good examples, and other baits may be used depending on the investigator's professional judgement. However, whenever bait is used and potentially consumed by the collected specimens (e.g., in live traps), a sample of the bait should also be sent for the same analyses as the tissue samples.

The bait used should be appropriate for the species being trapped and the type of trap used. For most species trapped in snap traps, bait should consist of a mixture of roughly 50:50 peanut butter and rolled oats. The relative proportions of each can be modified to suit field conditions (e.g., use less peanut butter in warmer weather). If shrews are among the target species, the traps should be baited with 50% bacon fat or melted suet and 50% peanut butter mixed with rolled oats. If shrews are required exclusively, then the traps may be baited with 100% bacon fat or suet. During summer months, paraffin may be added to the bacon fat to increase its melting point.

Kill traps should be baited so that the bait does not fall off the treadle. Live traps are usually baited with a small amount (1 teaspoon) of rolled oats or sunflower seeds. A small piece of apple (1 x ½ inch) added to the trap often increases capture success and provides a source of moisture for

trapped animals. Cotton nestlets may also be added as bedding material to increase survival during cool weather. If live shrews are required to meet the project objectives, an additional source of food (e.g., meal worms), as well as cotton bedding material, should be placed in the traps.

The technique of setting traps depends on the type of trap being set, although traps should always be set so the release mechanism is not impeded by vegetation or other obstructions.

Museum Special Traps

Museum Special traps are 5 ½ x 2 ¾ inch snap traps designed to kill a small animal (the size of mice and voles) instantly. They should be set so that the pin is under the treadle toward the "fast" release end (generally located at the left side of the treadle) for a more sensitive response.

Museum Special traps should be set along trap lines, but individual traps should be placed in areas most likely to be used by small mammals. Some species, such as voles, leave visible runways in grassy habitats. These runways typically are associated with higher trap success. Runways or other animal paths should be inspected carefully for evidence of fresh cuttings, feces, or other signs of animal activity. Traps should be placed accordingly to maximize trap success. Traps should seldom be set in open areas, since small mammals usually avoid these areas due to the increased likelihood of predation. In some habitats, such as meadows, this may be unavoidable. However, success can still be increased by placing traps along fallen logs, large roots, or in brushy areas. Care should be taken to set individual traps within 2-m of the trap line to keep the grid lines as straight as possible.

Mouse and Rat Traps

Mouse and rat traps are similar to Museum Special traps, but mouse traps are slightly smaller in size (4 x 1 7/8 inches) and rat traps are slightly larger (6 x 3 inches). Mouse traps are more suitable for smaller species (e.g., smaller mice or soricid shrews). Several species that can be caught in a Museum Special (e.g., meadow voles) may be too large to be captured consistently in a mousetrap. Rat traps are more suitable for larger species of rodents (e.g., rats, chipmunks, and squirrels). Unlike the Museum Special, the speed of the release mechanism of mouse and rat traps are generally not adjustable by treadle placement. However, bending the trap pin slightly so that it releases from the treadle more easily can increase the sensitivity of the release. Mouse and rat traps should be placed in the same manner as Museum Specials.

Sherman Traps

Sherman traps are lightweight aluminum box traps. They are available in several sizes and designed to capture animals alive. These traps are appropriate for capturing animals to be used for histopathological analysis, since postmortem autolysis of tissue is avoided. Sherman traps are also useful in preliminary studies designed to determine which species are present because animals may be released, and local populations are not affected. Sherman traps are also collapsible and easy to transport.

When setting Sherman traps, it is essential to check the effectiveness of the release mechanism by experimentally tripping the trap. The sensitivity of the release mechanism should be adjusted so that the trap releases easily if an animal weighing 10 grams or more enters the trap. In practice, a light tap on the trap should trigger the release. To adjust the release mechanism, push down or back on the tab holding the "front panel" of the trap to the floor. Sherman traps should be cleaned thoroughly to ensure that no bait or other material becomes lodged under the panel or near the release mechanism, thereby inhibiting the ability of the trap to release.

Sherman traps should be set so that the open end is facing the direction from which an animal is most likely to be traveling. For instance, if a trap is set near an opening in a tree stump, the open end of the trap should face the opening in the stump. Sherman traps are effective at catching a

variety of species, including mice, voles, and chipmunks. Animals that burrow are more prone to entering box traps if properly baited and set.

Longworth Traps

Longworth traps are especially useful for trapping voles, mice, and shrews. They are similar to Sherman traps, but consist of 2 parts, a tunnel through which an animal enters and a larger box where the animal is then confined. They are set by hooking the front (smaller) box into the larger box and securing the entrance door open. The sensitivity of the release can be modified slightly by bending the door pin.

Havahart and Tomahawk Style Traps

Havahart and Tomahawk style traps are live traps constructed of steel mesh. Like Sherman traps, they are available in a variety of sizes ranging from mice to raccoons, with entrances on one or both ends. These traps are generally not collapsible and are more difficult to set than Sherman traps or other box traps. However, if set properly, they may be effective for live trapping some species that avoid entering Sherman traps. This style trap set in runways does not necessarily have to be baited. Care should be taken to ensure that the traps release effectively in the vegetation where they are set.

As with Sherman traps, the effectiveness of the release mechanism of Havahart and Tomahawk style traps should always be tested before the traps are set in the field. This should be done after the traps are transported to the site, since in transport the sides of the trap may bend inward, resulting in only partial closure of the trap doors.

Pitfall Traps

If soricid shrews are included as a target species, or if the site objectives dictate an accurate estimate of the small mammal community composition, pitfall traps may be used. This trapping method requires extensive setup time and effort, and therefore may not be ideal for short-term investigations (one trapping period). It is ideally suited for long-term investigations and for studies where trapping is conducted over a number of trapping periods. Pitfalls should be used as kill-traps only when no other method will work (Sikes et al. 2016). If live trapping, pits should contain food and nesting material. A small (pencil-width sized) hole should be drilled into the bottom to facilitate water drainage. However, in heavy rainfall, pitfall traps should not be used for live trapping. Suitable for most shrew species, and the easiest to set, are small cans (e.g., coffee cans) set into holes made with a post-hole digger or shovel. Pitfall traps are often set in arrays interconnected with drift or silt fencing. The arrangement of traps and the optimum use of fencing may vary with the study objectives. Handley and Kalko (1993) present a review of the applications of different pitfall configurations.

6.10.10.3.5 Trap Checks

All personnel performing trap checks should wear appropriate personal protective equipment, including surgical gloves underneath an exterior pair of leather or thick rubber gloves (to prevent the interior gloves from getting torn on the sharp surfaces of the traps) and respirators (full or half-face) fitted with high efficiency particulate air (HEPA) filters. When checking traps in dry or dusty conditions, full-face respirators with HEPA filters (or half-face respirators with appropriate eye protection) should be worn, along with disposable coveralls (e.g., Tyvek). See Section 6.10.12 for health and safety concerns specific to small mammal collection.

Weather conditions and the species being trapped dictate the number of daily trap checks required to minimize stress to live animals and prevent damage to dead specimens from cold, heat, or scavengers. Generally, two checks per day are sufficient. Trap checks should be conducted as soon after dawn (less than two hours) as possible, and again in the late afternoon/early evening. If trapping for live shrews, traps should be checked every 4 to 6 hours and more frequently in cool or damp weather. For

diurnal species in warm weather, traps should be checked approximately every two hours (Sikes et al. 2016).

Investigators should carry a cooler containing wet ice, a 5-gallon plastic bucket containing replacement traps, resealable plastic bags for specimens, and fresh bait for re-baiting traps. The trap identification number and site of capture should be marked in a field notes. If a trap appears to have been visited but no specimen is present (e.g., if bait has been eaten, urine or droppings are visible, or trap has been sprung), the trap should be re-baited and reset.

Specimens caught live that are to be used for tissue analysis are generally euthanized in the field by cervical dislocation. Animals may also be euthanized by asphyxiation with a chemical inhalant (e.g., CO_2). Cervical dislocation and chemical inhalants meet the criteria of the American Veterinary Medical Association (AVMA) and the United States Department of Agriculture's Animal and Plant Health Inspection Service (USDA APHIS) for methods of euthanizing for small mammals (AVMA 2013, Sikes et al. 2016, USDA APHIS 2016). Dead specimens should be transferred to individual resealable plastic bags labeled with the trap location number, genus, species, date, time, and collector's affiliation and initials. This information should be recorded in a field notes as well. Bags containing specimens should be placed on wet ice for transfer to the laboratory or processing area and, if necessary, the traps can be re-baited and reset.

Upon completion of the study, traps should be tallied as they are removed from the trap line to ensure none are left behind. Damaged traps should be marked so that repairs can be made prior to the next sampling event.

All traps should be properly disinfected, preferably before leaving the site, but at a minimum before being returned to storage. To disinfect traps, they should be completely immersed in a dilute (5%) hospital-grade disinfectant or hypochlorite bleach solution (Kelt, et al. 2010). Sherman traps should have a hinge pin removed to allow the trap to be opened flat, so that all surfaces come in contact with the disinfectant. Any visible dirt, fecal material, nesting material, or bait should be scrubbed off with a brush and the traps should be left to soak in the disinfectant for at least 10 minutes. Detergents should not be used for cleaning traps. After soaking, the traps should be thoroughly rinsed with tap water, and set out to dry completely before being returned to storage.

When the disinfectant solution or rinse water baths become dirty with debris from the traps, the liquid should be disposed of properly, and new baths should be prepared. All work surfaces (e.g., necropsy tables) and processing tools (e.g., dissecting tools) should also be disinfected. All waste material from small mammal activities, including used paper towels, gloves, disposable coveralls, plastic bags, etc. should be placed in a plastic bag and disposed of properly.

6.10.10.3.6 Seasonal and Local Considerations

Factors such as climate and weather, habitat, and community composition need to be considered when trapping small mammals. Live animals may overheat, suffer hypothermia, or become otherwise stressed from capture, causing them to use fat reserves. Extreme temperature conditions can also alter tissue characteristics of both living and dead animals, making tissue unsuitable for analysis. Exposure of dead specimens to extreme cold can freeze tissue, making histopathological analysis difficult. Exposure to extreme heat can result in rapid tissue decomposition and possibly impact tissue physiology, which could bias both chemical and histopathological analyses. Under such conditions, the interval between trap checks should be shortened.

Additional procedures may need to be followed to increase trapping success and/or survival rates of captured animals. For example, during hot, dry periods, a slice of apple can be added to traps and traps should be placed under cover whenever possible. In cool or damp weather, cotton bedding material should be added; nestlets are particularly handy for field use (note, however, that cotton nesting material is not recommended for use during heavy rainfall). In the warmer months, ants can damage dead specimens, so care should be taken not to set traps near visible ant colonies. If ant

damage is noted, the specimen should not be used, the trap should be moved before being reset, and the interval between trap checks should be shortened. Weather can also affect trap success; many small mammals stay in their burrows on moonlit nights to avoid exposure to predators, and heavy rain can affect small mammal foraging patterns. Under such conditions, additional trap nights may be needed to compensate for a decrease in animal activity and to obtain a sufficient number of specimens to fulfill project needs.

Small mammal populations can become depleted and community species composition can be altered if trapping is conducted for an extended period. If populations become depleted, immigration into the trap area can occur and the resulting captures may include individuals not originally associated with the site. Thus, trapping should generally be limited to three or four consecutive nights.

Trapping methods may need to be modified based on regional or local factors, such as climate or interference by other animal species. For example, in some areas, ants may cause serious damage to bait or captured specimens. Predators, such as raccoons and foxes, can destroy trap lines and prey on captured animals. Extreme temperature conditions can affect survival of captured animals or alter tissue characteristics of both living and dead animals, biasing or preventing chemical and histopathological analyses. Under such conditions, trapping procedures may require special adjustments and the interval between trap checks should be shortened.

6.10.10.3.7 Sample Processing

Processing should take place as soon after trap checks as possible to reduce potential degradation of the specimens. Live animals should be killed by cervical dislocation or asphyxiation with CO_2 or other inhalant for processing. Asphyxiation by CO_2 can be performed by placing dry ice in a cooler, covering the dry ice with paper towels to prevent direct contact with the specimen, and then placing the trap with the live specimen directly in the cooler and closing the cooler until the specimen is dead. Dead specimens should be removed from the traps and transferred immediately to a resealable bag (one specimen per bag) labeled with the trap location number, genus, species, collector's initials, date, and time. Specimens should be removed from traps one at a time to minimize chances of mislabeling. The bags should be stored on wet ice in a small cooler for transport to the processing area or laboratory. Each specimen should be kept in its labeled bag whenever possible to avoid mixing up sample information.

All personnel within the small mammal processing area should don disposable boot covers, disposable coveralls, and a full-face respirator equipped with a HEPA filter (or a half-faced respirator and eye protection). Only after donning proper protective equipment should bags be opened and animals taken out for identification and processing. After processing, all samples should be placed in double containers (e.g., a sample jar inside a sealed bag, or a sealed bag inside a second sealed bag). To prevent the potential spread of pathogens, one technician should refrain from handling specimens and only assist the processor(s) with packaging the specimens for shipment. The assistant performs activities such as labeling clean bags or sample jars, holding bags or sample jars open while samples are placed inside, and placing packaged samples in the shipping coolers. This ensures that the outer bags and coolers are not contaminated for shipment and receipt at their final destination.

Each small mammal specimen should be documented on a specimen data sheet, including genus and species, sample location, date and time of collection, trap type, identification and affiliation of sampling and processing technician(s), habitat and weather conditions. Body metrics include: dorsal and ventral fur coloration (pelage), developmental stage (juvenile, subadult, adult), sex, total length, tail length, hind leg length, ear size, weight, gross abnormalities, and the presence of ectoparasites. If necropsy is performed, details are to be included on the specimen data sheet regarding sex organ weights and conditions, internal organ weights (e.g., liver, spleen, kidneys), internal parasites, and any abnormalities.

Statistical comparisons of body weight, organ weight, and other metrics among contaminant gradients can be confounded by the age structure of the populations. It is important to ensure that comparisons are made within the same age and sex class. Some species show readily identifiable differences in pelage that enable identification of age class in the field. For species in which age determination techniques are not described in the literature, eye lens weight and curves, body size and mass, tooth wear, and reproductive condition may be used to determine the relative age class (adult, sub-adult, or juvenile).

While it is more statistically sound to analyze individual organisms, there are times when that is not feasible. Depending on the number of contaminants of concern and the laboratory's analytical mass requirements, a single small mammal may not contain sufficient tissue mass for residue analysis. Individuals of the same species from locations within the same area of contamination may be composited for analysis, if (and only if) necessary. Multiple analyses of the same animal (e.g., metals, PCBs, and pesticides) may have to be prioritized if specimens do not provide sufficient tissue mass to conduct all of the required analyses. Percent moisture should always be included as an analytical parameter. If any contaminants of concern are lipophilic (e.g., PCBs or dioxin), percent lipids should also be included in the analytical parameters.

Tissue samples for residue analysis should be frozen in a freezer or by using dry ice. If tissue samples are to be shipped using dry ice, they should be thoroughly frozen prior to shipping and sufficient dry ice should be added to the shipping cooler to keep all samples frozen until they arrive at the lab. The quantity of dry ice must be listed on the air bill and on a dry ice warning placard.

Tissue samples used for histopathological analysis should be fixed in 10% neutral buffered formalin (37% formaldehyde), with the exception of male reproductive organs, which should be fixed with Bouin's fluid. These solutions are carcinogenic and should be handled with caution as detailed on their respective safety data sheets. Tissue samples fixed in Bouin's fluid should be transferred to 10% neutral buffered formalin solution after 10 days.

6.11 Toxicity Test (Bioassay) Sampling

Collection of effluent and/or dilution water for use in toxicity testing is often required as part of NJPDES compliance monitoring programs. Effluent may be either treated or untreated wastewater from NJPDES-permitted municipal or industrial point-sources which discharge to surface water. Dilution water is used in toxicity testing to dilute the effluent sample into a series of test concentrations (e.g., 100% effluent, 50%, 25%, 12.5%, 6.25%, 0%) to determine the toxicity of the effluent to permit-specified aquatic organisms (e.g., fish, daphnia, shrimp). Dilution water may be collected from the surface water body into which the effluent discharges, or it may be collected from suitable alternate source, approved by the NJDEP.

The following sections were summarized from N.J.A.C. 7:18 *Regulations Governing the Certification of Laboratories and Environmental Measurements* (Date Last Amended: September 4, 2018). Prior to collecting effluent and/or dilution water for use in toxicity tests, users should be familiar with the NJDEP's requirements as codified in N.J.A.C. 7:18-9.5 *Requirements for Acute Toxicity Testing Samples*, and N.J.A.C. 7:18-7 *Toxicity Testing*.

6.11.1 Dilution Water Sample Collection and Handling:

Dilution water samples shall either be representative of the receiving water into which the effluent is discharged or, as designated by the NJDEP in the NJPDES permit, be an alternate or reference water. Dilution water is acceptable for use in a toxicity test only if bioassay test organisms survive in it through acclimation pursuant to N.J.A.C. 7:18.

- In non-tidal waters, dilution water samples shall be collected from a location outside of the influence, but upstream of, the effluent outfall;
- In estuarine waters, dilution water samples shall be collected from a location outside the influence of the effluent, during the outgoing tide, up to and during low slack tide;
- In marine waters, dilution water samples shall be collected from a location outside the influence of the effluent being tested; and
- In marine and estuarine waters, the sampling location shall be such that the salinity of the sample is within the salinity range for the receiving water immediately outside of the effluent mixing zone.

When dilution water samples are collected from streams or rivers, an integrated sample shall be collected from the bottom to the top of the water column so that the sample is proportional to the flow. If only a grab sample can be taken it should be collected at mid-depth in midstream. When samples are collected from reservoirs or lakes, the effects of seasonal stratification, runoff, and previous rainfall upon the chemical-physical characteristics of the water shall be considered.

If the receiving water has a natural pH below 5.0 standard units, the dilution water samples shall be adjusted to a pH of 5.0 prior to their use in test organism acclimation and/or toxicity testing.

6.11.2 Alternate Dilution Water Sources

If the receiving water is influenced by other point sources of pollution so as to disqualify its use as dilution water in accordance with the NJPDES permit, then the dilution water samples shall be either obtained from a location just above the other point sources in the case of streams, or outside the zone of influence of other point sources in the case of other water bodies.

If acceptable dilution water cannot be obtained from the receiving water at any location because an effluent is discharged into the receiving water headwaters, then some other unpolluted water, meeting the following requirements, shall be used as an alternate in the following order:

1. Another surface water or ground water having a natural quality similar to that of the receiving water prior to its pollution; or
2. Reconstituted or artificial freshwater or saltwater having a natural quality similar to that of the receiving water prior to its pollution; and
3. An alternate dilution water shall have a total hardness, alkalinity, salinity, and specific conductance within 25 percent and a pH within 0.4 units of the receiving water prior to its pollution, but not less than a pH of 5.0 units.

Preparation of reconstituted freshwater or saltwater, as an alternate dilution water, shall comply with the following:

- Reconstituted freshwater shall be prepared by addition of reagent grade chemicals to laboratory pure water as specified in EPA's *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms* (EPA 2002).
- Reconstituted saltwater shall be prepared either through the use of a hypersaline brine as specified in N.J.A.C. 7:18, by using commercial sea salts, or by the addition of reagent grade chemicals to laboratory pure water as specified in EPA's *Methods for Measuring the Acute Toxicity of Effluents and Receiving Waters to Freshwater and Marine Organisms* (EPA 2002).

6.11.3 Alteration of Dilution Water Samples

Alteration of dilution water samples shall be limited to filtration and/or salinity adjustment. Filtration must be through screening made of a non-toxic material as specified in N.J.A.C. 7:18-7.4. Adjustment of

salinity shall be either by addition of laboratory pure water to lower the salinity, or by the addition of either hypersaline brine or artificial sea salts to raise the salinity.

6.11.4 Effluent Sample Collection and Handling

The effluent sampling location shall be the same as that specified in the NJPDES permit as the toxicity test analysis sampling point unless otherwise specified by the NJDEP. Samples shall be representative of the discharge, taking into account the plant operating conditions and the retention time of the effluent in the wastewater treatment plant.

When performing flow-through toxicity tests, if the facility discharges continuously, the effluent shall be pumped directly from the discharge to the bioassay dilutor system for the duration of the test. Alternatively, 24-hour composite samples consisting either of equal volumes taken once every hour, or flow-proportionate composite sampling shall be collected and transported to the dilutor daily for the duration of the test.

If the facility discharges intermittently, at least one composite sample of sufficient volume to supply the dilutor for 24 hours shall be collected daily for the duration of the test. When a facility treats and releases effluent in a batch discharge, a single grab sample of sufficient volume shall be collected to supply the dilutor. When the facility discharges to an estuary during an outgoing tide, a single grab sample or composite sample, of sufficient volume to set up the toxicity test shall be collected on the outgoing tide.

If a static toxicity test is to be conducted, effluent samples shall be collected only at the beginning of the test. If a renewal toxicity test is to be conducted, then effluent samples shall be collected at the beginning of the test and the test solutions renewed at least daily throughout the duration of the test.

When the effluent to be sampled is a stormwater discharge, collect a grab or composite sample either directly from the discharge pipe during the precipitation event or from the retention pond during or immediately after the precipitation event unless otherwise specified by the NJDEP in the NJPDES permit.

6.11.5 Alteration of Effluent Samples

Alteration of effluent samples shall be limited to filtration through screening having a mesh of 2 mm or larger; dechlorination as specified in N.J.A.C. 7:18-7.6; and the introduction of dry artificial sea salts or a hypersaline brine for the purpose of adjusting the effluent test concentration salinity according to the procedures in N.J.A.C. 7:18-7.6.

6.11.6 Sample Transport and Storage

Dilution water sample collection and transport containers shall meet the requirements listed in N.J.A.C. 7:18-7.3. Prior to sample collection, containers shall either be cleaned or rinsed, as specified in N.J.A.C. 7:18-9.6, and then filled so that there should be no air space in either the neck or the top of the container. Field collected dilution water samples shall not be stored for more than 150 hours and shall be collected as close as possible to the time of use.

Effluent sample collection and handling containers shall meet the requirements listed in N.J.A.C. 7:18-7.3. Prior to sample collection, containers shall either be cleaned or rinsed, as specified in N.J.A.C. 7:18-9.6, and then filled so that there should be no air space in either the neck or the top of the container. Toxicity testing shall begin within 36 hours of the collection of an effluent. For storm water discharge, the toxicity tests shall begin within 48 hours of collection.

Samples that are collected for offsite testing shall be chilled during or immediately after collection until adjustment to the test temperature prior to initiating the test. When the sample arrives at the laboratory, the laboratory shall log the sample in, measure the temperature of the sample and record it on the chain-of-custody form and the raw data sheet. If samples are not immediately prepared for testing, the laboratory shall store them between 1.0 and 4.4 degrees Celsius until used.

Prior to delivery of a sample to the certified environmental laboratory, the sample collector shall complete the appropriate chain-of-custody, listing at a minimum the:

- sample number;
- description of samples;
- specific location of sample collection;
- identity of person collecting the sample;
- date and time of sample collection;
- date and time of custody transfer to laboratory;
- identity of the person accepting custody;
- date and time of initiation of analyses;
- identity of person performing analysis; and
- name and identification number of the laboratory performing the analyses.

References

Abdul, Abdul, S., Sheila F. Kia, and Thomas L. Gibson, *Limitations of Monitoring Wells for the Detection and Quantification of Petroleum Products in Soils and Aquifers*, *Ground Water Monitoring Review*, Vol. IX, No. 2, p. 90-99, Spring 1989.

Acker, W.L. III, *Basic Procedures for Soil Sampling and Core Drilling,* Acker Drill Company, Scranton, PA, 1974.

American Society for Testing and Materials (ASTM) International, *Standards Related to Environmental Site Characterization, Sponsored by ASTM Committee D-18 on Soil and Rock*, ASTM, West Conshohocken, Pennsylvania, 1997.

ASTM International, *Standard Practice for Diamond Core Drilling for Site Investigation, D 2113-14*, ASTM, West Conshohocken, Pennsylvania, 2014.

ASTM International, *Standard Practice for Using the Disposable En Core Sampler for Sampling and Storing soil for Volatile Organic Analysis, D 6418-99*, ASTM West Conshohocken, Pennsylvania, 1999.

ASTM International, *Standard Practice for Environmental Site Assessments: Phase I Environmental Site Assessment Process*, E 1527-13, 2013.

ASTM International, *Standard Guide for Sampling Waste and Soils for Volatile Organic Compounds, D 4547-15*, ASTM West Conshohocken, Pennsylvania, 2015.

ASTM International, *ASTM Standards on Ground Water and Vadose Zone Investigations, sponsored by ASTM Committee D-18 on Soil and Rock*, *second edition*, ASTM West Conshohocken, Pennsylvania, 1994.

ASTM International, *Test Method for Sieve Analysis of Fine and Coarse Aggregates,* ASTM C136/C136M-14. ASTM West Conshohocken, Pennsylvania, 2014.

ASTM International, *Standard Test Method for Particle-Size Distribution (Gradation) of Fine-Grained Soils Using the Sedimentation (Hydrometer) Analysis*, ASTM D7928-17.

ASTM International, *Practice for Soil Investigation and Sampling by Auger Borings*, ASTM D1452/D1452M-16, ASTM West Conshohocken, Pennsylvania, 2016.

ASTM International, *Test Method for Penetration Test and Split-Barrel Sampling of Soils*, ASTM D1586-11, ASTM West Conshohocken, Pennsylvania, 2011.

ASTM International, *Classification of Soils for Engineering Purposes (Unified Soil Classification System),* ASTM D2487-17. ASTM West Conshohocken, Pennsylvania, 2017.

ASTM International, *Practice for Description and Identification of Soils (Visual- Manual Procedure),* ASTM D2488-17e1. 2017.

ASTM International, *Standard Guide for Sampling Waste Piles*, D6009-12. 2012.

ASTM International, *Guide for Soil Sampling from the Vadose Zone*, ASTM D4700-15. 2015.

ASTM International, *Test Method for Particle-Size Analysis of Soils*, ASTM D422-63.

ASTM International, *Standard Test Methods for Measuring the Toxicity of Sediment-Associated Contaminants with Fresh-Water Invertebrates*, ASTM E-1706-05, 2010.

ASTM International, *Standard Guide for Documenting a Ground Water Sampling Event*, ASTM D6089-15. 2015.

American Veterinary Medical Association (AVMA), *AVMA Guidelines for the Euthanasia of Animals: 2013 Edition,* AVMA, Schaumberg, Illinois, 2013.

Anderson, G., *Coring and Core Analysis Handbook*, PennWell Books, Tulsa, OK, 1975.

Applegate, Joseph L., Fitton, Douglas M., *Rapid Site Assessment Applied to the Florida Department of Environmental Protection's Dry Cleaning Solvent Cleanup Program*, Conference Proceedings, HazWaste World Superfund XVIII., Vol. 2, December 1997.

Bailey, Dr. Renata, *Improving Sampling Techniques for the Analysis of Lead in Ground Water: Determining Optimal Filtration Conditions*, State of New Jersey, Department of Environmental Protection, Division of Science, Research and Technology, Final Report 2002.

Barcelona, M.J., J.P. Gibb, J.A. Helfrich, and E.E. Garske, *Practical Guide for Ground-Water Sampling*, Illinois State Water Survey, ISWS Contract Report 314, 1985.

Barcelona, Gibb and Miller, *A Guide to the Selection of Materials for Monitoring Well Construction and Ground Water Sampling*, Champaign, Il., US Government Printing Office, August 1983.

Barcelona, M.J., J.A. Helfrich, E.E. Garskey, and J.P. Gibb, *A Laboratory Evaluation of Ground Water Sampling Mechanisms*, in Ground Water Monitoring Review, Spring, Vol. 4, No. 2, pp. 32-41. 1984.

Barcelona, M.J., J.A. Helfrich, E. E. Garske, and J.P. Gibb*, Field Verification of Sampling Methods and Materials Selection for Ground Water Contamination Studies*, Presented at: Symposium for Ground Water Contamination Studies and Their Standardization*,* ASTM, Cocoa Beach, Fla., Feb. 1986.

Barcelona, Michael J., Helfrich, John A., and Garske, Edward E., *Sampling Tubing Effects on Groundwater Samples,* Analytical Chemistry, 1985, vol. 57, p. 460-464.

Barth, D.S. and B.J. Mason, *Soil Sampling Quality Assurance and the Importance of an Exploratory Study*, ACS Symposium Series 267, Environmental Sampling for Hazardous Waste, ACS Publications, American Chemical Society, Wash. D.C., 1984.

BP Corporation North America and USEPA Region 4 and Region 5., *Monitoring Well Comparison Study: An Evaluation of Direct-Push versus Conventional Monitor Wells*, May, 2002.

Brady, N. and R. Weil, *The Nature and Property of Soils*, 12th ed., Prentice Hall.

Burmister, D.M., *Suggested Methods of Tests for Identification of Soils*, 1950.

Burton Jr., G. S. and P. F. Landrum, *New Standard Guide for Collection, Storage, Characterization and Manipulation of Sediments for Toxicological Testing, Draft 5*, Wright State University, Dayton, Ohio, December 1989.

California State University, Sacramento School of Engineering, *Water Treatment Plant Operation – A Field Study Training Program*, Sacramento, California, pp. 485-488, 1983.

Centers for Disease Control and Prevention (CDC), *Hantavirus,* 2018, https://www.cdc.gov/hantavirus/.

Christensen, Thomas H., Bjerg, Poul L., Kjeldsen, P., *Natural Attenuation: A Feasible Approach to Remediation of Ground Water Pollution at Landfills*, Ground Water Monitoring Review, Winter, 2000.

Church, Peter E., and Granato, Gregory E., *Bias in Ground Water Data Caused by Well-Bore Flow in Long-Screen Wells*" Ground Water, Vol.34, No.2, pp. 262-273, 1996.

Cohen, Robert M., Bryda, Anthony P., Shaw, Scott T., Spalding, Charles P., *Evaluation of Visual Methods to Detect NAPL in Soil and Water*, Ground Water Monitoring Review, Fall, 1992.

Cseh, Tibor, Sanschagrin, Sylvie, Hawari, Jalal, and Samson, Rejean, *Adsorption-Desorption Characteristics of Polychlorinated Biphenyls on Various Polymers Commonly Found in Laboratories,* Applied and Environmental Microbiology, Dec. 1989. P.3150-3154.

DeBlase, A.F. and R.E. Martin, *A Manual of Mammalogy with Keys to Families of the World (2nd ed.),* Wm C. Brown Company Publishers, Iowa, 463 pp., 1981.

DeVera, Emil R., Bart P. Simmons, Robert D. Stephens and David L. Storm, *Samplers and Sampling Procedures for Hazardous Waste Streams*, Cincinnati, USEPA Municipal Environmental Research Lab EPA-600/2-80-018, 1980.

Dragun, J., R.Gambino and W. Kuhn, *Coloration Changes of Geologic Media After Addition of Gasoline, Diesel Fuel, and Ethylbenzene,* The Journal of Soil Contamination, Vol. 5, No. 1, pp. 1 - 8, 1996.

Dragun, J., *The Fate of Hazardous Materials in Soil, What Every Geologist and Hydrogeologist Should Know,* Part 1, HMC, March/April 1988.

Driscoll, F.G., *Ground Water and Wells*, Second Edition, H.M. Smyth Company Inc., St. Paul, Minnesota, 1986

Elton, E.L. and E. Fendley, *Installing the Perfect Monitoring Well: Identifying, Quantifying, and Mitigating Interferences from Monitoring Well Installation Techniques*, Presented at: Symposium for Ground Water Contamination Studies and Their Standardization, ASTM Cocoa Beach, Fla., February 1986.

Environmental Research Laboratory, Robert S. Kerr, *Practical Guide for Ground Water Sampling*, Ada. OK, US Government Printing Office, EPA-600/2-85/104, 1985.

Fetter, C.W., Jr., *Contaminant Hydrogeology*, 1993.

Fink, Michael J., Boyajian, Ralph T.*, Decontamination Procedures for Ground Water Sampling Equipment*, Proceedings of the Third National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, May 1989.

Folk, R.L., *Petrology of Sedimentary Rocks,* Hemphill Publishing Company, 1974.

Foster, M., Stefanov, J, Bauder, T., Shinn, J., and Wilson, R., *Piezometer Installation Using a Cone Penetrometer* Ground Water Monitoring Review Fall, 1995.

Franson, MaryAnn H., Managing Ed., *Standard Methods for the Examination of Water and Wastewater 16th Edition*, Port City Press, Baltimore, Md., 1985.

Franson, Mary Ann H., Managing Ed*., Standard Methods for the Examination of Water and Wastewater 20th Edition*, American Public Health Association, Washington, D.C., 1998.

Gallant, R.F., J.W. King, P.L. Levins, J.F. Piecewicz, *Characterization of Sorbent Resins for Use in Environmental Sampling*, Research Triangle Park, N.C., US Government Printing Office, EPA-600/7- 78-054, 1978.

Gerlach, Robert W., Dobb, David E., Raab, Gregory A., and Mocerino, John M., *Gy Sampling Theory in Environmental Studies. 1. Assessing Soil Splitting Protocols*, Journal of Chemometrics, Vol. 16, pp. 321-328, 2002.

Gibbs, J., Brown, Allan G., Turner, Kenneth S., MacLeod, Cecilia L., Jelinski, James C., Koehnlein, Susan A., *Effects of Small-Scale Vertical Variations in Well-Screen Inflow Rates and Concentrations of Organic Compounds on the Collection of Representative Ground-Water Quality Samples*, Ground Water, Vol. 31, No.2, March-April, 1993.

Gibb, J.P., and M.J. Barcelona, *The Development of Effective Ground Water Sampling Protocols,* Presented at: Symposium of Field Methods for Ground Water Contamination Studies and Their Standardization, ASTM, Cocoa Beach, Fla., Feb. 1986.

Gibs, J., and Imbrigiotta,Thomas E., *Well Purging Criteria for Sampling Purgeable Organic Compounds*, Ground Water Vol.28, No. 1, pp 68-78, 1990.

Gibs, J., Imbrigiotta, Thomas E., Ficken, James H., Pankow, James F., Rosen, Michael E., *Effects of Sample Isolation and Handling on the Recovery of Purgeable Organic Compounds*, Ground Water Monitoring Review, Spring, 1994.

Gillham, R.W., M.J.L. Robin, J.F. Baker, and J.A. Cherry, *Ground Water Monitoring and Sample Bias*, American Petroleum Institute, APR Publication 4367, p 206, 1983.

Hacket, Glen, *Drilling and Constructing Monitoring Wells with Hollow-Stem Augers, Part 2 Monitoring Well Installation*, Ground Water Monitoring Review, pages 60 - 68, 1988.

Handley, C.O., Jr. And E.K.V. Kalko. *A Short History of Pitfall Trapping in America, with a Review of Methods Currently Used for Small Mammals*, Va. J. Sci. 44: 19-26, 1993.

Hart, Barbara F., Tomlinson, Rodger B., and Chaseling, J., *Using the Stabilization Plateau to Estimate Optimum Well Purge Volume*, Ground Water Monitoring Review, Summer, 2000.

Hayes, Heidi C., Benton, Diane J., and Khan, Noor, *Impact of Sampling Media on Soil Gas Measurements,* A&WMA Vapor Intrusion Update, Sep.13, Los Angeles, CA, 2006.Hewitt, A.D., *Enhanced Preservation of Volatile Organic Compounds in Soil with Sodium Bisulfate*, U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Special Report 95-26, 1995.

Hewitt, Alan D., Jenkins, Thomas F., Grant, Clarance L., *Collection, Handling and Storage: Keys to Improved Data Quality for Volatile Organic Compounds in Soil,* American Environmental Laboratory, February 1995.

Hewitt, Alan D., Lukash, Nicole J.E., *Obtaining and Transferring Soils for In-Vial Analysis of Volatile Organic Compounds*. U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Special Report 96-5, 1996.

Hewitt, Alan D., *Chemical Preservation of Volatile Organic Compounds in Soil*, Environmental Science and Technology, Vol. 31, No. 1, 1997.

Hewitt, Alan D., *Dynamic Study of Common Well Screen Materials*, Ground Water Monitoring Review, Winter, 1994.

Hewitt, Alan D., *Storage and Preservation of Soil Samples for Volatile Organic Compound Analysis*, U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Special Report 99-5, 1999.

Hewitt, A. D., Myers, K. F., *Sampling and On-Site Analytical Methods for Volatiles in Soil and Ground- water-A Field Guidance Manual*, U.S. Army Corps of Engineers, Cold Regions Research and Engineering Laboratory, Special Report 99-16, 1999.

Hewitt, Alan D., *Frozen Storage of Soil Samples for VOC Analysis*, Environmental Testing and Analysis, Vol. 8, No. 5, 1999.

Hewitt, Alan D., *Methods of Preparing Soil Samples for Headspace Analysis of Volatile Organic Com- pounds: Emphasis on Salting Out*, Proceedings of the Waste Testing and Quality Assurance Symposium, pp. 323-329, 1996.

Hewitt, Alan D., Jenkins, Thomas F., Grant, Clarance L., *Collection Handling and Storage: Keys to Improved data quality for Volatile Organic Compounds in Soil*, American Environmental Laboratory, February, 1995.

Hyman, Jennifer A., McLaughlin, Dennis G., *Multi-Level Sampling for Naphthalene In a Shallow, Sandy Aquifer*, Ground Water Management, Proceedings of the Fifth National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods. 1991.

Hutchins, Stephen R., Acree, Steven D., *Ground Water Sampling Bias Observed In Shallow, Conventional Wells*, Ground Water Monitoring Review, Winter, 2000.

Hutzler, Neil J., *Processes Controlling the Transport and Fate of VOCs in Soil*, National Symposium on Measuring and Interpreting VOCs in Soils: State of the Art and Research Needs, Las Vegas, Nevada, January 12-14, 1993.

Hutchins, Stephen R., Acree, Steven D., *Ground Water Sampling Bias Observed In Shallow, Conventional Wells*, Ground Water Monitoring Review, Winter, 2000.

Imbrigiotta, Thomas E., Gibs, J., Fusillo, T.V., Kish, George R., Hochreiter, Joseph J., *Field Evaluation of Seven Sampling Devices for Purgeable Organic Compounds in Ground Water*, Ground-Water Contamination: Field Methods, ASTM STP 963, A.G. Collins and A. J. Johnson, Eds., ASTM International, Philadelphia, PA 1998.

Jones, J.L. and L.M. Roberts, *The Relative Merits of Monitoring and Domestic Wells for Ground Water Quality Investigations*, Ground Water Monitoring and Remediation, Vol. XIX, No. 3, pp. 139-144, Summer 1999.

Jury, W.A., Russo, D., Streile, G., Sesham, E.A., *Evaluation of Volatilization by Organic Chemicals Residing Below the Soil Surface*. Water resources Research, Vol. 26, No. 1 pp.13-20, 1990.

Kaplan, E., Banerjee, S., Ronen, D., Magaritz,M., Machlin, A., Sosnow,M., Koglin, E., *Multilayer Sampling in the Water-Table Region of a Sandy Aquifer*, Ground Water, Vol. 29, No.2, 1991.

Kearl, P.M., N.E. Korte and T.A. Cronk, *Suggested Modifications to Ground Water Sampling Procedures Based on the Observations from the Colloidal Borescope*, Ground Water Monitoring Review, Vol. XII, No. 2, pp. 155-160, Spring 1992.

Kelt, D.A., M.S. Hafner, and the American Society of Mammalogists' Ad Hoc Committee for Guidelines on Handling Rodents in the Field, *Updated guidelines for protection of mammalogists and wildlife researchers from hantavirus pulmonary syndrome (HPS)*, Journal of Mammalogy, 91(6):1524-1527, 2010.

Kerri, Kenneth D., Proj. Dir., *Operation of Wastewater Treatment Plants, Sacramento, Ca*., California State University, 1983.

Kerri, Kenneth D., Proj. Dir., *Industrial Waste Treatment, Sacramento, Ca*., California State University, 1987.

Kerri, Kenneth D., Proj. Dir., *Pretreatment Facility Inspection, Sacramento, Ca*., California State University, 1988.

Lapham, W.W., F.D. Wilde, and M.T. Koterba, *Guidelines and Standard Procedures for Studies of Ground-Water Quality: Selection and Installation of Wells, and Supporting Documentation*, U.S.G.S. Water-Resources Investigations Report 96-4233, 1997.

Liikala, Terry L., Olsen, Khris B., Teel, Steven S., Lanigan, David C., *Volatile Organic Compounds: Comparison of Two Sample Collection and Preservation Methods*, Environmental Science and Technology, Vol. 30, No. 12, 1996.

Mackiewicz, Michael C., *A Simple 11 Step Procedure to Document the Accuracy, Precision and Significance of Measurements by Field Instrumentation*, Proceedings of the Fourth National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, Ground Water Management, 1990.

Marinelli, Fred, and Deanna S. Durnford, *LNAPL Thickness in Monitoring Wells Considering Hysteresis and Entrapment*, *Ground Water*, Vol. 34, No. 3, p. 405-414, 1996.

McAllister, P.M., Chiang, C.Y., *A Practical Approach to Evaluating Natural Attenuation of Contaminants in Ground Water*, Ground Water Monitoring Review, Spring, 1994.

McBee, K. And J.W. Bickham, *Mammals as Bioindicators of Environmental Toxicity*, Pp. 33-88 in: Current Mammalogy. H. Genoways (ed.). New York, NY, Plenum Press, 1990.

McCall, W., Stover,S., Enos, C., Fuhrmann,G., *Field Comparison of Direct Push Prepacked Screen Wells to Paired HAS 2" PVC Wells*, Conference Proceedings, HazWaste World Superfund XVIII, December, 1997.

McGinnis Services, *Engineered Technical Approach for the Installation & Sampling of the SVE/AS Well Project, Routes 532 & 72*, Woodland Private Study Group Site, 1998.

Mills, J.N., J.E. Childs, T.G. Ksiazek, C.J. Peters and W.M. Vaelleca, *Methods for Trapping and Sampling Small Mammals for Virologic Testing,* U.S. Department of Health and Human Services, Public health Service, Centers for Disease Control and Prevention, Atlanta, GA, 1995.

Millson, M., Eller, P.M., Ashley, K., *Evaluation of Wipe Sampling Materials for Lead in Surface Dust*, Journal of American Industrial Hygiene, Vol. 55, No.4 p.339-1994.

Minnesota Pollution Control Agency, Water Quality Division, *Sampling Procedures for Ground Water Monitoring Wells*, 1997.

Montgomery, John H., Welkom, Linda M., *Groundwater Chemicals Desk Reference*, Lewis Publishers, Chelsea, Michigan, 1990.

Morrison, Robert D, *Ground Water Monitoring Technology: Procedures, Equipment, and Applications*, Prairie DuSac, Wis., TIMCO Mfg., Inc., 1983.

Mukhtar, S., Rose, A.J., Capareda, S.C., Boriack, C.N., Lacy, R.E., Shaw, B.W., and Parnell Jr, C.B., *Assessment of Ammonia Adsorption onto Teflon and LDPE Tubing used in Pollutant Stream Conveyance,* Agricultural Engineering International, Dec. 2003, vol. 5. p.1-13.

Neilson, David M. and Gillian L. Yeates, *Comparison of Sampling Mechanisms Available for Small- Diameter Ground Water Monitoring Wells*, Ground Water Monitoring Review vs.Vol. 4, No. 2 pp. 83- 99, Spring, 1984.

Newell, Charles J., Lee, Robert S. Spexet, AnnMarie H., *No-Purge Ground Water Sampling: An Approach for Long-Term Monitoring*, American Petroleum Institute, October, 2000.

Newell, Charles J., Steven D. Acree, Randall R. Ross, and Scott G. Huling, *Light Nonaqueous Phase Liquids*, EPA Ground Water Issue, 1995.

New Jersey Department of Environmental Protection, *Alternative Ground Water Sampling Techniques Guide*, July, 1994.

New Jersey Department of Environmental Protection, *New Jersey Safe Drinking Water Act, N.J.A.C. 7:10-1.3.* Division of Water Resources.

New Jersey Department of Environmental Protection, *The Technical Requirements for Site Remediation*, N.J.A.C. 7:26E *et seq*.

New Jersey Register, Proposed New Rules: *N.J.A.C. 7:9D*, Monday, August 7, 2000.

Nyer, E.K., and Gearhart, M.J., *Plumes Don't Move*, Ground Water Monitoring Review, Winter, 1997.

Oneacre, John., and Figueras, Debbie., *Ground Water Variability at Sanitary Landfills Causes and Solutions, Proceedings of Uncertainty*, Geotechnical Engineering Division/ASCE, 1996.

Parker, Louise V. and Ranney, Thomas A., *Sampling Trace-Level Organic Solutes with Polymeric Tubing. Part-1. Static Studies*. Ground Water Monitoring and Remediation, Fall 1997, p.115-124.

Parker, Louise V. and Ranney, Thomas A., *Sampling Trace-Level Organic Solutes with Polymeric Tubing. Part-2. Dynamic Studies.* Ground Water Monitoring and Remediation, Winter 1998, p.148-155.

Parker, Louise V., *The Effects of Ground Water Sampling Devices on Water Quality: A Literature Review*, Ground Water Monitoring Review, Vol. 14, No. 2, pp. 130-141, 1994.

Parker, L.V. and T.A. Ranney, *Sampling Trace-Level Organics with Polymeric Tubings: Part 1. Static Studies*, Ground Water Monitoring and Remediation, Vol. 17, No. 4, pp. 115-124, 1997.

Parker, L.V. and T.A. Ranney, *Decontaminating Groundwater Sampling Devices*, Special Report 97-25, CRREL, 1997.

Parker, L.V. and T.A. Ranney, *Decontaminating Materials Used in Groundwater Sampling Devices*, Special Report 97-24, CRREL, 1997.

Parker, L.V. and T.A. Ranney, *Sampling Trace-Level Organics with Polymeric Tubings: Part 2. Dynamic Studies*, Ground Water Monitoring and Remediation, Vol. 18, No.1, pp. 148-155, 1998.

Parker, L.V. and T.A. Ranney**,** *Decontaminating Materials used in Ground Water Sampling Devices: Organic Contaminants*, Ground Water Monitoring and Remediation, Vol. 19, No. 1, pp. 56-68, 2000.

Parker, L.V. and T.A. Ranney. *Decontaminating Materials Used in Ground Water Sampling Devices: Organic Contaminants*. *Ground Water Monitoring Review.* pp. 56-68, 2000.

Paul, Cynthia J., and Puls, Robert W., *Impact of Turbidity on TCE and Degradation Products in Ground Water*, Ground Water Monitoring Review, Winter, 1997.

Pettijohn, F.J., *Sedimentary Rocks*, Harper & Row, 1975.

Public Service Electric and Gas Company, *Generic Remedial Investigation Work Plan*, Rock Coring - Standard Operating Procedure 310, November, 1997.

Public Service Electric and Gas Company, *Phase III Remedial Investigation Report for the Former Paterson Gas Plant, Paterson, NJ*, Woodward-Clyde Consultants.

Puls, Robert W., and Barcelona, Michael J., *Low-Flow (Minimal Drawdown) Ground-Water Sampling Procedures*, USEPA Report, EPA/540/S-95/504, April, 1996.

Puls, Robert W., Eychaner, James H., *Sampling of Ground Water for Inorganics – Pumping Rate, Filtration, and Oxidation Effects*, Ground Water Management Proceedings of the Fourth National Outdoor Action Conference on Aquifer Restoration, Ground Water Monitoring and Geophysical Methods, 1990.

Puls, R.W. and Powell, *Acquisition of Representative Ground Water Quality Samples for Metals,* Summer 1992 Ground Water Monitoring Review, Vol. XII, No. 3, pp. 167-176, 1997.

Radcliffe, M.J., B.W. Rehm, C.S. Peters, T.R. Stolzenburg, and S.D. Johannsen, *Sample Handling: The Impact of Filtering Ground Water Samples*, Proceedings of the Fourth Annual Hazardous Materials Management Conference, Atlantic City, NJ, June 1986.

Rajagopal, R., Williams, L. R., *Economics of Sample Compositing as a Screening Tool*, Ground Water Quality Monitoring, Vol. 9, No. 1, 1989.

Ranney, T.A. and L.V. Parker, *Comparison of Fiberglass and Other Polymeric Well Casings: Part III. Sorption and Leaching of Trace-Level Metals*, Ground Water Monitoring and Remediation, Vol. 18, No. 3, pp. 127-133, 1998.

Ranney, T.A. and L.V. Parker, *Comparison of Fiberglass and Other Polymeric Well Casings: Part II. Sorption and Leaching of Trace-Level Organics*, Ground Water Monitoring and Remediation, Vol. 18, No. 2, pp. 107-112, 1998.

Ricker, Michael J., *Determining Volatiles in Soils: A New Sampling Procedure*, Environmental Testing and Analysis, Vol. 8, No. 4, 1999.

Robbins, Gary A., Martin-Hayden, James M., *Mass Balance Evaluation of Monitoring Well Purging*

Journal of Contaminant Hydrology, Vol. 8, pp. 203-224, 1991.

Robbins, Gary A., Henebry, Brent J., Cummins, Timothy M., Goad, Christopher R., Gilbert, Edward J., *Occurrence of MTBE in Heating Oil and Diesel Fuel in Connecticut*, Ground Water Monitoring Review, Fall, 2000.

Robin, M.J.L., and Gillham, R.W., *Field Evaluation of Well Purging Procedures*, Ground Water Monitoring Review, Fall, 1987.

Rose, S., and Long, A., *Monitoring Dissolved Oxygen in Ground Water: Some Basic Considerations*, Ground Water Monitoring Review, Winter, 1998.

Ryan, Robert G., and Dhir, V.K., *The Effect of Interfacial Tension on Hydrocarbon Entrapment and Mobilization Near a Dynamic Water Table*, Journal of Soil Contamination, Vol. 5, No.1 pp.9-34. 1996.

Saar, R.A., *Filtration of Ground Water Samples: A Review of Industry Practice*, Ground Water Monitoring Review, pp. 56-62, 1997.

Scalf, Marion R. et. seq., *Manual of Ground Water Sampling Procedures*, USEPA and National Well Water Association, Worthington, OH, pp. 92-93, 1981.

Schumacher, Brian A., Ward, Steven, E., Q*uantitation Reference Compounds and VOC Recoveries from Soils by Purge and Trap GC/MS*., Environmental Science and Technology, Vol. 31, No. 8, 1997.

Schumacher, B.A., Shines, K.C., Burton, J.V., Papp. M.L., *A Comparison of Soil Sample Homogenization Techniques*, Hazardous Waste Measurements, Chapter 4. Lewis Publishers, Michigan, 1991.

Seanor, A.M. and L.K Brannaka, *Influence of Sampling Techniques on Organic Water Quality Analysis,* Presented at: Management of Uncontrolled Hazardous Waste Sites Conference, Washington, DC., Oct., 1984.

Siegrist, Robert L., *Measurement Error Potential and Control When Quantifying Volatile Hydrocarbon Concentrations in Soils*, Hydrocarbon Contaminated Soils, Vol. I, Lewis Publishers, pp. 205-215, 1991.

Siegrist, Robert L., Jenssen, Petter D., *Evaluation of Sampling Method Effects on Volatile Organic Compound Measurements in Contaminated Soils*, Environmental Science and Technology, Vol. 24, No. 9, 1990.

Sikes, R.S., and the Animal Care and Use Committee of the American Society of Mammalogists. *Guidelines of the American Society of Mammalogists for the use of wild mammals in research and education,* Journal of Mammalogy, 97(3):663-688, 2016.

Smith, M.H., R.H. Gardner, D.W. Kaufman and M.H. O'Farrell, *Density Estimation of Small Animal Populations,* Pp. 25-52 in: Small mammals: Their Productivity and Population Dynamics. F.B. Golley, K. Petrusewicz and L. Ryszkowski (ed.). Cambridge, U.K., Cambridge U. Press, 1975.

Sorini, Susan S., Schabron, John F., Rovani, Joseph F., Evaluation of VOC Loss From Soil Samples Contaminated Soil Sediment and Water, April/May, 2002.

Steila, D. and T. Pond, *The Geography of Soils, Formation, Distribution and Management,* 2nd edition, Rowman & Littlefield Publishers, Inc., 1989.

Stevenson, T.J., *Design of a Quality Assurance Program for the Assessment of Ground Water Contamination,* Presented at: NWWA Conference on Ground Water Management, Orlando, Fla., October, 1984.

Stone, William J., *Low Flow Ground Water Sampling-Is It a Cure-All?*, Ground Water Monitoring Review Spring, 1997.

Storch Engineers, *Standard PCB Transformer Sampling Procedures,* in SOP, 1986.

Tai, Doreen Y., Turner, Kenneth S., and Garcia, Lisa A., *The Use of a Standpipe To Evaluate Ground Water Samplers,* Ground Water Monitoring Review, Winter, 1991.

Testa, Stephen M., and Michael T. Paczkowski, *Volume Determination and Recoverability of Free Hydrocarbon*, *Ground Water Monitoring Review*, Vol. IX, No. 1, p. 120-128, Winter 1989, and errata sheet, Vol. IX, No. 2, p. 190 Spring 1989.

Testa, Stephen M., and Winegardner, Duane L., *Restoration of Contaminated Aquifers*, Lewis Publishers, New York, New York, 1991.

Thomas, J.M., J.R. Skalski, L.L. Eberhardt, and M.A. Simmins, *Field Sampling for Monitoring*, *Migration and Defining the Areal Extent of Chemical Contamination*, Presented at: Management of Uncontrolled Hazardous Waste Sites Conference, Washington, DC., Oct. 1984.

Triplett, Laura D., Burford, P., Sielaff, B., Clark, R.C., *Sampling Procedures for Ground Water Monitoring Wells*, State of Minnesota, Minnesota Pollution Control Agency, 1997.

United States Department of Interior, *Ground Water Manual, A Water Resources Technical Publication*, Bureau of Reclamation, Chapters 16 and 17, 1985.

United States Department of Agriculture, Animal and Plant Health Inspection Service, Animal Welfare Act Animal Care Regulations. https://www.nal.usda.gov/awic/animal-welfare-act, 2016 United States Environmental Protection Agency, *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells*, Office of Research and Development, EPA/600/4-89/ 034, Washington, D.C., March, 1991.

USEPA, *Ecological Risk Assessment Guidance for Superfund: Process for Designing and Conducting Ecological Risk Assessments,* Interim Final, EPA 540-R-97-006, Office of Solid Waste and Emergency Response, Environmental Response Team Center, Edison, NJ, 1997.

USEPA, *Field Analytical and Site Characterization Technologies Summary of Application*s EPA-542-R- 97-011, November, 1997.

USEPA, *Characterization of Hazardous Waste Sites: A Methods Manual Vol. II Available Sampling Methods*, EPA-600/4-83-040 Environmental Monitoring and Support Laboratory Las Vegas, NV, 1983.

USEPA, *Handbook for Sampling and Sample Preservation of Water and Wastewater*, EPA-600/4-82-029 Environmental Monitoring and Support Laboratory, Cincinnati OH, 1982.

USEPA, *Field and Laboratory Methods for Macroinvertebrate and Habitat Assessment of Low Gradient Non-Tidal Streams*, Mid-Atlantic Coastal Streams Workgroup, Environmental Services Division, Region 3, Wheeling, WV 26003, 23 pp., 1997.

USEPA, Barbour, M.T., J. Gerritsen, B.D. Snyder, and J.B. Stribling, *Rapid Bioassessment Protocols for Use in Wadeable Streams and Rivers: Periphyton, Benthic Macroinvertebrates, and Fish*, Second Edition, EPA 841-B-99-002, USEPA Office of Water, Washington, DC, 1999.

USEPA, *Methods for Measuring The Toxicity and Bioaccumulation of Sediment-Associated Contaminants with Freshwater Invertebrates*, Second Edition. EPA/600/R-99/064, USEPA Office of Research and Development and Office of Water, Washinton, DC, 2000.

USEPA, *Ground Water Monitoring Guidance for Owners and Operators of Interim Status Facilities*, EPA-SW-963, Office of Solid Waste and Emergency Response Washington, DC, 1983.

USEPA, *Handbook for Sampling and Sample Preservation of Water and Wastewater*, Cincinnati, OH, 1982.

USEPA, *Method 1669: Sampling Ambient Water for Trace Metals at EPA Water Quality Criteria Levels*, Office of Water Engineering and Analysis Division, April, 1995.

USEPA, *Suggested Operating Procedures for Aquifer Pumping Tests*, EPA/540/S-93/503, Office of Research and Development, Washington, DC, 1993.

USEPA, *Immunoassay Guidelines for Planning Environmental Projects*, USEPA Quality Assurance Unit Staff, Office of Environmental Measurement and Evaluation, October, 1996.

USEPA, *Light Non-Aqueous Liquids*, EPA/540/S-95/500, Office of Solid Waste and Emergency Response, 1995.

USEPA, *Non-Aqueous Phase Liquids Compatibility with Materials Used in Well Construction, Sampling and Remediation*, EPA/540/S-95/503, Office of Solid Waste and Emergency Response, 1995.

USEPA, *Suggested Operation Procedures for Aquifer Pumping Tests*, EPA/540/s-93/503, Office of Solid Waste and Emergency Response, February, 1993.

USEPA, *Standard Operating Procedure for Elemental Analysis Using the X-Met 920 Field X-Ray Fluorescence Analyzer*, Office of Environmental Measurement and Evaluation, November, 1996.

USEPA, *Soil Sampling and Analysis for Volatile Organic Compounds*, EPA/540/4-91/001, Office of Solid Waste and Emergency Response, 1991.

USEPA, *Lead in Drinking Water-Should You Be Concerned?*, Office of Water, February 1987. USEPA, *NPDES Compliance Inspection Manual*, Washington, D.C., 1984.

USEPA, *NPDES Compliance Sampling Manual*, Washington, D.C., 1977.

USEPA, *Contract Lab Program (CLP) Statement of Work (SOW) for Organic Analysis, Multi-Media, Multi-Concentration*, Document OLMO4.1, 1998.

USEPA, *Rapid Bioassesment Protocols for Use In Streams and Rivers*, 1989.

USEPA, *Test Methods for Evaluating Solid Waste Physical/Chemical*, SW-846 Final Update3 to the 3rd Edition, 1996.

USEPA, *Standard Operating Procedures, Model 5400 GeoprobeÔ Operation*, SOP 2050, 1996.

USEPA, *Clarification Memorandum from Elizabeth Cotsworth to Regions I-X Regarding Use of SW-846 Methods*, Office of Solid Waste, 1998.

USEPA, *Contract Lab Program Statement of Work for Organic Analysis, Multi-Media, Multi-Concentration*, Document OLMO4.2A Corrections/Modifications/Clarifications, 2000.

USGS, *Ground-Water Data-Collection Protocols and Procedures for the National Water-Quality Assessment Program: Collection and Documentation of Water Quality Samples and Related Data*, U.S. Geological Survey Report 95-399, 1995.

USGS, *Field Guide for Collecting Samples for Analysis of Volatile Organic Compounds In Stream Water for the National Water Quality Assessment Program*, U.S. Geological Survey Report 97-0401, 1997.

USGS, *Field Guide for Collecting and Processing Stream-Water Samples for the National Water-Quality Assessment Program*, U.S. Geological Survey Report 94-455, 1994.

University of Arizona, College of Agriculture, *Field Manual for Water Quality Sampling*, March, 1995.

Urban, Michael J., Smith, James S., Schultz, Elizabeth.K., Dickenson, Randall K., *Volatile Organic Analysis for a Soil, Sediment or Waste Sample*, Fifth Annual Waste Testing and Quality Assurance Symposium, July 24-28, Washington, D.C., pp. II-87 to II-101, 1989.

United State Geological Society, *Field Guide for Collecting Samples for Analysis of Volatile Organic Compounds in Stream Water for the National Water-Quality Assessment Program*, US Geological Survey Report 97-401, 1997.

USGS, *Ground-Water Data – Collection Protocols and Procedures for the National Water-Quality Assessment Program: Selection, Installation, and Documentation of Wells, and Collection of Related Data*, U.S. Geological Survey, Report 95-398, 1995.

USGS, *Guidelines for Collecting and Processing Samples of Stream Bed Sediment For Analysis of Trace Elements and Organic Contaminants for the National Water Quality Assessment Program*, US Geological Survey Report 94-458, 1994.

USGS, *Techniques of Water-Resources Investigations, Book 9, Handbooks for Water-Resources Investigations, National Field Manual for the Collection of Water-Quality Data,* August, 1998.

USGS, *U.S. Geological Survey Protocol for the Collection and Processing of Surface Water Samples for the Subsequent Determination of Inorganic Constituents in Filtered Water*, USGS Report 94-539, 1994.

USGS, *Quality-Control Design for Surface-Water Sampling in the National Water-Quality Assessment Program*, US Geological Survey Report 97-223, 1997.

USGS, *Use of an Ultra-Clean Sampling Technique with Inductively Coupled Plasma-Mass Spectrometry to Determine Trace-Element Concentrations in Water from The Kirkwood-Cohansey Aquifer System, Coastal Plain, New Jersey*, US Geological Survey Report 96-142, 1996.

Vroblesky, Don A., Borchers, James W., Campbell, Ted R., Kinsey, W., *Investigation of Polyethylene Passive Diffusion samplers for Sampling Volatile Organic Compounds in Ground Water at Davis Global Communications, Sacramento, California, August 1998 to February 1999*, U.S. Air Force Center for Environmental Excellence, 2000.

Vroblesky, Don A. Hyde, Thomas W., *Diffusion Samplers as an Inexpensive Approach to Monitoring VOC's in Ground Water*, Ground Water Monitoring Review, Summer, 1997.

Vroblesky, Don A., *User's Guide for Polyethylene-Based Passive Diffusion Bag Samplers to Obtain Volatile Organic Compound Concentrations in Wells*, Part 1 and Part 2., USGS Reports 01-4060 and 01-4061, 2001.

Vroblesky, Don A., Petkewich, Matthew D., *Diffusion Sampler Testing at Naval Industrial Reserve Ordnance Plant, Fridley, Minnesota, November 1999 to May, 2000.*

Vroblesky, Don A. and Peters, Brian C., *Diffusion Sampler Testing At Naval Air Station North Island, San Diego County, California, November 1999 to January 2000*, USGS Water Resources Investigation, Columbia, South Carolina, 2000.

Wells, R.B., *Cores, Cores, Cores*, National Drillers Buyers Guide, pp. 47, August, 1991.

West, Olivia R., Siegrist, Robert L., Mitchell, Toby J., Jenkins, Rodger A., *Measurement Error and Spatial Variability Effects on Characterization of Volatile Organics in the Subsurface*, Environmental Science and Technology, Vol. 29, No. 3, 1995.

Wickramanayake, Godage B., Gavaskar, Arun R., Kelley, Mark E., Nehring, Karl W., *Risk, Regulatory, and Monitoring Considerations Remediation of Chlorinated and Recalcitrant Compounds*, The Second International Conference on Remediation of Chlorinated and Recalcitrant Compounds, May 2000.

Wilson, Neal, *Soil Water and Ground Water Sampling*, Chapter 3, Lewis Publishers, 1995.

Wisconsin Department of Natural Resources, *Ground Water Sampling Desk Reference*, Report PUBL- DG-037 96, September, 1996.

Wisconsin Department of Natural Resources, *Ground Water Sampling Field Manual*, Report PUBL-DG- 038 96, September, 1996.

29 CFR 1910.120, *Hazardous Waste Operations and Emergency Response: Interim Final Rule*, Occupational Safety and Health Administration.

URLS

USGS Links

http://water.usgs.gov/owq/FieldManual/
USGS National Field Manual for the Collection of Water-Quality Data

http://water.usgs.gov/pubs/wri/wri004252/
USGS Water-Resources Investigations Report 00-4252. *Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation and Reporting.*

http://toxics.usgs.gov/pubs/FS-075-01/#4
USGS National Research Program: *Characterizing Ground-Water Chemistry and Hydraulic Proper- ties of Fractured-Rock Aquifers Using the Multifunction Bedrock-Aquifer Transportable Testing Tool (BAT³)*

http://water.usgs.gov/owq/pubs/wri/wri964233/wri964233.pdf
USGS Water Resources Investigation Report 96-4233: *Guidelines and Standard Procedures for Studies of Ground-Water Quality: Selection and Installation of Wells and Supporting Documentation*.

Soil Science

https://www.environment.nsw.gov.au/resources/soils/testmethods/usc.pdf
Soil Survey Standard Test Method, Unified Soil Classification System: *Field Method*

Soil Classification

http://www.seafriends.org.nz/enviro/soil/rocktbl.htm#soil%20properties
Classification of Common Rocks, Soil and More

https://www.osha.gov/laws-regs/regulations/standardnumber/1926/1926SubpartPAppA
US Dept. of Labor, Occupational Safety and Health Admin., Regulation (Standards - 29 CFR), *Soil Classification - 1926 Subpart P, Appendix A*

https://dot.ca.gov/-/media/dot-media/programs/maintenance/documents/office-of-concrete-pavement/pavement-foundations/uscs-a11y.pdf
California Department of Transportation's Table depicting the *Unified Soil Classification System*

Sediments

https://dots.el.erdc.dren.mil/
US Army Corps of Engineers: *Dredging Operations Technical Support Program*

http://www.sednet.org/
European Sediment Research Network

http://www.smwg.org/
Sediment Management Work Group: *Home Page*

https://clu-in.org/remediation/
EPA Clean-Up Information Remediation Technologies

General

https://www.nj.gov/dep/srp/regs/
NJDEP "Tech Rules" N.J.A.C. 7:26E *Technical Requirements for Site Remediation*

http://www.animatedsoftware.com/pumpglos/pumpglos.htm
The Internet Glossary of Pumps (Animated)

http://www.frtr.gov/
Federal Remediation Technologies Roundtable (FRTR)

https://esemag.com/archives/methods-of-napl-detection-and-measurement-in-monitoring-wells/

https://www.afcec.af.mil/Home/BRAC/Brooks-City-Base/

http://www.ngwa.org/

Appendix 6.1
Monitoring Well Construction and Installation

A.6.1.1 Introduction

Monitoring wells are installed to collect ground water quality data, hydrologic information and determine ground water flow direction. They can be installed either permanently or temporarily. The types of wells used for remedial investigations include Category 3, "Cased Environmental Resource and Geotechnical Wells" which include monitoring wells, air-sparging wells, soil vapor extraction (SVE) wells, and recovery wells installed for environmental remediation projects (see N.J.A.C. 7:9D-2.1). Category 4 "Uncased Environmental Resource and Geotechnical Wells" including test borings, probe holes, temporary wells, and borings involving use of direct-push methods (see N.J.A.C. 7:9D-2.1).

Their method of installation and construction can greatly impact the quality of ground water samples collected from them. For example, temporary wells that are driven or pushed do not always have filter packs, which may result in samples with high turbidity levels. This artifact would have to take this into consideration if samples are to be collected for metals analysis. The following text describes different methods of well drilling and monitoring well construction with considerations for their use and possible impacts on ground water samples. All wells must be installed by a New Jersey-licensed well driller of the appropriate class, pursuant to N.J.A.C. 7:9D. Prior to installing a well, the well driller must obtain a well drilling permit from the Bureau of Water Allocation & Well Permitting (BWAP), at https://www.state.nj.us/dep/watersupply/pw_permit.html, pursuant to N.J.A.C. 7:9D-1.11. Within 90 days of completing a well, the well driller must submit a well record to BWAP, pursuant to N.J.A.C. 7:9D-1.15.

The drilling methods described below also are applicable to the collection of subsurface soil samples. Profiles of subsurface conditions (i.e., description of the geologic materials and conditions encountered during advancement of the borehole), and well installation details must be recorded on logs and submitted with the completed well record to the Bureau of Water Allocation & Well Permitting per 7:9D – 1.15(a)3. Additionally, N.J.A.C 7:26E-1.6(b)7 requires stratigraphic geologic logs, field instrument readings and monitoring well certification forms A & B to be submitted to the Site Remediation and Waste Management Program. The information recorded should be consistent with applicable standard protocols including those of the American Society for Testing and Materials (ASTM). See also Section 6.2.3, *Soil Log.*

A.6.1.2 Conventional Well Drilling Methods

A.6.1.2.1 Hollow-Stem Augers (HSAs)

Wells can be installed in unconsolidated formations using solid-stem or hollow-stem augers (HSAs). The augers are advanced by rotation and the drill cuttings are brought to the surface by travelling up the outside of the auger flights in a screw-like manner. HSAs have the advantage of allowing the well to be installed inside the hollow stem of the auger, which prevents the borehole from collapsing. Upon reaching the planned well depth, well casing and screen are placed inside the HSAs and the flights are individually removed while the annular space around the well is filled with filter pack or grout, as appropriate. Conversely, solid-stem augers must be completely removed from the borehole before well installation, which can lead to collapse of the borehole. For this reason, solid stem augers are seldom used for the installation of monitoring wells.

HSAs come in a variety of sizes and allow collection of soil samples utilizing split spoons or Shelby tubes. Samples are collected ahead of the augers for determining soil/sediment type, stratigraphy, the depth to the water table, and for collecting soil samples for chemical analysis. During this process, the standard penetration test (SPT, ASTM Method D 1586-11) can also be performed. The HSA method also has an advantage over mud-rotary drilling techniques in that drilling mud is not used. Drilling mud can

contaminate the soil samples or and potentially reduce the yield of the wells.

A disadvantage of the method is that HSAs cannot be used to drill into competent bedrock or through large boulders. Also, "heaving or running sands" can be forced up inside the augers as a result of strong vertical ground water gradients, which can hamper efforts to collect soil samples or complete well installation. Furthermore, the maximum depth achievable using HSAs, which is generally shallower than other methods is dependent not only on the ability of the rig (e.g., horse- power, rig-torque, weight of augers etc.) but also the lithology of the material drilled.

A.6.1.2.2 Rotary Drilling

Rotary drilling can be performed by two different methods, air, and mud.

A disadvantage of using rotary methods while drilling in unconsolidated formations is the requirement of pulling the drill pipe out of the hole each time that a split-spoon soil sample is collected (and the SPT is performed). This can add up to a considerable amount of time when deep wells are being installed or when continuous split-spoon sampling is being performed.

Mud Rotary

Mud Rotary drilling methods include direct rotary and reverse-circulation rotary. Direct rotary is more commonly used in environmental investigations whereas reverse-circulation rotary is used in drilling large-diameter water supply wells. In direct rotary drilling the borehole is advanced by rotating the drill pipe (rods) and bit to produce a cutting action. The cuttings are removed from the borehole by continuous circulation of a drilling fluid. The fluid or "mud" is pumped down the inside of the drill pipe and is circulated back to the surface on the outside of the pipe. The fluid removes the drill cuttings from the borehole and cools and lubricates the bit. Mud used during direct rotary consists of additives (e.g., bentonite) water or air.

Reverse-circulation rotary drilling is similar to direct rotary except the drill rigs are larger and the flow of the drilling fluid is reversed. The drilling fluid moves upward inside the drill pipes and circulates back to the borehole via settling pits. The drilling fluid returns to the borehole via gravity and moves downward in the annular space between the drill pipe and borehole wall.

Drilling fluids for reverse circulation rotary are generally water and any suspended particles picked up from the surrounding formations.

Mud-rotary methods can be used to drill in both unconsolidated and consolidated (bedrock) formations. In addition, drilling mud stabilizes the borehole and limits the potential for borehole collapse. Disadvantages of using the mud-rotary method include the difficulty in determining the depth to the water table, the potential for drilling mud to impact soil samples and the dragging of contamination into deeper zones since the drill cuttings are recirculated in the borehole. The split spoons will capture some of the drilling mud when being lowered down the borehole. Wells installed using this method typically take longer to develop (see below) than wells installed using the HSA or air-rotary methods due to the invasion of mud filtrate into the formation.

Air Rotary

In air-rotary drilling, compressed air is directed down the inside of the drill pipe. As in mud-rotary drilling, air removes the cuttings and lubricates the bit. However, since air has no viscosity, it cannot be used to stabilize a borehole, therefore, casing may be needed in unconsolidated formations to keep the borehole open. This is why air rotary methods are best suited for drilling in bedrock formations. The percussion-type air-rotary "hammer" bit provides the best penetration rate when drilling bedrock consisting of crystalline rock. However, when drilling above the water-table, an air-rotary bit can grind the soil and bedrock to a fine powder which is blown out of the hole and has the potential to be inhaled. Therefore, drilling above the water table using air-rotary methods requires the addition of potable water to the borehole for dust control. In addition, the air compressor should be of the oil-less variety or have a

filter to prevent any oil from entering the borehole.

Bedrock Coring

A special type of rotary drilling is bedrock coring, wherein a special core bit and barrel are used to retrieve relatively undisturbed core samples of the bedrock. Coring allows better characterization of bedrock lithology and other features including orientation of fractures and bedding planes, which can control contaminant migration. Core barrels can either be unoriented or oriented. An oriented core is scribed with respect to magnetic north. Although more expensive than collecting an unoriented core, this method gives the true orientation of the features encountered in the core. The use of downhole cameras and acoustic televiewers has largely replaced the use of oriented coring. See the section on coring in Chapter 6, Section 6.3.4, *Rock Core Logging*.

A.6.1.2.3 Drilling Fluids

Drilling fluids are generally air (air-rotary) or bentonite and/or water (mud-rotary). Water added to a borehole must be of potable quality (N.J.A.C. 7:9D-2.2). The source of the potable water used during the installation (and development) of monitoring wells should be documented (e.g., in the Remedial Investigation Report).

Bentonite is high swelling clay with sodium montmorillonite as its primary clay mineral. Bentonite is added to water to increase the viscosity of the drilling fluid so that drill cuttings can be removed from the borehole more effectively. At the same time, the viscosity must be low enough to allow cuttings and coarse-grained particles to settle out once they are circulated out of the hole. Bentonite also adds weight to the drilling fluid, which helps to maintain borehole stability.

While all drilling fluids have the potential to impact ground water quality to some extent, the use of polymer-based drilling muds (e.g., Revert®) can significantly impact the quality of water samples collected from wells. Biologic activity related to the decomposition of these compounds can cause a long-term variation in the quality of the water sampled from the well (EPA, 1991, and Barcelona, 1983). To account for possible ground water quality issues, it is recommended that the use of a polymer based drilling mud be documented on the Bureau of Well Permitting well record, and any boring log or well as-built log submitted to the NJDEP.

A.6.1.3 Specialized Drilling Methods

A.6.1.3.1 Sonic Drilling

Sometimes called rotosonic drilling, this method involves driving a core barrel using vibration, rotation and a downward force to collect soil samples. A sonic drill rig looks and operates very much like a conventional top-drive rotary or auger rig. The main difference is that a sonic drill rig has a specially designed, hydraulically powered drill head or oscillator, which generates adjustable high-frequency vibrational forces. The oscillator uses two eccentric counter-rotating balance weights or rollers that are timed to direct 100 percent of the vibrational energy at 0 degrees and 180 degrees. There is an air spring system in the drill head that insulates or separates the vibration from the drill rig itself. The sonic head is attached directly to the drill pipe or outer casing, sending the high-frequency vibrations down through the drill pipe to the bit.

A core barrel is advanced using vibration, rotation, and downward force to collect continuous soil cores up to 20 feet in length. The bit at the end of the core barrel contains carbide teeth allowing the core barrel to be advanced through most overburden, soft bedrock, and minor obstructions such as bricks and boulders. Once the core barrel has been advanced, a secondary or “over-ride” casing is advanced down to the same depth as the inner core barrel. The over-ride casing keeps the borehole from collapsing while the inner core barrel is removed. Once the core barrel is removed, the soil core is pushed out of the core barrel through the use of vibration and either air or water pressure. Soil core diameters are dependent on

the size of the core barrel used, and range from 3 to 12 inches. The use of multiple over-ride casings of increasing diameter allows the borehole to be telescoped down through multiple confining units. Continuous soil cores to over 400 feet have already been installed in New Jersey using this method. The setup used in sonic drilling makes this drilling method amendable to collecting soil cores and installing wells in angled boreholes. With only the bottom of the inner and outer core barrel exposed to the aquifer at any given time, determining the location of the water table can be difficult.

When using this drilling method to collect soil cores that will be used to obtain soil samples for VOC or SVOC analysis, two issues of concern must be addressed: heating of the soil core during drilling, and disturbance of the soil core during drilling, extraction, and handling.

While this drilling method has the capability of drilling through and providing samples of coarse gravels, boulders and tight clays, these situations will result in slow drilling or advancement of the core barrel. The result is a hotter core barrel and a longer contact time between the core barrel and the encased soil core. The aforementioned conditions will increase the probability that the sonic method will raise the temperature of the soil core and facilitate VOC and SVOC loss. If heating of the soil core is a concern, the following procedures should be implemented:

Use rigid plastic liners to insulate the soil core from the metal casing.

- Collect soil cores in shorter runs. While some sonic rigs have the capability of collecting 20 feet of soil core at a time, the process of collecting the longer core results in the core being in contact with the core barrel for a longer period of time and consequently absorbing more heat from the core barrel itself.
- Add water between the inner core barrel and the outer over-ride casing. This water would reduce friction and adsorb heat between the inner core barrel and the outer over-ride casing.
- Maximize drilling advance rate. The faster the core barrel is advanced, the less likely the core barrel will heat up, and the less contact time the soil core has with the core barrel. Drilling with a 3-inch diameter core barrel and a 5-inch diameter over-ride casing, instead of the standard 4- inch core barrel and 6-inch over-ride casing, may increase advance rates and reduce the potential for soil core heating. If a significant decrease in drilling advance rate is observed, stop drilling and remove what soil core has accumulated in the core barrel. Resume drilling through the resistant material (gravel, boulder, hard clay, etc.). When the resistant material has been penetrated and the drilling advance rate increases, stop drilling and remove what material has accumulated in the core barrel. Wash down the core barrel with cool water to cool the core barrel and associated casing, and resume drilling.

Disturbance of the soil core is most likely to occur during removal of the soil core from the core barrel. The soil cores are usually vibrated out of the core barrel into plastic bags approximately 5 feet in length. As the plastic bags are very flexible, and are a little larger than the soil core itself, fragmentation of the soil core may occur as the core is extruded into the bag or while the bagged core is being moved in an unsupported manner. Soil conditions that are prone to disturbance include wet or dry zones that contain little or no fines, and well graded sands that contain significant volumes of water.

If integrity of the soil core is of concern, the following procedures should be implemented:

- Measures should be taken to ensure that the core, from the time it is extruded from the core barrel, is rigidly supported through the use of some type of cradle or carrying device.
- The core should not be removed from its cradle until all sampling of the core has been completed. Rigid liners are available for some core sizes and can be used to hold the core together upon removal from the core barrel.
- If the soil is to be sampled for VOCs, rigid liners should be used.

Sonic drilling has been used for:

- geologic profiling through the production of continuous soil cores;
- collection of in-situ ground water grab samples during borehole installation/advancement;
- well installation; and
- sampling of the soil core for metals, PCBs, and pesticides, VOCs and SVOCs.

Work plans including soil VOC sampling or the soil core sampling of oxygen sensitive compounds, should include provisions to minimize core fragmentation and heat generation, such as:

- the use of rigid liners in the core barrel so that the soil core does not have to be extruded out of the core barrel;
- limiting the length of soil core generated during a given downhole run and;
- implementing practices to reduce the residency time of the soil core in the core barrel. For the analysis of SVOCs, the use of the rigid liners is not required.

The large diameter of the core barrel enables ground water sampling equipment to be placed inside the core barrel so that depth discrete ground water samples can be collected during borehole advancement. If a well is to be installed in the borehole, the sandpack and grout are placed as the core-barrel and over-ride casing(s) are selectively vibrated out of the ground. The vibratory action reportedly facilitates the settlement of the sandpack and grout. Upon completion, no casing is left in the ground other than the well casing and screen.

Another application of the sonic method involves vibratory direct push installation of monitoring wells without drilling a borehole. Knowledge of the local stratigraphy (depth of confining layers, etc.) and depth to water should be known before the wells are installed. Soil coring using sonic methods or other, conventional methods (e.g., split-spoon sampling) should be performed prior to installing wells using the sonic direct push method. This method does not allow or require installation of filter pack and grout filling of annular space.

The ability to quickly install deep borings and wells, while generating a large-diameter continuous soil core, makes this drilling technique invaluable when continuous soil sampling is needed to assess deep or complex geological situations. However, sonic drilling's high cost, relative to other drilling methods, may be prohibitive for small projects or shallow boreholes. The higher cost of the drilling method should be weighed against the cost savings incurred due to its faster drilling rate and high quality of the soil core produced.

A.6.1.3.2 ODEX® Method

In situations where boreholes cannot be stabilized, conventional drilling methods may not be adequate for drilling soil borings or installing monitoring wells. In these situations, the ODEX® method can be used to simultaneously drill and case a borehole. This method involves use of an eccentric bit, along with a conventional rotary hammer, to drill a borehole of slightly larger diameter than the casing. See Figure A.6.1. The bit retracts to allow its passage through the casing.

Once below the casing, the bit is expanded and used to drill a slightly larger borehole. The bit can be retracted and retrieved through the casing to allow collection of soil and/or rock samples. A disadvantage of the method is the fact that installation of the casing is only temporary. Since the ODEX steel casing cannot be grouted in-place, the NJDEP does not allow for the steel ODEC casing to be left in-place. Another disadvantage of the method is the potential for rock cuttings to jam the bit and not allow it to be retracted and subsequently retrieved up through the casing.

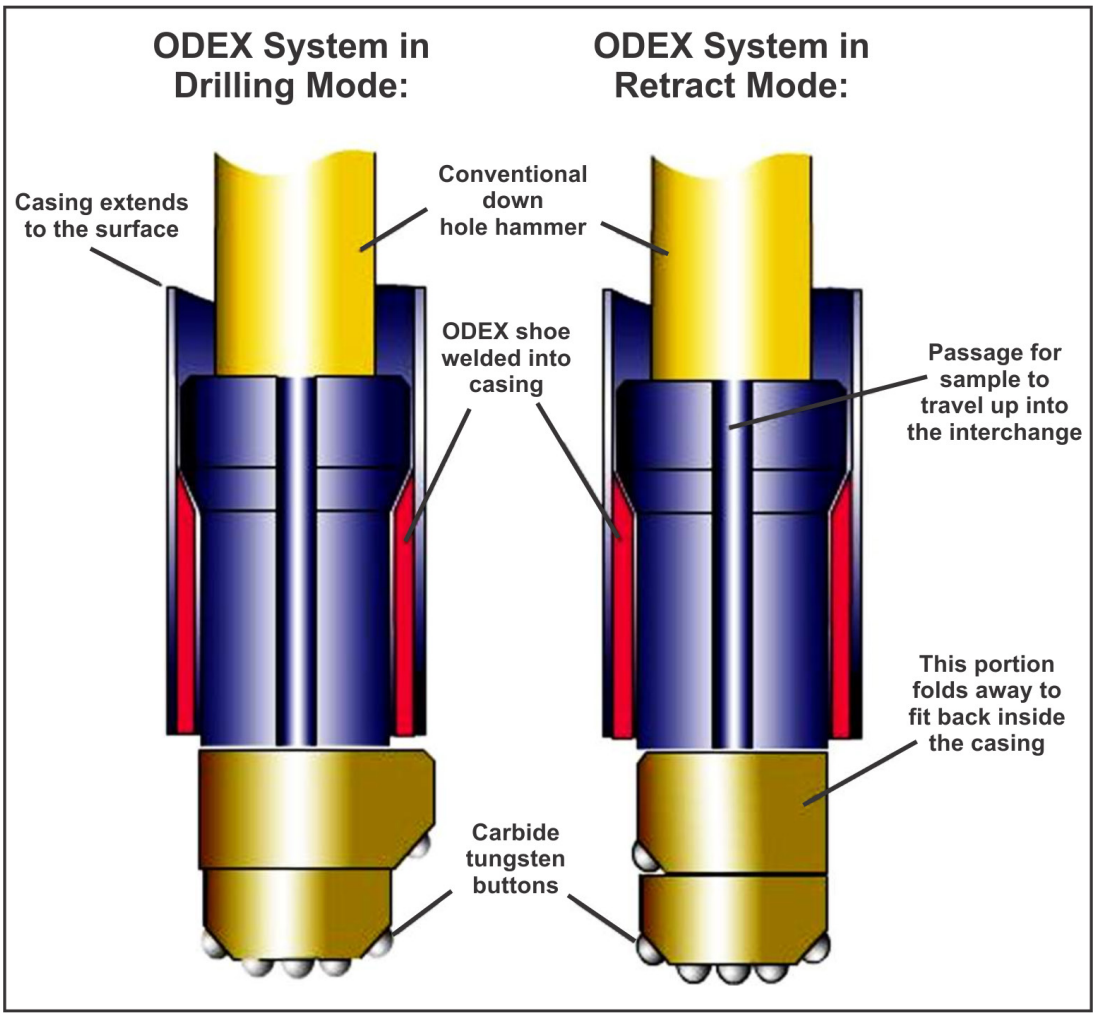


Figure A.6.1 ODEX® System. Source: http://www.midnightsundrilling.com/ODEX_system.html

A.6.1.3.3 Direct-Push Drilling

Direct-push technology was first developed in the geotechnical industry using cone penetrometer testing (CPT) methods to obtain information on soil/sediment type, stratigraphy and the depth to ground water without collecting actual soil samples or installing monitor wells. The method involves pushing rods into the subsurface under a constant weight while recording such parameters as sleeve friction stress, tip stress and pore pressure. The method has been expanded in the environmental industry to include the investigation for hydrocarbons (e.g., the fuel fluorescence detector or FFD® developed by Handex and the Laser Induced Fluorescence (LIF) Probe used in the SCAPS system), chlorinated solvents (membrane interface probe (MIP), Laser-Induced Fluorescence (DyeLIF®), and natural gamma and resistivity logging tools. These methods provide only screening-level data quality. However, they allow the collection of numerous data points in one mobilization without generating any soil cuttings, which would otherwise have to be characterized and disposed of.

A variation of the direct push method involves hydraulically pushing hollow rods into the subsurface for the purpose of collecting soil and/or ground water samples (e.g., Geoprobe®). The method can be used to install small-diameter wells used to collect ground water samples. These wells are usually installed for temporary use and subsequently retrieved, and the borehole abandoned (i.e., Category 4 Uncased

Environmental Resource and Geotechnical Borings). Per 7:9-1.11(g) temporary wells installed to a depth of 50 feet or less, are 8.5 inches in diameter or less, and remain in place 72 hours or less, do not require specific well permits, but can be installed under a general Permit-by-rule. Temporary wells installed to depths greater than 50 feet, or greater than 8.5 inches in diameter, or that remain in place longer than 72 hours require well drilling permits, and completion of well abandonment reports when decommissioned. All temporary wells and borings must be decommissioned as outlined in N.J.A.C. 7:9D-3.1 & 3.4.

Advantages of the direct-push method include the relatively quick collection of ground water samples and, when used along with a mobile laboratory, collection of data in "real" time. The method allows for collection of multiple samples in a day with the potential for achieving contaminant delineation in one mobilization of the field equipment. The data can also be used to select locations of permanent monitoring wells.

Disadvantages of the method include the fact that the data quality achieved are often (depending on how the temporary well is sampled) suitable only for screening purposes. Direct-push methods typically result in very turbid samples since an oversize borehole is not produced and a filter pack is not used. Turbid samples can produce higher metals concentrations in ground water samples since metals are typically adsorbed onto soil particles. Use of direct-push methods can also cause cross-contamination since contamination from shallow zones may be driven down to deeper zones. Due to the narrow diameter of the direct-push rods, samples are often collected with peristaltic pumps. When samples are collected for volatile organic compounds (VOCs) using peristaltic pumps, some of the volatiles may be lost due to the pressure drop produced by the suction lift. In such cases, the VOC data should be qualified as screening level data accordingly. For this reason, it is important that the method and equipment used to collect the ground water sample be recorded and footnoted whenever the data are listed.

Another disadvantage of using direct-push technology for collecting ground water samples is the potential to breech confining units. To prevent this problem, soil sampling using direct-push technology or conventional split-spoon sampling techniques should first be performed to identify the presence, depth, and lateral extent of confining units. Pushing through confining units should be avoided if the presence of dense, non-aqueous-phase liquid (DNAPL) or very soluble compounds such as MTBE are suspected, or the contaminant plume appears to be diving in the aquifer.

For additional information on well drilling methods, please refer to the, *Handbook of Suggested Practices for the Design and Installation of Ground-Water Monitoring Wells*, (EPA, 1991).

A.6.1.4 Monitoring Well Design and Construction Considerations

Well construction specifications for unconsolidated, confined and bedrock aquifers are provided in this Appendix. As provided in N.J.A.C. 7:9D, most wells used in the investigation of contaminated sites are Category 3 wells (cased resource evaluation wells including monitoring wells, air sparging wells, soil vapor extraction wells, recovery wells, and wells or well points installed for environmental projects) or Category 4 wells (uncased wells including geotechnical borings including test borings, probe holes and those involving direct-push technologies). Requirements for the construction and maintenance of Category 3 & 4 wells are provided at N.J.A.C. 7:9D-2.4. Any proposed deviations from these construction standards must be approved by the Bureau of Water Allocation & Permitting (BWAP), pursuant to N.J.A.C. 7:9D-2.8.

The following is a discussion of different aspects of monitoring well construction.

A.6.1.4.1 Well Diameter

Well construction varies depending on the intended use of the wells. Most permanent, overburden monitoring wells are constructed of two-inch- or four-inch-diameter polyvinyl chloride (PVC) or stainless steel, as most sampling devices can easily accommodate these diameters. For wells used to extract ground water (i.e., recovery wells), well diameters may need to be larger (e.g., six inches or greater) to accommodate submersible pumps.

There are no minimum diameters for Category 3 & Category 4 wells. As the diameter of downhole purging and sampling equipment decreases, the diameter of the well necessary to accommodate the equipment also decreases. Potential future uses of the well should be considered when determining the diameter of the well to install. Below a diameter of one inch, well flexibility increases greatly. The increased flexibility may result in the installation of wells that are not straight or plumb. Bends in the pipe may cause pinch points in the well, restricting the use of some equipment.

Small diameter wells are sometimes installed with the sole purpose of being used to collect depth to ground water measurements. These wells are commonly called piezometers. In New Jersey a piezometer is considered a well. If the piezometer meets the New Jersey definition of a well (see N.J.A.C. 7:9D-1.5), and is to be permanent (i.e., installed greater than 72 hours), the piezometer must be permitted, installed and constructed following the same requirements as a monitoring well. With the exception of wells installed by direct push technologies to depths up to 30 feet in unconsolidated aquifers (N.J.A.C. 7:9D-2.4(d)), permanent wells must be installed in oversize boreholes where the borehole diameter must be a minimum of four inches larger than the well casing diameter. For example, a borehole must be at least eight inches in diameter if a four-inch well casing will be installed.

A.6.1.4.2 Well Construction Materials

Overburden monitoring wells should be constructed with either PVC or stainless steel casing and screen. In general, PVC is acceptable for most applications. However, where free product is present use of PVC may not be appropriate since PVC can degrade in free product causing the well to collapse or the screen to fail. In this case, stainless steel should be used. However, stainless steel should not be used in highly corrosive waters since metals may leach from the stainless steel causing the detection of false positives in water samples analyzed for metals. In such waters, PVC should be used. Where the water is not corrosive, and metals are not a concern, galvanized steel may be an option.

Bedrock wells are typically constructed using carbon steel casing with the intake of the well being an open hole in the bedrock. In cases where the bedrock is friable, well casing and screen may be installed in the borehole of a bedrock well. Either PVC or stainless steel well casing and screen may be appropriate for installation in bedrock, depending on the type of contaminants present (see paragraph above). In this case, installation of an outer casing (double-cased well) may not be necessary, particularly where there is a thin overburden formation and the bedrock is shallow, and instead, a single-cased well that is consistent with the Monitoring Well Requirements for Unconsolidated Aquifers may be appropriate. However, the driller must submit a deviation request to the Bureau of Water Allocation that is consistent with N.J.A.C. 7:9D-2.8(a).

A.6.1.4.3 Screen Length

The maximum length of the well intake interval (screen or open borehole in bedrock wells) for monitoring wells is 25 feet (N.J.A.C. 7:9D-2.4(a)4). The purpose of this limitation is to minimize the potential to cross-contaminate within or between aquifers.

The shorter the well intake interval (i.e., well screen or open borehole length), the greater the probability that the water sample collected from that well represents the water quality of the well intake interval. However, the aforementioned statement must be balanced by the risk that the shorter the well intake interval, the greater the probability that the well intake interval will not be in direct hydrologic communication with the ground water contamination, or the depth interval containing the highest contaminant concentration. The installation of short well intake intervals (i.e., less than 10') may be appropriate in the following scenarios:

1) multiple wells with well intake intervals at different depths will be installed at a common location;
2) a specialty well with multiple sampling ports at different depths is installed;

3) previous work has documented the vertical extent and profile of the ground water plume in the area where the well will be installed;

4) the well is targeting a specific geologic zone/horizon or bedrock fracture previously documented; or

5) the well is focusing on the water table to facilitate an assessment related to LNAPL type contamination, VI concern, or ground water table measurements.

In cases where a well will be used for ground water recovery, injection, air sparging, soil vapor extraction or aquifer testing, construction of the well with more than 25 feet of screen or open borehole may be acceptable. Constructing a monitoring well with more than 25 feet of well intake interval will require an approved well construction deviation request.

A.6.1.4.4 Screen Slot Size and Filter Pack Materials

Filter pack material should be clean silica sand which is sized according to the texture of the borehole materials from sieve analysis data. The uniformity coefficient of the filter pack materials should not exceed 2.5. The screen slot size should be selected to retain at least 90% of the filter pack material. Per 7:9-2.4(a)5, no more than five feet of filter pack shall be placed above the well screen. The top of the filter pack may be graded from coarser to finer (going upward) to minimize penetration of the overlying grout.

A.6.1.4.5 Grouting Materials

The annular space around the well casing must be grouted/sealed to prevent the borehole from acting as a conduit for the vertical migration of contamination. Acceptable grouting materials are provided in N.J.A.C. 7:9D-2.9 and the required procedures for sealing the annular space of wells is specified in N.J.A.C. 7:9D-2.10. It is recommended that the grouting materials be installed as a slurry using a side-discharge tremie pipe to prevent invasion of the grout into the filter pack.

Well Depth

Pursuant to the Technical Requirements for Site Remediation, ground water contamination must be delineated both horizontally and vertically (N.J.A.C. 7:26E-4.1(a)). This may require the installation of wells in clusters at various depths (see also Multi-Screened Wells below). The well clusters not only provide information on changes in water quality with depth, but also provide information with respect to horizontal and vertical hydraulic gradients in the aquifers which is necessary to properly characterize the ground water flow system, and contaminant fate and transport.

Special considerations may be necessary for the construction of deep wells compared to shallow wells. For example, deep wells installed with 2-inch-diameter PVC casing and screen may require the use of Schedule 80 PVC (wall thickness 0.218 inches), rather than Schedule 40 PVC (wall thickness 0.154 inches), since it is more rigid. One possible downside of using the Schedule 80 PVC pipe is that the interior diameter of the PVC pipe is reduced due to the increased wall thickness (i.e., the outside diameter of the pipe remains the same). The reduction in interior diameter may prevent some sampling equipment commonly used in 2-inch wells from fitting into the well.

When installing 2-inch or smaller PVC well pipe in large lengths of open borehole (i.e., x>50') it is recommended that well centralizers be used to minimize bending or flexing of the well in the borehole during the installation and grouting of the well. Flexing or bending of the PVC pipe during its installation may cause certain sampling or downhole geophysical tools to get wedged in the pipe, limiting their use.

When installing small diameter PVC pipe in deep borings (e.g., 250' bedrock borehole), the heat of hydration of the cement grout should be considered as it may compromise the structural integrity of the well.

A.6.1.4.6 Multi-Screened Wells

Where ground water contamination is found to be present at depth, the use of multi-screened or multiple-level wells may provide information on the vertical extent of contamination. It is strongly recommended that these wells be installed as prescribed by the manufacturer and frequently require a well construction deviation request pursuant to N.J.A.C. 7:9D-2.8. Examples of such wells include the Waterloo Multilevel Ground water Monitoring System® and the FLUTe™ method. (This should not be construed to represent an official NJDEP endorsement of these methods; this discussion is for informational purposes only.) Seals installed between well intake zones should be at least two feet thick. Installation and placement of multiple grout seals or packers within a single borehole can be complicated and difficult. Accurate placement of the grout seals or packers is critical to the proper function of the well. Failure of packers can occur, resulting in a lack of a borehole seal.

In most cases, installation of well pairs (e.g., shallow and deep) and well clusters (e.g., shallow, intermediate and deep) may be more appropriate than installation of multi-screened wells since they use conventional well installation technology and do not share a common borehole.

Grout is less likely to invade well intakes (screens) if the wells are installed in separate boreholes. Regardless of which method is used (i.e., well clusters versus well nests and multi-screened wells), care must be taken to assure that any confining unit between aquifer zones is not breached without providing adequate protection of underlying/overlying aquifers (e.g., installing double casing and grout, etc.).

Disadvantages of multi-level wells include: 1) it is difficult, if not impossible, to repair the device if clogging occurs, 2) it is difficult to prevent and/or evaluate sealant and packer leakage, 3) there is a potential for the sampling ports to be labeled or identified incorrectly, and 4) these installations are more expensive than single-level monitoring wells.

The FLUTe™ (Flexible Liner Underground Technologies, Ltd., http://www.flut.com) system involves the use of a flexible liner that can be used to temporarily seal a boring in unconsolidated materials or an open borehole in bedrock. As the FLUTe liners are unrolled down into the borehole, water in the borehole must be displaced. The rate at which the FLUTe unrolls down the borehole is related to the rate at which the water below the FLUTe can be displaced into the sides of the borehole. As such, the rate at which the FLUTe unrolls down the borehole is related to the hydrologic conductivity of the borehole section remaining below the FLUTe at that time.

The liners can also be used to sample ground water within boreholes at specific depths through the installation of dedicated sample ports and associated tubing constructed within the liners. In addition, vapor samples can be obtained in the unsaturated (vadose) zone. The liners can be installed in both vertical and horizontal wells.

The liner can be impregnated with a hydrophobic dye that reacts with some chlorinated solvent DNAPL. The liner is installed in the open borehole, then retrieved from the borehole and inspected for signs of DNAPL contact with the dye. The presence of reacted dye on the liner represents the depth where DNAPL exists and a possible depth to set a well intake interval.

The liner can also be coated with a material (e.g., hydrocarbon-detecting paste) that reacts with NAPL. The liner then can be installed through the interior of a cone penetrometer rod. Water is added to the inside of the liner causing the liner to dilate in the hole but not in the CPT rods, which are then removed. After the reaction with the NAPL occurs, the liner is removed from the hole and the NAPL stains and their depths are observed and recorded.

A.6.1.4.7 Pre-Packed Well Screens

Pre-packed PVC well screens are manufactured with filter pack materials (silica sand) inside them, or

they can be filled with sand in the field. They may also have bentonite seals or a foam bridge, which seals the well and prevents water from above from entering the screen. They have been developed for use with direct-push samplers (see above). The purpose of the pre-packed screen is to reduce the turbidity of the water samples collected using the direct-push method. The pre-packed well screen is placed inside of the direct-push rods. Upon reaching the targeted sample depth, the rods are retrieved leaving the screen in the ground. The seal expands to allow collection of water from a discrete depth. The screens are typically 3/4, 1 1/4 or 2 inches in diameter and 2.5 to 5 feet long. As with any direct-push sampling method, care must be taken to assure that confining units are not breached, and contaminants are not permitted to migrate downward into formerly uncontaminated portions of the aquifer.

A.6.1.4.8 Horizontal Wells

Horizontal wells must be installed by a New Jersey-licensed well driller who must obtain a well permit from the Bureau of Water Allocation and Permitting. Depending on well construction and usage, a horizontal well may require a well construction deviation request. Information usually required by the NJDEP includes the purpose of the well (e.g., monitoring well or recovery well), type of well (e.g., blind or continuous), depths of the well/screened intervals, proposed construction diagram, the method used to install and centralize the well casing and screen, and the grouting procedure.

A.6.1.4.9 Wells Used to Investigate LNAPL and DNAPL

Any well installed to detect floating product, or light, non-aqueous-phase liquid (LNAPL), needs to be screened across the water table. Any overburden well installed in either LNAPL or dense, non-aqueous-phase liquid (DNAPL) should be constructed of stainless steel if the NAPL has the potential to cause failure of a PVC well.

Wells installed to detect DNAPL should be constructed so that DNAPL can enter the well screen. N.J.A.C. 7:9D-2.4(c)1 states that the screened interval or the filter pack shall not extend across the interface between a confining layer and an aquifer. However, a well screened down to the top of a confining unit will not necessarily detect DNAPL present on the confining unit if the thickness of the DNAPL is not sufficient enough for it to enter the screen. Most well screens are not slotted down to the bottom of the screen; the lowest slot may be two or three inches above the bottom of the well. In addition, the bottom well cap also raises the well slots from the bottom of the well. For these reasons, the bottom one to two feet of the screen should extend into the confining unit to create a sump for the DNAPL to accumulate in. To facilitate the detection and capture of the DNAPL, the bulk of the well installed into the confining material should constitute a well sump constructed of solid bottom well casing. If possible, the majority of the annular space around the sump should be grouted instead of sandpacked to prevent the DNAPL from accumulating in sandpack material around the sump. Pursuant to N.J.A.C. 7:9D-2.8, this well construction will require a well construction deviation. Care must be taken to prevent the well from completely penetrating the confining unit.

Wells installed in bedrock must meet the construction requirements outlined in N.J.A.C. 7:9D-2.4. These requirements include installing steel casing a minimum of 10 feet into competent bedrock to case off the overburden. However, if DNAPL and/or dissolved contamination is suspected or likely to be present in the weathered bedrock, or at the bedrock overburden contact, the ten-foot casing requirement will hide the DNAPL from detection. Per N.J.A.C. 7:9D-2.4, wells that are screened across the bedrock overburden interface shall be constructed with a maximum of 10 feet of well screen. If casing and screen will be installed in the bedrock aquifer, installation of the outer steel casing may not be required. Variations to the above will require a request for well construction deviation.

A.6.1.4.10 Lysimeters

Contamination moving from the surface toward the water table passes through the vadose zone. Because the soil water in the vadose zone is under tension, it cannot flow into a well under gravity. If soil water

needs to be sampled, it must be collected with a suction lysimeter.

A suction lysimeter is a porous cup located on the end of a hollow tube (Fetter, 1993). The tube can be PVC or stainless steel. The porous cup can be ceramic, nylon, Teflon® or stainless steel. A suction is applied to the hollow tube and held for a period of time. The flow of soil moisture to the porous cup can be slow, and it may be necessary to hold the vacuum overnight to supply a sufficient volume of water for chemical analysis.

Suction lysimeters are considered to be Category 4 wells, pursuant to N.J.A.C. 7:9D-2.1(a)4, and must be installed and decommissioned accordingly, pursuant to N.J.A.C.7:9D-2.4 and N.J.A.C. 7:9D-3.1& 3.4, respectively.

A.6.1.5 Miscellaneous Well Construction Considerations

A.6.1.5.1 Well Development

In accordance with N.J.A.C. 7:9D-2.11(b) all well development or redevelopment work shall be performed by a licensed well driller of the proper class. The objective of a monitoring well is to provide a representative sample of water as it exists in the formation. The process of well development is to mitigate damage done to the formation adjacent to the borehole during the drilling process by increasing the hydrologic connection between the well and the surrounding formation. Monitoring well development is required to:

1) remove drilling fluid residues remaining in the borehole or surrounding aquifer;
2) remove imported drilling water lost to the aquifer during the drilling procedure;
3) restore the hydraulic properties of the formation immediately surrounding the monitoring well; and
4) sort the filter pack material to allow ground water to freely flow to the monitoring well.

There are three primary factors that influence the development of a monitoring well: 1) the type of geologic material the well is installed in, 2) the design and completion of the well, and 3) the type of drilling method employed to install the well (EPA, 1991). Any of these factors can affect the success of, and the level of effort needed to develop the well.

Acceptable well development methods include: bailing, over-pumping, mechanical surging, air-lift surging, and water jetting. The best methods involve surging water flow back and forth through the well screen to sort the filter pack materials. See Figure 6.8 (Driscoll, 1986). Pumping alone will tend to cause particles moving toward the well to “bridge” together or form blockages that restrict subsequent particulate movement. The best methods include bailing, pumping/over-pumping/backwashing, and surging with a surge block or a combination of these methods. Following the use of these methods, the wells should be pumped to remove fines that have accumulated in the well.

Air-lift methods may be used to effectively develop wells installed in permeable formations. However, they may introduce air into the aquifer surrounding the monitoring well, and this air has the potential for altering ground water quality, particularly for volatile organics. For these reasons, air-lift methods should not be performed within a well screen unless the double-pipe method is used. Whenever an air compressor is used, an air filter should be used to filter out any entrained oil.

Over-pumping involves pumping a well at a rate that substantially exceeds the rate that the formation can deliver water. This rate is usually much higher than the rate that will be induced during subsequent purging and sampling of the well. This higher rate causes rapid and effective migration of particulates toward the pumping well. However, over-pumping alone does not effectively develop monitoring wells since a surging action is needed to properly sort the filter pack and permit removal of particulates from the borehole. Where there is no backflow-prevention valve installed, the pump can be alternately started

and stopped. This allows the column of water that is initially picked up by the pump to be alternately dropped and raised up in a surging action (backwashing). Also, over-pumping of a monitoring well during development may draw ground water to the monitoring well from considerable distances and draw ground water of quality not representative of the immediate vicinity of the monitoring well, especially in anisotropic and/or bedrock aquifers.

Well yields determined during the development of monitoring wells, and the well development method(s) used should be recorded on all well logs, well records, and as-built construction diagrams. The well yields should be taken into consideration when designing a sampling program. It is recommended that well development not be performed until the day after (i.e., a minimum of eight hours after) the well has been installed. This will allow time for the cement grout to set prior to well development.

A.6.1.5.2 Well Protection

To adequately protect the well from the outside environment and potential physical damage the top of the well should be finished in a method appropriate to the location (flush-mounted, standpipe well, vault).

A standpipe well is finished with a protective steel casing installed above ground surface with a lockable cap on the outside. Standpipe wells must be installed in accordance with N.J.A.C. 7:9D-2.4. The steel casing should be firmly set in concrete. See figure A.6.2.

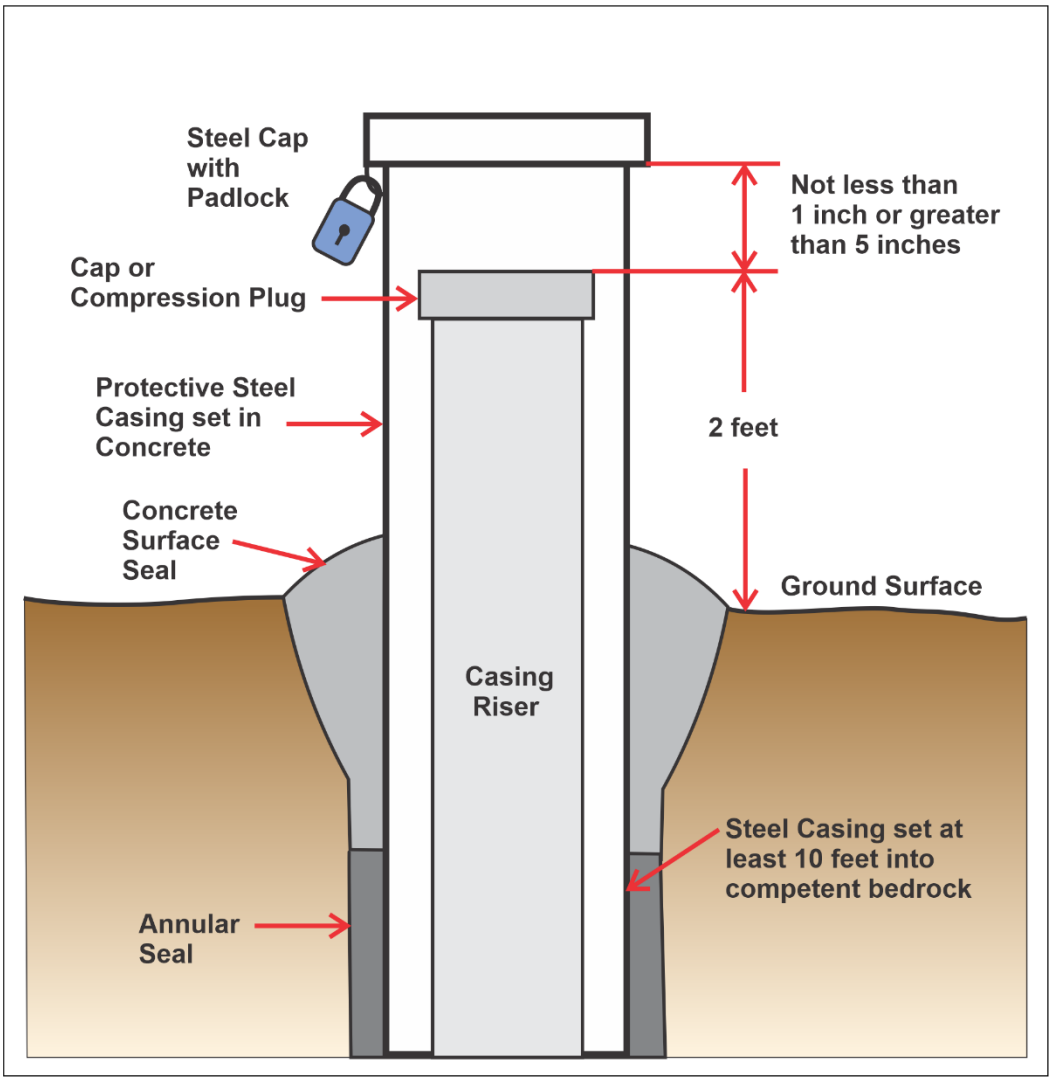


Figure A.6.2 Typical Standpipe Completion. Illustration by P. Bauer.

In some circumstances (e.g., operating service station), it may be impractical to install wells with casing above the surface. In such situations, flush mounted wells may be installed. Flush mounted wells must be installed in accordance with N.J.A.C. 7:9D-2.4. The manhole should be of the type with bolt-down lids, waterproof and able to withstand vehicular traffic. The well should be clearly labeled, and the well permit number and identifier affixed to the well. The manhole should be firmly anchored to, or embedded in, a concrete surface seal. The concrete seal should be sloped away from the box, providing drainage for water and facilitating vehicular traffic. When installed in non-roadway or mowed areas it is recommended that the manhole extend slightly above the surface (1-2 inches) to prevent pooling of water on the bolt-down lid.

By the nature of their design, flush-mounted well boxes cannot be locked from the outside. As such, flush-mounted well boxes must be completed with a lockable cap on the inner casing. This cap must be watertight. No vent hole shall be drilled in the cap or casing. In addition, flush-mounted well boxes must be large enough to allow adequate room to install and remove the lock and cap from the inner casing. There must also be adequate room to secure the flush-mounted box lid with the inner cap locked in place. See Figure A.6.3.

Some wells may also be installed in below-grade vaults (e.g., recovery/extraction wells). The vaults must be watertight. Large vaults, whose maintenance would require someone to enter them, may be confined spaces, and they would have to be entered with the appropriate precautions.

After installation of a well, a reference point should be marked on the top of the inner casing (with an indelible marker or by notching the top of the casing) for future water-level measurements. The well must be labeled with the owner's well number and NJDEP's well permit number.

While flush-mount manholes are required to be watertight, the reality is that with time and multiple openings of the manhole, the water-tight gaskets get torn, broken or lost. The result is that rainwater and surface water can seep into the manhole. If the expansion cap in the wells is watertight, the area within the manhole may completely fill up with water, making access to the well difficult. While not required, it is recommended that an angled hole or a piece of open tubing extend from the bottom of the annular space inside the flushmount cap, through the concrete anchoring the flushmount box, and into the surrounding soils. This angled conduit would allow water that seeps into the manhole to drain into the surrounding soils.

A.6.1.5.3 Maintenance of Wells

Sediment may accumulate in wells over time. This may be the result of poor well construction (e.g., incorrect filter pack materials or incorrect screen slot size) or cases where wells are installed in fine-grained sediments (e.g., silt). When this occurs, it may be very difficult to obtain a low turbidity sample. Where sediment accumulation is significant, the standing column of water in the well intake interval may be reduced making it more difficult to purge the well. Where the accumulation of sediment in the well affects the ability to obtain a representative sample, it is requested that the well be redeveloped. Acceptable well development methods are discussed earlier in this Appendix and in the section on ground water sampling (see Section 6.9.2.1 on Well Development).

Wells may become damaged due to weather conditions, accidents or vandalism. A well maintenance program should be developed to assure that wells are properly maintained so that samples can be collected that are representative of aquifer conditions and to prevent contaminants at the ground surface from seeping into wells and contaminating ground water. Periodic inspections should be performed to assure that caps are present and locked, concrete collars are not cracked or broken, and that flush-mounted well boxes remain watertight (i.e., lid and gasket are present). Compression plugs should be examined and replaced when needed to maintain well integrity.

If standing water is encountered within a flush-mount well box, and the water level in the well box is level with the top of the well pipe, it is likely that the expansion plug in the well top is leaking and

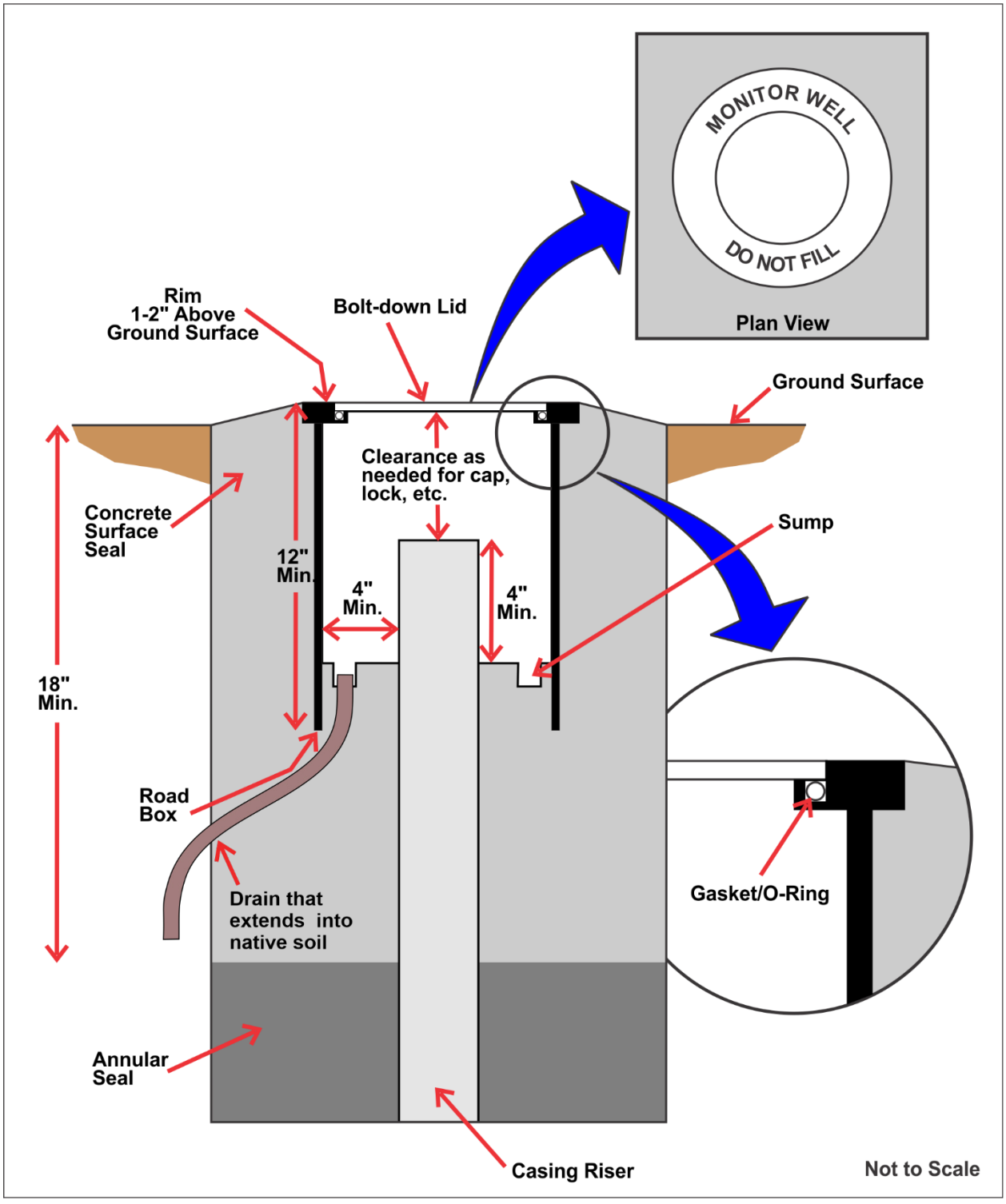


Figure A.6.3 Typical Flush-Mount Completion. Illustration by M. Romanell.

allowing surface water to recharge into the well. If this situation is encountered, the water in the well box should be removed and the expansion plug removed and inspected. If cleaning and re-installing the plug

does not result in a watertight seal, the expansion plug should be replaced.

When a flush-mount well box is installed NJDEP recommends that actions be implemented to allow water that seeps into the well box to drain out of the well box. The drain system should extend from the interior of the well box to the native soils outside the borehole. The top of the drain should be below the top of the well casing. Suggested options include:

1) construct a drain system made out of pieces of ½-inch or larger rigid PVC pipe that is placed before the flush-mount box and associated cement are installed;
2) install a piece of flexible tubing (½-inch ID or larger) that extends from the well box interior to the native soils outside the borehole before the flush-mount box and associated cement are installed, or
3) create an angled drain hole in the well box cement that extends into the native soil outside the borehole.

For new well construction the hole can be installed by pouring the anchoring cement around a preset wooden dowel which is removed prior to hardening of the cement, or driving the dowel through the cement shortly after placement, and removing the dowel prior to hardening of the cement. For an existing well the drain hole can be installed by drilling a hole through the cement with a long drill bit designed for drilling in concrete.

A.6.1.5.4 Subsurface and Overhead Utilities

It is the responsibility of the well driller to assure that well drilling activities do not encounter any subsurface or overhead utilities to avoid both disruption to utility services and for health and safety considerations. The driller must comply with all applicable OSHA requirements, pursuant to 29 CFR 1910, during well drilling operations and obtain utility markouts prior to starting drilling activities. At least three business days prior to commencing drilling activities, the driller should call 811 or 1-800-272-1000 or, from out of state, 1-908-232-1232. Well drillers should also be participating in a Medical Surveillance Program (MSP) and wear appropriate personal protective equipment.

A.6.1.5.5 Well Decommissioning Requirements

All Category 3 monitoring wells must be sealed upon abandonment using the methods specified at N.J.A.C. 7:9D-3.1 (general requirement for decommissioning all wells). All Category 4 wells and geotechnical borings must be sealed within 72 hours in accordance with N.J.A.C. 7:9D-3.4.

Upon sealing a monitoring well or permitted boring, the New Jersey-licensed well driller of the proper class must submit a Well Abandonment Report to the Bureau of Water Allocation within 90 days of decommissioning the well pursuant to N.J.A.C. 7:9D-1.15(c).

Borings 25 feet or less in depth may be decommissioned by back-filling with cuttings, or a clean fill material, pursuant to N.J.A.C. 7:9D-3.4(b). However, where borings of less than 25 feet encounter NAPL, or NAPL may be present, and/or where confining layers are, or potentially were encountered, NJDEP recommends that the borehole be sealed with an acceptable grout irrespective of depth. (see N.J.A.C. 7:9D-3.1 for acceptable grouting materials).

All borings 25 feet or greater in depth must be decommissioned using an approved sealing material in accordance with N.J.A.C. 7:9D-3.1.

Appendix 6.2
NJDEP Monitoring Well Specifications for Bedrock, Unconsolidated and Confined Aquifers

A.6.2.1 Monitoring Well Requirements for Bedrock Formation

(See Figure A.6.4)

1. The construction of all monitoring wells shall be in accordance with the requirements of N.J.A.C. 7:9D-2.2 et seq.
2. The use of glues or solvents is prohibited in the installation of well screens, riser pipes and well casings.
3. The locking cap must be made of steel.
4. A New Jersey-licensed surveyor must survey top of the innermost casing (excluding cap) to the nearest 0.01 foot. The survey point shall be the highest point of the casing. If the casing is level, the survey point shall be established on the northern side of the casing. The survey point must be marked on each well via notching or indelible marker.
5. Wells should be developed to a turbid-free discharge.
6. As the well intake interval is limited to 25', some bedrock wells may require the installation of a smaller PVC well inside the bedrock borehole (e.g., 2-inch PVC in 6-inch borehole or 4-inch PVC in 8-inch borehole).

Notice is Hereby Given of the Following:

The NJDEP does not review well locations or depths to ascertain the presence of, or the potential for, damage to any pipeline, cable, or other structures.

The permittee (applicant) is solely responsible for the safety and adequacy of the design and construction of monitoring well(s) required by the NJDEP.

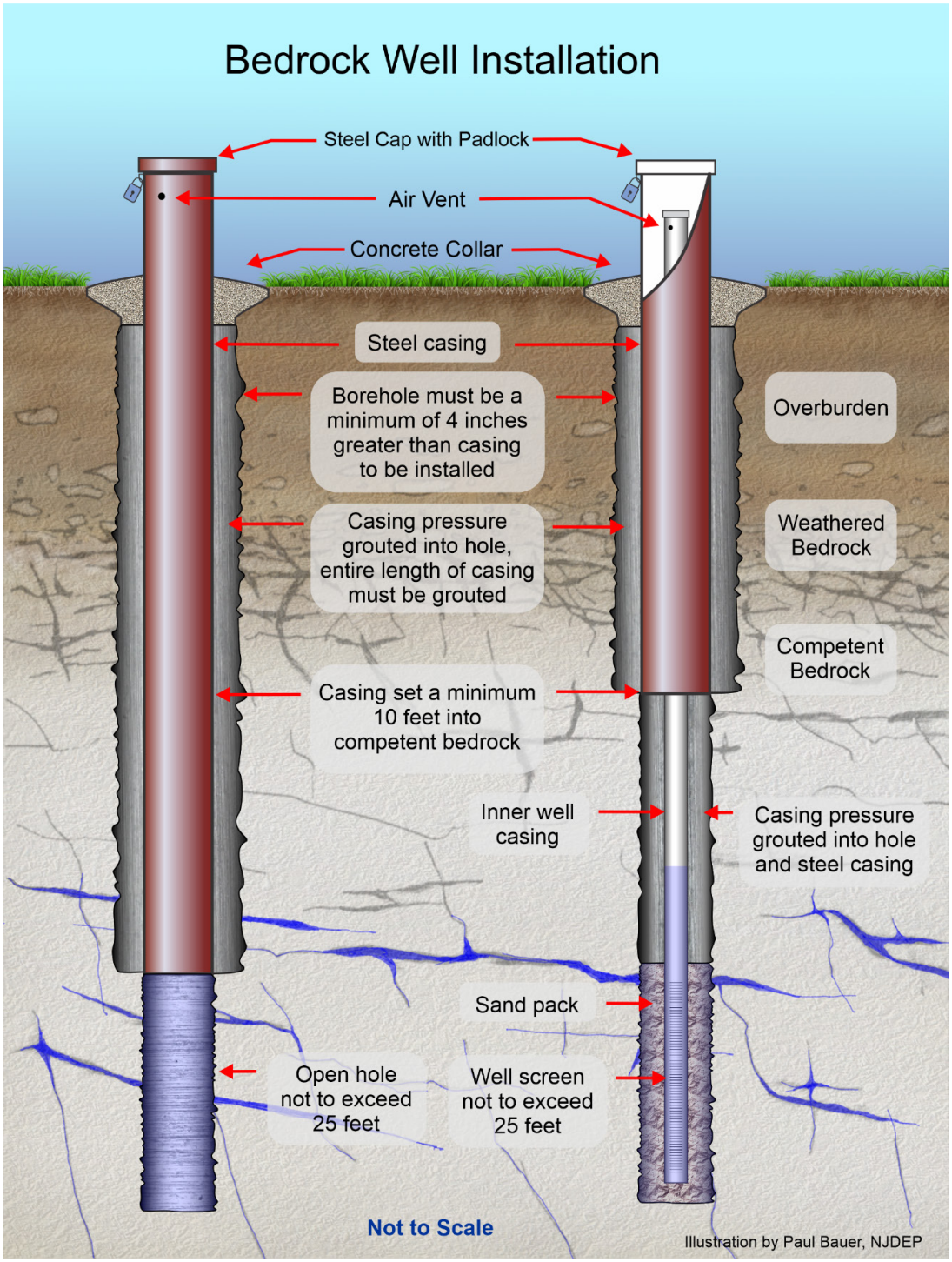
The permittee (applicant) is solely responsible for any harm or damage to person or property which results from the construction or maintenance of any well; this provision is not intended to relieve third parties of any liabilities or responsibilities which are legally theirs.

A.6.2.2 Monitoring Well Requirements for Unconsolidated Aquifers

(See Figure A 6.5)

1. The construction of all monitoring wells shall be in accordance with the requirements of N.J.A.C. 7:9D-2.2 et seq.
2. Minimum screen and riser pipe inner diameter is 2 inches.
3. The use of glues or solvents is prohibited in the installation of well screens, riser pipes and well casing.
4. To prevent any induced interconnection between the overburden/weathered bedrock and competent bedrock, the well screen shall not extend across the aforementioned interface.
5. Wells must have a filter pack installed.
6. When grouting the annular space directly above a filter pack, the grout should be discharged horizontally from the tremie pipe.
7. The locking cap must be made of steel.

8. A New Jersey-licensed surveyor must survey top of the innermost casing (excluding cap) to the nearest 0.01 foot. The survey point shall be the highest point of the casing. If the casing is level, the survey point shall be established on the northern side of the casing. The survey point must be marked on each well via notching or indelible marker.
9. Wells should be developed to a turbid-free discharge.



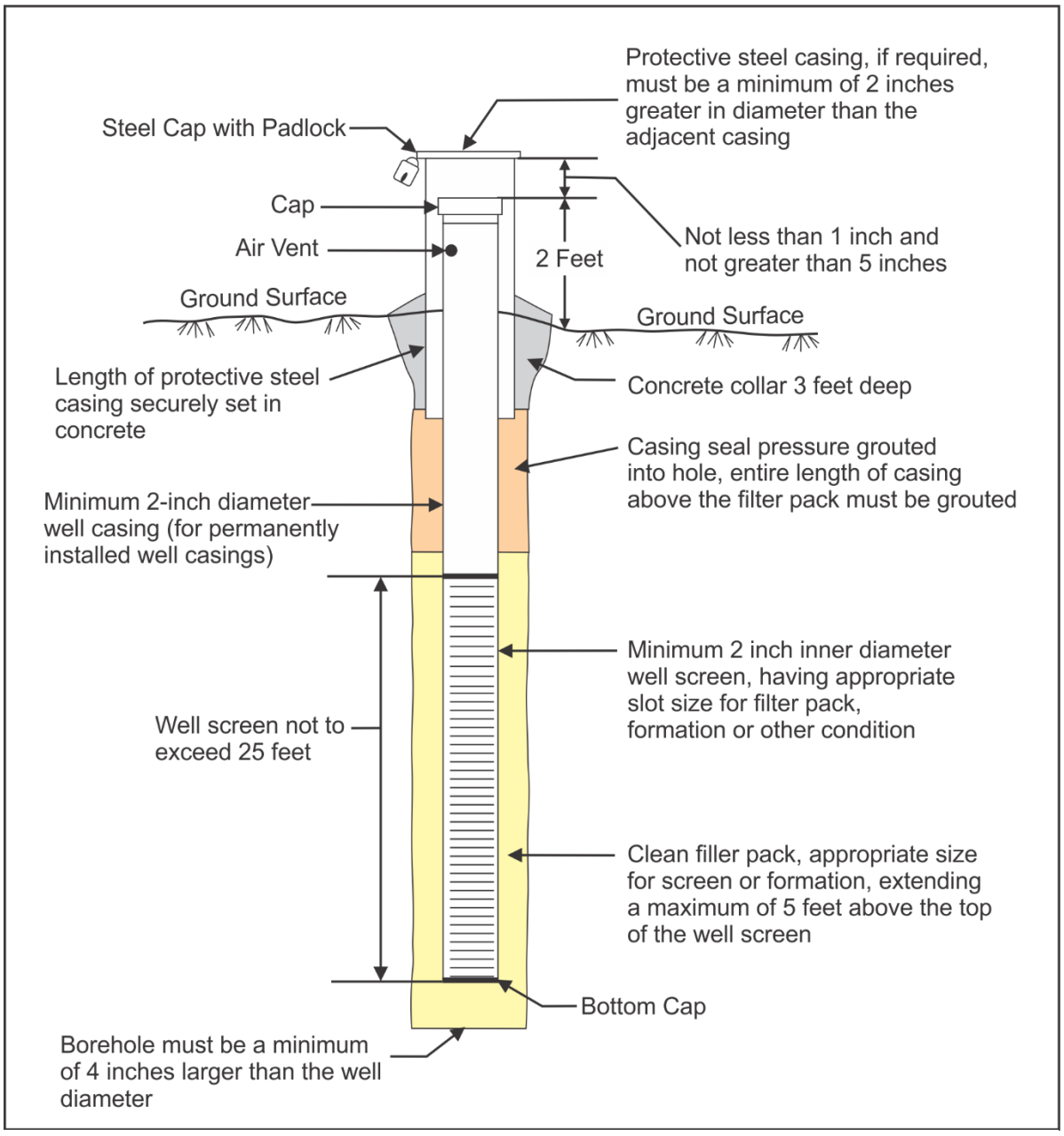


Figure A.6.5 Unconsolidated Aquifer Well

Notice is Hereby Given of the Following:

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A.6.2.3 Monitoring Well Requirements for Confined Unconsolidated Aquifers

(See Figure A.6.6)

1. The construction of all monitoring wells shall be in accordance with the requirements of N.J.A.C. 7:9D-2.2 et seq.
2. Minimum screen and riser pipe inner diameter is 2 inches.
3. The use of glue or solvents is prohibited in the installation of well screens, riser pipes and well casing.
4. To prevent any induced interconnection between the overburden/weathered bedrock and competent bedrock, the well screen shall not extend across the aforementioned interface.
5. Wells must have a filter pack installed.
6. When grouting the annular space directly above a filter pack, the grout should be discharged horizontally from the tremie pipe.
7. The locking cap must be made of steel.
8. A New Jersey licensed surveyor must survey top of the innermost casing (excluding cap) to the nearest 0.01 foot. The survey point shall be the highest point of the casing. If the casing is level, the survey point shall be established on the northern side of the casing. The survey point must be marked on each well via notching or indelible marker.
9. Wells should be developed to a turbid-free discharge.

Notice is Hereby Given of the Following:

The NJDEP does not review well locations or depths to ascertain the presence of, or the potential for, damage to any pipeline, cable, or other structures.

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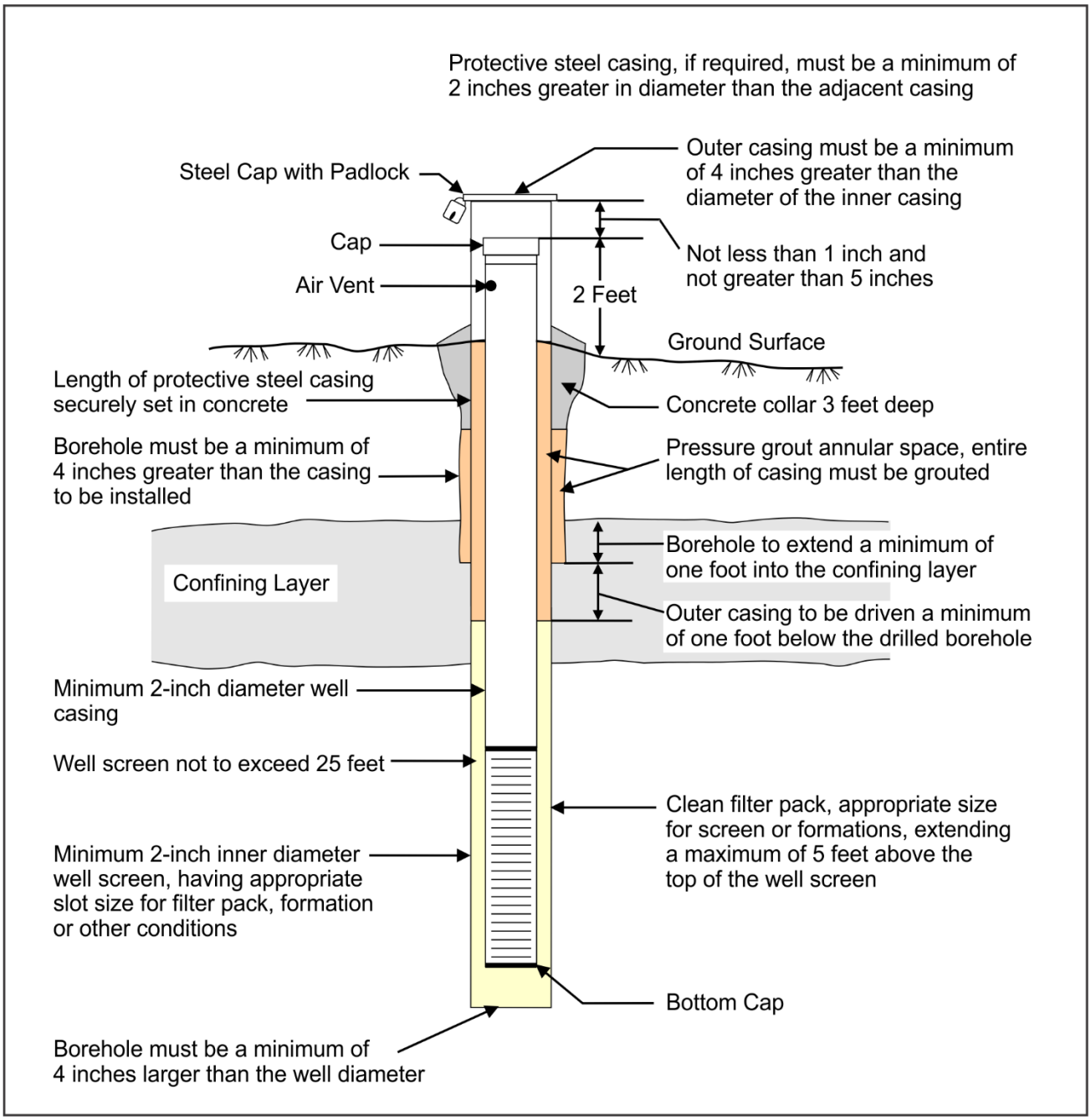

Figure A.6.6 Confined Unconsolidated Aquifer Well