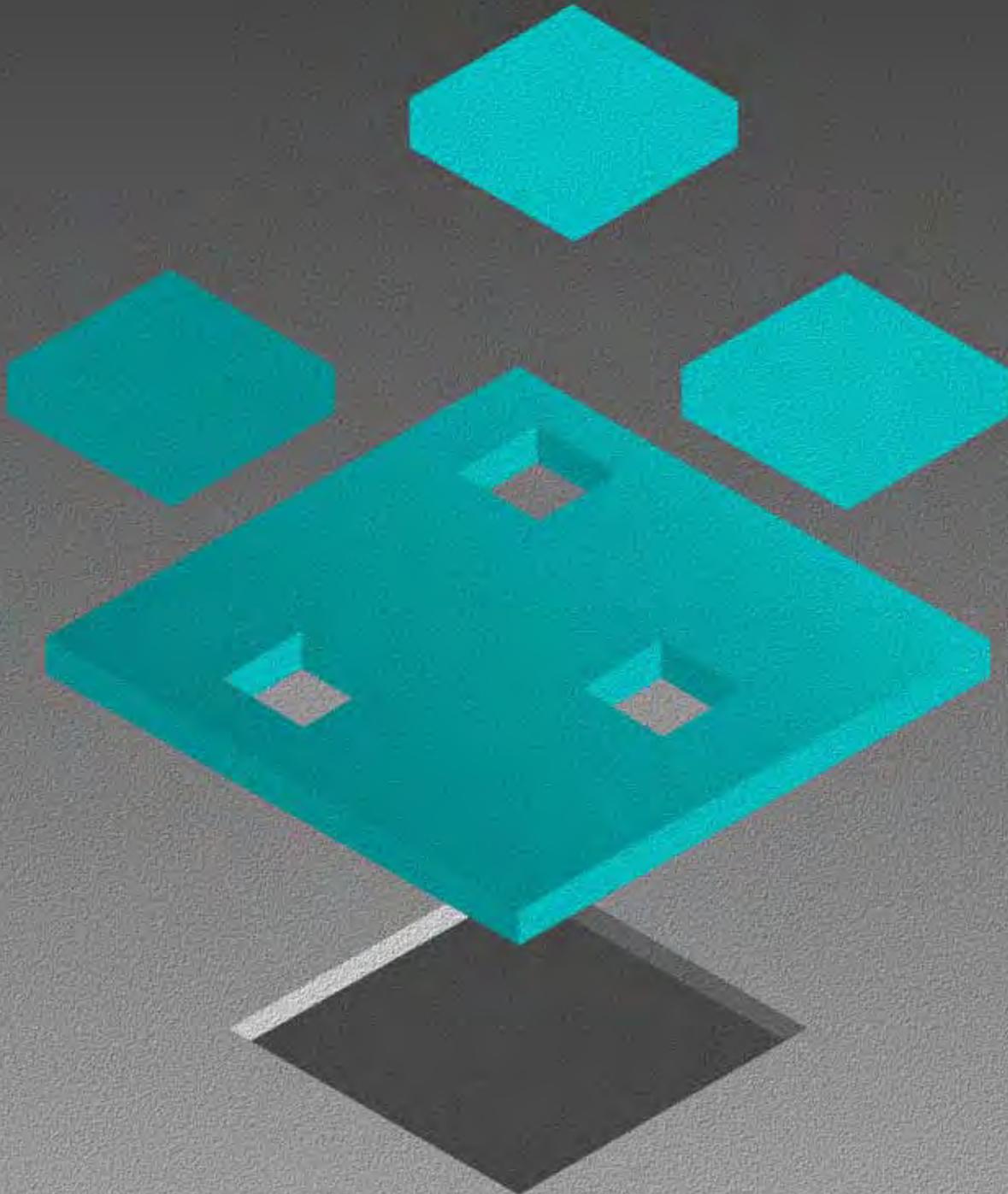




New Jersey
Department of Environmental Protection
Field Sampling Procedures Manual
August 2005



Acknowledgements

Dear Reader:

The information contained in the NJDEP's *Field Sampling Procedures Manual* is drawn from existing manuals, various reference documents and a broad range of colleagues with considerable practical and educational backgrounds. As Technical Editor, I would like to extend a sincere thank you to the many individuals within the Department who provided their scientific and technical expertise. The fact that this manual has been traditionally held in high regard beyond New Jersey's borders is a testament to their continuing commitment to provide the public with considerable insight and innovative and useful knowledge. This latest edition should prove to be no different. At the risk of excluding someone who may have played a critical role behind the scenes, I would like to acknowledge the following major contributors from the NJDEP who provided new information for entire chapters or extended sections. The list includes Chad VanSciver, Jeff Story, Victor Poretti, Allan Motter, Nancy Stanley, George Nicholas, Kathleen Grimes, Lynn Vogel, Dave Hall, Greg Giles, Atiya Wahab and Mike Miller.

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Finally, though no less important, has been the significant improvement to the manual's revised format and graphic presentation. To those individuals familiar with past editions, the changes are strikingly obvious. Responsible for making that quantum leap is Kathy Pietras from the Bureau of Information Services and Program Support. Kathy, as always, I am humbled by the depth of your technical computer knowledge and graphic talents and I am indebted to your tolerance of my complete lack of those very skills.

Sincerely,

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Front Cover: Grayson Design Group

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Introduction

Welcome to the latest edition of NJDEP's *Field Sampling Procedures Manual*. This new manual replaces the 1992 edition as the most current technical guidance associated with procedures and equipment utilized for the collection of environmental samples. It also represents the first edition published on the World Wide Web, which brings the benefit of improved access to information for the public and regulated community.

The primary intent of the manual has always been to promote accuracy and consistency when environmental samples are collected and prepared for chemical analysis by public and private entities. The validity of analytical data is directly dependent upon the integrity of the field procedures employed to obtain a sample. The methods and procedures described herein are intended for use by those State of New Jersey regulatory agencies that require chemical, physical and certain biological analysis of samples for remedial evaluation and monitoring purposes. Since these methods are applicable to such a wide variety of regulatory programs throughout the Department, any site and/or regulatory specific questions/issues regarding a particular sampling technique must be discussed with the applicable program personnel prior to going out into the field.

Furnishing guidance for a broad range of field activities is meant to improve the planning, implementation and documentation of most field-sampling activities. Said guidance may often suggest several ways to collect a sample, all of which may be scientifically correct under site or matrix specific circumstances. Hyperlinks that direct the reader to a variety of web sites are intended to enhance specific information with the emphasis on enhance, not necessarily replace. Maintaining a balance between the evolving nature of environmental sampling and well-established regulatory oversight means that care should be taken when preparing documents based on the procedures outlined herein. All methodologies presented in this manual may not be applicable to specific site situations; a certain procedure, though included in the text of the manual or by hyperlink reference may be disallowed at the discretion of NJDEP program personnel if determined inappropriate in a particular situation.

This manual has been prepared in an effort to represent the best available technology for field sampling activities associated with hazardous site investigations and remedial actions. It is also an appropriate reference for certain aspects of water data acquisition, water allocation, wastewater treatment operations, radiological assessment, geophysical investigations and other regulated programs that require field sampling. Procedures outlined herein have been developed through internal peer review, extensive literature research, practical field application and analysis of data from a quality assurance perspective.

Environmental sampling inherently may present extraneous variables, which may ultimately affect the outcome of analytical results. Since the nature of environmental media sampling warrants the analysis of a small aliquot relative to the bulk material, proper sampling techniques must be employed to obtain a sample which retains its scientific integrity and is legally defensible. To meet these conditions a sample must be collected and handled so as to keep its original physical form and chemical composition to as great an extent as possible. For a sample to be "representative" of a larger body of material in question, it is imperative to ensure sample integrity and maintain quality assurance standards in the field. The sampling procedures put forth in the text of this manual or by direct reference are designed to minimize any possibility of altering the sample's integrity.

The achievement of consistency in sampling procedures and techniques helps to ensure the provision of data having acceptable quality, comparability and usability. The importance of data quality has been recognized through stringent laboratory quality control programs. This manual is intended to compliment these processes by establishing appropriate quality control during sampling collection. Quality assurance measures coupled with a comprehensive site specific sampling plan will improve the chance of collect-

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ing representative samples. This is important to ensure that public and private monetary resources are utilized in an effective manner.

NJDEP's *Field Sampling Procedures Manual* (FSPM) details the scope of field sampling protocol for site investigation and monitoring activities. From sampling plan preparation through chain of custody procedures, the manual details the handling requirements and offers a variety of collection techniques for sample collection of various matrices. Related concerns such as personnel protection, geophysical investigation techniques, use of portable instrumentation, etc. are also included.

The reader is cautioned to be aware of the differences between materials presented in this manual as guidance, and specific requirements contained within control documents (e.g., promulgated regulations, permits or Administrative Consent Orders). Control documents have legal precedence over this manual and may prescribe certain sampling activities or methods unique to a particular program, site or matrix. In all cases and when sampling within specific conditions set forth by any control documents, this manual should be utilized as a technical guidance document only.

It is recognized by the Department that alternative sampling methods are continually being developed and accepted for use by various regulatory agencies. Examples of these include methods for the collection of ambient air and soil gas using summa canisters, monitoring ground water using passive diffusion bags, certain field analytical methods and other newly designed equipment for sample acquisition. Use of new or alternative-sampling devices should be reviewed and approved for site use by the regulatory program governing the investigation. Recognized groups such as the American Society for Testing and Materials (ASTM) the Interstate Technology and Regulatory Council (ITRC) and the U.S. Geological Survey (USGS) will no doubt continue to publish recommended procedures that improve efficiency, accuracy as well as specific devices.

As a result, the Department will be updating this manual as needed to keep the most current and accepted sampling methods available to the public. To that end, be advised that documents such as the *Alternative Ground Water Sampling Techniques Guide* (AGWSTG) and the *Field Analysis Manual* (FAM) are incorporated herein. While the AGWSTG will remain available as a stand-alone reference on the Site Remediation Web Page, the FAM is now contained completely within the FSPM (Chapter 7). Also, inquiries related to obtaining certification for certain analyze immediately parameters related to environmental sampling should be made directly to the Office of Quality Assurance. These include Laboratory Certification pursuant to N.J.A.C. 7:18, certification related to the Triad initiative and certification associated with the Private Well Testing Act. The Department also remains available for and encourages open discussion regarding uses and applications of additional procedures not presented herein, or suggestions for modifications to procedures presented. To that end we hope your experience using this manual is useful, informative and interactive.

Any questions on information contained in the manual may be addressed to:

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Inquires of a specific nature involving the requirements of the New Jersey Laboratory Certification Program, the NJDEP Water Monitoring and Standards Program and the Water Supply Administration Program should be directed as follows:

N.J. Laboratory Certification Program
Office of Quality Assurance
609-292-3950

Water Monitoring and Standards Program
Bureau of Fresh Water and Biological Monitoring
Bureau of Marine Water Monitoring
609-292-4543

Water Supply Administration Program
Bureau of Safe Drinking Water
Bureau of Water Allocation
609-292-5550

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Chapter 1

The Sampling Plan

1.1 Introduction

There are a wide variety of reasons for collecting samples and various sampling strategies for different situations. It is important that the purpose of the sampling and associated data quality objectives be identified before fieldwork begins. For example, samples may be collected to determine the existence and/or to define the extent of contamination at a site, to allow waste characterization and classification for disposal or recovery, or to determine compliance with existing regulations. Once the objective is known, decisions about analytical parameter selection, NJ certified laboratory selection, quality control samples, sample location and frequency; etc. can be made more confidently. In sampling to assess permit compliance, some of these selections may have been mandated by the Department. Here, the permit applicant has the responsibility of assuring that any proposed requirements will be achievable if made mandatory. Defining sampling and data quality objectives is important to assure that the sampling plan is complete. Environmental sampling is often conducted to gather data that will be the basis for remedial decisions. Because of the potential threat to health and environment and high costs usually associated with site remediation, strict adherence to quality assurance measures are strongly recommended. In such a case, the objective of the sampling helps to dictate what should be prescribed in the sampling plan.

An integral part of any sampling program is planning. Before a plan can be written, site-specific information must be gathered to insure that the plan is logical, will meet the required objectives and the course of action is achievable.

The purpose of developing a sampling plan is to detail a “plan of action.” The person writing the plan must be very familiar with the site specific conditions and those implementing the plan must be very familiar with the plan’s contents. A properly prepared sampling plan that is correctly implemented will allow the sampling objectives to be met, help avoid confusion in the field, preserve health and safety, and ultimately save time and money. In the development of the sampling plan other pre-sampling activities must be heavily relied upon. Some factors to be taken into account include the following.

1.2 The Triad Approach

The New Jersey Department of Environmental Protection is committed to streamlining the site investigation and remediation process at contaminated sites without compromising data quality and reliability. This goal can sometimes be better achieved by implementing the Triad approach, a process that integrates systematic planning, dynamic work plans, and real-time measurements to achieve more reliable, timely and cost-effective site characterization and cleanup. The Triad approach seeks to recognize and manage the uncertainties involved in generating representative data from heterogeneous environmental matrices. The Department supports and encourages the use of the Triad approach for sites undergoing investigation and remediation within the Site Remediation and Waste Management Program. The Department has evaluated the Technical Requirements for Site Remediation, N.J.A.C. 7:26E, in the context of Triad approach, and has determined that the concepts embodied in Triad approach can be implemented within the framework of the rules. The Department encourages persons interested in using the Triad approach to enter into Memoranda of Agreement, as described in N.J.A.C. 7:26C, because successful implementation of the Triad approach requires close interaction with the Department to ensure that appropriate considerations have been addressed. More information and details on the Triad approach may be found at <http://www.nj.gov/dep/srp/triad>.

Detailed information on application of real-time measurements may be found in Chapter 7 of this Manual.

1.3 Site History – Evaluating Existing Data/File Information

The first step in a site investigation should be the gathering of background information. Information concerning the history of activity at a site (including locations and age of buildings, drainage pathways, contours, building layout, foundations, septic systems, tanks, etc.; processes and materials for manufacture, storage and disposal both past and present, or historical spills) can be extremely useful in planning sampling events. A file search may reveal areas of a site used for specific processes (aerial site history, site plans, area land use may also be useful) and will help in the logical placement of sampling locations. Data from the DEP's Geographic Information System (GIS) are a valuable resource that can provide additional background information to investigators, enabling the ability to analyze mapped datasets on computer. GIS datasets relevant to the history of activity at a site include statewide land use, soils, geology, and digital aerial orthophotography. Visit the NJDEP GIS website for more information and data downloads at <http://www.state.nj.us/dep/gis> and the New Jersey Spatial Data Clearinghouse at <http://njgeodata.state.nj.us/>. For more specific information go to <http://www.state.nj.us/dep/srp/regs/guidance.htm#techgis2>.

By revealing what materials were handled on site, a file search may provide guidance in choosing which parameters to include for analysis. Additionally, while caution must still be used, judgments regarding health and safety requirements can be made. When no information is available, field personnel must consider that worst case conditions may exist and take proper precautions to insure safety.

The following is a list of federal, state, local and other agencies or sources where additional information regarding site history may be obtained. Addresses and phone numbers can be found in the Blue Pages of Governmental Listings in the Verizon Yellow Pages.

U.S. Government

- U.S. Department of Justice
- U.S. Geological Survey
- U.S. DOA - Soil Conservation Service
- U.S. DOA - Forest Service
- U.S. DOI - Fish and Wildlife Agencies
- U.S. Army Corps of Engineers
- U.S. Nuclear Regulatory Commission
- Federal Emergency Management Agency
- National Oceanic and Atmospheric Administration
- U.S. Environmental Protection Agency

State of New Jersey

- NJ State Library
- NJ State Attorney General Office
- NJ Geological Survey
- NJ Department of Transportation
- NJ Department of Agriculture
- NJ Department of Health

NJ Department of Environmental Protection

Division of Watershed Management

Division of Water Quality

Regional Enforcement (Northern, Central and Southern)

Bureau of Freshwater and Biological Monitoring (see 305b report, STORET)

Bureau of Case Management

Bureau of Site Management

Bureau of Air Pollution Control

Bureau of Emergency Response

Bureau of Environmental Evaluation and Responsibility Assessment

Bureau of Environmental Evaluation and Risk Assessment

Bureau of Environmental Measurements and Site Assessment

Information Resource Center

Bureau of Geographic Information and Analysis

(Digital aerial orthophotography and other GIS data sets) at <http://www.state.nj.us/dep/gis> and <http://njgeodata.state.nj.us>

Bureau of Tidelands (Hard copy historical aerial photography)

Radiation Protection Programs

Pesticide Control Program

Office of Community Relations

Office of Brownfields Remediation

County Government

County Health Department

County Planning Board

County Library

Local Government

Local Health Department

Tax Assessors Office

Economic Development Officer

Environmental Commission

Local Planning Board

Town Engineer

Local Chamber of Commerce

Local Airport

Local Library

Local Well Drillers

Local Historical Society

Other Sources

Facility Records

Employee Records

Citizens residing nearby

Local and regional waste haulers and generators

New Jersey Environmental Digital Library (<http://njedl.rutgers.edu>)

Non-profit environmental organizations (e.g., nature conservancies, watershed associations etc.)

1.4 Defining the Physical Environment

Equal in importance to finding out what may be on-site is determining where it is most likely to be located. A pre-sampling site visit should be conducted to gather additional background information. Labels and DOT numbers on drums and tanks may be useful. Files found on-site may include information about materials that were manufactured, stored or disposed of on-site. Product names may be determined from shipping labels or manifests. Any and all information will be useful in sampling plan preparation, and in formulating a site-specific Health and Safety Plan (see Chapter 4, *Site Entry Activities*).

The fate of environmental contaminants is dictated by the source, the characteristics of the contaminant itself, (i.e., persistency and toxicity) and perhaps most importantly, by the physical environmental system into which it is released. Contaminants move at varying rates and to varying degrees when released into different kinds of matrices. Defining what kind of environmental system the site is a part of is extremely important to the success of achieving the sampling objectives. An investigation into the local geology, hydrology (including flow rates of nearby surface waters, average depth to ground water and flow direction, identification of areas of recharge, etc.), and climatology is necessary. The biological system should also be assessed. The flora and fauna of the area (including identification of sensitive environments and/or species, stressed vegetation, potential for bioaccumulation and biotransformation in the plant and animal life, especially agricultural) are definite factors to be taken into account. Stressed vegetation may serve as an indicator for contaminant migration to a particular area. A GIS system and GIS data can assist investigators in defining both the environmental and biological systems. Specific NJ based GIS data is available for download at no charge can be found at <http://www.state.nj.us/dep/gis> and <http://njgeodata.state.nj.us/>. These data elements include CAFRA, Pinelands boundary, soil type, hydrography, landuse, wetland delineation, surface contours and more. Overall, by defining the physical environment, the fate of contaminants can be predicted. Migration pathways should also be identified assuring that samples will be collected in the most appropriate area.

The factors addressed above offer an overview of considerations that must be evaluated for a sampling plan to be complete. The more information that is obtained, the more that will be known about the source, movement, and concentrations of contaminants in the media to be sampled. With this knowledge, it will be easier to write a complete, site specific sampling plan.

Along with the historical and physical information needed prior to sampling plan development, the following topical areas of basic information are necessary components for an inclusive sampling plan.

1.5 Sample Locations and Numbers

The objective of the sampling event is important when choosing the location of sampling points. Samples are sometimes collected to characterize a site for which limited background information is available and/or obvious contaminated areas do not exist. In such a case, a random sampling scheme may be useful. Random sampling depends on the theory of random chance probabilities to choose the most representative sample. This process is utilized when there are numerous available sampling locations and there are no satisfactory reasons for choosing one location over another.

Tables of random numbers are readily available from many sources and should be used to eliminate any possible bias generated by those collecting the sample, assuming a random approach is used.

Also important when choosing sample locations is consideration of the site's physical environmental setting and how these factors can influence the concentration and movement of the material of concern. Sampling at hazardous waste sites is usually conducted in an attempt to discover contamina-

tion and to define its extent and variability. With such an objective, it is most logical to choose sample locations that will yield the most information about site conditions. Here, judgment (or biased) sampling should be employed. Biased samples are those collected at locations that were chosen based on historical information, knowledge about the location and behavior of the contaminant(s), and/or knowledge about the effects of the physical system on the contaminants' fate.

Both biased and random sampling techniques can be used together to thoroughly address an entire site. Some samples may be biased to potentially contaminated areas (e.g., stained soil, former process or disposal areas) or potentially impacted areas (e.g., areas of stressed vegetation, sediment downstream from discharge pipe). In areas less likely to be contaminated or areas with little available background information, random samples may be used to allow adequate assessment of the entire site.

There are seven factors that determine the number of samples required for site characterization:

1. Exposure pathways
2. Statistical performance objectives
3. Data quality objectives
4. Quality assurance objectives
5. Background samples
6. Sampling objectives
7. Site specific conditions

For example, if the objective of the event is to determine whether the site is contaminated, a limited number of samples, from properly chosen locations, will yield useful information. A greater number of samples may be needed however, if the site is known to be contaminated and delineation of the contamination is the objective. In many cases statistical considerations can be helpful in determining sampling strategy. For site suspected of having contamination caused by radioactive material, refer to Chapter 12, *Radiological Assessments*, for specific sampling considerations.

An additional consideration should be made if the sampling locations and result are to be analyzed or modeled in GIS with other spatial data. Accurate sampling locations (NJ State Plane Coordinates) must be determined in order to reference the data spatially. Depending on the accuracy requirements of the analysis, these locations could be determined through high accuracy surveys (including elevation), the use of Global Positioning System (GPS) receivers or from digital aerial orthophotography data on the GIS. General NJDEP GPS Standards and GIS Mapping and Digital Data Standards can be reviewed at <http://www.state.nj.us/dep/gis>. Review of the SRPs *Guidance for the Submission and Use of Data in GIS Compatible Formats Pursuant to Technical Requirements for Site Remediation (TECHGIS2)* at <http://www.state.nj.us/dep/srp/regs/guidance.htm#techgis2>. Sampling points inside a structure should be identified by physical and logical connections and relative locations with respect to other fixed structures and equipment.

1.6 Sample Methodology and Matrix

Once the appropriate numbers and locations have been chosen, consideration must be given to what collection method will be used to assure that representative samples of site conditions are obtained. The selected sampling methodology will be matrix dependent. In some instances, there may be several acceptable options available for collecting a sample. In other instances, site-specific conditions may dictate that only one approach will work, even though that method may not be the preferred method. In all cases, the construction material of the sampling device, its design, decontamination, and proper use are critical factors and should be included in the proposed sampling plan.

Use of a device constructed of undesirable material may compromise sample quality by the material leaching into the sample or absorbing materials from the sample after repeated use and decontamination. Sampler design is also important. For example, a ground water sampling device that aerates the sample during collection may yield a sample that is not representative of actual aquifer conditions. Finally, even the most well designed, constructed and cleaned sampling device will yield a non-representative sample if used improperly. All personnel involved in sample collection must receive training on the use, care and limitations of different sampling equipment.

Further, decontamination of the chosen device must be considered. The sampling device must be resistant to the decontamination solutions and should be constructed to allow ease of cleaning and assure thorough decontamination. (See Chapter 2. *Quality Assurance*, for decontamination procedures).

1.7 Laboratory Selection

Prior to submitting samples to a laboratory for analysis, the certification status of the laboratory must be determined. Laboratories submitting analytical data to the State of New Jersey must hold current certification where applicable under the *Regulations Governing the Certification of Laboratories and Environmental Measurements* N.J.A.C. 7:18 and/or under the National Environmental Laboratory Accreditation Program (NELAP). The Office of Quality Assurance offers certification in the following categories:

- Drinking Water Program
- Water Pollution Program
- Radon/Radon Progeny in Air
- Solid and Hazardous Waste Programs
- CERCLA-CLP Programs

The State of New Jersey Certification Program requires certification for the “Analyze Immediately” parameters under the Safe Drinking Water, Water Pollution, and the Solid and Hazardous Water Programs. Certification for those parameters can be obtained from the Office of Quality Assurance. Additionally, immunoassay methods that are considered laboratory or field methods require certification under the Solid and Hazardous Waste Program. Regardless of whether a company or organization is or is not a laboratory, certification must be obtained. This includes but is not limited to responsible parties, contractors and facilities.

The Office of Quality Assurance may be contacted to obtain additional information regarding laboratory certification requirements. Current Information on the NELAP and the National Environmental Laboratory Accreditation Conference can be found on the USEPA website at http://www.epa.gov/quality/qa_docs.html.

1.8 Electronic Submission of Data for Site Remediation and Waste Management

1.8.1 General Requirements

According to the Technical Requirements for Site Remediation (N.J.A.C. 7:26E) herein called the Tech Regs, the results of environmental sample analysis must be submitted to NJDEP Site Remediation and Waste Management (SRWM) in an electronic format. This requirement is first mentioned in the section addressing with the Site Investigation Report (3.13(c)3v), and applies to all subsequent phases of the remedial process. Furthermore, every sample point must be geographically referenced using approved accuracy standards. NJDEPs GIS compatibility requirements can be re-

viewed at <http://www.state.nj.us/dep/gis> link to *Digital Data Standards and Guidance for the Submission and Use of Data in GIS Compatible Formats Pursuant to Technical Requirements for Site Remediation* (TECHGIS2) at <http://www.state.nj.us/dep/srp/regs/guidance.htm#techgis2>.

Prior to conducting sampling, it is important to consider the type and format of data that will be required when the results are submitted to SRP, as well as other information that must be gathered while in the field, such as geographic location of sampling points.

The current requirements call for the submission of three files. HZSAMPLE contains field sampling information; HZRESULT contains analytical results; DTST identifies the data submission. The complete requirements are outlined in detail at <http://www.state.nj.us/dep/srp/hazsite>. This site contains numerous guidance documents and related software to assist in the preparation of an electronic data submission. Both the *Getting Started Guide* and the *SRP Electronic Data Interchange Manual (SRP-EDI)* will assist in this effort. The SRP-EDI, in particular, specifies the three data tables that must be submitted, the fields in each of those tables, and the data requirements, such as field length and valid values, etc. Note that the SRP-EDI is updated periodically. The website should be accessed prior to preparing data to ensure that the latest requirements are met. Another important tool available at the website is the “Environmental Data Submittal Application Checking” (EDSA) program. Once samples have been collected and data prepared, the data should be run through EDSA to determine compliance with data requirements.

1.8.2 Consistency in Data Fields Among Data Tables

In DEP’s system, three fields are used to link together the three data tables that comprise a complete submission. The fields are SRP ID, Sample Date, and Sample Number. Therefore, it is imperative that these fields are created per the SRP-EDI definitions, and are reproduced EXACTLY the same in each of the tables. Consistency among these fields is particularly important when one party, such as a consultant, is preparing the part of the submission related to sample collection, and a second party, such as a laboratory, is providing the analytical results information. Please review the definitions of the three fields SRP ID, Sample Number, and Sample Date that are in the most current version of the SRP-EDI prior to collecting samples, supplying samples to the laboratory for reference in the result table, and preparing a submission.

1.8.3 Securing Laboratory Services

Prior to securing the services of a laboratory, it is important to know what services they provide for meeting these electronic data requirements. Several laboratories already have exports from their Information Management Systems that meet the required results format. Ensure that the laboratory has submitted results successfully in the past and that they will run the SRP data checker program, called EDSA, on the result file to ensure that it meets the required data format.

1.8.4 Geographically Referenced Points

All sample results must be submitted with a geographically referenced location associated with them. Locations should be provided in State Plane Feet, using North American Datum 1983. Additional accuracy standards are defined in the NJDEP, Mapping and Digital Data Standards, at <http://www.state.nj.us/dep/gis>.

Detailed instructions outlining the specific map elements, support data and metadata requirements for GIS compatible digital map submissions for SRP are included in, *Guidance for the Submission and Use of Data in GIS Compatible Formats* at <http://www.state.nj.us/dep/srp/regs/guidance.htm#techgis2>.

1.8.5 Permit Application and Compliance

Several permitting programs have provided for permit application data and/or sampling data required by permits to be submitted electronically. Since software development is an ongoing process, interested persons should contact the appropriate permitting bureaus for current capabilities and procedures.

1.9 Quality Assurance Considerations

Quality assurance measures must be associated with each sampling and analysis event as an additional measure of control to assure that the sample delivered to the lab for analysis is representative of site conditions. The sampling plan should outline how the representative quality of the samples will be assured. This will include, but not be limited to: data quality objectives, laboratory SOPs, field SOPs, sample bottle preparation, equipment decontamination, trip blanks, field blanks, duplicates, split samples, performance evaluation samples, sample preservation and handling, chain of custody, analysis request, analytical methods, parameters, and deliverables (See Chapter 2. for further quality assurance information).

1.10 Health and Safety Concerns

Prior to any work being performed at a hazardous waste site, as defined by 29 CFR 1910.120, the organization, or company, engaged for the work must develop a written Health and Safety Program for its employees. As part of the overall Health and Safety Program, a site-specific safety and health plan, which addresses the safety and health hazards at a particular site, must be developed and kept available at the site during the duration of all site work. Typically, a Health and Safety Program will address the following areas: organizational responsibilities, risk analysis, underground utility markouts, employee training, personnel protection, medical surveillance, air surveillance, site control, decontamination, site standard operating procedures, contingency planning, confined space operations, and spill containment. Depending on the types of contaminants and other hazards present and the type of work that is anticipated some of these concern areas may not be applicable all aspects of a particular sampling episode. (See Chapter 4 for more information on Site Entry Activities.)

1.11 Schedule

Scheduling information may or may not be applicable for your particular sampling plan development. If it were necessary, the type of information to include would be time frames for various milestone-sampling episodes.

References

National Environmental Laboratory Accreditation Conference USEPA/ORD EPA600/R-99-068.

New Jersey Department of Environmental Protection (NJDEP), *Remedial Investigation Guide*, March 1990, Prepared by the Division of Responsible Party Site Remediation (DRPSR), CN 028, Trenton, NJ 08625.

NJDEP, *Environmental Cleanup Responsibility Act (ECRA) Cleanup Plan Guide*, Prepared by the DRPSR, Industrial Site Evaluation Element, CN 028, Trenton, NJ 08625.

NJDEP, *Regulations Governing the Certification of Laboratories and Environmental Measurements*, N.J.A.C. 7:18.

USEPA *Guidance for Choosing a Sampling Design for Environmental Data*, QA/G5S).

USEPA *Guidance for Data Quality Objectives Process* (G-4).

USEPA *Guidance for the Data Quality Objectives for Hazardous Waste Sites* (G-4HW) EPA/600/R-00-007 January 2000.

USEPA *Requirements for QA Project Plans*(QA/R-5).

USEPA *Guidance on Quality Assurance Project Plans* (G-5) EPA /600/R-98/-18.

USEPA *Guidance for Data Quality Assessment: Practical Methods for Data Analysis* (G-9) QA00 Version EPA/600/R-96/084 July 2000.

The Final Rule for Hazardous Waste Operations and Emergency Response, Part 1910.120 of Subpart H of 29 CFR, Occupational Safety and Health Administration, U.S. Department of Labor effective March 6, 1990.

USEPA, *Guidance for Conducting Remedial Investigations and Feasibility Studies Under CERCLA*, EPA/540/G-89/004, 1989.

USEPA, *Risk Assessment Guidance for Superfund*, EPA/540/I-89/002, 1989.

USEPA, *Interim Final Guidance for Data Usability in Risk Assessment*, Office of Solid Waste and Emergency Response (OSWER), Directive #9285.

URLs

http://www.epa.gov/quality/qa_docs.html

<http://www.state.nj.us/dep/gis>

<http://www.state.nj.us/dep/srp/hazsite>

<http://www.state.nj.us/dep/srp/regs/guidance.htm#techgis2>

<http://njgeodata.state.nj.us/>

Chapter 2

Quality Assurance

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Chapter 2

Quality Assurance

2.1 Introduction

This chapter provides the user with quality assurance requirements and procedures for conducting environmental measurement sampling episodes. In order to generate analytical data of known and defensible quality, adherence to established quality assurance protocol is necessary. Quality assurance measures coupled with a statistically based sampling plan will improve sample collection while maintaining the integrity of the samples prior to analysis. The NJDEP has established standard operating procedures to maintain consistency in sample collection and handling. Standard operating procedures may vary among the specific regulatory programs (i.e. CERCLA, RCRA, Drinking Water, Radiation and NJPDES).

Monitoring projects for the Clean Water Act, Safe Drinking Water Act Programs, RCRA and CERCLA are based on approved Quality Assurance Project Plans (QAPP) which ensure environmental monitoring data is of known quality. Plans are prepared by using a variety of standard references including, but not limited to, *EPA Requirements for QA Project Plans (QA/R-5)* and *Guidance on Quality Assurance Project Plans (G-5)*. These documents can be found on the USEPA Website at http://www.epa.gov/quality/qa_docs.html. Quality Requirements for non-EPA organizations are defined in the Code of Federal Regulations. The USEPA issues documents to provide information on satisfying the Federal Regulations. These documents contain policy statements (equivalent to EPA Order 5360) that identify and discuss mandatory elements of the USEPA Quality Systems.

Finally, this chapter highlights decontamination and QA/QC procedures for certain aspects, which may be required or encountered when conducting sampling episodes. Do not assume that all aspects or scenarios are discussed herein. The “site specific” nature of sampling makes it incumbent upon those responsible to indicate in the sampling plan any known unique feature that may contribute or impart a bias to data quality and what steps, if any, will be taken to address those specific conditions.

2.1.1 Laboratory Certification

The certification status of the laboratory must be determined prior to submitting environmental samples to a laboratory for analysis. Laboratories submitting analytical data to the State of New Jersey must hold current certification where applicable under the *Regulations Governing the Certification of Laboratories and Environmental Measurements* N.J.A.C. 7:18 and/or voluntary certification under the National Environmental Laboratory Accreditation Program (NELAP). The Office of Quality Assurance offers certification in the following categories:

- Drinking Water Program
- Water Pollution Program
- Radon/Radon Progeny in Air
- Solid and Hazardous Waste Programs
- CERCLA-CLP Programs
- Air Methods
- Radiological Parameters other than Air

2.1.2 Analyze Immediately – Environmental Laboratory Certification

N.J.A.C. 7:18 (Laboratory Certification) requires that any environmental laboratory* submitting analytical data to the department, regardless of quality level, must be certified by the Office of

Quality Assurance. This includes certification for the “Analyze Immediately” parameters under the Safe Drinking Water, Water Pollution, and the Solid and Hazardous Water Programs. Environmental samples analyzed in the field under this heading include Chlorine Dioxide, Free Chlorine Residual, Ozone, pH, Temperature, Chlorine Total Residual (TRC), Oxygen Dissolved (probe), and Sulfite. Environmental laboratories measuring these parameters in the field must first be certified by the NJ Office of Quality Assurance before sample collection. *Environmental laboratory is defined as any laboratory, facility, consulting firm, government or private agency, business entity or other person that the department has authorized.

2.1.3 Field and Laboratory Immunoassay Analysis Certification

Additionally, immunoassay methods that are considered laboratory or field methods require certification under the Solid and Hazardous Waste Program. Regardless of whether a company or organization is or is not a laboratory, certification must be obtained. This includes but is not limited to responsible parties, contractors and facilities. The New Jersey Office of Quality Assurance must be contacted to obtain additional information regarding the above laboratory, immunoassay and field instrument certification requirements.

2.2 Data Quality Levels

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For Site Remediation projects, selection and application of site-appropriate Data Quality Levels should be discussed in the Field Sampling Plan- Quality Assurance Project Plan (FSP-QAPP). The requirements of the FSP-QAPP are based on the, *EPA Requirements for QA Project Plans (QA/R-5)* and *Guidance on Quality Assurance Project Plans (G-5)*. To develop reliable site investigation data for NJDEP lead, publicly funded CERCLA (Superfund) or non Superfund publicly funded sites, the prime consultant/contractor awarded a term contract for the Remedial Investigation/Feasibility Study (RI/FS) or Engineering Design work has the responsibility to develop and implement a Field Sampling Plan-Quality Assurance Project Plan (FSP-QAPP). This document must present the organization, functional activities and specific Quality Assurance/Quality Control (QA/QC) activities needed to attain specific project goals and data quality objectives. Any sampling conducted by state contract vendors, including sampling associated with removal actions or operations and maintenance contracts, requires the development and implementation of a Quality Assurance Project Plan. The Department will approve these plans prior to implementation by a contractor. Requirements for these plans are generally specified in state contracts. Regardless of a document’s title or “deliverable” name (e.g. QAPP, FSP-QAPP), NJDEP and USEPA require these plans for all sampling events that are conducted in the state. It is recommended that these plans be contained in a stand-alone document.

For permit compliance sampling, a quality assurance program is often necessary to assure analytical accuracy sufficient to demonstrate compliance. Permits may require the permittee to achieve detection of pollutants if they are present at certain minimum concentrations, or to eliminate discharges if they exceed concentrations, which may not be detectable, unless proper quality assurance methods are implemented.

2.2.1 Quality Assurance Programs

The procedures established to control the collection and handling of samples are an integral part of the Quality Assurance Program operating within NJDEP. The importance of a controlled environmental sample collection process and analytical data protocol is demonstrated through integration of this information into the decision making process. All phases of this process rely on the provision of accurate, precise, comparable and complete analytical data.

Sample collection, preservation and holding times for New Jersey certified parameters and methods are listed in the *Regulations Governing the Certification of Laboratories and Environmental Measurements* N.J.A.C 7:18. The criteria established in the Certification Regulations are required. However, as changes and additions are made by the USEPA, any changes published in the code of Federal Regulations for the samples being analyzed under the Safe Drinking Water Act and the Clean Water Act must follow the latest Code of Federal Regulations. Those requirements are published annually in 40 CFR Parts 141 and 136 respectively. Changes to the USEPA SW846 Methods are issued by the USEPA Office of Solid Waste (OSW) and are not final until adopted by Federal Regulations. The USEPA Contract Laboratory Program (USEPA CLP) revises or issues a new Statement of Work (SOW), these requirements will supercede the NJ Certification Regulations. The current requirements are summarized in the Tables at the back of this section.

Current requirements for samples collected under the Safe Drinking Water Act and the Clean Water Act are published annually in 40 CFR Parts 136 and 141 and may be found on the USEPA Website at <http://www.epa.gov/epahome/cfr40.htm>

Current requirements for samples to be analyzed in accordance with the USEPA SW846 Methods are published in the latest final update of the USEPA SW846 *Test Methods for Evaluating Solid Waste – Physical and Chemical Methods 3rd Edition* issued 1996 and amended. They may be found on the USEPA Website at <http://www.epa.gov/epaoswer/hazwaste/test/sw846.htm>.

Current requirements for samples to be analyzed in accordance with the USEPA Contract Laboratory Program are published in the latest version of the USEPA CLP SOWs. These documents may be found on the USEPA Website at <http://www.epa.gov/oerrpage/superfund/programs/clp/index.htm> or at <http://www.epa.gov/superfund/programs/clp/index.htm>

The following quality assurance requirements have been established to maintain sample integrity. Their prime objectives are to maintain the physical form and chemical composition of the sample and to prevent contamination from other sources or changes in contaminant concentration. To meet these objectives, there must be a measure of control over all sample-handling procedures beginning with sample container cleaning procedures and ending with laboratory analysis. This chapter focuses on the first half of the control process including the procedures leading up to and ending with sample packaging and transport to the laboratory. Sample packaging and transport are discussed in Chapter 12.

2.2.2 Field Analytical Methods

Almost all projects require screening or semi-quantitative data during the field screening phase of the site investigation. For example, headspace gas chromatography (GC) can be simple and fast for the analysis of VOCs in soil and water samples during underground storage tank removal or well installation and monitoring. Enzyme kits can provide rapid detection of polychlorinated biphenyls (PCBs) or explosives during site characterization

The main advantage to engaging field analytical methods is they can allow for the performance of rapid characterization with only a few mobilizations via a dynamic sampling plan. Field analytical methods can provide data of sufficient quality to meet the predetermined data quality objectives providing that supporting QA/QC procedures are in place.

To be “effective,” the field data generated must be of sufficient quality, with respect to measurement precision or reproducibility, accuracy, sensitivity, and have good correlation with the standard laboratory methods to support the objective of the site investigation or cleanup and the DQO. Several factors to be considered before mobilization include the following (the factors are not intended to be all inclusive):

- The action levels for field decisions shall be established as part of the DQOs.
- The project objective shall permit screening and semi-quantitative data in addition to quantitative data to meet DQO.
- The percentage of samples to be analyzed in the field as well as sent off-site for laboratory confirmation shall be determined.
- The methodology to compare field and laboratory data shall be established, for example using duplicate (field duplicate samples) and/or performance evaluation samples in addition to initial and daily calibrations.
- For the field instrument or the analytical method, the measurement selectivity, sensitivity, precision, accuracy, representativeness and action levels shall be determined.
- The standard operating procedures and method detection limit studies are completed before mobilization to evaluate any matrix interference that might be associated with a particular field technology.
- If applicable, the field technician performing the analyses shall have proof of training by the manufacturer/vendor of the test method.
- If sample preservation is required, samples shall be preserved in the field immediately after collection according to the method specific table in Appendix 2 of this document.

The New Jersey Department of Environmental Protection (NJDEP) is committed to streamlining the site investigation and remediation process at contaminated sites. The site investigation shall follow the Technical Requirements for Site Remediation, N.J.A.C. 7:26E, <http://www.state.nj.us/dep/srp/regs/techrule> that places emphasis on laboratory analytical methods. However, field analytical methods may be employed if sufficient documentation can be provided to the NJDEP to support the proper application of the method. Persons wishing to use a field analytical method shall submit the proposal to the project team for approval (see Chapter 7, *Field Analysis*).

2.3 Sample Containers

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Prior to the collection of a sample, consideration must be given to the type of container that will be used to store and transport the sample. The party requesting the analysis is responsible for requesting the proper sample containers, or, providing the laboratory with an accurate description of the matrix being sampled in order that the laboratory can provide the proper quantity and type of sample container. Selection is based on the sample matrix, potential contaminants to be encountered, analytical methods requested, and the laboratory's internal quality assurance requirements. Selection of appropriate sample containers should also be based upon review of the criteria listed below, as well as the information provided in the analytical methods, the Tables at the end of this Chapter and the NJ Laboratory Certification Regulations Subchapter 9 <http://www.state.nj.us/dep/oqa/labcert.html>.

2.3.1 Reactivity of Container Material With Sample

Choosing the proper composition of sample containers will help to ensure that the chemical and physical integrity of the sample is maintained. For sampling potentially hazardous material, glass is the recommended container type because it is chemically inert to most substances. Plastic containers are not recommended for most hazardous wastes because the potential exists for contaminants to adsorb to the surface of the plastic or for the plasticizers to leach into the sample.

In some instances, the sample characteristics or analytes of interest may dictate that plastic containers be used instead of glass because some metals species will adhere to the sides of glass

containers in an aqueous matrix. However, the methodology being used for the sample analysis must always be reviewed first to determine the required bottle type. For example, USEPA Method 1631 *Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry* requires the use of either fluoropolymer bottles with fluoropolymer or fluoropolymer-lined caps, or borosilicate glass bottles. Polyethylene bottles are prohibited under this method.

In the case of a strong alkali waste or hydrofluoric solution, plastic containers may be more suitable because glass containers may be etched by these compounds creating adsorptive sites on the container surface. Prior to ordering bottles from the laboratory, the method requirements should always be reviewed with the laboratory

2.3.2 Volume of the Container

The analytical method and the sample matrix will dictate the volume of sample to be collected. The sampler must supply sufficient volume of matrix for the laboratory to perform the required analysis. In most cases, the methodology dictates the volume of sample material required to conduct the analysis. Individual labs may provide larger volume containers for various analytes to ensure sufficient quantities for replicates or other quality control checks. However, if the expected concentrations in the sample are significant, such as in waste samples, the sample volume required by the laboratory may be less, to minimize the hazardous waste disposal problems.

2.3.3 Color of Container

The analytical method can dictate the color of the sample container. Whenever possible, amber glass containers should be used to prevent photodegradation of the sample, except when samples are being collected for metals analysis. Containers used for metals analysis should be white or uncolored. If amber containers are not available, containers should be protected from light at all times when practical during shipping and handling. Laboratories often provide clear glass 40ml vials for volatile organic aqueous analysis so that any air bubbles in the sample can be easily detected. These are acceptable for use.

2.3.4 Container Closures

Container closures may be specified by method. Container closures should form a leakproof seal (i.e., screw caps or ground glass stoppers). Closures must be constructed of a material that is inert with respect to the sampled material, such as PTFE (e.g., Teflon[®]) or as specified by the method. Alternately, the closure may be separated from the sample by a closure liner that is inert to the sample material such as PTFE liner or septum. No amendments must be added to ground glass stoppers to facilitate opening.

2.3.5 Decontamination of Sample Containers

Pre-cleaned certified sample bottles can be purchased from bottles supply companies. Pre-cleaned bottles must be accompanied by supplier's certificate indicating the certified use of the bottles. The certificates issued provide a bottle specific use on a compound basis. Sample containers can also be laboratory cleaned, preferably by the laboratory performing the analysis. The cleaning procedure is dictated by the specific analysis to be performed on the sample.

2.3.6 Chain of Custody

The sample bottles should be prepared for shipment accompanied by a chain of custody and the cooler or shuttle containing them should be custody sealed. The chain of custody must also accompany the bottles during transportation to the field, sample collection, and transportation

back to the lab, during analysis and to identify final disposal of the sample container. When collecting a sample, personnel should record the seal number associated with each sample shuttle or cooler and record whether the seal was intact upon arrival in the field. This assures that the sample containers were not tampered with in the time between their preparation and their arrival in the field. After sample collection, the bottles again should be sealed into the shuttle or cooler and the seal number should be recorded in the field logbook. Upon arrival at the lab, the person receiving the sample should note the number and condition of the custody seal. Refer to Chapter 11, Documentation, for additional information on Chain of Custody.

2.3.7 Sample Bottle Storage and Transport

No matter where the sample bottles are, whether at the lab waiting to be packed for shipment or in the field waiting to be filled with sample, care must be taken to avoid contamination. Sample shuttles, or coolers, and sample bottles themselves must be stored and transported in clean environments. Sample bottles and clean sampling equipment must never be stored near solvents, gasoline, or other equipment that is a potential source of contamination. When under chain of custody, sample bottles must be secured in locked vehicles, custody sealed in shuttles or in the presence of authorized personnel.

The analytical methods may specify maximum or minimum sample temperatures that are required to be met during transport of the samples during shipment and upon receipt of the samples at the laboratory. These temperatures are specified as part of the sample collection, preservation and holding times for New Jersey certified parameters and methods are listed in the *Regulations Governing the Certification of Laboratories and Environmental Measurements* N.J.A.C 7:18. The current requirements are summaries in the Tables at the back of this section.

2.4 Decontamination Procedures

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An important aspect of quality control is the decontamination of field sampling equipment. Improperly cleaned and prepared sampling equipment can lead to misinterpretation of environmental data due to interference caused by cross-contamination.

In addition, sampling equipment left in-situ for purposes of obtaining multiple samples over a period of time (e.g., periodic sampling for permit compliance) will often need to be cleared of accumulated contaminants, silt, soot, dust etc. This will assure that the samples are free of such material as may accumulate on the sampling equipment itself between uses.

The following four sampling equipment cleaning procedures form the basis of the standard NJDEP requirements. These four procedures cover decontamination of aqueous and non-aqueous equipment over a broad range of contaminant exposures for all programmatic needs.

Provided at the end of this section are general considerations intended to raise decontamination awareness when cleaning pumps, heavy equipment, equipment related to direct push technology, monitor well casings and screens, and selection of cleaning location. This is followed by discussion on the disposal of decontamination fluids and drill cuttings. Exception to the following procedures may be evaluated and approved by NJDEP on a case-by-case basis if justifications to do so, involving site specific issues or conditions, are presented and verified beforehand.

In most instances fixed laboratory decontamination serves as the preferred alternative to field decontamination. Advantages include: 1) decontamination takes place in a controlled environment; 2) reduced need to transport, handle or dispose cleaning solvents, acids or wash water; 3) more attention can be focused upon sampling with field decontamination labor reduced or eliminated; 4) reduced

probability of cross-contamination due to improperly field decontaminated equipment and; 5) laboratory documentation of cleaning procedures and materials used. Disadvantages may include: 1) relative cost to scope of sampling event; 2) constraints meeting demands in emergency situations and; 3) logistics.

While the option exists to use field decontamination procedures for almost all non-aqueous sampling and certain aqueous sampling equipment (e.g., foot check valves, filtering equipment, stainless steel/ Teflon® pumps, automatic wastewater composite samplers), field decontamination of bailers is not acceptable. Bailers are required to be laboratory cleaned, packaged and dedicated for exclusive use at one sample location for that day's sampling (see definition of "laboratory cleaned" in the glossary). Field decontamination of bailers elevates the potential of cross-contamination to unacceptable levels. The possibility of contaminating a clean well is also of concern when using improperly cleaned sampling devices.

In certain instances the use of "disposable" bailers presents an option to circumvent the logistics associated with decontamination of standard reusable bailers. To insure quality control over these devices, disposable bailers must be decontaminated at the source of manufacture and proof of decontamination must accompany their purchase. They must be sealed in a protective covering prior to shipment from the manufacturer. Since these bailers will be used on a one time only basis, inflexibility as to standard material of construction requirements may be waived. For example, in approved instances, disposable bailers constructed of polypropylene are acceptable when sampling for trace metal analysis.

Generally, sampling devices must be protected from ambient contact during storage and remain protected until used in the field. Non-aqueous equipment may be wrapped in aluminum foil when sampling for organics only and/or sealed in plastic bags or equivalent material when sampling for inorganics, then custody sealed for identification. Equipment should be handled as little as possible prior to use and disposable gloves must be worn at all times when handled. Sampling equipment must never be stored near solvents, gasoline, exhaust emissions, or other equipment and/or materials that may impact the integrity of prepared sampling instruments. A record should be kept of the date and time when cleaned and this information should be labeled on the sampling device.

Exhaust producing equipment must be situated in such a manner as to not compromise the decontamination process. The decontamination station must also be set up in such a way as to not adversely impact a clean environment.

Whenever sampling, regardless of how equipment has been cleaned, always start sampling in the area of the site with the lowest contaminant probability and proceed to the areas of highest known or suspected contamination. Following this procedure will add another measure of quality control keeping cross contamination interference to a minimum.

All equipment utilized for sampling must be decontaminated using distilled and deionized water. Through distillation, all ionized solids and a broad range of organic constituents will be removed, thus making it an ideal solvent for use when sampling for organic parameters. Deionized water is water that has been effectively freed from any existing ionic impurities. The use of distilled and deionized water, commonly available from commercial vendors, is acceptable provided that the lot number and the associated analysis are available upon request to the NJDEP, and, it meets ASTM Type II specifications.

There are four individual decontamination procedures from which to choose when preparing a sampling plan. Matrix, level of contamination and programmatic considerations drive selection. The Eight-Step, the Three-Step and a third, based upon US Army Corps of Engineers Cold Regions

Research and Engineering Laboratory studies, apply to aqueous and non-aqueous matrices for most levels of contamination encountered in New Jersey. The fourth, a synopsis of USGS procedures, applies specifically to the cleaning of ground and surface water sampling equipment when analysis for trace levels of inorganic, organic, biological or toxicity constituents and interference from extraneous sources of contamination must be highly controlled. This procedure, referred to here as “Ultra Clean,” is treated separately from the others in this section. There should be no crossover or mixing of procedures once an approval process is finalized. The application of these procedures has the concurrence of USEPA Region II Monitoring Management Branch.

2.4.1 Eight-Step Decontamination Procedure For Aqueous and Non-Aqueous Sampling Equipment – Laboratory Only

This procedure is based, in part, upon the American Society for Testing and Materials, *Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites*, number D 5088-90. The first step, a detergent and water wash, is to remove all visible particulate matter and residual oils and grease. This may be preceded by a steam or hot water, high pressure water wash to facilitate residual removal. A generous tap water rinse and a distilled and deionized water rinse to remove the detergent follow this. If aqueous sampling is to be performed, the following additional steps must be completed. An acid rinse, included if metals samples are to be collected, provides a low pH media for trace metals removal. It is followed by another distilled and deionized water rinse. If the sample is not to be analyzed for metals, the acid rinse and water rinse can be omitted. Next, a high purity solvent rinse is designated for trace organics removal. Acetone has been chosen because it is an excellent solvent, miscible in water and is not a targeted analyte in Priority Pollutant Analysis. If acetone is known to be a contaminant at a given site or Target Compound List analysis is to be performed, Methanol or another solvent may be substituted on a case by case basis with approval from NJDEP. Note, methanol can not be used when sampling gasoline and its by-products. The solvent must be allowed to evaporate and then a final distilled and deionized water rinse is performed. This rinse removes any residual traces of the solvent.

The field sampling equipment cleaning and decontamination procedures are as follows:

- Laboratory grade glassware detergent plus tap water wash
- Generous tap water rinse
- Distilled and deionized (ASTM Type II) water rinse
- 10% nitric acid rinse (trace metal or higher grade HNO₃ diluted with distilled and deionized (ASTM Type II) H₂O)
- Distilled and deionized (ASTM Type II) water rinse*
- Acetone (pesticide grade) rinse**
- Total air dry or pure nitrogen blow out**
- Distilled and deionized (ASTM Type II) water rinse**

All sampling equipment decontaminated via this procedure must be laboratory cleaned, wrapped and/or sealed, and dedicated to a particular sampling point or location during a sampling episode. In instances where laboratory cleaning is not feasible, permission for field cleaning must be obtained from the NJDEP prior to the collection of any samples and be referenced in the approved quality assurance project plan. Sampling devices should be numbered in a manner that will not

*Only if sample is to be analyzed for metals.

**Only if sample is to be analyzed for organics.

affect their integrity. Equipment should be custody sealed and information concerning decontamination methodology, date, time, and personnel should be recorded in the field logbook.

The use of distilled and deionized water commonly available from commercial vendors may be acceptable for sampling equipment decontamination. NJDEP may require specific lot numbers from containers or analytical verification that the distilled and deionized water meets ASTM Type II specifications.

Hexane is not a necessary solvent for dioxin, PCB, or other chlorinated organic sampling. The cleaning procedure outlined above is adequate for all sampling episodes. In those instances where acetone is a parameter of concern another solvent may be used. All substitutes must be approved by NJDEP.

In the field, decontamination should be carried out over a container and the material properly disposed off-site. Decontamination wastes must be disposed of properly.

2.4.2 Three-Step Equipment Decontamination Procedure Non-Aqueous Matrix Only – Laboratory and Field

While it is preferred that all non-aqueous field sampling equipment be laboratory cleaned, wrapped, and dedicated to a particular sampling point or location during a sampling episode, field cleaning may be more practical. Refer to the general field decontamination considerations above. The first step, a detergent and water wash, is to remove all visible particulate matter and residual oils and grease. This may be preceded by a steam or high pressure water wash to facilitate residual removal. A generous tap water rinse and a distilled and deionized water rinse to remove the detergent follow this. If visual contamination persists, or gross contamination is suspected, the full eight-step decontamination procedure is required.

The field sampling equipment cleaning and decontamination procedures are as follows:

- Laboratory grade glassware detergent and tap water scrub to remove visual contamination
- Generous tap water rinse
- Distilled and deionized (ASTM Type II) water rinse

All sampling equipment decontaminated via this procedure must be wrapped and/or sealed during storage and prior to use. Wherever possible, sampling devices should be numbered in a manner that will not affect their integrity. Information concerning decontamination methodology, date, time, and personnel should be recorded in the field logbook.

The use of distilled and deionized water commonly available from commercial vendors may be acceptable for sampling equipment decontamination. NJDEP may require specific lot numbers from containers or analytical verification that the distilled and deionized water meets ASTM Type II specifications.

In the field, decontamination should be carried out over a container and the residual liquid material must be properly disposed. Decontamination wastes must be disposed in accordance with current NJDEP policy (see Chapter 2, Section 2.4.5.7, *Disposal of Development, Purge, Pump Test and Decontamination Water*).

When analysis for metals is required it may be necessary to use carbon steel split spoon sampling devices instead of stainless steel. If this is the case and it is necessary to utilize the acid rinse for removal of visible contamination, the nitric acid rinse may be lowered to a concentration of 1% instead of 10% so as to reduce the possibility of leaching metals from the spoon itself.

2.4.3 US Army Cold Regions Research and Engineering Laboratory Decontamination Procedures for Use Primarily on Water Sampling (or Ground-Water Sampling) Equipment – Laboratory and/or Field Exclusively for Organics Including Pesticides

Extensive study, by the US Army Corps of Engineer's Cold Regions Research and Engineering Laboratory in New Hampshire, has affirmed what many have suspected regarding certain aspects of solvent use during the decontamination process and sorptive/desorptive properties of commonly used materials during contaminant exposure. Paraphrasing, their conclusions indicate that if sampling equipment is not decontaminated, there will be significant carry over ($\mu\text{g/L}$) of hydrophilic and hydrophobic organic contaminants for both permeable and non-permeable materials. They also found that organic contaminants (including pesticides) could be removed from non-permeable stainless steel and rigid PVC surfaces using a hot detergent wash and DI water rinse thereby eliminating the commonly practiced step of an acetone, methanol or hexane solvent rinse.

Other polymeric materials, such as other plastics or various fluoropolymers such as polytetrafluoroethylene (PTFE) or Teflon, were generally less readily decontaminated. Decontamination of polymers is a function of analyte; rigidity, porosity or sorptive nature of the material; and contact time for sorption and desorption. A hot water detergent wash and distilled (DI) water rinse removed organic contaminants from less sorptive rigid PVC however, more sorptive PTFE required additional oven drying to remove selected VOCs. Oven drying speeded diffusion of adsorbed contaminants out of the polymer.

Their findings strongly suggest that solvent rinsing for organic contaminant removal (use of acetone, methanol or hexane) may not be necessary for devices of stainless steel and rigid PVC construction. They did note that removal of pesticides from low-density polyethylene was aided somewhat by solvent use, however the hot water detergent wash procedure followed by hot air oven drying outperformed solvent use.

Hot air oven drying is a departure from currently accepted procedures and is offered here as a new alternative, if the following steps are performed without exception. Exposure of ground water sampling equipment to hot air drying must be conducted over a 24-hour period for most pieces of equipment. Temperatures must be maintained at 110°C (approx. 230°F). This includes devices of polymer construction such as bailers and bladder pumps. In the field, an air-drying oven can be set up inside a trailer or building to facilitate this logistical consideration. For ground water sampling pumps, check with the manufacturer for heat tolerance of sealed internal electrical parts or size and shape distortion tolerances for bladder pumps constructed of permeable materials.

Sampling equipment constructed of polymers may be heat sensitive in terms of distortion tolerance (USACE observed warping in the oven although they did not observe any problems when rigid PVC was heated). When distortion or uneven heat distribution are of concern, the use of a hot-water (100°C) high-pressure washer may offer an alternative to hot water/heated drying. Hot-water (100°C) high-pressure cleaning may be applied to large dimensional sampling equipment constructed of stainless and/or carbon steel equipment typically associated with direct push sampling technology. Sampling equipment, whether rigid PVC, stainless steel, or other permeable plastic materials, exposed to neat compounds or contaminants at high concentrations pose limitations to the effectiveness of this, or any, decontamination technique. This specific procedure is considered most effective when contaminant concentrations are 100 parts per million or less. If this decontamination procedure is the chosen method in instances of equipment exposure to contaminant levels above 100 ppm, then the collection rate of quality control field (equipment) blanks must be increased. For rigid PVC or stainless steel sampling equipment, collect an additional field (equipment) blank if organic concentrations in the last sample collected exceeded 100 ppm.

These decontamination procedures are not applicable to any forms of tubing, as USACE has never demonstrated this technique as an effective means to decontaminate tubing of any construction material.

The field sampling equipment cleaning and decontamination procedures are as follows:

- For Permeable Polymeric Materials (Teflon[®], Teflon[®]-lined PE, Polyethylene)
 - Laboratory grade glassware detergent and hot (approx. 100°C) DI water scrub to remove visual contamination from extruded or machine shaped pieces.
 - Generous DI water rinse for extruded or machine shaped pieces.
 - Exposure to hot air (117°C) drying for 24 hour period.
- For Rigid PVC and Stainless Steel
 - Laboratory grade glassware detergent and hot (approx. 100°C) DI water scrub to remove visual contamination.
 - Generous DI water rinse
 - Optional use of hot-water (100°C) high-pressure washing¹

2.4.4 Ultra Clean Sampling Equipment Decontamination – Laboratory or Field

In certain cases when contaminant and general chemistry levels are being measured at their respective lowest method detection levels and the end user requires analytical data that must be free from any conceivable sample equipment interference, this cleaning method may be considered. These procedures, currently used by the US Geological Society for cleaning most ground and surface water sampling equipment, are not typically used by the Department's Site Remediation Program. Most NJDEP site investigations document levels of contamination that are above the lowest detection levels and have data quality objective plans which assure sampling equipment interference can be quickly identified and rectified. "Ultra Clean" procedures are designed to address contaminants not normally associated with SRP investigations e.g., inorganic indicators of water quality like cobalt, copper, zinc, manganese and iron. Therefore, the most likely SRP-use scenarios would include measurement of those lowest of contaminant concentration investigations where long term trends of environmental and ambient sensitive constituents are being monitored, e.g. parameters associated with Monitored Natural Attenuation. However, the Department's Bureau of Freshwater and Biological Monitoring, whose main focus and objectives are more aligned with the USGS and the NJGS, does routinely use these cleaning procedures. Their investigations of surface water are geared to monitor long terms changes of inorganic, organic, biological and general chemistry constituents whose sensitive analytical nature dictate the use of such an intensive decontamination procedure. The cleaning procedures outlined and paraphrased below, are taken from the USGS *National Field Manual for the Collection of Water-Quality Data, Book 9, Chapter A3* and are not presented here in their 65 page entirety. For complete details visit the USGS Internet address: (http://water.usgs.gov/owq/FieldManual/chapter3/Ch3_contents.html). If Internet access is not available, contact the USGS @ 412 National Center, 12201 Sunrise Valley Drive, Reston, VA 20192.

When sampling for inorganic analysis, do not use cleaning agents or items that might leach or sorb metals. Basins, brushes and other items used for cleaning should be constructed of a suitable

¹Hot water (100°C) high-pressure washing of large dimensional rigid PVC, stainless steel and direct push technology sampling equipment is acceptable.

nonmetallic material such as uncolored or white polypropylene, polyethylene or other plastic. When sampling for organic analysis do not use cleaning agents or items that might leach, sorb or leave residues of organic substances that could bias or interfere with the analysis.

All cleaning equipment is subject to specified cleaning procedures prior to use on sampling equipment. Simplified, wash basins and standpipes are filled with non-phosphate detergent solution whereupon wash bottles, scrub brushes and other small items are placed within and soaked for 30 minutes. All items are then subject to a tap and DI water rinse, followed by a 30 minute soak in 5% HCl. (and/or 10% HNO₃). Acid solutions are neutralized before disposal and cleaning equipment given several final DI rinses before air-drying. Visit the above Internet address for more details.

Surface and ground water sampling equipment is subject to a very precise cleaning procedure. As stated above, contaminant exposure levels sampled by the USGS are often at the low end of the method detection level and the focus is research oriented. The procedures below, for the cleaning of submersible pumps and submersible pump tubing, are taken from Section 3.3.9.B of Book 9, Chapter 3 of the *USGS National Field Manual*. The procedures are divided into Office-laboratory cleaning and Field-site cleaning. For more discussion on cleaning other sampling devices visit the above Internet address.

Office-laboratory Cleaning

Fluorocarbon-polymer tubing used to collect water containing large concentrations of volatile organic compounds (VOC) can be difficult to clean adequately.

- Collect additional blanks if VOC concentrations in last sample collected through the tubing were greater than 500 µg/L.
- Pump tubing should be replaced rather than cleaned if VOC concentrations in last sample exceeded about 700 µg/L.
- Most submersible pumps have a stainless steel casing and other metal parts and should not be acid rinsed.
- To clean pumps that are excessively contaminated, a dilute acid rinse followed by copious water rinsing can be used occasionally without damaging the pump.
- Repeated rinsing with dilute acid solution can pit or corrode the pump's stainless steel surface.
- If the surface appears dulled, the pump must not be used for collecting trace-metal samples.

Lubrication water inside water-lubricated pumps (for example, the Grundfos RediFlo2™) can become contaminated and cause contamination of subsequent samples. Replace the lubrication water with volatile organic blank water each time after sampling and when cleaning the pump. Follow the manufacturer's instructions.

Step 1. Preparation.

- Wearing appropriate gloves, prepare several gallons of a laboratory-grade nonphosphate detergent solution (about 0.1 or 0.2 percent, v/v; use up to 2-percent solution for excessively contaminated pump systems).
- Preclean washbasins and standpipes.
- Place pump into sink or washbasin and scrub exterior surfaces with soft brush and detergent solution; rinse thoroughly with tap water.
- Disassemble the pump and place components into a detergent-solution washbasin.

Table 2.1 Ultra Clean Supplies for Water Sampling Device Cleaning	
Item	Description
Acid Solution	Hydrochloric: American Chemical Society trace element grade (5 percent by volume in distilled/deionized water). Hydrochloric is required if analyzing for nitrogen species. Nitric: ACS trace element grade (10 percent by volume in distilled/deionized water).
Aluminum foil	Organics only: Heavy duty, for work surfaces and equipment
Bags, plastic or fluorocarbon Polymer Noncolored plastic sheeting	Sealable bags with uncolored closures strips Recyclable trash bags for large equipment storage. Clean sheeting used to provide a clean work surface.
Brushes and sponges	Uncolored; plastic components needed for inorganic work.
Distilled/deionized water	Maximum specific electrical conductance, 1 µS/cm.
Detergent	Nonphosphate laboratory soap.
Gloves, disposable	Powerless, noncolored vinyl, latex or nitrile (latex or nitrile for use with methanol).
Inorganic grade blank water	Blank water with certificate of analysis prepared and/or quality assured by the analyzing laboratory.
Jerricans or carboys	For waste solutions and as neutralization container. Neutralization container: 25- to 30-liter polyethylene, wide mouth, with layer of marble chips.
Methanol	ACS pesticide grade.
Neutralization materials	Marble landscape chips. (Agricultural limestone, soda ash, baking soda or crushed shells not recommended.)
Pesticide-grade blank water, Volatile-grade blank water	Blank water prepared and/or quality assured by the analyzing laboratory; required for collecting blank samples for respective blank sample analysis. Pesticide or volatile grade blank water can be used for Total Organic, Dissolved Organic and Suspended Organic Carbon analysis.
Standpipes for submersible pumps	Plastic, glass or other suitable material; for example, Pipette jars or capped PVC casing; one standpipe labeled for blank water and one each for each cleaning solution. (Do not use PVC with methanol).
Tapwater	If quality is questionable, substitute distilled/deionized. Tapwater is more effective for initial and rapid removal of detergent residue.
Tissues	Laboratory grade, lint free.
Washbasins	One washbasin for each cleaning solution; white or uncolored plastic, nonleaching. (Stainless steel for methanol)
Wash bottles	Labeled to indicate contents. Fluorocarbon polymer needed for methanol, and pesticide, volatile and inorganic blank water.

USGS, Handbooks for Water Resources Investigations, Book 9, *National Field Manual for the Collection of Water-Quality Data, Chapter A3.*

Step 2. Detergent wash and tap water rinse pump components and tubing.

- Soak pump components in the detergent solution for 30 minutes.
- Scrub pump components with soft sponge or brush.
- Rinse thoroughly with tap water.

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- Raise discharge end of tubing above the rest of the tubing. Using a peristaltic or valveless fluid-metering pump, fill the pump tubing with fresh detergent solution until solution rises to the end of the tubing. Plug the tubing end(s).
- After 30 minutes remove plug from discharge end of tubing and flush detergent solution from tubing by pumping copious amount of tap water through the tubing. Change gloves.

Step 3. Check sampling requirements.

- If pump will be used for collecting samples for inorganic constituent analysis, reassemble the pump and go to Step 4.
- Complete Step 4 if pump will be used for collecting samples for analysis of both inorganic and organic analytes before proceeding to Step 5.
- If the pump will be used for collecting samples for organic compound analysis only, go to Step 5.

Step 4. DIW rinse.

- Place pump components into washbasin and dispense DIW from a wash bottle to thoroughly rinse all pump components.
- Using a peristaltic pump and appropriate clean tubing, pump DIW through the sample tubing to rinse.
- Reassemble pump and connect pump tubing. Change gloves.
- If collecting equipment blanks to verify that the pump has been adequately cleaned.
- Rinse a clean standpipe dedicated to blank water with blank water.
- Insert pump into blank-water standpipe only after pump exterior has been rinsed with blank water or air-dried after the methanol rinse.
- Pour IBW into the standpipe and pump at least one tubing volume to waste before collecting the blank sample.

Step 5. Rinse with blank water followed by a methanol rinse.

- Change to latex or nitrile gloves. Put pump components into solvent-resistant washbasin.
- Working under a fume hood, dispense methanol (or appropriate solvent) from a fluorocarbon-polymer wash bottle to rinse each pump component and the exterior pump casing. Collect the used solvent into a nonflammable container for storage until disposal.
- Do not reuse methanol or other solvents.
- Work under a fume hood, if possible, or in a well-ventilated area outside of the office laboratory, as methanol fumes can contaminate other equipment.
- Place methanol-rinsed components on a clean, aluminum foil surface and allow the pump components and casing to completely air dry before reassembling the pump.
- Using a valveless fluid metering pump and fluorocarbon-polymer tubing, pump about 2 L of methanol through sample tubing and to the methanol waste container.
- Reassemble the pump and connect the pump tubing. Change gloves and dispose of the methanol-contaminated gloves appropriately.
- Pour an organic-grade water (PBW or VBW) into a clean PBW/VBW standpipe. Insert pump and pass about two tubing volumes of organic grade blank waster (PBW or VBW) through the pump and tubing to waste.

Field-site cleaning procedure for submersible pumps and pump tubing.**Step 1. Preparation.**

- Preclean the standpipes (one standpipe for each cleaning solution to be used). The standpipes need to be of sufficient height to supply necessary head for proper pump operation. Separate standpipes are designated for detergent solution and tap water rinse, DIW rinse, methanol rinse, and blank water. Double-bag each cleaned standpipe for transport to the field site.
- Estimate the volumes of cleaning solution and blank water that will be needed for the field effort. The volume of storage in tubing, V_s , of a set of pump-reel and extension tubing can be estimated as follows:

$$V_s = [(L_p \times C_p) + (L_e \times C_e) + V_{sp}] \times C_{sp}$$

Where,

V_s is the volume of storage in tubing, in gallons.

L_p is length of pump-tubing segment being cleaned, in feet

L_e is length of extension tubing, in feet

C_p (or C_e) = 0.023 liter per foot for a 3/8-inch tubing inside-diameter

Or = 0.041 liter per foot for a 1/2-inch ID tubing

V_{sp} is volume of solution needed to fill standpipe to minimum level required to operate pump, in liters

C_{sp} = 0.264 gallon per liter.

- Prepare the volumes of cleaning solutions needed for the field effort, using appropriate bottles for short-term storage and transport.

Step 2. Detergent wash and tap water rinse.

- Put on disposable, powderless gloves (usually vinyl). Rest pump in a washbasin or pail partially filled with detergent solution and clean exterior of pump and tubing with a soft brush. Rinse thoroughly with tap water. (DIW can be substituted for tap water, but is less efficient in detergent removal and requires a greater volume of water than tap water.)
- Place pump into standpipe, add detergent solution to level above pump intake, and route intake and discharge end of pump tubing to the standpipe.
- Begin pumping:
 - Record the pumping rate.
 - Record the time it takes to fill the sample tubing.
 - Calculate the time it takes for a segment of solution to complete one cycle.
- Circulate detergent solution for about three cycles through the tubing and back to the standpipe. If possible, pump detergent solution through tubing at alternating high and low speed, and (or) introduce air segments between aliquots of the detergent solution to increase cleaning efficiency.
- Remove the discharge end of tubing from the standpipe and pump about two tubing volumes of detergent solution to waste, adding fresh solution to the standpipe as needed. Remove pump from standpipe.
- Rinse detergent from standpipe with tap water until sudsing stops.
- Rinse pump exterior with tap water. Place rinsed pump into standpipe; add tap water/DIW to level above pump intake. Begin pumping through sample tubing. Do not recirculate rinse water,

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but add water as needed to maintain water level above pump intake. Continue for five or more tubing volumes. Direct rinse water to waste away from the vicinity of the wellhead and sampling area and (or) contain as required for disposal.

- Collect rinse water into a small bottle and stop the pump. Shake the bottle – if sudsing is observed in the rinse water, continue the rinse procedure until no suds appear in the rinse water. Change gloves.

Step 3. Check sampling requirements.

- If pump will be used for collecting samples for inorganic constituent analysis, reassemble the pump and go to Step 4.
- Complete Step 4 if pump will be used for collecting samples for analysis of both inorganic and organic analytes before proceeding to Step 5.
- If the pump will be used for collecting samples for organic compounds analysis only, go to Step 5.

Step 4. DIW rinse.

- A separate DIW rinse is not required if DIW was substituted for tap water.
- Use a clean DIW-dedicated standpipe, not the tap water standpipe, and rinse with DIW. Rinse pump exterior with DIW to remove any detergent residue. Place pump into the DIW standpipe and add DIW to level above pump intake. Change gloves.
- Start pumping DIW. Rinse DIW through sample tubing without recirculating, using about 3 tubing volumes of DIW. Keep the DIW level above pump intake.
- Collect DIW rinse water in a clean bottle, shake, and check for suds. Continue to DIW rinse until rinse water is free of suds.
- If collecting field blanks to verify that the pump has been adequately cleaned:
- Change gloves. Rinse clean blank-water standpipe with IBW. Rinse pump exterior with blank water.
- Place pump into the standpipe and add IBW to cover the pump intake.
- Turn on pump and displace any water residing in the pump and tubing. Continue pumping IBW for one tubing volume before collecting the blank sample.

Step 5. Methanol rinse.

- Make certain that the pump or other nearby electrically powered equipment is grounded, the power cord is intact, and potential sources of sparks do not exist before rinsing pump with methanol.
- Change to latex or nitrile gloves. Wear safety glasses and apron. Work in a well-ventilated area outside of the field van and downwind of the sampling area.
- Place pump into a clean, dedicated, solvent-resistant standpipe and route discharge end of sample tubing to a methanol waste container. Add methanol solution to level above pump intake.
- Pump about 2 L of methanol through sample tubing into methanol waste container, keeping the level of solution above pump intake. The operator should stand back from the pump as a safety precaution in the event that an electrical spark ignites the methanol. Carefully put any unused

methanol from the bottom of standpipe into methanol waste container. Let methanol in the standpipe evaporate to dryness. Change gloves.

- Rinse pump exterior with organic-grade water and place pump into standpipe. Add organic-grade water to the standpipe to push the methanol out of the tubing and into the methanol waste container. Pump at least an additional 0.1 gallon (about 0.38 L) of organic-grade water through the system for every 10 ft. (about 3.05 m) of methanol-wetted tubing to the methanol waste container after used methanol is collected.
- Repeat the above with blank water (PWB or VBW) pumped from a blank-water standpipe if blank samples will be collected for analysis of organic compounds.
- Storage of the cleaned submersible pump and tubing:
- Place pump into two clean, noncontaminating storage bags and close bags.
- Cover the pump reel and tubing with doubled plastic bag or sheeting for transport to the next site.
- For long-term storage (longer than 3 days), the pump and exterior and interior of the tubing must be dry before being placed into plastic bags. Blowing filtered air or filtered (inert) gas through the tubing can dry tubing. If tubing cannot be dried, store chilled to prevent bacterial growth. If bacterial growth has occurred, reclean before use.

2.4.5 General Decontamination Considerations

The following discussion is intended to assist personnel engaged in the decontamination of select equipment. Unless otherwise stated, use one of the above four decontamination procedures as it relates to the device's aqueous or non-aqueous nature and the sampling objectives.

2.4.5.1 Decontamination of Pumps

2.4.5.1.1 Purging Only

2.4.5.1.1.1 Submersible

When submersible pumps (gear, reciprocating, progressive cavity or centrifugal) are only used to evacuate stagnant ground water in the well casing (volume-average sampling), they must be cleaned and flushed prior to and between each use. This cleaning process consists of an external laboratory grade glassware detergent wash and tap water rinse, or steam cleaning of pump casing and cables, followed by a 20

Technical Note:

Inspect the integrity of the seals and O-rings on the pump-motor/pump-body housing. Water inside the motor housing may indicate that methanol vapors could enter the motor. Direct-current motors inherently spark because of the commutator ring. AC motors might spark if the insulation is frayed or burnt on the motor windings or any associated wiring.

If flammable liquids are required for cleaning electrical pump systems, use extreme caution. Vapors from solvents such as methanol can ignite if a disruption in the motor lead-insulation system occurs in the vapor-enriched zone. (Ignition from a spark from an AC induction-type motor in good operating condition is not a concern if rated as using the National Electrical Code (NEC) at Class 1, Group 5.)

gallon flush of potable water through the pump. This flushing can be accomplished by the use of a clean plastic overpack drum or a plastic garbage can filled with potable water. This must be followed by a distilled and deionized rinse of the outside of the pump. For submersible pumps smaller than four inches in diameter, the recommended number of gallons required for flushing may be proportionately reduced (i.e. three-inch 15-gallons, two-inch 10-gallons). For Grundfos® Redi Flo 2 pumps, follow the manufacturer's *Installation and Operating Instruction* manual for cleaning the inside of the stator housing by completely removing the motor shaft and in order to achieve a *complete* replacement of motor fluid (distilled/deionized water). Pumps constructed of plastic parts or sealed inner workings are not an equipment option for consideration because of their limited ability to be decontaminated thoroughly and their demonstrated ability to sorb and desorb contaminants.

Exercise caution to avoid contact with the pump casing and water in the drum while the pump is running (do not use metal drums or garbage cans) to avoid electric shock. Always disconnect the pump from power source before handling. Surface pumps (centrifugal and diaphragm) used for well evacuation need not be cleaned between well locations if a check valve is used. New tubing should be used for each well and discarded after use. If the evacuation tubing is not disposed between locations, it must also be decontaminated in the same manner as the pump. The submersible pump and tubing should always be placed on clean polyethylene sheeting to avoid contact with the ground surface. All tubing must be rinsed/wiped with distilled and deionized water and paper towels to remove any residual material during installation. (Refer to ASTM D-5088-90, *Practice for Decontamination of Field Equipment Used at Nonradioactive Waste Sites.*)

2.4.5.1.1.2 Surface Centrifugal and Diaphragm Pumps

When surface centrifugal and/or diaphragm pumps are used for purging, there is no need for decontamination of the pump or diaphragm housings. It is, however, a good practice to flush the housing/diaphragms with potable water between wells in order to control the build up of silt or other debris inside the housing/diaphragm. This practice will prolong the life of the pumps and maintain operating efficiency by reducing the potential for excessive wear.

2.4.5.1.2 Sampling

2.4.5.1.2.1 Submersible (Low Flow Purging and Sampling Method)

The importance of proper pump decontamination for sampling can not be stressed enough because the pump and tubing form the sampling equipment. Proper decontamination is especially true for pumps that are rented and utilized on a well-to-well basis (typically variable speed submersible centrifugal). Never assume that rented pumps have been thoroughly cleaned. Pumps constructed of plastic parts or sealed inner workings are not an option for LFPS consideration because of their limited ability to be decontaminated thoroughly.

Almost all pumps have an individual aspect that requires attention to detail when it comes to decontamination. One such pump, the variable speed 2-inch submersible, is a popular choice for well-to-well sampling; however, close attention to decontamination is warranted. One manufacturer, Grundfos®, clearly states in their operational handbook that for thorough cleaning, the pump must be completely disassembled,

including removal of the motor shaft from the stator housing and all components within the impeller housing. Care must be taken upon reassembly to insure 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 the pump.

2.4.5.1.2.2 Bladder Pumps

Most bladder pumps can not be easily decontaminated in the field due to their unique construction. For that reason bladder pumps **are not** employed for sampling on a well-to-well basis **unless** they are constructed with easy to clean parts and *disposable* bladders. Bladder pumps with non-disposable bladders are best suited for dedicated (permanently installed) scenarios. If they are constructed with disposable bladders, proper decontamination should include exchanging the used bladder and a thorough eight-step decon procedure.

2.4.5.2 Decontamination of Heavy Equipment

Heavy equipment associated with a sampling episode must be cleaned prior to usage. Items such as drill rigs, well casing, auger flights, and backhoes all present potential sources of interference to environmental samples. These items may come in contact with the materials adjacent to the matrix being sampled or may be attached to actual sampling equipment that has been cleaned in accordance with procedures set forth above. Heavy equipment may potentially retain contaminants from other sources such as roadways, storage areas or from previous job sites and not have been removed. In addition to initial on-site cleaning, these items must be cleaned between use at each sample location. (Refer to ASTM D-5088-90).

Two options are available to accomplish cleaning of heavy equipment: steam cleaning and manual scrubbing. The use of a steam generator can remove visible debris and has several advantages. Steam generators using potable water provide a heated and high-pressure medium that is very effective for residuals removal. They are also efficient in terms of ease of handling and generate low volumes of wash solutions. Potential disadvantages include the need for a fixed or portable power source and they may not be cost effective for use on small pieces of equipment or for one day sampling events.

A second option involves manual scrubbing of equipment using a solution of laboratory grade glassware detergent followed by a thorough water rinse. This procedure can be as effective as steam cleaning or preferred in situations where steam cleaning fails to remove visible materials. The disadvantages to manual scrubbing include intensive labor and generation/disposal of wash and rinse solutions.

The above requirements for cleaning heavy equipment should be incorporated into Field Sampling – Quality Assurance Project Plans where applicable.

2.4.5.3 Decontamination of Direct Push Equipment

Direct push technology can be applied to the collection of samples from aqueous and non-aqueous matrices. This versatility can be extended to samples collected for either fixed laboratory analysis or field analytical methods. Regardless of the sampling objectives, decontamination of the equipment can not be taken lightly since this equipment contacts the sample directly. At a minimum, to effectively clean the type of heavy equipment associated with the technology, a hot-water high-pressure system must be utilized after a pre-soap and water wash to clean all

equipment. Logistically, this will require additional support equipment to be on-site, typically a trailer with a “steam jenny” or equivalent and water tank capable of holding several tens of gallons of potable water. As with general heavy on-site equipment, all sampling equipment must be initially cleaned upon arrival at the site and again between each sample location. If vertical delineation is driving the investigation, each interval must be sampled with decontaminated equipment.

This decontamination process follows closely the US Army Corps of Engineers Cold Regions cleaning procedure. If the required sampling involves collection strictly from a non-aqueous source, the decontamination procedure may be abbreviated to the Three Step procedure discussed in Section 2.4.2 of this chapter. If however, heavy organics are visibly encountered and a hot-water high-pressure system is not on-site, then incorporation of solvents (e.g. acetone) must be included into the decontamination procedure. For large heavy equipment this will require large amount of the solvent to be on-site and consideration for drying time and disposal must also be factored. In addition, if the Three-Step procedure is chosen over the USACE method, additional field (equipment) blanks beyond the normal QA/QC requirement should be considered.

All decontamination should take place in an area removed from close proximity to all sample locations. Consideration for disposal of spent decontamination fluids must be made prior to site activity. In most instances use of hot-water high-pressure systems generates limited volumes of decontamination fluids and if those fluids can be controlled from leaving the site or from creating an erosion issue, then adsorption back into the soil is generally acceptable. Only in cases where contamination may threaten to leave the site or when creation of a possible erosion issue is unavoidable should containerization of fluids be considered.

2.4.5.4 Decontamination of Monitor Well Casing and Screen

Before installation, field cleaning of well casing must consist of a manual scrubbing to remove foreign material and steam cleaning, inside and out, until all traces of oil and grease are removed. Special attention to threaded joints may be necessary to remove cutting oil or weld burn residues. The casing should then be handled and stored in such a manner so as to prevent cross contamination prior to installation.

2.4.5.5 Cleaning Location

It is preferred, given site-specific conditions, that cleaning of all equipment take place in one central location on-site. A designated area or decontamination pad should be established to conduct all cleaning. All equipment such as drill rigs, backhoes, and other mobile equipment should receive an initial cleaning *prior* to use at a site. The frequency of subsequent cleanings while on-site will depend on how the equipment is actually used in relation to taking environmental samples. Unless otherwise specified and approved, all wash/rinse solutions should be collected and contained on-site. The actual fate of this material will be determined after review of analytical data generated from samples and on site discharge impacts have been evaluated.

2.4.5.6 Disposal of Drill Cuttings

During the routine course of site investigation, where materials are known (via field instrumentation or visual observation) or suspected (historic information) to be contaminated, sampling activity (i.e., soil boring or installation of monitoring wells) will produce waste intrinsic to the site. The disposition of this material must be carried out in a manner such as not to contribute further environmental degradation or pose a threat to public health or safety.

Contaminated material may be disposed of on-site provided:

- that the soils are deemed to be non-hazardous;
- the disposed soil/water will not erode/flow either off-site or on-site onto uncontaminated areas;
- no potential to contaminate an uncontaminated aquifer exists, and;
- the potential to create a health hazard to adjoining property owners through airborne exposure is non-existent.

If any of the above conditions cannot be met on-site, the materials must be placed in containers (drums, rolloffs, etc.) and stored in a secure area of the site (fenced or access by unauthorized persons prevented) or transported to a central, secured location. The need to perform analyses of the secured material will be determined by NJDEP. The material will be retained for remediation or disposal in accordance with regulations as part of the selected site remedy.

When test pits are utilized for investigation, the excavated material may be returned to the hole. If the test pit is excavated below the water table, contaminated soils may not be returned to the test pit excavation below the water table; certified clean fill must first be used to bring the bottom of the test pit above the level of the water table. Holes produced from soil borings are to be grouted in accordance with the “Subsurface and Percolating Waters Act,” N.J.S.A. 58:4A-4.1 et seq., their implementing regulations (N.J.A.C. 7:9D-1.1 et seq.) and any NJDEP-approved changes to these specifications including repeals, new rules and amendments. Holes less than 25 feet in depth may be filled with sufficient quantities of uncontaminated soil material to make up for the amount of soil sampled and account for settling, thus allowing the hole to return to natural grade.

When materials of a noncontaminated nature are to be disposed of on-site, the following guidelines must be considered:

- disposed cuttings, soil or water will not erode or flow off-site;
- disposed water will not flow through an area of contamination and thereby spread it to a clean area; or
- NJDEP approves the disposal procedures.

Finally, at off-site (i.e., background) locations where no contamination is expected, the primary consideration is the wish of the property owner. If acceptable to the property owner, drill cuttings and mud from well installation may be raked into adjacent soils. If the property owner requests the uncontaminated material be removed from the site, it is to be properly contained and removed to the site under investigation and disposed of or stored per decision of the NJDEP. If drill cuttings and/or development water are expected to be contaminated, they are to

be removed from the off-site location to a secure on-site location and retained for remediation or disposed of per applicable regulations.

2.4.5.7 Disposal of Installation, Development, Purge, Pump Test and Decontamination Waters

Similar to drill cuttings, an initial determination as to whether these wastewaters should be considered contaminated should be made by evaluating field instrumentation readings or by previous analytical information. Additional field-tests to assist in that determination (e.g., pH, color, other physical or chemical characterizations) must be utilized to the maximum extent possible.

Essentially, water generated that is not considered to be contaminated may be re-applied directly to the ground surface and permitted to percolate back into the ground water system. Care should be taken, however, to avoid nuisance situations where the discharge may cause undue concern on the part of property owners or the community. In such cases, it is advisable to dispose of the water into a local stormwater or sanitary sewer system, or collect and discharge the water slowly to avoid such a condition. Please note that all discharges of pollutants to surface water and/or the sanitary sewer are subject to the permit requirements contained in the NJPDES regulations.

Where the water is considered to be contaminated, the water generated may be re-applied to the ground surface provided all the following conditions are met:

- The water is not permitted to migrate off-site.
- There is no potential for contaminating a previously uncontaminated aquifer (for example, the discharge will not be permissible if a lower aquifer is being tested and is contaminated while the upper aquifer is not).
- The discharge will not cause an increase to ground surface soil contamination.
- If the above conditions cannot be met, the water shall be collected and secured at a single location (preferably the primary site under investigation).
- Collected water may be subsequently re-applied to ground surface only if, based on analytical results, there are indications that the above conditions can be met. If not, arrangements for proper disposal must be accomplished prior to the event.

In addition to the above considerations, the requirements of the New Jersey Pollutant Discharge Elimination System (NJPDES) must be followed for all discharges of pollutants to ground water and stormwater. The NJPDES Regulations requires the issuance of either an individual or general permit, or a permit-by-rule authorization (see N.J.A.C. 7:14A-7.5), for these discharges. If an individual NJPDES Discharge to Ground Water permit has already been issued for the facility, all discharges from the development and sampling of monitoring wells, done in accordance with the permit, are deemed to have a permit-by-rule without any additional written approval required [see N.J.A.C. 7:14A-7.5(a)4]. A NJPDES DGW permit-by-rule may also be available at other facilities for on-site disposal of development, purge, pump test and decontamination waters generated during the course of a site remediation. The most current NJPDES regulations at N.J.A.C. 7:14A-7.5 must be consulted. An unofficial version of the NJPDES regulations can be accessed via the NJDEP web site at: <http://www.nj.gov/dep/dwq/714a.htm>, however it may not include the most recent changes. Department staff familiar with the most recently promulgated regulations should be consulted.

It is preferable to complete discharges of development, purge, and decon waters at a single, known contaminated area on-site. This area will be selected by the NJDEP. In cases where such

an area cannot be located, as with contaminated well field projects, discharges will occur as close to the well or sampling location as reasonably possible.

2.5 Procedures For Quality Assurance and Quality Control (QA/QC)

QA/QC samples are intended to provide control over the collection of environmental measurements and subsequent validation, review, and interpretation of generated analytical data. The various types of blank samples currently required by the NJDEP are designed to address QA/QC concerns related to sample bottle and equipment preparation, packaging, handling, and sample collection technique.

The trip blank (field reagent blank) is primarily used to measure possible cross contamination of samples during shipping to and from the site. The analysis is typically for volatile organics and only when environmental samples are of an aqueous matrix. However, various USEPA Drinking Water Methods require the collection of field reagent blanks for non-volatile methods. Additionally, non-aqueous samples collected utilizing methanol preservation techniques may require trip blank analysis. Anticipated trip blank collection should be stated in the QAPP to avoid confusion in the field and possible rejection of data. For aqueous sampling, the trip blank water should be from the same source as the method blank water used in the laboratory during analysis. Regardless of whether the trip blank is associated with aqueous or non-aqueous samples, it is never opened and travels to and from the site with the empty or full sample bottles in an effort to simulate sample-handling conditions. Contaminated trip blanks may also indicate inadequate bottle cleaning or blank water of questionable quality.

The primary purpose of this type of blank is to detect additional sources of contamination that might potentially influence contaminant values reported in actual samples both quantitatively and qualitatively. The following have been identified as potential sources of contamination.

- Laboratory reagent water
- Sample containers
- Cross contamination in shipment, bottle handling and storage
- Ambient air or contact with analytical instrumentation during preparation and analysis at the laboratory
- Laboratory reagents used in analytical procedures

The purpose of a field blank is to place a mechanism of control on sample equipment and its related handling, preparation, storage, and shipment. Since the field blank travels and is stored with the sample bottles, and is also representative of bottle shipment effects on sample quality. The field blank water should be from the same source as the method blank water used in the laboratory. By being opened in the field and transferred over a cleaned sampling device (where applicable), the field blank is indicative of ambient conditions and/or equipment conditions that may potentially affect the quality of the associated samples.

The primary purpose of this type of blank is to provide an additional check on possible sources of contamination beyond that which is intended for trip blanks. A field blank serves a similar purpose as a trip blank regarding water quality and sample bottle preparation. However, it is primarily used to indicate potential contamination from ambient air as well as from sampling instruments used to collect and transfer samples from point of collection into sample containers (it may also be referred to in the literature as a field rinsate blank).

The following is a breakdown by matrix of blank sample requirements.

2.5.1 Non-Aqueous Matrix

2.5.1.1 Field Blanks

2.5.1.1.1 Description

The performance requirement for field blank collection begins with two (2) sets of identical bottles (method dependent); one set filled with demonstrated analyte free water provided by the laboratory performing the sample analysis, and one empty set of bottles. The bottles should also be identical to those provided for aqueous sample collection. Note: Since field blanks are aqueous; the lab must provide water for volatile analysis in 40ml septum vials. For soil preserved in methanol see Chapter 6 Section 6.2.7.4.5, *Closed-System Vials, Chemical Preservation – Methanol* for more discussion on methanol preserved soil collection. At the field location, in an area suspected to be contaminated, the water is passed from the full set of bottles through the dedicated or field decontaminated sampling device(s) and into the empty set of bottles. This will constitute identical bottle to bottle transfer. Field blanks must be preserved in the same manner as samples and only need to be collected and analyzed for volatile organics when volatile organics constitute a parameter being investigated. On a site-specific basis, QA parameter requirements may be amended at the discretion of NJDEP. Note: for logistical purposes it is recommended that the lab provide at least one extra full 40ml vial to perform the field blank.

Various USEPA Methods such as, USEPA Method 1631 *Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry* requires the use of additional field blanks as well as equipment blanks as part of the method requirements. Therefore, the analytical methods should be reviewed to determine method requirements.

2.5.1.1.2 Frequency

For sampling events lasting more than one day, field blanks associated with a non-aqueous matrix should be performed at a rate of 10% of the total number of samples collected throughout the event. If, for example, 40 samples were to be collected over a six-day period, then only four field blanks would be required. For one-day sampling events, with the total number of samples collected being less than 10, it is required that one field blank be collected. On a site-specific basis, QA frequency requirements may be amended at the discretion of NJDEP. However, it is not necessary to collect more than one field blank per day.

2.5.1.2 Trip Blanks

Trip blanks are not required for the non-aqueous matrix unless specifically requested for by Special Analytical Services (SAS) consideration or when specifically required by the analytical method.

2.5.2 Aqueous Matrix

2.5.2.1 Field Blanks

A description of field blanks for the aqueous matrix is the same as 2.5.1.1.1 above with one exception: Field blanks must be analyzed for all the same parameters that the samples collected will be analyzed.

Field Blanks are generally not required for potable well sampling events or when a sample is collected directly from a source into a sampling container.

Field Blanks may be required to detect cross contamination from ambient air during potable sampling events if known sources of contamination are within close proximity or monitoring instruments indicate the presence of contamination above background levels.

Frequency – Field blanks for the aqueous matrix must be performed at a rate of one per day.

Various USEPA Methods such as, USEPA Method 1631 *Mercury in Water by Oxidation, Purge and Trap, and Cold Vapor Atomic Fluorescence Spectrometry* requires the use of additional field blanks as well as equipment blanks as part of the method requirements. Therefore, the analytical methods should be reviewed to determine the method requirements

2.5.2.2 Trip Blanks (Field Reagent Blanks)

2.5.2.2.1 Description

Trip blanks are required for aqueous sampling events. They consist of a set of sample bottles filled at the laboratory with laboratory demonstrated analyte free water. Trip blanks accompany sample bottles into the field and are returned to the laboratory along with the collected samples for analysis. These bottles are never opened. Trip blanks must return to the lab with the same set of bottles they accompanied to the field. At a minimum, trip blanks must be analyzed for volatile organic parameters. The inclusion of additional parameters or amendments to the requirements for trip blanks is at the discretion of NJDEP. Trip blanks and associated samples shall not be held on-site for more than two calendar days unless prior agreement to extend the sampling handling time has been granted by the oversight program.

2.5.2.2.2 Frequency

Trip blanks must be included at a rate of one per sample shipment (not to exceed two (2) consecutive field days). However, USEPA has issued analytical methods that require additional Trip Blanks or each batch of twenty samples submitted to the laboratory. Therefore, the analytical methods must be reviewed prior to determining the required number of Trip Blanks.

2.5.3 Air Matrix

Trip and field blank procedures and frequencies for the various air sampling methods available should follow the specifications of the individual analytical method utilized. QA sample requirements may be amended at the discretion of NJDEP.

2.5.4 Blank Water Quality

The demonstrated analyte free water used in the field and trip blanks must originate from one common source and physical location within the laboratory and must be the same as the method blank water used by the laboratory performing the specific analysis. The use of commercially prepared water or water not originating from the laboratory analyzing the samples is generally not permitted. An exception to this requirement is allowable if:

- It is the same water used for method blank analysis,
- The laboratory has analyzed that water and generated data from a specific batch/lot of containers,

- The blank sample is drawn from an unopened container from the same batch/lot thus documenting the water is free of contaminants (demonstrated analyte free).

Lab certification requirements for the source of blank/method water can be found in Section 7:28-3.3-9 of the *Regulations Governing the Certification of Laboratories and Environmental Measurements* N.J.A.C. 7:18. Basically, it states that a source of water which meets the required standards of quality for each type of testing shall be available for use in the preparation of reagents, standards and for glassware rinsing. If the water of the required quality is not produced in the environmental laboratory, it shall be purchased from commercial suppliers. The environmental laboratory shall maintain a field of the required analysis for each lot of water. A source of purified water is not necessary for radon/radon progeny-in-air analyses.

The laboratory performing the analysis may be required to provide documentation that trip and field blank water was demonstrated analyte free if contamination is detected in blanks, or at NJDEP's discretion. This would be verified by analytical results of method blanks run by the laboratory on the day of trip and field blank preparation and shipment. This does not, however, change requirements for the analysis of method blanks on the day of sample analysis at the laboratory.

A method blank is carried through the entire sample preparation procedure and analysis at the laboratory. It is utilized as a check on laboratory procedures as well as possible contamination from laboratory equipment (i.e. reagents, glassware, etc.).

2.5.5 Sample Handling and Holding Times

2.5.5.1 Handling Time

Field and trip blank samples must travel with sample containers and must arrive on-site within one day of their preparation in the lab. Blanks and their associated samples may be held on-site for no longer than two calendar days, and must arrive back in the lab within one day of shipment from the field. This constitutes the maximum 4-day handling time. Exceptions to this NJDEP QA/QC imposed requirement may be granted by managers overseeing a project when legal holidays or weekend sampling conflict with laboratory shipment practices. Without exception, blanks and all samples must be maintained at 4°C while stored on-site and during shipment. Sample bottles and blanks must be handled in the same manner prior to their return to the laboratory.

The only standing exception, which requires no prior approval to handling time requirements, is when sampling storm water runoff. The spontaneity of storm conditions precludes any possibility for preplanning sample bottle shipment. Therefore, due to these obvious logistical constraints, trip and field blanks are not normally required.

While the exception is understandable, the storage of these sample bottles must be carefully controlled to ensure the possibility of cross contamination is kept to an absolute minimum.

2.5.5.2 Maximum Holding Time

The clock governing holding times for samples and blanks analyzed by Contract Laboratory Program (CLP) methodologies begins when the sample is received in the laboratory as documented on the laboratory's external chain of custody form. This is known as the Verified Time of Sample Receipt (VTSR). Holding times for individual parameters are dictated by the specific analytical method being used. The holding time clock for all other certified methods and parameters begins at the time of sample collection in the field. Please refer to the Tables at the end of this chapter for additional information.

Current Requirements for samples collected under the Safe Drinking Water Act and the Clean Water Act are published annually in 40 CFR Parts 136 and 141 and may be found on the USEPA Website at <http://www.epa.gov/epahome/cfr40.htm>.

Current Requirements for samples to be analyzed in accordance with the USEPA SW846 Methods are published in the latest final update of the USEPA SW846 *Test Methods for Evaluating Solid Waste – Physical and Chemical Methods 3rd Edition* issued 1996 and amended and may be found on the USEPA Website at <http://www.epa.gov/epaoswer/hazwaste/test/sw846.htm>.

Current Requirements for samples to be analyzed in accordance with the USEPA Contract Laboratory Program are published in the latest version of the USEPA CLP SOWs. These documents may be found on the USEPA Website at <http://www.epa.gov/oerrpage/superfund/programs/clp/index.htm>

2.5.6 Special Analytical Services (SAS)

It is important to note that both trip and field blanks are only capable of determining that contamination of samples may have occurred from additional sources other than the actual environmental matrix being investigated. They cannot identify, but may suggest, possible sources of additional contaminant contribution to the reported analytical values. NJDEP may also implement additional types of QA/QC blanks (Special Analytical Services – SAS) when initial sampling episodes produce blank contamination that cause the generated data to become suspect. SAS has been developed to help identify the specific source(s) of blank contamination in a particular analytical fraction to aid in the assessment of reported analytical values. To date its primary purpose has been to confirm or eliminate laboratory contaminant sources in blank samples.

An example of special analytical services may be the inclusion of additional blank samples that are prepared at the same time and in the same manner as the trip and field blanks, but are designated for placement in laboratory storage areas, sample preparation areas or perhaps at ambient air ventilators or other field locations. These additional blanks are then subject to the same analysis as the samples to determine if location specific cross contamination during handling/storage may be occurring. SAS may also include the use of alternate analytical methodologies for unique, site specific parameters of concern.

It is important to note that many methods have additional quality control requirements that have evolved to monitor both storage and analytical procedures. All parties, including the laboratory, must be aware of these changes as new or revised methods are issued by USEPA or other governmental agencies in response to changes in regulation, contractual requirements and instrumentation.

Two recent changes to consider are as follows

- The USEPA CLP Program in the Low/Medium Level Organics and the Low Concentration Organics Statement of Works require the analysis of instrument blanks and storage blanks. The purpose of instrument blanks is to determine the level of contamination associated with the instrumental analysis itself, particularly with regard to the carry over of analytes from standards or highly contaminated samples into other analyses. The storage blank indicates whether contamination may have occurred during storage of samples. A storage blank is used for volatile organics, and upon receipt of the first sample in a Sample Delivery Group or a batch, two 40 mL screw-cap volatile vials with a PTFE- faced silicone septum are filled with reagent water. The vials are stored with the samples in the Sample Delivery Group under the same conditions. After all samples in the Sample Delivery Group have been analyzed, the storage blank is analyzed.
- The USEPA Method 1631 requires the preparation and analysis various blanks not normally found in other method. Three of the blanks are described below of bubbler blanks, bottle blanks,

blanks and reagent blanks. A bubbler blank is used to demonstrate freedom from system contamination. A least three bubbler blanks must be run per analytical batch by placing a clean gold trap on the bubbler immediately following analysis of a sample, and analyzing the sample a second time. Filling a sample bottle with reagent water acidified to pH <2, capping the bottle, allowing the bottle to stand for a minimum of 24 hours and analyzing the water generates a bottle blank. A reagent blank is generated by adding aliquots of BrCl, HN_2OH_2 , and SNCL_2 to previously purged reagent water in the bubbler and analyzing the reagents water. Reagents blanks are used to identify contamination from the reagents.

2.5.7 Additional QA/QC Samples

Additional parameter blanks may be required in specific cases. NJDEP may make such a determination during review of the site-specific sampling portion of a project plan.

2.5.7.1 Duplicate Samples Obtained in the Field (Field Duplicates)

Collection of duplicate samples provides for the evaluation of the laboratory's and field sampling team's performance by comparing analytical results of two samples from the same location. Duplicate samples are to be included for each matrix at a minimum rate of one for every twenty samples (5% of total) and be submitted to the lab as "blind" samples. If less than twenty samples are collected during a particular sampling episode, one duplicate should be performed. Duplicate requirements may be waived or expanded depending on the particular regulatory program or remedial phase involved. Keep in mind that various USEPA Methods require a higher frequency of Field Duplicate Samples. Therefore, the analytical methods must be reviewed to determine the appropriate number of Field Duplicates.

2.5.7.1.1 Aqueous Matrix Duplicates

Duplicates of water samples (potable well, monitor well, surface water) should be obtained by alternately filling sample containers from the same sampling device for each parameter. Samples for volatile organics analysis from monitor wells should be filled from the same bailer full of water whenever possible and be the first set of containers filled. When other sampling devices are re-used, the vials for volatile organics should be alternately filled. If heterogeneity is suspected, separate samples of each phase should be collected as the nature of phased liquids precludes homogenization. It is generally not necessary to homogenize ground water or surface water samples.

2.5.7.1.2 Non-Aqueous Matrix Duplicates

Obtaining duplicate samples in a soil or sediment matrix requires homogenization of the sample aliquot prior to filling sample containers. Regardless, volatile organic samples must always be taken from discrete locations or intervals without compositing or mixing. This practice is necessary to prevent loss of volatile constituents and to preserve, to the extent practicable, the physical integrity of the volatile fraction (see Chapter 6. *Sample Collection*, Section 6.2.7, *VOC Sample Collection for Soils*, for further information). Homogenization of the sample for remaining parameters is necessary to generate two equally representative samples. Note that enough sample must be collected at one time in order to fill all the necessary sample containers. It may be necessary to co-locate or depth-integrate collection so enough sample volume is available. A description of this process should be provided in the sampling plan. Moisture content, particle size, and adsorption properties of various

soils, sediments, and waste materials may inhibit the ability to achieve complete mixing prior to filling sample containers.

Homogenization should be accomplished by filling a properly decontaminated stainless steel tray or bowl with the sample and mixing it with a decontaminated stainless steel or Teflon® instrument. The extent of mixing required will depend on the nature of the sample and should be done to achieve a consistent physical appearance prior to filling sample containers.

Once mixing is completed the sample should be divided in half and scooping sample material alternately from each half should fill containers. Several laboratory methodologies for compositing samples published by the American Society for Testing and Materials (ASTM) have been suggested for use in the field; however, they were not specifically designed for homogenization of known or suspected hazardous materials and often must be “modified” to be useful. They tend to assume a uniform sample exists to begin with and their intent may be to calculate average grain size, predict weight to volume ratios, or to reduce the size of a sample to one more convenient for handling and analysis. They also tend to assume a much larger volume of material will be subject to the particular methodology. Therefore, these methods are not recommended for generating duplicate samples in the field.

2.5.7.2 Splitting Samples with Responsible Parties

When various sites are under investigation, property owners and other interested parties may desire to obtain samples for analysis which are duplicates of those obtained by NJDEP personnel or contractors. If this becomes necessary, procedures for obtaining duplicate samples described above should be followed.

In order to maintain the integrity of any sample “split” between interested parties, the following procedures shall be followed:

- Personnel authorized by NJDEP (e.g. contractors or treatment facilities) using approved NJDEP sampling methods shall be permitted to obtain all sample aliquots.
- Other interested parties must provide their own sample containers, blank samples, preservatives, sample shuttles, chain of custody forms, etc.
- NJDEP personnel shall witness the sampling procedures to verify consistent handling and packaging of each set of samples.
- Duplicate samples, trip blanks and field blanks must be included as part of those samples, which are split between the two or more parties, involved.
- All interested parties desiring to obtain split samples during planned sampling episodes must provide the Department with a minimum of two weeks notice. This is essential for planning purposes and to avoid confusion or delays in the field.
- Use of the same analytical methods must be conducted between all parties in order to allow for comparability of data. Choice of analytical methodologies must be agreed upon prior to the sampling event.

2.5.7.3 Background Samples

When background samples are required for comparison of site conditions to the surrounding environment they should be collected and handled in the same manner as all other samples.

Requirements for inclusion of background samples are determined on a program specific and/or case by case basis.

2.6 Sample Preservation Requirements

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Certain analytical methodologies for specific analytes require chemical additives in order to stabilize and maintain sample integrity. Generally this is accomplished under two scenarios:

- Preservative may be added to the sampling bottles by the laboratory prior to shipment into the field or,
- Preservatives are added in the field immediately after the samples are collected.

Many laboratories provide pre-preserved bottles as a matter of convenience and to help ensure that samples will be preserved immediately upon collection. A problem associated with this method arises if not enough sample is collected, resulting in too much preservative in the sample. More commonly encountered problems with this method include the possibility of insufficient preservative provided to achieve the desired pH level or the need for additional preservation due to chemical reactions caused by the addition of sample liquids to pre-preserved bottles. NJDEP approves the use of pre-preserved bottles. However, field-sampling teams must always check the pH level and be prepared to add additional preservatives to samples if necessary.

When samples are preserved after collection, special care must be taken. The transportation and handling of concentrated acids into the field requires additional preparation and adherence to appropriate preservation procedures. The analytical methods must be reviewed to determine the correct grade of acid that are required for preservation.

The following guidelines are recommended to achieve safe and accurate preservation of samples in the field:

- Sampling teams must be properly equipped to conduct preservation of samples in the field. To accomplish this task the following items are necessary:
 - Graduated pipettes
 - Pipette bulbs
 - Preservatives in glass containers with their content and concentration clearly labeled
 - Limited range pH paper (important that the sampler note the “use by” date and that the paper is properly stored and maintained)
 - Carrying case clearly labeled and constructed of appropriate material to facilitate safe transportation of preservatives in vehicles and in the field.
- Sampling teams must also be properly equipped with appropriate health and safety equipment. Use of and immediate access to the following items are strongly recommended:
 - Protective goggles
 - Disposal gloves
 - Lab apron
 - First aid kit
 - Portable eye wash station
 - Containerized tap water for immediate flushing if spillage occurs onto clothing
- A level surface area should be designated to conduct preservation activities. A clean sheet of plastic sheeting should be placed over the area and secured.

- Personnel assigned to conduct preservation activities must be familiar with specified preservation requirements and verify that the necessary pH level has been achieved. To accomplish this task, a small amount of the preserved sample aliquot should be placed into a separate clean beaker or the container lid. The liquid should then be checked with pH paper so as to indicate that the desired pH level has been achieved. Under no circumstances should the test sample aliquot be returned into the container retaining the sample for analysis.
- Preservation requirements are method and parameter specific. Additional information may be found in Appendix 2-1 following this chapter. These charts may indicate any additional preservation required upon arrival of samples at the laboratory as cited in the specific methodologies. The laboratory and the samplers are required under the certification regulations to know the additional preservation requirements. The source of preservatives is also of concern. They may be provided in bulk by the laboratory performing the analysis or purchased from a commercial laboratory supply vendor. All preservative containers must be labeled with respect to contents, concentration, laboratory grade and the date of purchase or preparation. Again, under no circumstances should the test sample aliquot be returned into the container retaining the sample for analysis.
- Preservation must take place immediately upon sample collection except when samples are to be filtered. Samples requiring filtration must be processed immediately after collection. Filtered samples are then preserved immediately following the filtration process.
- In rare cases a chemical reaction between the preservative and an aqueous sample may induce effervescence. Should this be observed during sample collection, immediately notify both the laboratory and the oversight program before continuing. A decision will have to be rendered in the field regarding whether or not to continue sample collection. If expeditious shipping and laboratory analysis of an unpreserved sample can be negotiated (based on analytical method requirements) in order to maintain sample integrity, the sample should be discarded, the interior of the sample container rinsed with the sample source and an unpreserved sample volume collected. The fact the sample is unpreserved must be noted on the chain of custody and why it was unpreserved. The laboratory must be notified that an unpreserved sample is being submitted.
- If a soil sample reacts with a required preservative, a new sample bottle or sampling device is required, an unpreserved sample must be submitted to the laboratory and the laboratory notified that an unpreserved field sample is being submitted. Some methods, such as USEPA Method 624, specifies that if an unpreserved sample is submitted, it must be analyzed with 7 days of sample collection. Therefore, it is important to the sampler and the laboratory to be knowledgeable about the analytical methods
- Samples must be placed into a cooler and maintained at 4°C immediately upon collection and preservation.

Note: there are methods that such as 1631 and 1630 (methyl mercury) that allow samples to be optionally preserved at the laboratory, so long as they are received at the laboratory within 48 hours of sample collection.

Current information on required holding times can be found at the following USEPA websites:

Current Requirements for samples collected under the Safe Drinking Water Act and the Clean Water Act are published annually in 40 CFR Parts 136 and 141 and may be found on the USEPA Website at: <http://www.epa.gov/epahome/cfr40.htm>.

Current Requirements for samples to be analyzed in accordance with the USEPA SW846 Methods are published in the latest final update of the USEPA SW846 *Test Methods for Evaluating Solid Waste* -

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Physical and Chemical Methods 3rd Edition issued 1996 and amended and may be found on the USEPA Website at: <http://www.epa.gov/epaoswer/hazwaste/test/sw846.htm>.

Current Requirements for samples to be analyzed in accordance with the USEPA Contract Laboratory Program are published in the latest version of the USEPA CLP SOWs. These documents may be found on the USEPA Website at: <http://www.epa.gov/oerrpage/superfund/programs/clp/index.htm>

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- <http://www.state.nj.us/dep/srp/regs/techrule>
- http://water.usgs.gov/owq/FieldManual/chapter3/Ch3_contents.html
- <http://water.usgs.gov/owq/FieldManual/mastererrata.html#Chapter3>

Appendix 2.1 Tables of Analytical Methods

The tables in this section are similar to those found in the New Jersey Regulations Governing the Certification of Laboratories and Environmental Measurements N.J.A.C. 7:18. The tables were updated to reflect the current methodology changes and new methods that have been added since the Regulations have been written. These tables are provided for guidance only if there is a conflict between the Tables and the information provided by the Office of Quality Assurance or their regulations, the Office of Quality Assurance information or decision always takes precedent over the tables. Note: Throughout these tables “P or G” in the Container column means “Plastic or Glass, either soft or hard” respectively with the exception of Fluoride which is polyethylene only. Footnotes appear on the last page of this Appendix.

Table 2.2 Required Preservation, Container, and Maximum Holding Times for Drinking Water Samples, Except Radiochemical Parameters

Parameter	Preservation	Container	Maximum Holding Time
Total Coliform Finished Drinking Water	Cool 4°C, 0.008% sodium thiosulfate (Na ₂ S ₂ O ₃)	P or G	30 hours
Heterotrophic Plate Count Finished Drinking Water	Cool 4°C, 0.008% Na ₂ S ₂ O ₃	P or G	8 hours
Total Coliform Source Water	Cool 4°C, 0.008% Na ₂ S ₂ O ₃	P or G	8 hours
Fecal Coliform Source Water	Cool 4°C, 0.008% Na ₂ S ₂ O ₃	P or G	8 hours
Cryptosporidium	Cool 0-8°C, No Freezing	LPDE Cubitainer	Elution must begin within 96hrs of sampling ¹⁴
Giardi cysts	Cool 0-8°C, No Freezing	LPDE Cubitainer	Elution must begin within 96hrs of sampling ¹⁴
Alkalinity	Cool 4°C	P or G	14 days
Antimony	Conc. HNO ₃ to pH < 2	P or G	6 months
Arsenic	Conc. HNO ₃ to pH < 2	P or G	6 months
Asbestos	Cool 4°C	P or G	Filter within 48 hours
Barium	Conc. HNO ₃ to pH < 2	P or G	6 months
Beryllium	Conc. HNO ₃ to pH < 2	P or G	6 months
Bromate	50 mg/L Ethylenediamine (EDA) solution	P or G	28 days
Bromide	None	P or G	28 days
Cadmium	Conc. HNO ₃ to pH < 2	P or G	6 months
Calcium	Conc. HNO ₃ to pH < 2	P or G	6 months
Chlorate	50 mg/L Ethylenediamine (EDA) solution	P or G	28 days
Chloride	None	P or G	28 days
Chlorite	50 mg/L Ethylenediamine (EDA) solution Cool 4°C	P or G	14 days
Chlorinated Hydrocarbons	Refrigerate at 4°C. After collection, Ascorbic acid	Glass with foil or Teflon®-lined cap	14 days until extraction; 40 days after extraction

Table 2.2 (continued) Required Preservation, Container, and Maximum Holding Times for Drinking Water Samples, Except Radiochemical Parameters

Parameter	Preservation	Container	Maximum Holding Time
Chlorinated Pesticides	80mg/L Na ₂ S ₂ O ₃ if residual chlorine (Cl ₂) is present, Cool 4°C	Glass with Teflon®-lined septum	7 days until extraction; 14 days after extraction
Chlorinated Phenoxy Acids	80mg/L Na ₂ S ₂ O ₃ if residual chlorine (Cl ₂) is present, Cool 4°C	Glass with Teflon®-lined septum	14 days until extraction; 28 days after extraction
Chlorine Dioxide	None	P or G	Analyze Immediately
Chlorinated Acids	Refrigerate at 4°C after collection, Ascorbic acid	Glass with foil or Teflon®-lined cap	7 days until extraction; 30 days after extraction
Chromium	Conc. HNO ₃ to pH < 2	P or G	6 months
Copper	Conc. HNO ₃ to pH < 2	P or G	6 months
Cyanide	NaOH to pH > 12, Cool 4°C, 0.6 g Ascorbic acid	P or G	14 days
EDB/DBCP/1,2,3-TCP	Cool 4°C, 0.08% Na ₂ S ₂ O ₃	Glass with Teflon®-lined septum	extract: 14 days; 24 hours to analysis
Fluoride	None	Polyethylene only	28 days
Free Chlorine Residual	None	P or G	Analyze Immediately
Lead	Conc. HNO ₃ to pH < 2	P or G	6 months
Mercury	Conc. HNO ₃ to pH < 2	P or G	28 days
N-Methyl-Carbamoyloximes N-Methyl-Carbamates	Monochloroacetic acid to pH 3, 80mg/L Na ₂ S ₂ O ₃ , Cool 4°C until storage, Store at -10°C	Glass with Teflon®-lined septum	28 days at -10°C
Nickel	Conc. HNO ₃ to pH < 2	P or G	6 months
Nitrate-Nitrate	Conc. H ₂ SO ₄ to pH < 2; Cool 4°C	P or G	28 days
Nitrate-N	Cool 4°C	P or G	48 hours
Nitrite-N	Cool 4°C	P or G	48 hours
Nitrogen- and Phosphorus-Containing Pesticides	80mg/L Na ₂ S ₂ O ₃ (if residual Cl ₂) Cool 4°C	Glass (dark) with Teflon®-lined septum	14 days until extraction; 14 days after extraction
o-Phosphate	Cool 4°C	P or G	48 hours
Perchlorates	None Required	P or G	28 days

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Table 2.2 (continued) Required Preservation, Container, and Maximum Holding Times for Drinking Water Samples, Except Radiochemical Parameters

Parameter	Preservation	Container	Maximum Holding Time
Odor	Cool 4°C	P or G	24 hours
Organic Compounds	If residual Cl ₂ 40-50 mg sodium arsenite or sodium thiosulfate; if unchlorinated, 6 N HCl to pH < 2	Glass with Teflon®-lined septum	7 days until extraction; 30 days after extraction
Organohalide Pesticides and Commercial PCB Products (Arochlors)	3mg Na ₂ S ₂ O ₃ or 7uL Na ₂ S ₂ O ₃ (0.04g/mL), Cool 4°C until analyzed	Glass with Teflon®-lined septum	If Heptachlor, 7 days until extraction; 40 days after extraction. If no extraction, analysis within 14 days
Ozone	None	G	Analyze Immediately
pH	None	P or G	Analyze Immediately
Selenium	Conc. HNO ₃ to pH < 2	P or G	6 months
Silver	Conc. HNO ₃ to pH < 2	P or G	6 months
Sodium	Conc. HNO ₃ to pH < 2	P or G	6 months
Sulfate	Cool 4°C	P or G	28 days
Temperature	None	P or G	Analyze Immediately
Thallium	Conc. HNO ₃ to pH < 2	P or G	6 months
TTHMs	Na ₂ S ₂ O ₃ if residual Cl ₂ and 6N HCl	Glass with Teflon®-lined septum	14 days
Total Dissolved Solids	Cool 4°C	P or G	7 days
Turbidity	Cool 4°C	P or G	48 hours
Volatile Aromatic and Unsaturated Organic Compounds	1:1 HCl to pH < 2 Cool, 4°C until analysis, Ascorbic acid	Glass with Teflon®-lined septum	14 days
Volatile Halogenated Organic Compounds	1:1 HCl to pH < 2 Cool, 4°C until analysis, Ascorbic acid	Glass with Teflon®-lined septum	14 days
Volatile Organic Compounds	1:1 HCl to pH < 2 Cool, 4°C until analysis, Ascorbic acid	Glass with Teflon®-lined septum	14 days

Table 2.3 Required Preservation, Container, and Maximum Holding Times for Wastewater Samples and Solid/Hazardous Waste Samples (Aqueous Matrices), Except Radiochemical Parameters

Parameter	Preservation	Container	Maximum Holding Time
Bacterial Tests			
Coliform (fecal)	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	P, G	6 hours
Coliform (total)	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	P, G Cool	6 hours
Fecal streptococci	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	P, G	6 hours
Enterococci	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	P, G (sterile)	6 hours
Escherichia coli	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	P, G (sterile)	6 hours
Heterotrophic Plate Count	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	P, G (sterile)	8 hours
Salmonella sp. Bacteria	Cool 4°C	P, G (sterile)	24 hours
Helminth Ova	Cool 4°C	P, G (sterile)	24 hours
Enteric Viruses ¹³	Cool 4°C	P, G (sterile)	8 hours
Toxicity Test			
Acute or Chronic Toxicity	Cool 4°C	P, G	36 hours ¹²
Inorganic Tests			
Acidity, as CaCO ₃	Cool 4°C	P, G	14 days
Alkalinity as CaCO ₃	Cool 4°C	P, G	14 days
Aluminum-total ³	HNO ₃ to pH < 2	P, G	6 months
Ammonia (as N)	Cool 4°C H ₂ SO ₄ to pH < 2	P, G	28 days
Antimony-total ³	HNO ₃ to pH < 2	P, G	6 months
Arsenic-total ³	HNO ₃ to pH < 2	P, G	6 months
Barium-total ³	HNO ₃ to pH < 2	P, G	6 months
Beryllium-total ³	HNO ₃ to pH < 2	P, G	6 months
Biochemical Oxygen Demand	Cool 4°C	P, G	48 hours
Boron-total ³	HNO ₃ to pH < 2	P, G	6 months
Bromide ³	None required	P, G	28 days
Cadmium-total ³	HNO ₃ to pH < 2	P, G	6 months
Calcium-total ³	HNO ₃ to pH < 2	P, G	6 months
Carbonaceous Biochemical Oxygen Demand	Cool 4°C	P, G	48 Hours

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Table 2.3 (continued) Required Preservation, Container, and Maximum Holding Times for Wastewater Samples and Solid/Hazardous Waste Samples (Aqueous Matrices), Except Radiochemical Parameters

Parameter	Preservation	Container	Maximum Holding Time
Chemical Oxygen Demand (COD)	Cool 4°C H ₂ SO ₄ to pH < 2	P, G	28 days
Chloride	None required	P, G	28 days
Chlorine total residual (TRC)	None required	P, G	Analyze Immediately
Chromium VI (dissolved)	Cool 4°C	P, G	24 hours
Chromium-total ³	HNO ₃ to pH < 2	P, G	6 months
Cobalt-total ³	HNO ₃ to pH < 2	P, G	6 months
Color	Cool 4°C	P, G	48 hours
Copper-total ³	HNO ₃ to pH < 2	P, G	6 months
Cyanide-total ³	Cool 4°C, NaOH to pH > 12, 0.6g ascorbic acid	P, G	14 days (24 hours when sulfide is present) ²
Cyanide amenable to chlorination ³	Cool 4°C, NaOH to pH > 12, 0.6g ascorbic acid	P, G	14 days (24 hours when sulfide is present) ²
Fluoride	None required	Polyethylene only	28 days
Gold-total ³	HNO ₃ to pH < 2	P, G	6 months
Hardness-total as CaCO ₃	HNO ₃ to pH < 2 H ₂ SO ₄ to pH < 2,	P, G	6 months
Hydrogen ion (pH)	None required	P, G	Analyze Immediately
Iridium-total ³	HNO ₃ to pH < 2	P, G	6 months
Iron-total ³	HNO ₃ to pH < 2	P, G	6 months
Kjeldahl & Organic Nitrogen	Cool 4°C, H ₂ SO ₄ to pH < 2	P, G	28 days
Lead-total ³	HNO ₃ to pH < 2	P, G	6 months
Magnesium-total ³	HNO ₃ to pH < 2	P, G	6 months
Mercury-dissolved ¹¹ (does not include methyl mercury)	5mL/L of 12 N HCl or 5mL/L of 12 N BrCl Cool 4°C	Fluoropolymer with fluoropolymer or fluoropolymer lined cap	28 days
Mercury-dissolved ¹¹ (includes methyl mercury)	5mL/L of 12 N HCl Cool 4°C	Fluoropolymer with fluoropolymer or fluoropolymer lined cap	28 days
Mercury-total ³	HNO ₃ to pH < 2	P, G	28 days
Mercury-total ¹¹ (does not include methylmercury)	5mL/L of 12 N HCl or 5 mL/L of 12 N BrCl	Fluoropolymer with fluoropolymer or	28 days

Table 2.3 (continued) Required Preservation, Container, and Maximum Holding Times for Wastewater Samples and Solid/Hazardous Waste Samples (Aqueous Matrices), Except Radiochemical Parameters

Parameter	Preservation	Container	Maximum Holding Time
	Cool 4°C	fluoropolymer lined cap	
Mercury-total ¹¹ (includes methylmercury)	5mL/L of 12 N HCl Cool 4°C	Fluoropolymer with fluoropolymer or fluoropolymer lined cap	28 days
Molybdenum-total ³	HNO ₃ to pH < 2	P, G	6 months
Nickel-total ³	HNO ₃ to pH < 2	P, G	6 months
Nitrate (as N)	Cool 4°C	P, G	48 hours
Nitrate-Nitrite(as N)	Cool 4°C, H ₂ SO ₄ to pH < 2	P, G	28 days
Nitrite (as N)	Cool 4°C	P, G	48 hours
Oil and grease	Cool 4°C HCl or H ₂ SO ₄ to pH < 2	G	28 days
Organic carbon-total (TOC)	Cool 4°C, HCl or H ₂ SO ₄ to pH < 2 or phosphoric acid	P, G	28 days
Orthophosphate (as P)	Filter Immediately, Cool 4°C	P, G	48 hours
Osmium-total ³	HNO ₃ to pH < 2	P, G	6 months
Oxygen dissolved (probe)	None Required	Glass bottle and top	Analyze Immediately
Oxygen dissolved (Winkler)	Fix on site and store in dark	Glass bottle and top	8 hours
Palladium-total ³	HNO ₃ to pH < 2	P, G	6 months
Petroleum Hydrocarbons	HCl to pH 2	G	7 days
Phenols	Cool 4°C, H ₂ SO ₄ to pH < 2	G only	28 days
Phosphorus (elemental)	Cool 4°C	G	48 hours
Phosphorus-total	Cool 4°C, H ₂ SO ₄ to pH < 2	P, G	28 days
Platinum-total ³	HNO ₃ to pH < 2	P, G	6 months
Potassium-total ³	HNO ₃ to pH < 2	P, G	6 months
Residue-total	Cool 4°C	P, G	7 days
Residue-filterable (TDS)	Cool 4°C	P, G	7 days
Residue-nonfilterable (TSS)	Cool 4°C	P, G	7 days
Residue-settleable	Cool 4°C	P, G	48 hours
Residue-volatile	Cool to 4°C	P, G	7 days
Rhodium-total ³	HNO ₃ to pH < 2	P, G	6 months
Ruthenium-total ³	HNO ₃ to pH < 2	P, G	6 months

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Table 2.3 (continued) Required Preservation, Container, and Maximum Holding Times for Wastewater Samples and Solid/Hazardous Waste Samples (Aqueous Matrices), Except Radiochemical Parameters

Parameter	Preservation	Container	Maximum Holding Time
Salinity	Cool 4°C	G	28 days
Selenium-total ³	HNO ₃ to pH < 2	P, G	6 months
Silica-dissolved	Cool 4°C	P	28 days
Silver-total ³	HNO ₃ to pH < 2	P, G	6 months
Sodium-total ³	HNO ₃ to pH < 2	P, G	6 months
Specific conductance	Cool 4°C	P, G	28 days
Sulfate	Cool 4°C	P, G	28 days
Sulfide	Cool 4°C, add zinc acetate & NaOH to pH > 9	P, G	7 days
Sulfite	None required	P, G	Analyze Immediately
Surfactants	Cool 4°C	P, G	48 hours
Temperature	None required	P, G	Analyze Immediately
Thallium-total ³	HNO ₃ to pH < 2	P, G	6 months
Tin-total ³	HNO ₃ to pH < 2	P, G	6 months
Titanium-total ³	HNO ₃ to pH < 2	P, G	6 months
Turbidity	Cool 4°C	P, G	48 hours
Vanadium-total ³	HNO ₃ to pH < 2	P, G	6 months
Zinc-total ³	HNO ₃ to pH < 2	P, G	6 months
Organic Tests⁴			
Acenaphthene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ Store in dark	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Acenaphthylene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃	Glass, Teflon®-lined cap Store in dark	7 days until extraction; 40 days after extraction
Acrolein	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ Adjust pH to 4-5 ⁶	Glass, Teflon®-lined septum	14 days
Acrylonitrile	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ Adjust pH to 4-5 ⁶	Glass, Teflon®-lined septum	14 days ⁶
Anthracene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Benzene	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ HCl to pH 2	Glass, Teflon®-lined septum	14 days
Benzidine ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃	Glass, Teflon®-lined cap	7 days until extraction ⁸

Table 2.3 (continued) Required Preservation, Container, and Maximum Holding Times for Wastewater Samples and Solid/Hazardous Waste Samples (Aqueous Matrices), Except Radiochemical Parameters

Parameter	Preservation	Container	Maximum Holding Time
Benzo(a) anthracene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ Store in dark	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Benzo(a)pyrene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Benzo(b) fluoranthene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Benzo(g,h,i) perylene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Benzo(k) fluoranthene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Benzyl chloride	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon [®] -lined septum	14 days
Benzyl butyl phthalate ⁷	Cool 4°C	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Bis(2-chloroethoxy) methane ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Bis(2-chloroethyl) ether ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Bis(2-ethylhexyl) phthalate ⁷	Cool 4°C	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Bromodichloro-methane	Cool 4°C 0.008% Na ₂ S ₂ O ₃ ¹ , HCl to pH 2 ⁵	Glass, Teflon [®] -lined septum	14 days
Bromoform	Cool 4°C 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon [®] -lined septum	14 days
Bromomethane	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon [®] -lined septum	14 days
Carbon tetrachloride	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon [®] -lined septum	14 days
4-Chloro-3-methylphenol ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Chlorobenzene	Cool 4°C 0.008%Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon [®] -lined septum	14 days
Chloroethane	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon [®] -lined septum	14 days
2-Chloroethylvinyl ether	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon [®] -lined septum	14 days
Chloroform	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon [®] -lined septum	14 days

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Table 2.3 (continued) Required Preservation, Container, and Maximum Holding Times for Wastewater Samples and Solid/Hazardous Waste Samples (Aqueous Matrices), Except Radiochemical Parameters

Parameter	Preservation	Container	Maximum Holding Time
Chloromethane	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon®-lined septum	14 days
2-Chloronaphthalene ⁷	Cool 4°C	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
2-Chlorophenol ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
4-Chlorophenylphenyl ether ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Chrysene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Dibenzo (a,h)anthracene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Dibromochloro-methane	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon®-lined septum	14 days
1,2-Dichloro-benzene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon®-lined septum	14 days
1,3-Dichloro-benzene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon®-lined septum	14 days
1,4-Dichloro-benzene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon®-lined septum	14 days
3,3'-Dichloro-benzidine ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon®-lined septum	14 days
Dichlorodifluoro-methane	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon®-lined septum	14 days
1,1-Dichloroethane	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon®-lined septum	14 days
1,2-Dichloroethane	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon®-lined septum	14 days
1,1-Dichloroethene	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon®-lined septum	14 days
trans-1,2-Dichloro-ethene	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon®-lined septum	14 days
2,4-Dichlorophenol ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
1,2-Dichloropropane	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon®-lined septum	14 days
cis-1,3-Dichloro-propene	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon®-lined septum	14 days

Table 2.3 (continued) Required Preservation, Container, and Maximum Holding Times for Wastewater Samples and Solid/Hazardous Waste Samples (Aqueous Matrices), Except Radiochemical Parameters

Parameter	Preservation	Container	Maximum Holding Time
trans-1,3-Dichloro-propene	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon®-lined septum	14 days
Diethyl phthalate ⁷	Cool 4°C	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
2,4-Dimethylphenol ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Dimethyl phthalate	Cool 4°C	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Di-n-butyl phthalate ⁷	Cool 4°C	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Di-n-octyl phthalate ⁷	Cool 4°C	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
2,3-Dinitrophenol ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
2,4-Dinitrotoluene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
2,6-Dinitrotoluene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Epichlorohydrin	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon®-lined septum	14 days
Ethylbenzene	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon®-lined septum	14 days
Fluoranthene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Fluorene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Hexachlorobenzene ⁷	Cool 4°C	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Hexachlorobutadiene ⁷	Cool 4°C	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Hexachlorocyclopentadiene ⁷	Cool 4°C	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Hexachloroethane ⁷	Cool 4°C	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Ideno(1,2,3-cd)pyrene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Isophorone ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction

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Table 2.3 (continued) Required Preservation, Container, and Maximum Holding Times for Wastewater Samples and Solid/Hazardous Waste Samples (Aqueous Matrices), Except Radiochemical Parameters

Parameter	Preservation	Container	Maximum Holding Time
Methylene chloride	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon [®] -lined cap	14 days
2-Methyl-4,6-dinitrophenol ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Naphthalene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Nitrobenzene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
2-Nitrophenol ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
4-Nitrophenol ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
N-Nitrosodimethylamine ^{7, 10}	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
N-Nitrosodi-n-propylamine ^{7, 10}	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
N-Nitrosodiphenylamine ^{7, 10}	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
2,2'-Oxybis(1-chloropropane)	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
PCB-1016 ⁷	Cool 4°C	Glass, Teflon [®] -lined cap,	7 days until extraction; 40 days after extraction
PCB-1221 ⁷	Cool 4°C	Glass, Teflon [®] -lined cap,	7 days until extraction; 40 days after extraction
PCB-1232 ⁷	Cool 4°C	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
PCB-1242 ⁷	Cool 4°C	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
PCB-1248 ⁷	Cool 4°C	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
PCB-1254 ⁷	Cool 4°C	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
PCB-1260 ⁷	Cool 4°C	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Pentachlorophenol	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Phenanthrene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction

Table 2.3 (continued) Required Preservation, Container, and Maximum Holding Times for Wastewater Samples and Solid/Hazardous Waste Samples (Aqueous Matrices), Except Radiochemical Parameters

Parameter	Preservation	Container	Maximum Holding Time
Phenol ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Pyrene ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ Store in dark	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
2,3,7,8-Tetra-chlorodi-benzo-p-dioxin ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
1,1,2,2-Tetrachloro-ethane	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon [®] -lined septum	14 days
Tetrachloroethene	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon [®] -lined septum	14 days
Toluene	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon [®] -lined septum	14 days
1,2,4-Trichloro-benzene ⁷	Cool 4°C	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
1,1,1-Trichloroethane	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon [®] -lined septum	14 days
1,1,2-Trichloroethane	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon [®] -lined septum	14 days
Trichloroethene	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon [®] -lined septum	14 days
Trichlorofluoro-Methane	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2 ⁵	Glass, Teflon [®] -lined septum	14 days
2,4,6-Trichloro-phenol ⁷	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Vinyl chloride	Cool 4°C, 0.008% Na ₂ S ₂ O ₃ ¹ HCl to pH 2	Glass, Teflon [®] -lined septum	14 days ⁵
Pesticides Tests⁷			
Aldrin	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Ametryn	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Aminocarb	Cool 4°C pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Atraton	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Atrazine	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction

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Table 2.3 (continued) Required Preservation, Container, and Maximum Holding Times for Wastewater Samples and Solid/Hazardous Waste Samples (Aqueous Matrices), Except Radiochemical Parameters

Parameter	Preservation	Container	Maximum Holding Time
Azinphos methyl	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Barban	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
alpha-BHC	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
beta-BHC	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
delta-BHC	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Gamma-BHC (Lindane)	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Captan	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Carbaryl	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Carbophenothion	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Chlordane	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Chlorpropham	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
2,4-D	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
4,4'-DDD	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
4,4'-DDE	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
4,4'-DDT	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Demeton-O	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Dementon-S	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Diazinon	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Dicamba	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction

Table 2.3 (continued) Required Preservation, Container, and Maximum Holding Times for Wastewater Samples and Solid/Hazardous Waste Samples (Aqueous Matrices), Except Radiochemical Parameters

Parameter	Preservation	Container	Maximum Holding Time
Dichlofenthion	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Dichloran	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Dicofol	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Dieldrin	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Dioxathion	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Disulfoton	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Diuron	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Endosulfan I	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Endosulfan II	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Endosulfan Sulfate	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Endrin	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Endrin aldehyde	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Ethion	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Fenuron	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Fenuron-TCA	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Heptachlor	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Heptachlor epoxide	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Isodrin	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Linuron	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction

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Table 2.3 (continued) Required Preservation, Container, and Maximum Holding Times for Wastewater Samples and Solid/Hazardous Waste Samples (Aqueous Matrices), Except Radiochemical Parameters

Parameter	Preservation	Container	Maximum Holding Time
Malathion	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Methiocarb	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Methoxychlor	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Mexacarbate	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Mirex	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Monuron	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Monuron-TCA	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Nuburon	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Parathion methyl	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Parathion ethyl	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
PCNB	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Perthane	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Prometron	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Prometryn	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Propazine	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Propham	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Propoxur	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Secbumeton	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction
Siduron	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon®-lined cap	7 days until extraction; 40 days after extraction

Table 2.3 (continued) Required Preservation, Container, and Maximum Holding Times for Wastewater Samples and Solid/Hazardous Waste Samples (Aqueous Matrices), Except Radiochemical Parameters

Parameter	Preservation	Container	Maximum Holding Time
Simazine	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Strobane	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Swep	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
2,4,5-T	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
2,4,5-TP (Silvex)	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Terbutylazine	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Toxaphene	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction
Trifluralin	Cool 4°C, pH 5-9 ¹⁰	Glass, Teflon [®] -lined cap	7 days until extraction; 40 days after extraction

Table 2.4 Required Preservation, Container and Maximum Holding Times for Radiochemical Measurements in Drinking Water and Wastewater Samples

Parameter	Preservation	Container	Maximum Holding Time
Gross alpha	Conc. HCl or HNO ₃ to pH 2*	P or G	6 months
48-Hour Rapid Gross Alpha*	Conc. HCl or HNO ₃ to pH 2*	P or G	48-hours**
Gross beta	Conc. HCl or HNO ₃ to pH 2*	P or G	6 months
Strontium-89	Conc. HCl or HNO ₃ to pH 2	P or G	6 months
Strontium-90	Conc. HCl or HNO ₃ to pH 2	P or G	6 months
Radium (total)	Conc. HCl or HNO ₃ to pH 2	P or G	6 months
Radium-224	Conc. HCl or HNO ₃ to pH 2	P or G	4 days (recommended)
Radium-226	Conc. HCl or HNO ₃ to pH 2	P or G	6 months
Radium-228	Conc. HCl or HNO ₃ to pH 2	P or G	6 months
Cesium-134/137	Conc. HCl or HNO ₃ to pH 2	P or G	6 months
Iodine-131	None	P or G	8 days
Tritium	None	G	6 months
Uranium	Conc. HCl or HNO ₃ to pH 2	P or G	6 months
Plutonium	Conc. HCl or HNO ₃ To pH 2	P or G	6 months
Photon emitters (including Cobalt-60, Zinc-65, Ruthenium-106, and Barium-133)	Conc. HCl or HNO ₃ to pH 2	P or G	6 months
Radon-222***	Cool 4°C	G	4 days (recommended)

Drinking water samples that are to be subject to radiochemical measurements shall be handled and preserved in accordance with the requirements of Table 2.4 and the requirements listed below. Table 2.4 includes requirements from the USEPA’s Manual for the Certification of Laboratories Analyzing Drinking Water, USEPA-815-B-97-001. If there is any conflict between Table 2.4 and the USEPA publication (including any amendments or supplements) on which any part of Table 2.4 is based, the USEPA rule or publication shall control, except in reference to 48-Hour Rapid Gross Alpha and Radium-224 Methods.

* If HCl is used to acidify samples that are to be analyzed for gross alpha or gross beta activities, the acid salts shall be converted to nitrate salts before transfer of the samples to planchets.

**48-hour Rapid Gross Alpha Method applies to CWS compliance monitoring, as well as testing for radium under private well testing Act (PwTA). Maximum holding time to initial counting of the plancheted sample shall be 48 hours from sample collection. (N.J.A.C 7:18-6.4(a)3ii).

*** The method for sampling described in EPA/600/2-87/082-1989 “Two Test Procedures for Radon in Drinking Water” shall be followed.

Sample shall be acidified at the time of collection, in accordance with the requirements listed under “Preservation” in Table 2.4. A minimum of 16 hours shall elapse between acidification and analysis. If suspended solids activity is to be measured, then a second unpreserved sample shall be taken for this measurement; and if the sample is shipped in its original container to a certified environmental laboratory or storage area, acidification of the sample (in its original container) may be delayed for a period not to exceed five days.

Table 2.5 Required Preservation, Container and Maximum Holding Times for Radiochemical Measurements in Solid/Hazardous Waste Samples (Soils, Liquids, Sediments, and Sludges)

Parameter	Preservation	Container Volume	Maximum Holding Time
Gross Alpha-Beta	Cool to 4 ° C	1 liter	6 months
Radium-Total	Cool to 4 ° C	1 liter	6 months
Radium-226	Cool to 4 ° C	1 liter	6 months
Radium-228	Cool to 4 ° C	1 liter	6 months
Photon Emitters: Co-60, Zn-65, Cs-134/137, Ba-133	Cool to 4 ° C	1 liter	6 months
Strontium-89, 90	Cool to 4 ° C	1 liter	6 months
Uranium	Cool to 4 ° C	1 liter	6 months
Thorium	Cool to 4 ° C	1 liter	6 months

Solid/hazardous waste samples (non-aqueous) shall be handled and preserved in accordance with requirements of Table 2.5. Table 2.5 incorporates requirements from SW-846. If there is any conflict between Table 2.5 and SW-846 (including any amendments or supplements), SW-846 shall prevail.

Table 2.6 Required Preservation, Container and Maximum Holding Times for Solid/Hazardous Waste Samples (Soils, Liquids, Sediments, Sludges, and Ambient Air)

Parameter	Preservation	Container	Maximum Holding Time
Volatile Organics for soil/ sediment, and sludge	Cool 4°C	Glass Teflon®-lined cap	14 days
Volatile Organics (Non-Aqueous sample)	Cool 4°C, dark	Encore™ or equivalent field core sampling/ storage containers & 60 ml septum sealed glass vial	Transfer immediately upon receipt to methanol and sodium bisulfate solution, analyze within 14 days
Volatile Organics (Non-Aqueous sample)	Cool 4°C, dark	Field preserved vials methanol & sodium bisulfate Glass, 40 ml vial stir bar [sodium bisulfate only], septum sealed glass vial & 60 ml septum sealed glass vial	14 days
Volatile organics in liquid samples	Cool 4°C, if residual Cl ₂ add Na ₂ S ₂ O ₃ and HCl to pH < 2	Glass, Teflon®-lined cap	14 days
Acrolein and Acrylonitrile in liquid samples	Cool 4°C Adjust to pH 4-5	Glass, Teflon®-lined cap	14 days
Semivolatile organics/ organochlorine pesticides/ PCBs and herbicides for soil/sediment, and sludge	Cool 4°C	Glass, Teflon®-lined cap	14 days until extraction; 40 days after extraction
Semivolatile organics/ organochlorine pesticides/ PCBs and herbicides for concentrated waste samples	Cool 4°C	Glass, Teflon®-lined cap	14 days until extraction; 40 days after extraction
Metals except Cr VI and Hg (total) for liquid samples	Cool 4°C, HNO ₃ to pH < 2	P, G	6 months
Metals except Cr VI and Hg (dissolved) for liquid samples	Cool 4°C, Filter on-site HNO ₃ to pH < 2	P, G	6 months
Metals except Cr VI and Hg (suspended) for liquid samples	Cool 4°C Filter on-site	P, G	6 months

Table 2.6 (continued) Required Preservation, Container and Maximum Holding Times for Solid/Hazardous Waste Samples (Soils, Liquids, Sediments, Sludges, and Ambient Air)

Parameter	Preservation	Container	Maximum Holding Time
Metals except Cr VI and Hg for solid samples	Cool 4°C	P, G	6 months
Chromium VI for solid samples	Cool 4°C	P, G	30 days to digestion; analysis 168 hours after digestion
Chromium VI for liquid samples	Cool 4°C	P, G	24 hours
Mercury (total) for liquid samples	HNO ₃ to pH < 2	P, G	28 days
Mercury (dissolved) for liquid samples	Filter on-site HNO ₃ to pH < 2	P, G	28 days
Mercury (total) for solid samples	Cool 4°C	P, G	28 days
Ambient Air Analysis			
TO-15 Volatile Organics in Specially Prepared Canisters – GC/MS	None	Specially prepared canisters	30 days from sample collection
TO-17 Volatile Organics in Ambient Air using Active Sampling onto Sorbent Tubes	Cool ≤4°C after sample collection and in refrigeration unless samples are analyzed the same day of collection. The samples must be stored in an organic solvent free environment. Small packages of activated charcoal/silica gel must be with each shipment container of multiple tubes.	Sorbent Tubes	30 days from sample collection; except 7days if limonene, carene, labile sulfur, bischloromethylether or nitrogen containing volatiles

Table 2.7 Required Preservation, Container and Maximum Holding Times From VTSR for CERCLA-CLP Aqueous and Non-Aqueous Samples

Parameter	Preservation	Container	Maximum Holding Time From Validated Time of Sample Receipt (VTSR)
Volatile Organics (Aqueous)	Cool 4°C, dark 0.08% Na ₂ S ₂ O ₃ if residual Cl ₂	Glass, white polypropylene or black phenolic plastic screw Teflon®-lined septum	10 days
Volatile Organics (Non-Aqueous)	Cool 4°C, dark	Glass, polypropylene cap, white Teflon® liner	10 days
Volatile Organics (Non-Aqueous)	Cool 4°C, dark	Encore™ or equivalent field core sampling/ storage container & 60 ml septum sealed glass vial	Transfer immediately upon receipt to methanol and sodium bisulfate solution analyze within 10 days
Volatile Organics (Non-Aqueous)	Cool 4°C, dark	Field preserved vials methanol & sodium bisulfate glass, 40 ml vial stir bar [sodium bisulfate only], septum sealed glass vial & 60 ml septum sealed glass vial	10 days
Pesticide/PCBs	Cool 4°C, dark	Amber Glass, white polypropylene or black phenolic, baked polyethylene cap	Extraction Aqueous: continuous liquid-liquid extraction must be started within 5 days, Non-Aqueous: 10 days analysis, 40 days from VTSR
Polychlorinated Dibenzo-p-Dioxins (PCDDs) and Dibenzofurans (PCDFs) (Non Aqueous)	Cool 10°C, dark	Amber Glass, white polypropylene or black phenolic, baked polyethylene cap	Extraction: 30 days from VTSR, analysis 45 days from extraction

Table 2.7 (continued) Required Preservation, Container and Maximum Holding Times From VTSR for CERCLA-CLP Aqueous and Non-Aqueous Samples

Parameter	Preservation	Container	Maximum Holding Time From Validated Time of Sample Receipt (VTSR)
Polychlorinated Dibenzop-Dioxins (PCDDs) and Dibenzofurans (PCDFs) (Aqueous)	Cool 4°C, dark	Amber Glass, white polypropylene or black phenolic, baked polyethylene cap	Extraction: 30days from VTSR, analysis: 45 days from extraction
Polychlorinated Dibenzop-Dioxins (PCDDs) and Dibenzofurans (PCDFs) (Fish and Tissue Samples)	Cool 4°C, dark until prepared then-10°C until analysis	Wrapped in aluminum foil in field	Extraction: 1 year from VTSR. Once thawed, must be analyzed within 24 hours. Analysis: 45 days from extraction
Cyanide, total amenable to chlorination	Aqueous - 0.6g ascorbic acid if residual Cl ₂ , NaOH to pH>12, cool 4°C, CaCO ₃ in presence of sulfide	Plastic bottle, plastic cap, plastic liner	14 days
Metals except Hg (Aqueous)	HNO ₃ to pH<2, cool 4°C, until analyzed	Plastic bottle, plastic cap, plastic liner	180 days
Metals – Dissolved except Hg (Aqueous)	Field filter 0.45 µm pore diameter filter, rinse bottle with sample then immediately HNO ₃ to pH<2, cool 4°C until analyzed	Plastic bottle, plastic cap, plastic liner	180 days
Metals except Hg (Non-Aqueous)	Cool 4°C until analyzed	Flint glass bottle, black phenolic cap, polyethylene liner	180 days
Hg (Aqueous)	HNO ₃ to pH<2, Cool, 4°C until analyzed	Plastic bottle, plastic cap, plastic liner	26 days
Hg – Dissolved (Aqueous)	Field filter 0.45 µm pore diameter filter, rinse bottle with sample immediately, HNO ₃ to pH<2, Cool, 4°C until analyzed	Plastic bottle, plastic cap, plastic liner	26 days
Hg (Non-Aqueous)	HNO ₃ to pH<2, Cool, 4°C until analyzed	Flint glass bottle, black phenolic cap, polyethylene liner	28 days

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Table 2.7 (continued) Required Preservation, Container and Maximum Holding Time From VTSR for CERCLA-CLP Aqueous and Non-Aqueous Samples

Parameter	Preservation	Container	Maximum Holding Time From Validated Time of Sample Receipt (VTSR)
Cyanide (Aqueous)	0.6g ascorbic acid if residual Cl_2 NaOH to pH>12, cool 4°C until analyzed	Plastic bottle, plastic cap, plastic liner	14 days
Cyanide (Non-Aqueous)	Cool 4°C, until analyzed	Plastic bottle, plastic cap, plastic liner	14 days
Low Level Volatile Organics	Cool 4°C, dark, 0.008% $\text{Na}_2\text{S}_2\text{O}_3$	Glass, black phenolic or white polypropylene screw cap, Teflon®-lined septum	7 days
Low Level Semi-volatile Organics	Cool 4°C, dark	White polypropylene or black phenolic, baked polyethylene cap	Extraction: continuous extraction must be started within 5 days of VTSR. Analysis: 40 days from start of extraction
Low Level Pesticides/PCBs Organics	Cool 4°C, dark	Amber glass, white polypropylene or black phenolic, baked polyethylene cap	Extraction: continuous extraction must be started within 5 days of VTSR. Analysis: 40 days from start of extraction

Footnotes

- ¹ Use only in the presence of residual chlorine.
- ² Optionally, all samples may be tested with lead acetate paper before pH adjustment in order to determine if sulfide is present. If sulfide is present, it can be removed by the addition of cadmium nitrate powder until a negative spot test is obtained. The sample is filtered and then the NaOH is added to pH 12.
- ³ Filter samples immediately on-site before adding preservatives for dissolved metals.
- ⁴ Applies to samples to be analyzed by GC, LC, or GC/MS for specific compounds.
- ⁵ Sample receiving no pH adjustment shall be analyzed within seven days of sampling.
- ⁶ The pH adjustment is not required if acrolein will not be measured. Samples for acrolein receiving no pH adjustment shall be analyzed within three days of sampling.
- ⁷ When the extractable analytes of concern fall within a single chemical Category, the specified preservative and maximum holding times shall be observed for optimum safe guard of sample integrity. When the analyses of concern fall within two or more chemical categories, the sample may be preserved by cooling to four (4) degrees Celsius, reducing residual chlorine with 0.008% $\text{Na}_2\text{S}_2\text{O}_3$, storing in the dark and, for pesticides only, adjusting the pH to 6-9. Samples preserved in this manner may be held for seven days before extraction and 40 days after extraction. Exceptions to this optional preservation and holding time procedure are noted in reference 1 (regarding the requirement for thiosulfate reduction of residual chlorine), and references 8 and 9 (regarding the analysis of benzidine).
- ⁸ Extracts may be stored up to seven days before analysis if storage is conducted under an inert (oxidant-free) atmosphere.
- ⁹ For the analysis of diphenylnitrosamine, add 0.008% $\text{Na}_2\text{S}_2\text{O}_3$ and adjust pH to 7-10 with NaOH within 24 hours of sampling.
- ¹⁰ The pH adjustment may be performed upon receipt at the environmental laboratory and may be omitted if the samples are extracted within 72 hours of collection. For the analysis of aldrin, add 0.008% $\text{Na}_2\text{S}_2\text{O}_3$.
- ¹¹ Method 1631 Revision B: Mercury in Water by Oxidation, Purge and Trap and Cold Vapor Atomic Fluorescence Spectrometry is required. Samples may be shipped to laboratory unpreserved if collected in fluoropolymer bottles, filled to top with no headspace, capped tightly, and maintained at 4°C from time of collection until preservation. The samples must be acid preserved within 48 hours after sampling.
- ¹² First use of samples shall begin within 36 hours of collection. For storm water discharges, first use of the sample shall begin within 48 hours of collection.
- ¹³ Once collected if the assay can not begin within 8 hours then the sample must be frozen. Once defrosted, the sample can be held at 4°C until the assay begins. The assay must then be done the day that the sample is defrosted.
- ¹⁴ Elution, concentration and the application of the purified sample to the slide must be completed in one work day. The sample must be stained within 72 hours of the application of the purified sample to the slide. Up to 7 days are permitted between sample staining and examination.

Table 2.8 Analysis of BIOLOGICAL Samples Using NJDEP Methodologies for Freshwater, Estuarine And Marine Samples

Parameter	Sample Container	Container Volume	Preservation ⁽¹⁾	Maximum Holding Time	Analytical Methodology	Sample Container Cleaning
PHYTOPLANKTON FRESHWATER						
Species Composition						
(live samples)	P,G	250 ml	Cool, 4° C	24 hours	SM17:10200 EPA73: Plankton 3,4	(2)
(preserved)	P,G	1000 ml	50 ml neutralized formalin store/transport in dark, cool container	1 month	As Above	As Above
Chlorophyll a	P,G amber or foil-covered	250 ml	Cool, 4° C store/transport in dark	48 hours	SM17:10200H EPA73: Plankton 5.2	As Above
MARINE AND ESTUARINE						
Species Composition						
(live samples)	P,G	250 ml	Cool, 4° C	24 hours	SM17:10200 EPA73: Plankton 3,4	(2)
(preserved)	P,G	1000 ml	10 ml or more Lugol’s solution to maintain weak tea color. Store/transport in dark, cool container.	48 hours	As Above	As Above
PHYTOPLANKTON MARINE AND ESTUARINE						
Chlorophyll a	P,G amber or foil-covered	250 ml	Cool, 4° C store/transport in dark	48 hours	SM17:10200H EPA73: Plankton 5.2	As Above
ZOOPLANKTON						
Freshwater	P,G	6,000 ml	300 ml neutralized formalin. Store in cool container	1 month	SM17: 10200 EPA73: Plankton 3,4	(2)

Table 2.8 (continued) Analysis of BIOLOGICAL Samples Using NJDEP Methodologies for Freshwater, Estuarine And Marine Samples

Parameter	Sample Container	Container Volume	Preservation⁽¹⁾	Maximum Holding Time	Analytical Methodology	Sample Container Cleaning
Marine & Estuary	P,G	As Above	5% formalin (5 ml neutralized formalin/100 ml tap water), store and transport in cool container	As Above	As Above	As Above
PERIPHYTON						
DIATOMETER SLIDES AND ROCK SCRAPINGS						
Species composition	125ml jar polyseal cap	N/A	Lugol’s solution (4% buffered formalin, “M3” fixative, or, 2 % glutaraldehyde), store and transport in iced container in the dark	1 month	SM17: 10300 EPA99 Periphyton.6	As Above
PERIPHYTON						
Chlorophyll a	P,G	30 ml	90% neutralized acetone, cool 0-4° C, store and transport in dark container	48 hours	SM17: 10300 EPA73: Periphyton 3.2	(2)
Ash Free Weight	120 ml jar polyseal cap	30 ml	90 % neutralized acetone, cool 0-4° C, store and transport in dark container	N/A	SM17:10300 EPA73: Plankton 5.1	As Above
MACROINVERTEBRATES						
Species composition	P,G	N/A	5% neutralized formalin (5 ml neutralized, formalin/100 ml sample water [95% ethanol, isopropyl alcohol])	N/A	SM17:10500 EPA99: Macroinvertebrates 7	As Above

(1) Neutralized formalin = 100 % neutralized formalin with sodium tetraborate to pH 7.0 – 7.3

(2) Warm detergent solution wash, thorough rinse in tap and distilled water.

Chapter 3

Gaining Entry to Inspect Sites For Actual or Suspected Pollution

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Chapter 3

Gaining Entry to Inspect Sites For Actual or Suspected Pollution

3.1 General Rules and Exceptions

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As a general rule, NJDEP employees do not have the right to enter on private property (other than a permitted facility) without a search warrant. Evidence, which is obtained during the course of an illegal search or inspection, may be suppressed in a legal proceeding. A NJDEP employee who has entered on private property without permission may be subject to a charge of trespassing.

- 3.1.1 The most important exception to the general rule requiring search warrants (for the Department's purposes) is voluntary consent to the search or inspection given by a person responsible for the property to be entered. Once consent to entry is given, a search warrant is not required and the investigator can no longer be considered a trespasser. However, consent must be given voluntarily; it must not be coerced.
- 3.1.2 In those cases, which the Department of Environmental Protection has issued a permit containing as a condition, a right of entry to inspect, the courts have decided that no search warrant is required prior to inspection to determine compliance with the terms of the permit, (in re: Department of Environmental Protection, 177 NJ Super. 304 (App. Div. 1981), commonly called the "Vineland Chemical Company Case"). Therefore, if a facility is subject to such a permit, or has a Departmental permit, voluntary consent to entry is not required for a warrantless search to determine compliance.
- 3.1.3 In some instances, a court will order a facility to permit warrantless inspections by NJDEP employees. These orders are usually conditioned upon notice to the property owner prior to entry. While such orders permit warrantless entry without voluntary consent, their terms must be strictly adhered to in order to preserve the validity of any evidence obtained and to avoid a trespass charge.
- 3.1.4 When an emergency which threatens the public health or safety arises which necessitates immediate entry onto property, such entry may be permitted without a warrant or prior consent. If, under the circumstances, obtaining consent or a warrant would take so much time that the public would be endangered, entry to investigate and mitigate the danger is permissible. This situation is most likely to occur in the case of spills or other accidental emissions of hazardous substances. Even in cases of an emergency, however, a reasonable attempt to gain consent prior to entry should be made.

3.2 Procedure to be Followed to Gain Entry to a Site Where No Emergency Exists

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- 3.2.1 Initial approach:
 - 3.2.1.1 Present your NJDEP identification card and/or badge and request to speak with the owner of the premises and/or person in charge.
 - 3.2.1.2 Explain the nature of your visit and request consent for your inspection from the responsible party or the highest ranking facility person available.

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3.2.1.3 If necessary, point out the general Departmental authority to enter and inspect any place for investigating an actual or suspected source of pollution, N.J.S.A. 13:1D-9, on your I.D. card.

3.2.1.4 If necessary and applicable, apprise the person in charge of the permit condition, Administrative Consent Order provision, or Court Order providing for entry to inspect.

NOTE: Consent is not required for observations of things that are in plain view (i.e., that a member of the public could be in a position to observe). This includes observations made while on private property in areas that are not closed to the public (i.e., matters observed while the inspector presents his credentials).

3.2.1.5 Consent may be given with “conditions.” When such “conditional” consent is proposed, guidance should be sought from the Department of Law and Public Safety (DLPS), prior to further activity. This should be done through the appropriate Bureau Chief. “Conditions” must be accurately recorded.

3.2.1.6 Consent to conduct an inspection may be withdrawn at any time. That segment of the inspection completed before the withdrawal of consent remains valid. Withdrawal of consent is equivalent to refused entry.

3.2.2 If voluntary consent is initially refused:

3.2.2.1 Do not attempt to coerce the person in charge; avoid confrontation.

3.2.2.2 Request the name and telephone number of the person in charge and of that person’s (or company’s, whichever is appropriate) attorney.

3.2.2.3 The Bureau Chief should contact the DLPS and request that a Deputy Attorney General (DAG) contacts the person in charge of the site to be inspected and/or the attorney, to obtain consent.

3.2.3 If consent cannot be obtained by the DLPS and time is not of the essence:

3.2.3.1 Write a letter to the responsible person requesting permission to inspect and state the reason for the inspection. Cite the appropriate general (N.J.S.A. 13:1D-9) and any specific statutory authority for entry and inspection. Also cite, where applicable, the permit condition, administrative consent or judicial order provision concerning right of entry. If relying on a permit condition, cite the Vineland Chemical Case (see section VIA.2.) for the holding that the NJDEP has the right to conduct warrantless searches of facilities subject to a permit condition providing for the right of entry to inspect.

3.2.3.2 If consent is gained in response to the letter, conduct the inspection at a mutually agreed upon time.

3.2.4 If consent cannot be obtained in response to a letter, or if time is of the essence:

3.2.4.1 At a site which is subject to a permit condition, administrative consent, or judicial order provision requiring submission to inspection by NJDEP, and your entry would be in compliance with the terms of the permit or order:

Request the DAG to assist you.

3.2.4.1.1 If so advised contact the local Police Department or State Police and request assistance in gaining entry, citing N.J.S.A. 2C: 29-1. Meet with the officer and his supervisors, if necessary, and explain the situation. Inform them of your right to inspect and the regulatory authorities involved.

- 3.2.4.1.2 If any problems are encountered in obtaining a law enforcement officer to accompany you to the site, call the DLPS or request the officer to call the DLPS for confirmation of authority to conduct a warrantless search.
 - 3.2.4.1.3 Have the officer accompany you to the site and again speak to the person in charge and apprise them of your right to enter and inspect.
 - 3.2.4.1.4 Be firm but polite and leave any threat of prosecution under N.J.S.A. 2C:29-1 to the law enforcement officer.
 - 3.2.4.1.5 Write a memo to your supervisor giving the details of the procedure which you followed to gain entry.
- 3.2.4.2 At a site, which is not subject to a permit condition, administrative consent or judicial order provisions for right of entry or if your entry would not be in compliance with the terms of the permit or order:
- 3.2.4.2.1 Request the DAG to assist you in obtaining an administrative search warrant. The investigator should prepare a case status brief which substantiates the need for the warrant. It is important that the site be accurately described, especially those specific areas for which the warrant is to apply. Additionally, sample or evidence collection plans should be included.
 - 3.2.4.2.2 A warrant can usually be obtained to allow an entry and inspection within two days. The following is a general outline of the procedure to be followed: Bring all information available which gives you probable cause to believe that pollution exists on the site to be inspected to a meeting with the DAG. The purpose of this meeting will be to prepare an affidavit if necessary, and sign an application for a search warrant.

The DPLS will have a DAG assigned to obtain the warrant.

- Make arrangements to accompany the DAG to court, in the county in which the site is located to obtain the warrant.
- Arrange to have a member of the local police department or State Police accompany you to the site to serve the warrant.
- Serve the warrant on the responsible person at the site, giving him/her a copy and retaining the original.
- Conduct the inspection in strict compliance with the warrant, i.e. search only those places and undertake only those activities specified in the warrant.
- If anything is taken from the site, i.e. samples or copies of records give the responsible person a receipt for the items taken, request that they sign it and retain a copy the receipt.

NOTE: The chain of command should be notified, aware, and involved in all steps of this process.

3.3 Procedure to be Followed to Gain Entry to a Site When an Emergency Exists

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- 3.3.1 If time permits and a person responsible for the site is readily available, identify yourself by presenting your NJDEP identification and explain that it is necessary for you to enter the site in response to the emergency.

- 3.3.2 If consent to enter is refused, immediately contact the local Police Department or State Police, who may already be on scene. Identify yourself, explain the necessity for your obtaining access to the site and request their assistance in gaining entry.
- 3.3.3 If a problem arises with obtaining the assistance of a law enforcement officer, have the appropriate Bureau Chief call the DLPS or request the officer to call the DLPS for confirmation of your authority to enter the site.
- 3.3.4 If no responsible party is readily available from who to request consent, enter the site in a manner, which is non-destructive of property. If entry cannot be gained to the site of the emergency (i.e., a locked door or fence), request the assistance of a law enforcement officer as in 2. and 3. above.
- 3.3.5 Write a memo to your file giving the details of the procedure which you followed to gain entry.

3.4 Statutory Authority to Conduct Searches

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N.J.S.A. 13:1D-9 (General Department Authority)

[The department shall...have the power to:] Enter and inspect any building or place for the purpose of investigating an actual or suspected source of pollution of the environment and ascertaining compliance or noncompliance with any code, rules and regulations of the department.

N.J.S.A 58:10A-6 (Water Pollution Control Act)

g. The Commissioner and a local agency shall have a right of entry to all premises in which a discharge source is or might be located or in which monitoring equipment or records required by a permit are kept, for purposes of inspection, sampling, copying or photographing.

N.J.S.A. 58:10A-30 (Underground Storage of Hazardous Substances Act)

The Department shall have the authority to enter any property or place of business where underground storage tanks or non-operational storage tanks are or may be located; to inspect said tanks or photograph any records related to their operation; and to obtain samples or evidence of discharge from the surrounding air, soil, surface or groundwater.

N.J.S.A. 13:1E-42.1 (Solid Waste Management Act)

The Department of Environmental Protection and Energy shall conduct a complete inspection, at least weekly, of each major hazardous waste facility.

N.J.S.A 13:1E-65 (Major Hazardous Waste Facility Siting Act)

The Department and the local board of health or the county health department, as the case may be, shall have the right to enter any major hazardous waste facility at any time in order to determine compliance with the registration statement and engineering design, and with the provisions of all applicable laws or rules and regulations adopted pursuant thereto.

N.J.S.A. 26:2C-9b (Air Pollution Control Act)

[The department...shall have the power to -] (4) Enter and inspect any building or place, except private residences for the purpose of investigating an actual or suspected source of air pollution and ascertaining compliance or non-compliance with any code, rules and regulations of the department.

N.J.S.A. 26:2C-9.1 (Air Pollution Control Act)

No person shall obstruct, hinder or delay, or interfere with, by force or otherwise, the performance by the department or its personnel of any duty under the provisions of this act, or refuse to permit such personnel to perform their duties by refusing them, upon proper identification or presentation of a written order of the department, entrance to any premises at reasonable hours.

N.J.S.A 58:12A-4 (Safe Drinking Water Act)

(f) The Commissioner shall have the right to enter any premises upon presentation of appropriate credentials during regular business hours, in order to test, inspect or sample any feature of a public water system and in order to inspect, copy or photograph any monitoring equipment or records required to be kept under the provisions of this act.

N.J.S.A 58:16A-9 (State Flood Control Facilities Act)

(4) Notwithstanding the provisions of any general, special, or local law, the Commissioner, his officers or agents, when engaged on flood control projects may enter upon property for the purpose of making surveys, test pits, test borings, or other investigations.

N.J.S.A. 26:2D-9 (Radiation Protection Act)

[The department shall:] (j) Enter and inspect radiation sources, their shielding and immediate surroundings and records concerning their operation for the determination of any possible radiation hazard.

N.J.S.A. 13:1F-9 (Pesticide Control Act of 1971)

[The department shall have power, in addition to those granted by any other law, to] c. Enter and inspect any building or place, except private residences, for the purpose of investigating an actual or suspected violation of law relating to pesticides and ascertaining compliance or noncompliance with any rules, regulations or order of the [D]epartment.

N.J.S.A. 58:10A-6 et. seq. (Clean Water Enforcement Act)

g. The Commissioner and a local agency shall have a right of entry to all premises in which a discharge source is or might be located or in which monitoring equipment or records required by a permit are kept, for purposes of inspection, sampling, copying or photographing.

Chapter 4

Site Entry Activities

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Chapter 4 Site Entry Activities

4.1 Introduction

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Personnel performing site investigative activities may encounter known and/or unknown hazards associated with those efforts. When it is anticipated that potentially hazardous activities are to be conducted, or where there is a potential for contact with hazardous materials or contaminants, a health and safety program must be established, and a site-specific health and safety plan (HASP) must be developed prior to any hazardous site work. Both the health and safety program and the site-specific HASP shall comply with 29 CFR 1910.120 (b)(1)(iv) and (1)(v) of the OSHA Standard for Hazardous Waste Operations.

4.2 Health and Safety Program Plans

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Below is a summary of the information that shall be provided in a written health and safety program and/or a site-specific health and safety plan:

4.2.1 Organizational Structure

A list, or organizational chart, of key personnel involved in all phases of on-site operations must be provided. It should include the functions and responsibilities of each person identified. A Health and Safety Supervisor shall have the authority and knowledge necessary to develop and implement the health and safety program and/or site-specific HASP, and, verify compliance with applicable safety and health requirements.

4.2.2 Hazard Analysis and/or Site Risk

A hazard analysis for each location and the associated tasks to be performed must be submitted. This shall include a description of the site conditions, be based upon the best information available regarding the contaminants and conditions present as well as the practices, tools and other equipment to be applied in the operation and shall include, but not be limited to, the following:

- The site's historical use
- A preliminary evaluation of the site's existing characteristics
- An evaluation of the known or suspected contaminants and conditions that may pose inhalation, skin absorption/contact, exposure or ingestion hazards
- An evaluation of known or potential safety hazards associated with each task

In summary:

- Size and location of the site
- Site topography, accessibility and special features (e.g., structures, vessels, tanks, etc.)
- Description of the operation and tasks to be performed
- Approximate duration of each operation and task
- Known or suspected pathways of contaminant dispersion pertinent to the operations and tasks performed
- Safety and health hazards expected on the site

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- Status and capabilities of emergency response teams that shall provide assistance during site emergencies, including those providing medical treatment and transport of any contaminated injured persons.

4.2.3 Training Requirements for On-Site Personnel

4.2.3.1 Pursuant to 29 CFR 1910.120, et al, all workers that are engaged in on-site activities must have met one of the following requirements prior to the start of operations at the site:

4.2.3.1.1 General site workers (such as equipment operators, general laborers, and supervisory personnel) engaged in hazardous substance removal, or other activities that expose or potentially expose workers to hazardous substances and health hazards, shall receive a minimum of 40 hours of instruction off the site, and a minimum of three (3) days actual field experience under the direct supervision of a trained, experienced supervisor.

4.2.3.1.2 Workers on site only occasionally for a specific limited task (such as, but not limited to, ground water monitoring, land surveying, or geophysical surveying) and who are unlikely to be exposed over permissible exposure limits and published exposure limits shall receive a minimum of 24 hours of instruction off the site, and a minimum of one day actual field experience under the direct supervision of a trained, experienced supervisor.

4.2.3.1.3 Workers regularly on site, who work in areas that have been monitored and are fully characterized indicating that exposures are under permissible exposure limits and published exposure limits where respirators are not necessary, and the characterization indicates that there are no health hazards or the possibility of an emergency developing, shall receive a minimum of 24 hours of instruction off the site and a minimum of one day actual field experience under the direct supervision of a trained, experienced supervisor.

4.2.3.1.4 Workers with 24 hours of training who are covered by paragraphs 4.2.3.1.2 and 4.2.3.1.3 of this section, and who become general site workers or who are required to wear respirators, shall have the additional 16 hours and 2 days of training necessary to total the training specified in paragraph 4.2.3.1.1.

4.2.3.1.5 In addition, an annual 8-hour minimum refresher course after the initial training shall be provided to all field (site) personnel in order to continue on site employment eligibility.

4.2.3.2 On-site management and supervisors directly responsible for or who supervise employees engaged in site operations, including the on-site HSO, shall have also received 8 hours additional training in managing such site operations prior to the start of site activities as stipulated in 29 CFR 1910.120.

4.2.3.3 Employees who have been designated as responsible for responding to on-site emergencies shall have received additional training in how to respond to such expected emergencies prior to the start of site operations as stipulated in 29 CFR 1910.120.

4.2.3.4 Employees who have not received the required training prior to the start of site operations are not to engage in on-site operations until such training has been completed.

4.2.3.5 The employer must maintain a summary list of the health and safety topics and elements administered to each employee.

4.2.3.6 A written certification statement of completed training and/or acquired experience for all employees designated to engage in on-site activities shall be provided. A member of top-level management, a corporate officer, or the health and safety program manager shall endorse such certification.

4.2.3.7 Site specific training and performance of daily safety briefings regarding planned operations, the site-specific HASP, the form and warning properties of potential hazards, work zones, locations of emergency/safety equipment, local emergency response procedures and any changes in site characteristics, levels of protection, communications, decontamination procedures, emergency facilities and signals, and evacuation procedures shall be conducted.

4.2.4 Engineering Controls and Personnel Protection

4.2.4.1 The need to apply engineering and/or work practice controls as a means of protecting personnel in the performance of site-specific tasks must be considered. When practicable, engineering controls shall be implemented to reduce and maintain employee exposures to or below safe levels for those tasks demonstrating known or suspected hazards. Work practice controls shall next be applied when engineering controls are impractical and shall be incorporated as site-specific standard operating procedures (SOPs) for personnel precautions and routine operations.

4.2.4.2 Personnel Protective Equipment (PPE) and Levels of Protection

4.2.4.2.1 The use of personnel protective equipment (PPE) should be considered only when engineering and/or work practice controls have been deemed impractical or insufficient to protect employees during site operations.

4.2.4.2.2 The selection of PPE shall be based on an evaluation of performance characteristics, site-specific tasks and known, or suspected hazards, and shall assemble the PPE into Levels of Protection (LOPs), or ensembles appropriate for the site.

4.2.4.2.3 HASPs shall include a list of components for each protective ensemble, the LOP selected for each task, the rationale for each task-specific selection, and any contaminant action levels to be followed in LOP decision making.

4.2.4.2.4 If the site-specific HASP provides for respiratory protection, it shall include a description of the respiratory protection program and the method of respirator fit testing employed.

4.2.4.2.5 Only NIOSH/MSHA approved respiratory protective equipment shall be used. Any other PPE selected shall be in conformance with appropriate ANSI standards for that equipment.

4.2.4.2.6 A PPE program must address the following elements:

- Site hazards
- PPE selection
- PPE use and limitations
- Duration of site operations
- PPE maintenance and storage
- PPE decontamination and NJDEP approved disposal
- PPE training and proper fit
- Donning and doffing procedures

- PPE inspection prior to, during and after use
- Evaluation of program effectiveness
- Heat stress and temperature limitations

For further information regarding PPE see Chapter 14.

4.2.5 Medical Surveillance Program

4.2.5.1 A medical surveillance program (MSP) for employees engaged in on-site operations must be implemented if any of the following 29 CFR 1910.120(b) criteria are met:

4.2.5.1.1 All employees who are, or may be, exposed to hazardous substances, or health hazards, at or above the permissible exposure limits, or if there is no permissible exposure limit, above the published exposure levels for these substances, without regard to the use of respirators, for 30 days or more a year.

4.2.5.1.2 All employees who wear a respirator for 30 days or more a year or as required by 29 CFR 1910.134/139

4.2.5.1.3 All employees who are injured due to overexposure from an emergency incident involving hazardous substances or health hazards.

4.2.5.1.4 Members of HAZMAT teams.

4.2.5.2 The employer shall retain all medical surveillance records and personnel exposure monitoring data for 30 years as described in Subpart C of 29 CFR 1910.120.

4.2.5.3 The employer shall provide written certification of the medical fitness for work of all employees designated to engage in on-site operations prior to the start of those operations. A member of senior management, a corporate officer shall endorse such certification, or the health and safety program manager and shall be incorporated into the site HASP.

4.2.5.4 As dictated by seasonal conditions, heat and/or, cold stress monitoring shall be incorporated the health and safety program and into the site-specific HASP. The program shall include employee awareness of the signs and symptoms of heat and/or cold stress, preventive measures, and employee and/or environmental parameters that will be measured. The employer shall maintain a daily heat and/or cold stress log on all employees wearing protective ensembles on-site and shall describe the log in the site HASP.

4.2.6 Air Monitoring

4.2.6.1 Site Specific Monitoring

An air-monitoring program must be implemented to identify areas of elevated airborne contaminant concentrations and to determine the level of the concentrations relative to background. The employer shall provide the personnel, instruments, and materials necessary to perform such air monitoring and identify the individual responsible for administering the program. The air-monitoring program shall be included in the HASP and contain the following information.

4.2.6.1.1 Type, make, and model of instrument(s) selected for use

4.2.6.1.2 All instrument settings for each instrument used

4.2.6.1.3 Method of instrument calibration, including calibrant and sample calibration data sheet

4.2.6.1.4 Method of field checks, including field check materials and record of checks

4.2.6.1.5 Manner and frequency of calibration and pre and post (or greater) field checks

4.2.6.2 Areal and Personnel Air Sampling

4.2.6.2.1 The need, or lack thereof, to develop and implement areal and personnel air sampling programs during the project must be evaluated and shall be included in the site HASP.

4.2.6.2.2 Special considerations shall be given to intrusive or high-risk tasks and the potential for exposure to those performing such tasks.

4.2.6.2.3 All necessary sampling devices, pumps, collection media, and support equipment to perform the air sampling must be provided and identified in the HASP. The sampling devices and pumps must bear all approvals necessary for use in combustible or flammable atmospheres.

4.2.6.2.4 The sampling devices, pumps, collection media, and any necessary support equipment shall be appropriately calibrated according to the manufacturer's specifications and field checked on a regular basis to insure it is functioning properly.

4.2.6.2.5 A daily sampling record must be established as part of the air-sampling program. Depending on the contamination present and the complexity of the sampling event, the record shall include the following:

- Collection date
- Sample identification number
- Location and/or task monitored
- Wind speed and direction during each sample collection period
- Duration of each sample collected, including the start/stop times of each sample
- Ambient temperature and humidity of sampling period
- Pre-and post sampling train flow-rate checks
- Instrument readings, calibration and field checks
- Any pertinent comments

4.2.6.2.6 When required, the laboratory selected for sample analysis must be accredited by the AIHA for the analysis required. Sampling and analytical methods of first NIOSH, then OSHA, must be used preferentially when such methods are available for the samples collected and all appropriate QA and QC provisions regarding sample collection, transport, and holding times must be followed.

4.2.6.3 Records Retention and Data Reporting

4.2.6.3.1 The employer shall retain all personnel exposure sampling results and monitoring data in accordance with the requirements set forth in OSHA, Subpart C of 29 CFR 1910.120. The employer shall follow all other pertinent provisions of that regulation.

4.2.6.3.2 A daily air-monitoring log shall include, as a minimum, the following information:

- Monitoring date
- Location and/or task monitored
- Wind speed, direction, ambient temperature, and humidity
- Instruments used including make and model and all instrument settings
- Instrument readings

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- Pertinent comments or information
- Results of instrument calibration checks, including date and time of each check, the calibration agent used, and its concentration, for each instrument employed.

4.2.7 Site Control

4.2.7.1 Personnel or equipment leaving the site shall conduct operations at the site in such a controlled fashion as to reduce the possibility of contact with any contaminants present and to prevent the removal of contaminants. Work zones will be delineated in which specific operations, or tasks, will occur and site entry and decontamination procedures at designated control points will be identified.

4.2.7.2 Three work zones shall be established to perform this work: an exclusion (contaminated) zone, a contamination reduction zone and a support (clean) zone. A map or diagram showing the specific work zones and a description of the site control plan shall be included in the HASP.

4.2.7.3 A daily site entry control log shall be kept. The log shall include:

- Personnel visiting the site
- Affiliation
- Date
- Arrival time
- Departure time
- Purpose of visit and locations visited

4.2.7.4 All unauthorized personnel must be prevented from entering exclusion zones of the site.

4.2.8 Decontamination

4.2.8.1 All contaminated personnel and equipment exiting the exclusion zone, or other potentially contaminated areas, must be decontaminated prior to entering the support zone, or leaving the site. This decontamination must be performed in order to prevent contamination from being transferred into clean areas and contaminating or exposing unprotected personnel.

4.2.8.2 Personnel and equipment decontamination procedures appropriate for the site shall be included the site HASP. The procedures shall include the necessary equipment and number of steps to achieve the objective, provisions for any personnel protection, and a diagram outlining the steps or stations in the procedures.

4.2.8.3 The procedures must ensure adequate containment and removal of any decontamination solutions and spent disposable protective apparel.

4.2.8.4 Provisions shall be made to facilitate personal hygiene at breaks and following daily operations. Where decontamination procedures indicate shower usage and change rooms away from the exclusion zone, they shall meet the requirements of 29 CFR 1910.141 and 1926.51.

4.2.9 Emergency Contingency Planning

4.2.9.1 Emergency Response Plan, (ERP) to handle anticipated on-site emergencies, must be developed prior to the start of site operations.

4.2.9.2 The ERP shall be incorporated into the site HASP as a separate section of that document and shall be periodically reviewed and amended, as necessary, to keep it current with new or changing site conditions or information.

4.2.9.1.1 The ERP shall address, as a minimum, the following:

- Preplanning of site operations to prevent emergencies
- Personnel roles and lines of authority
- Key personnel at the site authorized and responsible for implementing the plan
- Emergency recognition and control measures
- Evacuation routes and procedures, and the frequency of emergency drills
- Safe distances and places of refuge
- Emergency security and site control measures
- Decontamination measures not previously listed in the HASP and specific for all anticipated emergencies.
- Emergency medical treatment and first aid
- Emergency alerting and response procedures
- Site communications
- Site diagrams showing general layout, work zones, and prevailing weather conditions
- Procedures for reporting incidents to pertinent local, state, and Federal agencies
- A list of emergency telephone contacts including the name, location, telephone number, written directions and a route map to the nearest medical facility that will provide emergency medical services.
- Measures to review and follow up on site responses
- Emergency and personal protective equipment kept at the site for emergencies, with an equipment list and a drawing indicating their on site location.

4.2.9.1.2 Prior to start up of site operations, local officials and/or those responsible for local emergency management and public safety shall be notified. These agencies include but are not limited to:

- Fire
- Ambulance
- Police
- Local/County health officials
- Gas company

4.2.9.1.3 Special First Aid/CPR Training – At least one person holding up-to-date certifications (American Red Cross or equivalent) in basic first aid and CPR is present at the site during all site operations.

4.2.9.1.4 Verification of Medical Facility Preparedness – A local medical facility shall be selected for inclusion into the ERP to ensure that said facility is willing and is capable of providing that medical support necessary to satisfy those anticipated hazards and emergencies detailed in the ERP. Material Safety Data Sheets (MSDS), product information, or any technical information on hazard, exposure and treatment of anticipated/known hazards should be provided to the medical facility

4.2.10 Confined Space Operations

4.2.10.1 Should site operations include activities within confined spaces, a confined space entry program and relevant SOPs shall be incorporated into the HASP pursuant to 29 CFR 1910.146.

If the confined space entry meets the OSHA definition of a permit required confined space entry, then a section addressing such entries shall be included in the HASP.

4.2.10.1.1 An Entry Permit System must be developed to ensure that the following are addressed and complied with:

- A confined space entry training program
- Identification of all confined spaces to all employees
- Identification of hazards in the confined space
- A system of monitoring for atmospheric hazards
- A system of calibration of monitoring equipment
- A system of barricades, to prevent unauthorized entry
- A system of identifying authorized entrants, attendants, rescuers and those authorized to sign the entry permit
- A procedure for emergency evacuation
- Emergency rescue procedures
- Procedures to test the program to ensure effectiveness

4.2.10.1.2 Pre-entry briefings shall be held prior to initiating any confined space entries and at other times as necessary to ensure that employees are aware of the HASP provisions governing such activities and that the special provisions are being followed. The completed permit shall be made available at the time of entry to all authorized entrants, by posting it at the point of entry or by any other equally effective means, for assurance that the pre-entry preparations have been completed.

4.2.10.2 Inspections shall be conducted by a Health and Safety Officer or, in the absence of that individual, another qualified individual acting on behalf of the HSO as necessary to determine the effectiveness of the confined space SOP with regard to those confined spaces identified on site

4.2.10.3 A qualified individual shall test the atmosphere of the confined space prior to entry and during work to ensure that all measures necessary to protect the health and safety of employees entering have been taken. Monitoring shall be appropriate for the contaminant(s) that are known or suspected of being present in the space.

4.2.10.4 The employer shall provide appropriate protective and entry equipment for all entrant personnel necessary for the Permit Required entry. On site rescue personnel must be present or off site rescue must be able to respond to the site within 3 minutes of notification. Equipment necessary for a rescue must be identified and present at the point of entry.

4.2.10.5 Federal OSHA training requirements for all personnel involved in confined space entry must be complied with. A training program must be administered to all personnel involved in confined space entry before entrance can be initiated. Rescue teams shall practice at least annually at the confined space or at representative openings having the same size, configuration and accessibility as the confined space from which an actual rescue would be performed. A record of training and authorized personnel shall be kept on-site and listed in the HASP.

4.2.11 Other Special Operations

4.2.11.1 Spill Containment - A spill containment program shall be developed and written, when required, to handle the possibility of a spill or leakage of drummed or containerized hazardous

materials. The contractor shall identify the following on-site and off-site personnel and equipment or services necessary to isolate, contain and mitigate the spill:

- Clean up contractor or personnel
- Estimate of response time of off site contractors
- Spill containment procedures (diking, over pack, etc.)
- Special safety precautions (fire, corrosive, radioactivity, etc.)
- Equipment and supplies on hand at site or readily available to respond to contain and clean up the spill

4.2.11.2 Excavations and Trenching - All excavation work shall comply with 29 CFR 1926, Subpart P and other state and federal regulations governing excavations and trenching. The need to perform any excavations or trenching as part of the site operations must be described in the HASP. Information shall include, but not be limited to:

4.2.11.2.1 Detailed methods of preparing the trench or excavation including descriptions of sloping, shoring and guarding.

4.2.11.2.2 Observation of proper equipment spacing, use of barriers, means of exit, and placing of machinery and spoils.

4.2.11.2.3 Training of personnel working around and in trenches and excavations in such operations to assure knowledge of hazards, safe operations and procedures to be followed in the event of an emergency.

4.2.11.2.4 Measures to be taken to avoid overhead electric lines, underground utilities, storage structures, and service passageways and include in the HASP drawings, measurements and descriptions. All pertinent sections of 29 CFR 1910, Subpart S and 29 CFR 1926, Subpart K for electrical safety must be complied with and identified in the HASP.

4.2.11.2.5 No ground intrusive work (including excavation, trenching, digging, probing, boring and drilling) is to commence without a **current** under ground utility mark out as per N.J.S.A. 48:2-73 and in compliance with OSHA Regulation 1926.651. This includes, but is not limited to all gas, water, sewer, cable, phone and electric or process related utilities. The One-Call system (1-800-727-1000) must be notified not less than 3 full business days before digging. Other means of locating underground utilities must be identified for utilities not covered by One-Call system. The One Call Markout Ticket Confirmation Number(s) will be recorded in the HASP, or at a minimum, be kept at the site for the duration of any ground intrusive work during the project.

4.2.11.3 Hot Work – The performance of Hot Work such as welding, cutting, etc. during site operations must be addressed in the HASP. A Hot Work “Permit” procedure must be included in the HASP if hot work is performed and must comply with the sections of OSHA 1910.119(k), OSHA 1910.146 and OSHA 1926.64 (k) et al as they apply to these operations.

4.2.11.3.1 All hot work procedures should be outlined and shall comply with both state and local fire codes as well as with OSHA regulations.

4.2.11.3.2 All electrical supply wiring and distribution shall comply with the local and National Electric Codes, as well as any state and OSHA 1926.400 Subpart K, governing such installations.

4.2.11.3.3 Proper utilization and storage of flammable cutting gases and other compressed gases shall comply with the requirements of OSHA 1926.350 et al. All gas cylinders shall be secured to prevent falling or potential damaged.

4.3 General Safety Measures

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4.3.1 Personal Practices

4.3.1.1 Levels of protection shall be established for a given site and shall be based upon the best available information regarding known or suspected hazards and the type of planned activity. Activities shall then be performed in accordance with those site-specific levels of protection. Changes in levels of protection should be made only when the level of site specific information improves sufficiently to warrant any change. When sufficient information is lacking or when the conditions of a site are unknown, or in doubt, all site entries and on-site activities will be performed in Level B protection, as a minimum, until the knowledge on site-specific hazards has improved.

4.3.1.2 The use of respiratory protective equipment shall be in accordance with current OSHA requirements. Air purifying respirator cartridges should be changed at least once each workday on-site. Only NIOSH/MSHA approved respirators shall be used. (See Chapter 15, *Personnel Protection*.)

4.3.1.3 Eating, drinking, chewing gum or tobacco, smoking or any other practice which increases the tendency for hand-to-mouth contact shall be prohibited within the contaminated zone(s) and prior to washing hands and face within the contamination reduction corridor or decontamination line.

4.3.1.4 Medicine and alcohol can intensify the effects of exposure to toxic chemicals. Alcohol, caffeine products and certain medications can contribute to and exacerbate the effects of heat stress. Personnel during site activities should not take prescription and non-prescription drugs when the potential for absorption, inhalation, or ingestion of toxic substances exists, unless specifically approved by a qualified physician. The intake of alcoholic or caffeine beverages should be avoided during response activities.

4.3.1.5 Contact with surfaces known or suspected of being contaminated should be avoided during on-site activities. Avoid walking through puddles, mud, or discolored surfaces; kneeling on ground; leaning, sitting, or placing equipment on drums.

4.3.1.6 All personnel connected with a site and engaging in field activities must be familiar with standard operating safety procedures and any additional instructions contained in the Site Safety Plan. Further, all personnel, upon their initial visit to a site, shall read the HASP before performing any site related activities and shall confirm that reading with their signature.

4.3.2 Operations Management

4.3.2.1 For sites where entry/work is to be conducted in contaminated areas, a site map designating work zones must be established prior to any initial site entry and all individuals involved must be familiar with it. The zones are to be connected by Access Control Points to restrict entry and exit. Work zones can be adjusted as more becomes known about the site. The designated work zones include:

4.3.2.1.1 **The Exclusion or Contamination Zone** - The area suspected to contain contamination, or uncontrolled hazardous substances. This zone may be divided into subsets based upon varying levels of hazard and/or the nature of the tasks to be performed.

All personnel within the Exclusion Zone must wear the required level of protection based on those site-specific conditions.

4.3.2.1.2 **The Contamination Reduction Zone** - The buffer area provides a transition between contaminated and clean zones. This zone is to contain any decontamination activities deemed necessary and must be separated from the Exclusion Zone by the Hot Line and from the Support Zone by the Contamination Control Line.

4.3.2.1.3 **The Support Zone** - This is the outermost part of the site, which is considered to be clean or uncontaminated. This zone is the location for command posts and site support facilities. It should be positioned upwind of the Exclusion Zone.

4.3.2.2 Communications using radios or other means must be maintained between initial entry members at all times. Emergency communications should be prearranged in case of radio failure, necessity for evacuation of site or other reasons.

4.3.2.3 Before proceeding on-site, consideration must be given to the manpower requirements necessary for the job. Due to the nature of hazardous materials, especially materials of unknown concentrations, a minimum of two persons should be present. Under no circumstances should field personnel go on site alone. In extremely hazardous situations, two teams of personnel should be employed: one sampling team and one backup/rescue team. Personnel on-site must use the “buddy system” when wearing respiratory protective equipment. At a minimum, a third person, suitably equipped, as a safety backup is required during initial entries. Visual contact must be maintained between “pairs” on site and safety personnel. Entry team members should remain close together to assist each other during emergencies. During continual operations, on-site workers act as safety backup to each other. Off-site personnel provide emergency assistance.

4.3.2.4 A Pre-Work Safety Meeting must be conducted among personnel present at a site prior to:

- The start of each day’s activities
- Changes in shift
- The arrival of new or additional personnel to a site
- The further performance of site activities following the occurrence of any significant changes on site. Topics to be covered should include the use of necessary protective clothing and equipment, chemical and physical hazards, tasks to be performed, special equipment or procedures, and emergency contacts and procedures to be followed.

4.4 Site Entry And Reconnaissance

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4.4.1 Objectives

- Characterize the hazards that exist or potentially exist and may affect the public health, the environment, and response personnel
- Verify existing information and/or obtain data about the site
- Evaluate the need for prompt mitigative action
- Collect supplemental information to determine the safety requirements for personnel initially and subsequently entering the site
- Perform simple or immediate mitigative actions when necessary

4.4.2 Preliminary Off-Site Evaluation

4.4.2.1 The need to enter a site must be based on some type of preliminary hazard evaluation. Prior to performing any initial site entry, an effort should be made to collect and examine as much information (records, off-site studies, shipping manifests, transportation placards, container types and labels, etc.) about the site as possible. The information should primarily concern real or potential hazard(s), degree(s) of severity, and the associated risk(s). Subsequent site entries should only be made after examining similar information gathered during previous entries.

4.4.2.2 Off-site (peripheral) atmospheric monitoring must be conducted prior to any initial site entry and must be incorporated into plans for any subsequent on-site activities. Individuals performing such monitoring should maintain upwind positions when possible and utilize proper personal protective equipment. When off-site readings become significant, the site Health and Safety Plan must be adjusted to maintain safety.

4.4.3 Preliminary On-Site Evaluation

4.4.3.1 The initial site entry process is to be considered a rapid site screening procedure for the collection of preliminary data on any immediate hazards. Fire, explosion, oxygen-deficient atmospheres, radiation, airborne contaminants, containerized or pooled hazardous substances could affect workers during subsequent operations. For the purpose of monitoring, on-site hazards may be placed into several groups. (See Table 4.1 at the end of this Chapter).

4.4.3.1.1 Combustible Gases - The presence or absence of combustible vapors or gases must be determined. If readings approach or exceed 5% of the lower explosive limit (LEL), extreme caution should be exercised in continuing the investigation. If readings approach or exceed 10% LEL, personnel should be withdrawn immediately. Before resuming any on-site activities, project personnel, in consultation with experts in fire or explosion prevention, must develop procedures for continuing operations.

4.4.3.1.2 Oxygen deficiency - At sea level, ambient air must contain at least 19.5% by volume of oxygen. At lower percentages, air-supplied respiratory protective equipment is needed. Oxygen measurements are of particular importance for work in confined spaces, low-lying areas, or in the vicinity of accidents that have produced heavier-than-air vapors, which could displace ambient air. These oxygen-deficient areas are also prime locations for taking organic vapor and combustible gas measurements, since other substances have displaced the air. Oxygen-enriched atmospheres increase the potential for fires.

4.4.3.1.3 Organic gases and vapors - If the type of organic substance(s) present at a site is known and is volatile or can become airborne, air measurements should be made with one or more appropriate, properly calibrated survey instruments or established sampling techniques.

4.4.3.1.3.1 When the presence, or identity of organic vapors/gases are unknown, instruments such as a portable photoionization detector and or, a portable hydrocarbon gas/vapor analyzer, operated in the general survey, or total readout mode, should be used. The readings obtained in this mode indicate total atmospheric concentrations to which the instrument is responding. Identification of the individual components may permit some instruments to be specifically calibrated and used as analytical tools.

4.4.3.1.3.2 Sufficient data should be obtained during the initial entry to map or screen the site for various levels of organic vapors. These gross measurements can be used on a preliminary basis to: 1) determine levels of personnel protection, 2) establish site work zones, and 3) select candidate areas for more thorough qualitative and quantitative studies. Readings in excess of background concentrations may indicate toxic levels as well as the displacement of oxygen or the presence of combustible vapors. For the purpose of “Levels of Protection” decision-making, the following scheme should be used when only gross concentration data are available:

- **Level C** - 0 to 5 ppm above background when measured in the breathing zone and when sustained for a 15-minute period or longer.
- **Level B** - greater than 5 ppm up to 500 ppm above background when measured in the breathing zone.
- **Level A** - greater than 500 ppm up to 1000 ppm above background, general ambient concentration.

4.4.3.1.3.3 Readings in excess of 1000 ppm above background shall result in withdrawal from the site of all on-site personnel and shall trigger reassessment of site conditions and further on-site activities.

4.4.3.1.3.4 When the contaminant present are known, the Levels of Protection utilized can be based on OSHA regulated Permissible Exposure Limits (PELs).

4.4.3.1.4 Inorganic gases and vapors - The ability to detect and quantify nonspecific inorganic vapors and gases is extremely limited. If specific inorganics are known, or suspected to be present, measurements should be made with appropriate instruments.

4.4.3.1.5 Radioactive materials - Radiation monitoring should be incorporated in the initial survey where radioactive materials may be present, for example, fires at warehouses or hazardous material storage facilities, transportation incidents involving unknown materials, or abandoned waste sites.

4.4.3.1.5.1 Normal gamma radiation background is approximately 0.01 to 0.02 milliroentgen per hour (mR/hr) on a gamma survey instrument. Work can continue with elevated radiation exposure rates, however, if the exposure rate increases to 3-5 times above gamma background, a qualified health physicist should be consulted. At no time should work continue with an exposure rate of 0.1 mR/hr or more above background without the advice of a health physicist. The Bureau of Emergency Response and the Radiation Protection Programs within NJDEP have radiation specialists on staff for assistance.

4.4.3.1.5.2 The absence of gamma readings above background should not be interpreted as the complete absence of radioactivity. Radioactive materials emitting low-energy Γ (gamma), α (alpha), or β (beta) radiation may be present, but for a number of reasons may not cause a response on the instrument. Unless airborne, these radioactive materials should present minimal hazard but more thorough surveys should be conducted as site operations continue to completely investigate the presence of any radioactive material.

4.4.3.1.6 Direct Reading Instruments - A complex variety of toxic air pollutants (including organic and inorganic vapors, gases, or particulates) can be produced at abandoned waste sites. Direct-reading field instruments will not detect or measure all of these

substances. Thus negative readings should not be interpreted as the complete absence of airborne toxic substances. Verification of negative results can only be done by collecting air samples and analyzing them in a laboratory or in an off-site location using portable analyzers.

- 4.4.3.1.7 Visual Observations - While on-site, the entry team should make visual observations to help evaluate site hazards, for example: animals, stressed vegetation, wind direction, labels on containers indicating explosive, flammable, toxic or corrosive materials, conditions conducive to splash or contact with unconfined liquids, sludges, or solids, and other potentially hazardous conditions.
- 4.4.3.2 Although the initial entry is considered a rapid activity, its duration can be quite variable. The time actually needed to conduct the initial survey depends on the urgency of the situation, type of incident, information needed, size of site, availability of resources, level of protection required for site entry personnel, etc. Consequently, initial surveys may need hours or days to complete and consist of more than one entry. Because of this variability, priorities must be established for atmospheric monitoring during a given initial entry operation. The following conditions must be considered when developing those priorities.
 - 4.4.3.2.1 The immediate concern to initial entry personnel is atmospheric conditions, which could affect their safety. These conditions are airborne toxic substances, combustible gases or vapors, lack of oxygen, and to a lesser extent, ionizing radiation. Priorities for monitoring these potential hazards must be established after careful evaluation of known or suspected conditions before initiating entry.
 - 4.4.3.2.2 When the type of material(s) involved in an incident are identified and release into the environment is suspected or known, the material's chemical/physical properties and the prevailing weather conditions may help determine the order of monitoring. An unknown substance(s) presents a more difficult monitoring problem.
- 4.4.3.3 In general, for poorly ventilated spaces (e.g., buildings, sewers, boxcars, or bulk tanks) which must be entered, combustible vapors/gases and oxygen-deficient atmospheres should be monitored first with team members wearing, as minimum, Level B protective equipment. Toxic gases/vapors and radiation should be measured as the next priority. Further, such spaces may be confined spaces and, therefore, special confined space entry procedures must be followed.
 - 4.4.3.3.1 For open, well-ventilated areas, combustible gases and oxygen deficiency are lesser hazards and require lower priority. However, areas of lower elevation on-site (such as excavations, ditches and gullies) and downwind areas may have combustible gas mixtures, in addition to toxic vapors or gases, and may lack sufficient oxygen to sustain life. Entry teams, therefore, must exercise caution by approaching and monitoring from upwind areas.
 - 4.4.3.3.2 Any indication of atmospheric hazards (toxic substances, combustible gases, and lack of oxygen, radiation, and other specific materials) should be viewed as a sign to proceed with care and deliberation. Readings indicating non-explosive atmospheres, low concentrations of toxic substances, or other conditions may increase or decrease suddenly thereby changing the associated risks. Extreme caution must be exercised in continuing site entry activities when atmospheric hazards are indicated. Table 4.1 provides some guidelines for use during preliminary on-site evaluations.

Table 4.1 Atmospheric Hazard Guidelines			
Monitoring Equipment	Hazard	Level	Action
Combustible Gas Indicator	Explosive atmosphere	<5% LEL	Continue investigation.
		5%-10%	Continue on-site monitoring with extreme caution as higher levels are encountered.
		>10% LEL	Explosion hazard: withdraw from area immediately.
Oxygen concentration meter	Oxygen	<19.5%	Monitor wearing SCBA. NOTE: Combustible gas readings are not valid in atmospheres with <19.5% oxygen.
		19.5-23%	Continue investigation with caution, SCBA not needed, based on oxygen content only.
		>23.0%	Discontinue inspection; fire hazard potential. Consult specialist.
Photoionization Detector	Organic vapors/gases	Depends on species	Consult standard reference manuals for air concentration/toxicity data.
		Total response mode	For unknown contaminants. Use strict guidelines to determine level of protection
Flame Ionization Detector	Organic gas/vapor	Depends on species	Consult standard reference for air concentrations/ toxicity data.
		Total response mode	For unknown contaminants, use strict guidelines to determine level of protection
Radiation survey	Radiation		Review text, Section 3.v. "Radiation materials". Consult Radiation Protection Program for information regarding hazard levels.

4.4.4 Other Considerations

4.4.4.1 Atmospheric hazards in off-site areas peripheral to the on-site zone must be periodically monitored with direct-reading instruments. Peripheral monitoring should include upwind readings within any established decontamination areas as well as within and near any command post. It is suggested that no fewer than four (4) readings be taken in each designated off-site area for each eight- (8) hour workday. Negative readings off-site should not be considered a definite indication of local atmospheric conditions, but only another piece of information to assist in the preliminary evaluation. When possible, atmospheric samples should be collected before the initial site entry is begun.

4.4.4.2 Because monitoring performed during the initial site entry produces only a preliminary evaluation of atmospheric hazards; a program for periodic on-site evaluation must be established. Materials detected during the initial entry survey require a more comprehensive examination of on-site hazards and analyses for specific components. Since site activities and weather conditions change, a continuous program to monitor atmospheric changes must be implemented utilizing a combination of monitoring and sampling techniques.

4.4.4.3 It is imperative that personnel using monitoring instruments be thoroughly familiar with their use, limitations, and operating characteristics. All instruments have inherent constraints in their ability to detect and/or quantify the hazards for which they were designed. Unless trained personnel use the instruments and assess data readout, airborne hazards can be grossly misinter-

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preted, endangering the health and safety of response personnel. In addition, only safety tested and approved instruments should be used until the absence of combustible gases or vapors can be confirmed.

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Chapter 5

Sampling Equipment

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References

USGS Links of Interest

USEPA Links of Interest

Other URLs of Interest

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Chapter 5

Sampling Equipment

5.1 Introduction

Collection of environmental and waste samples often requires various types of sampling equipment to compliment specific situations encountered in the field. Selection of approved sampling equipment is based on the sample type, matrix, and physical location of the sample point and other site-specific conditions. Consideration must also be given to the compatibility of the material being sampled with the composition of the sampler.

This chapter addresses sampling equipment for the following types of environmental samples: soil, sediment, ground water, surface water and air; wastewater samples; biological samples; and residual and waste samples which are comprised of process wastes or other man-made waste materials. This chapter is divided into two sections: *Aqueous and Other Liquid Sampling Equipment*, which is further divided into ground water, wastewater, surface water, and containerized liquids and; *Non-Aqueous Sampling Equipment*, which is further divided into soil, sediment, sludge, and containerized solids/waste piles. Table 5.3, at the end of this chapter, lists NJDEP recommended waste material samplers and their application.

In order to minimize interference and cross contamination, all environmental, residual and waste sampling equipment used for the collection of environmental samples should be of polytetrafluoroethylene (PTFE, e.g., Teflon®), stainless steel or of a material approved or required for a specific parameter. PTFE is always the preferred material, but may not always be practical. Therefore, there are specific conditions under which material other than PTFE may be used. Some of these include the use of stainless steel equipment for soil and sediment sampling, carbon steel split spoons for soil sampling at depth, or disposable bailers constructed of polyethylene for the collection of ground water samples being analyzed for inorganics. In some cases of surface water, potable and wastewater sampling, collection directly into the laboratory provided sample container eliminates the need for sampling equipment, as well as field blank quality assurance samples. Use Table 5.1 as a guide for construction material of ground water sampling equipment.

While the preferred material of construction for sampling equipment used in waste sampling is PTFE or stainless steel, collection of some waste samples may not be possible with standard equipment. Therefore, alternate equipment constructed of different material may be necessary (e.g. glass COLOWASA or drum thief). In all cases, the material of construction should be compatible with the sample being collected and should not interfere or be reactive with the parameters of concern.

This chapter lists and describes a wide variety of sampling equipment, their application, and a brief description of how to use them. Not all equipment presented here is applicable in all sampling situations. This chapter should be used along with the information provided in Chapter 6, *Sample Collection*, to assist in selecting the most appropriate sampling equipment. It is recognized that the dynamics of environmental sampling and related technological advances bring to the market sampling equipment that may not be included in this text. Aside from the NJDEP, the USEPA, U.S. Geological Survey, the U.S. Department of Defense, the U.S. Army Corps of Engineers, the American Society for Testing and Materials and other state and federal governmental agencies are continually active in testing and reviewing various types of sampling equipment and methodologies. Check the URLs at the end of this chapter for web sites offering reviews or discussion related to sampling equipment. Should interest in a novel approach be considered, it is recommended that the assigned NJDEP site or case manager grant approval before proceeding. Participants orchestrating sampling episodes under

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Table 5.1 Materials of Construction for Ground Water Sampling Equipment			
Construction Material for Sampling Equipment (Does Not Apply to Well Casing)		Target Analyte(s)	
Material	Description	Inorganic	Organic
Plastics¹			
Fluorocarbon polymers ² (other varieties available for differing applications)	Chemically inert for most analytes.	√ (Potential source of fluoride.)	√ (Sorption of some organics.)
Polypropylene	Relatively inert for inorganic analytes.	√	Do not use.
Polyethylene (linear)	Relatively inert for inorganic analytes.	√	Do not use.
Polyvinyl chloride (PVC)	Relatively inert for inorganic analytes.	√	Do not use.
Silicon	Very porous. Relatively inert for most inorganic analytes.	√ (Potential source of Si.)	Do not use.
Metals³			
Stainless Steel 316 (SS-316)	SS-316 Metal having the greatest corrosion resistance. Comes in various grades. Used for submersible pump ³ casing.	√ (Potential source of Cr, Ni, Fe, and possibly Mn and Mo. Do not use for surface water unless encased in plastic (does not apply to submersible pumps).	√ Do not use if corroded. ⁴
Stainless Steel 304	Similar to SS-316 but less corrosion resistant.	Do not use	√ Do not use if corroded. ⁴
Other metals: brass iron, copper, aluminum, galvanized and carbon steels	Refrigeration-grade copper or aluminum tubing are used routinely for collection of ³ H/ ³ He and CFC samples	Do not use	√ Routinely used for CFCs. Do not use if corroded.
Glass			
Glass, borosilicate (laboratory grade)	Relatively inert. Potential sorption of analytes.	√ Potential source of B and Si.	√
<p>¹ Plastics used in connection with inorganic trace-element sampling must be uncolored or white.</p> <p>² Fluorocarbon polymers include materials such as Teflon™, Kynar™, and Tefzel™ that are relatively inert for sampling inorganic or organic analytes.</p> <p>³ Most submersible sampling pumps have stainless steel components. One can minimize effects on inorganics sample by using fluorocarbon polymers in construction of sample-wetted components (for example, for a bladder, stator, or impeller) to the extent possible.</p> <p>⁴ Corroded/weathered surfaces are active sorption sites for organic compounds.</p> <p>√ Generally appropriate for use shown; Si, silica; Cr, chromium; Ni, nickel; Fe, iron; Mn, manganese; Mo, molybdenum; ³H/³He, tritium/helium-3; CFC chlorofluorocarbon; B, boron.</p>			

Table taken from the U.S. Geological Survey's Book 9, *Handbooks for Water-Resources Investigations, National Field Manual for the Collection of Water-Quality Data*, Chapter A2, *Selection of Equipment for Water Sampling*, (<http://water.usgs.gov/owq/FieldManual/>)

the auspices of the Site Remediation Program may contact the Bureau of Environmental Measurements and Site Assessment with related equipment questions. Sample collection inquiries of a more ecological nature may contact the Bureau of Freshwater and Biological Monitoring. The Technical Requirements for Site Remediation (N.J.A.C. 7:26E) offer an avenue for contractors to proceed with an innovative sampling approach should that technique be documented in peer reviewed scientific journals.

Selection of sampling equipment should always take into consideration its proper decontamination before use and, in the case of ground water sampling, the dedication of decontaminated equipment to individual wells for each day's sampling. Where general rules do not apply and alternate equipment is necessary, acceptability of its use will be determined on a case by case basis by NJDEP.

5.2 Aqueous And Other Liquid Sampling Equipment

Liquids, by their aqueous nature, are a relatively easy substance to collect. Obtaining representative samples, however, is more difficult. Density, solubility, temperature, currents, and a wealth of other mechanisms cause changes in the composition of a liquid with respect to both time and space. Accurate sampling must be responsive to these dynamics and reflect their actions.

The following discussion is subdivided into four sections: ground water; wastewater; surface water; and containerized liquids. The ground water section is concerned with obtaining samples from subsurface waters. The wastewater section previews manual and automatic samplers. The surface water section includes any fluid body, flowing or otherwise, whose surface is open to the atmosphere. The containerized liquid section will address sampling of both sealed and unsealed containers of sizes varying from drums to large tanks. Overlap may occur between sections as some equipment may have multiple applications; when in doubt, all sections should be consulted.

5.2.1 Ground Water Sampling Equipment

The importance of proper ground water sampling cannot be over emphasized. Even though the monitor well or temporary well point may be correctly located and constructed, precautions must be taken to ensure that the collected samples are representative of the ground water at that location. Extreme care must be taken to ensure that the sample is neither altered nor contaminated by the sampling equipment, sampling process or the sample handling procedure. This care extends to any purging equipment chosen to prepare the well for sampling.

Water within the well casing and filter pack may not be entirely representative of the overall ground water quality at the site. At the screened interval, this may be due to the presence of drilling fluids or general substrate disturbance following construction. Within the water column above the screen, physical and chemical conditions may vary drastically from conditions in the surrounding water-bearing zones. For these reasons, *one* of the following three general procedures must be employed prior to sample collection: 1) standing water above the screened interval must be evacuated *from the top* of the water column; 2) water within the screened interval must be removed until well stabilization is observed or; 3) a non-purge sampling technique may be employed, but only after pre-approved. (See Chapter 6, *Sample Collection*, Section 6.9., *Ground Water Sampling Procedures*, for more on sampling collection). Choosing the proper purging and sampling equipment will depend upon the chosen sampling technique which, in turn, will be determined by the sampling objectives.

5.2.1.1 Bottom Fill Bailer

One of the oldest and simplest methods of monitor well sampling is bailing. Bailer design is simple and versatile, consisting of a cylindrical length of PTFE or stainless steel with a check

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valve at the bottom. Bailers (Figures 5.1 and 5.2) are available in numerous dimensions to accommodate a wide variety of well diameters. Their low relative cost allows them to be utilized for a one-time use per well per sampling episode.

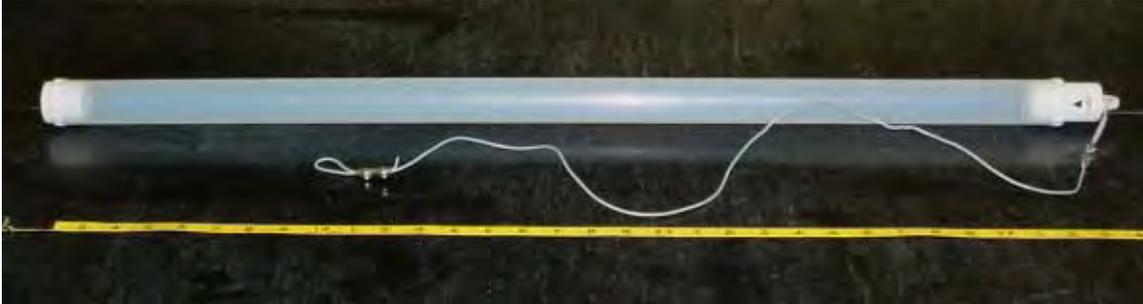


Figure 5.1 Bottom fill bailer with Teflon® coated stainless leader (Photograph by J. Schoenleber)

The leader or bailer line that comes in contact with the water must be constructed of PTFE coated stainless steel. Above the leader, dedicated polyethylene cord is acceptable, if it does not contact the water.

The bailer, and any other equipment entering the well, must be laboratory cleaned and handled with new surgical gloves to prevent cross contamination. Surgical gloves must be changed between each sample location. Clean sampling equipment and any other objects entering the well should not be allowed to contact the ground or any

other potentially contaminated surfaces (e.g. gasoline-fueled generators). If this should occur, that item should not be placed in the well or utilized for sampling. It is always a good practice to have extra laboratory cleaned bailers available at the site. Additionally, bailers and sample bottles must be physically separate from pumps or generators during transport and storage.

Disposable bailers are available in Teflon® and polyethylene construction. Teflon® disposable bailers can be used for any analysis, however, polyethylene disposable bailers can only be used for metals analysis. Disposable bailers are typically decontaminated by the manufacturer and must be provided in a sealed polyethylene bag. The manufacturer must be prepared to provide certification that the bailers are clean and state in writing the methods used to achieve decontamination. These bailers may then be acceptable for use depending on site-specific objectives and conditions.



Figure 5.2 Teflon® constructed bailer with Teflon® ball check valve (Photograph by J. Schoenleber)

Despite their attractive nature, bailers, even when carefully handled, result in some disturbance of the sample. Samples collected with bailers must be recovered with a minimal amount of aeration. This can be accomplished if care is taken to gradually lower the bailer *until* it contacts the water surface and is then allowed to fill as it slowly sinks in a controlled manner. However, despite the care taken to control aeration during the fill process, filling and emptying the bailer *will* alter dissolved oxygen concentrations. Due to these reasons (operator induced turbulence and air exposure) this device can not be relied upon to deliver accurate and reproducible measurements of any air sensitive parameter including, but not limited to, dissolved oxygen, pH, carbon dioxide, iron and its associated forms (ferric and ferrous). In addition, volatile organic analytical results may be biased low (due to aeration) and metals analytical results may be biased high (due to turbidity). Regardless, if this device is approved for use to collect analytical samples for data submission to the Department, it can not be used for data submission of the air sensitive parameters mentioned above. The Technical Requirements for Site Remediation (N.J.A.C. 7:26E-3.7) require that monitor well purge data accompany every ground water sample collected. Since bailers, by their nature, cannot provide for certain aspects of that requirement, a variance request for collection of any air sensitive parameter measurement by a bailer must be submitted for approval prior to sampling. Use the, US Geological Survey's, Book 9, *Handbooks for Water-Resources Investigations, National Field Manual for the Collection of Water-Quality Data*, Chapter 6A, *Field Measurements*, 6.2.1.C, *Measurement/Ground Water*, (<http://water.usgs.gov/owq/FieldManual/>), or, chose one of the references at the end of this chapter for documentation upon which to base the variance request.

Procedures for Use:

- i. Remove laboratory decontaminated dedicated bailer from protective covering and connect to laboratory decontaminated dedicated leader/cable.
- ii. Lower bailer slowly using polyethylene line until it contacts the water surface.
- iii. Allow bailer to sink and fill with a minimum of disturbance to the sample.
- iv. Slowly raise the bailer to the surface. Avoid contact of the bailer line to the well casing and/or ground.
- v. Tip the bailer to allow a slow discharge from the top gently down the side of the sample bottle to minimize turbulence. A bottom-emptying device may also be utilized and may prove more useful when sampling for volatile organics. When applicable, always fill volatile organic sample vials first, to zero headspace, with the first bailer full of water.
- vi. Repeat steps ii. to v. until a sufficient sample volume is acquired.
- vii. Follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).
- viii. Place used bailer in bag for return to lab for decontamination and dispose of polyethylene line.
- ix. Procure an additional lab decontaminated bailer and proceed to the next sampling location. Repeat procedure.
- x. When split sampling is required, sample from the bailer is used to alternately fill each bottle for every parameter of concern between all interested parties.

Advantages:

- no external power source required
- economical enough that a separate laboratory cleaned bailer may be utilized for each well, therefore eliminating cross contamination
- available in PTFE or stainless steel construction
- disposable bailers acceptable when material of construction is appropriate for contaminant
- simple to use, lightweight, portable

Disadvantages:

- limited volume of sample collected
- unable to collect discrete samples from a depth below the water surface
- field cleaning is not acceptable
- may not be used for well evacuation
- representativeness of sample is operator dependent
- reusable polyethylene bailers are not acceptable sampling devices for chemical analysis:
- ball check valve function susceptible to wear, dimension distortion and silt buildup resulting in leakage. This leakage may aerate succeeding sample and may gather unwanted material by rinsing unwanted material from well casing.
- cannot provide reliable or reproducible data for air sensitive parameters, e.g., dissolved oxygen, pH, carbon dioxide or iron and its associated forms. As a result, operator must submit to the Department a request for a variance from the Technical Requirements for Site Remediation Regulations (N.J.A.C. 7:26E-3.7), which requires the sampler to measure, record and submit well purging data.
- volatile organic analytical results may be biased low (due to aeration) and metals results may be biased high (due to turbidity).
- dedicating a bailer and leaving it in a well for long term monitoring is not recommended due to the potential risk of accumulated contamination.

5.2.1.2 Peristaltic Pump

[◀ Return to TOC](#)

A peristaltic pump (Figure 5.3) is a self-priming suction lift (negative air pressure) pump utilized at the ground surface, which consists of a rotor with ball bearing rollers. One end of dedicated tubing is inserted into the well. The other end is attached to a short length of flexible tubing, which has been threaded around the rotor, out of the pump, and connected to a discharge tube. The liquid moves totally within the tubing, thus no part of the pump contacts the liquid. Tubing used for well evacuation may also be used for sample collection. Teflon®-lined polyethylene tubing is recommended for sampling. Medical grade silastic tubing is recommended for tubing in contact with the rotors. Based upon the required analysis and sampling objectives other materials are acceptable, but must first be approved on a case by case basis.

Due to the undesirable effects of negative pressure, which this pump continuously imparts to a sample, accurate and reproducible measurement of air sensitive parameters can not be obtained. This bias is extended to samples collected for, but not limited to, the following analyses: volatile organics, dissolved oxygen, pH, carbon dioxide, iron and its associated forms (ferric and ferrous). As a result, this device is restricted from the collection of surface and ground

water samples for volatile and semi-volatile organic analysis. Since the Technical Requirements for Site Remediation (N.J.A.C. 7:26E-3.7) require that field measurements of dissolved oxygen, pH, temperature and specific conductivity accompany all sample collection data and, since this device is incapable of accurately delivering these measurements, a variance from the Technical Requirements must be obtained by the sampler. Use the US Geological Survey's Book 9, *Handbook for Water-Resources Investigations, National Field Manual for the Collection of Water-Quality Data*, Chapter A6, *Field Measurements*, 6.2.1.C, *Measurement/Ground Water* for documentation on which to base the variance request (<http://water.usgs.gov/owq/FieldManual/>).



Figure 5.3 Geopump™ Peristaltic Pump (Photograph by J. Schoenleber)

For the reasons stated above, this device may not be employed when utilizing the low-flow purging and sampling technique. Since some air sensitive parameters may support a scientific basis for choosing Monitored Natural Attenuation as a remedial strategy, use of this device may lead to unfounded decisions.

Procedures for Use

- i. Check tubing at rotor for cracks or leaks, replace if necessary.
- ii. Thread flexible length of tubing through rotor/pump.
- iii. Insert dedicated length of tubing in well and attach to flexible tubing at rotor.
- iv. Tubing depth introduced into the water column should not exceed 12 inches.
- v. If necessary, add a small stainless steel weight to tubing to aid introduction of tubing into well casing (especially helpful in 2-inch diameter wells).
- vi. Attach evacuation line to outlet of flexible pump tubing such that the discharge is directed away from pump and well.
- vii. Engage pump and commence evacuation. Pump speed must be maintained at a rate that will not cause significant drawdown (>0.3 ft.). After well has been properly evacuated begin sampling.
- viii. Collect sample into laboratory cleaned sample bottles and follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*)

Advantages:

- may be used in small diameter wells (2")
- sample does not contact the pump or other sampling equipment other than tubing prior to collection
- ease of operation
- speed of operation is variably controlled
- commercially available
- no decontamination of pump necessary (however, all tubing must be changed between wells)
- can be used for sampling inorganic contaminants
- purge and sample with same pump and tubing when analysis is limited to inorganics

Disadvantages:

- depth limitation of 25 feet
- potential for loss of volatile fraction due to negative pressure gradient, therefore volatile, semivolatile and air sensitive parameters cannot be collected through this device
- cannot provide reliable or reproducible data for air sensitive parameters e.g. dissolved oxygen, pH, carbon dioxide or iron and its associated forms. As a result, operator must submit to the Department a request for a variance from the Technical Requirement for Site Remediation Regulations (N.J.A.C. 7:26E-3.7), which requires the sampler to measure, record and submit well purging information associated with above parameters.
- may not be used as a pump in a low-flow purging and sampling scenario

5.2.1.3 Bladder Pump

[◀ Return to TOC](#)

An example of positive-displacement, the bladder pump (Figure 5.4) consists of a PTFE (e.g., Teflon®) or stainless steel housing that encloses a flexible Teflon® membrane. Below the bladder, a screen may be attached to filter any material that may clog check valves located above and below the bladder. The pumping action begins with water entering the membrane through the lower check valve and, once filled, compressed gas is injected into the cavity between the housing and bladder. Utilizing positive-displacement, water is forced (squeezed) through the upper check valve and into the sample discharge line. The upper-check valve prevents back flow into the bladder. All movement of gas and sample is managed through a series of regulators housed in a control mechanism at the surface. The source of gas for the bladder is either bottled (typically nitrogen or ultra zero air) or via an on-site oil-less air compressor. Flow rates can be



Figure 5.4 Example of a Teflon® constructed bladder pump, complete (top) and exploded version illustrating internal Teflon® bladder (Photograph by J. Schoenleber)

reduced to levels much like the variable speed centrifugal submersible pump without fear of motor stall.

Bladder pumps must be laboratory cleaned and dedicated to each well. This means that bladder pumps are permanently installed for long-term monitoring as long as the bladder is made of material not affected by long-term exposure to contaminants.

Field cleaning of bladder pumps is acceptable only if the following conditions are met: 1) the bladder pump housing is constructed of stainless steel with an internal disposable bladder and 2) one of either the eight-step, Cold Regions or ultra clean decontamination methods are employed.

Procedures for Use:

- i. Check all fittings for tightness.
- ii. Lower decontaminated pump and dedicated tubing into the well below the water table.
- iii. Connect compressor to power source ensuring the power source is downwind to prevent fumes from entering sampling area. If compressor is not used, connect to external air source.
- iv. Engage air source (compressor or external) via control box. Full water flow will begin after five to fifteen pumping cycles. After stabilization of well water has been observed and recorded, sampling may begin.
- v. Adjust the refill and discharge cycles to optimize pumping efficiency. This can be performed by the following process:
- vi. Adjust the refill and discharge cycles to 10-15 seconds each. Measure the water volume discharged in a single cycle.
- vii. Shorten the discharge cycle time until the end of the discharge cycle begins to coincide with the end of water flow from the pump outlet.
- viii. Shorten refill cycle period until the water volume from the discharge cycle decreases 10-25% from the maximum value measured in the first step.
- ix. Reduce the flow rate, by adjusting the throttle control, to 100-150 ml/min or less while sampling volatile and semi-volatile organics.
- x. Collect sample directly from discharge line into laboratory cleaned sample bottles after well has stabilized and follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).

Advantages:

- positive-displacement
- acceptable for well evacuation and sample collection for all parameters
- simple design and operation
- operational variables are easily controlled
- minimal disturbance of sample
- in-line filtration possible
- available in a variety of diameters

- no variances from the Technical Requirements for Site Remediation necessary

Disadvantages:

- large gas volumes may be needed, especially for deep installations
- only pumps with disposable bladders may be field cleaned for portable use when approved decontamination methods are employed

5.2.1.4 Variable Speed Submersible Centrifugal Pump

[◀ Return to TOC](#)

Improvements in the design of submersible centrifugal pumps over the last decade have resulted in pumps significantly reduced in overall size with variable speed discharge control. These two key features, coupled with stainless steel and Teflon® construction have enhanced the desirability of this pump for application of low-flow purging and sample collection. The Grundfos® Redi-Flo 2 (Figure 5.5) is one of the more common models of this style pump commercially available for sample collection. However, there are some limitations to this model pump, which when properly identified and anticipated, will allow the user to overcome commonly encountered situations.

The variable speed feature is one of the key design items, which allows for application of low-flow purging and sample collection. In order to compensate for the reduction in impeller dimension without significant loss of pump capacity, the motor must turn at a high rate of speed. In the process of achieving high speed, low-end torque (power) has been sacrificed. The result is that to start, or restart the pump, the speed control has to be increased considerably to overcome head pressure, especially if water must open a check valve. This sudden and increased change in flow rate may mobilize unwanted material from the surrounding formation. To address this potential “restart” issue, especially during the course of a low-flow purging and sampling episode, one must make sure that the generator supplying power to the pump is properly fueled to avoid power loss. In addition, when selecting check valves, look for valves that open with the least amount of resistance and can be placed in-line at the surface. Accessibility to a check valve at the surface may eliminate the need to pull the pump from the well in order to remove the standing column of water within the tubing. Pulling the pump from the well to relieve head pressure will result in extending the time it takes to reach stabilization due to unwanted disturbance of the well.

Low yielding wells can also test the limits of variable speed design. When low yield wells are encountered and excessive drawdown restricts flow rates to 100 ml/min or less, pump speed control becomes sensitive. In these



Figure 5.5 Grundfos® Pump. Illustration published with permission of Grundfos® Pumps Corporation

conditions, the pump may stall and the flow rate cease altogether creating another “restart” situation where pump speeds have to be increased significantly to overcome head pressure. This is not the desired scenario when attempting low flow purging and sampling. To avoid this circumstance, make sure that the control box is equipped with a “ten-turn-pot” frequency control knob. This accessory will allow for much better control over flow rates and incidental pump stoppage when sampling low yield wells.

Reduced overall pump dimension and high turning motor speeds make temperature control critical to overall performance. The pump is designed to use water flowing along the surface of the pump housing to prevent an increase in motor temperature. Elevated water temperature generated by the motor must be considered especially when a low-flow purging and sampling technique is being utilized. Well casing diameters play a factor in the control equation. For large-diameter cased wells (> 4 inch), where flow to the pump intake is more horizontal than vertical, Grundfos® manufactures a sheath attachment to redirect flow patterns and control heat buildup. In small-diameter wells, movement is more conducive to the design function until low-yielding conditions are encountered. For those instances where temperature is being monitored and there is a steady and significant increase in temperature, do not alternately turn the pump on and off to control temperature buildup. This action will only serve to disrupt the well. Instead, make note of the condition in the field log and disregard any attempt to achieve temperature stabilization prior to sample collection. Where there is a significant increase in temperature, the Department may qualify the VOC and SVOC data accordingly.

When using variable speed submersible pumps to collect the field blank, one must follow the same general rules for all ground water sampling equipment. This includes the requirement that “all” sampling equipment, which comes in contact with the sample, must also come into contact with the field blank water. To overcome some of the difficulties that sampling through the inside of a pumping system creates, the following procedure is strongly recommended. Prepare field blank collection by filling a 1000ml decontaminated graduated glass cylinder with method 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 with additional method blank water. This procedure will require that the laboratory supply field blank water in a non-traditional manner: 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 can not be practically satisfied in this circumstance. The identical bottle to bottle field blank requirement is waived for this sampling technique procedure only.

Finally, this particular pump (Grundfos® Redi Flo 2) is designed to utilize a coolant fluid (deionized water) that is stored internally to assist in heat movement. This fluid is separated from the sample intake by a Viton® seal through which the spinning motor shaft passes. Wear on this seal can allow for fluid exchange with the sample intake. For this reason, proper decontamination of this pump is critical and includes the complete disassembly of the motor shaft from the stator housing (Figure 5.6). For proper cleaning, use the decontamination procedures for ground water sampling equipment (see Chapter 2, *Quality Assurance*, and read the Redi Flo 2 manufacturer’s instructions). Always refill the housing with fresh distilled/deionized water. Note: always move (jiggle) the motor shaft while filling to ensure any trapped air is displaced by water, otherwise damage to the motor through overheating is possible. Replace the Viton® seal periodically and remember that care must also be taken with this pump during periods of



Figure 5.6 Grundfos® Pump being prepared for decontamination (Photograph by J. Schoenleber)

cold weather to avoid freezing of the coolant water. Proper decontamination and maintenance not only helps to ensure more reliable data; it also prolongs the life of any pump.

Procedures for use:

- i. Decontaminate pump, electrical leader and all associated fittings.
- ii. For low-flow purging and sampling, attach precut tubing whose length has been predetermined based upon well-specific pump intake depth (See Chapter 6, *Sample Collection*, for specifics regarding low-flow procedures).
- iii. For volume-average sampling, set the pump either within three feet of the top of water column, or, immediately above the well screen depending on chosen method.
- iv. Install pump slowly through water column wiping down tubing with DI saturated paper towel.
- v. If a portable gasoline generator is used, it should be placed downwind. The generator should not be operating while a sample is being collected.
- vi. Initiate purge based on procedure selected.
- vii. After purging, collect sample as specified in approved sampling plan.

Advantages:

- Positive-displacement
- Versatile and light weight
- Variable speed control at surface allows for fine tuning of flow rate
- Stainless steel and Teflon® construction

- Complete disassembly allows for access to all parts for thorough decontamination
- Acceptable for low-flow purging and sampling

Disadvantages:

- During low-flow purging and sampling temperature increases may be observed
- At extremely low-flow rates, motor stall possible. To reestablish flow, high pumping rate may be needed to restart
- Should manufacturer’s disassembly instructions for decontamination not be followed, cross-contamination of well is possible.

5.2.1.5 Gear Pump

A positive-displacement pump, this small lightweight pump manufactured by Fultz Pumps, Inc, also has the capacity for variable speed control (Figure 5.7). The applications of this pump are similar to the variable speed submersible centrifugal pump. Choose a pump with stainless steel housing and Fluorocarbon polymer rotors or gears (Figure 5.8). Internal parts (gears) are not readily accessible, therefore careful attention must be made when cleaning. This must be considered when choosing to use this pump for a portable application. Many are designed with the power supply molded into the sample tubing. This makes custom length of tubing based on



Figure 5.7 Fultz Pump. Illustration published with permission of Fultz Pumps, Inc.

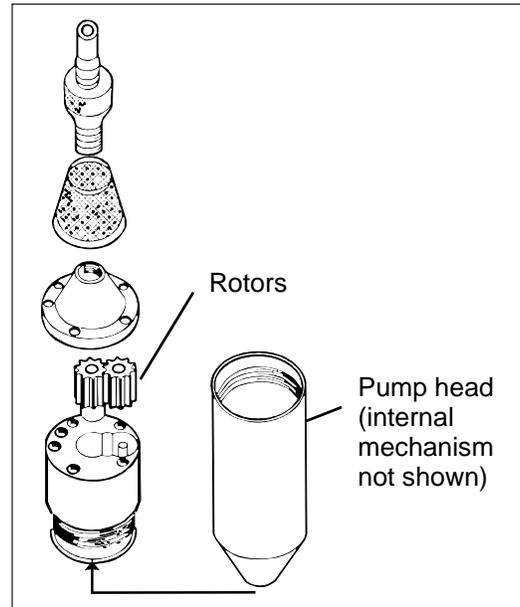


Figure 5.8 Gear Pump. Illustration published with permission of Fultz Pumps, Inc.

individual well requirements impractical during a portable application. Single molded power supply and sample tubing is also difficult to decontaminate when using this pump on a portable basis. Instead, choose pumps whose power supply and pump discharge lines are separate. This pump may be best applied when used in a dedicated system.

Procedures for use:

- i. Decontaminate pump, electrical leader and all associated fittings
- ii. For low-flow purging and sampling, attach precut tubing whose length has been predetermined based upon well-specific targeted zone of influence information. (See Chapter 6, *Sample Collection*, for specifics regarding low-flow procedures)
- iii. For volume average sampling, set the pump either within three feet of the top of water column, or, immediately above the well screen depending on chosen method.
- iv. Install pump slowly through water column wiping down tubing with DI saturated paper towel
- v. Initiate purge based on procedure selected
- vi. At end of purge, collect sample as specified in approved sampling plan.

Advantages:

- Positive-displacement
- Light weight
- Good variable speed control, especially at low rates
- Acceptable for Low-flow Purging and Sampling

Disadvantages:

- For portable sampling, many designed with power supply molded into tubing, which is difficult to decontaminate.
- Turbid purge water wears on Fluorocarbon gears

5.2.1.6 Progressing Cavity Pump

Another example of positive-displacement pump, progressing cavity pumps (Figure 5.9) are lightweight, manufactured in a variety of sizes and materials and pump rates are controllable at the surface. This is another example of a pump whose power delivery may be molded into the discharge tubing creating the need to decontaminate tubing between each sample. Choose pumps with stainless steel housings, chemically resistant stators and whose power and discharge tubing is separate. Many are powered by 12-volt battery and are limited to depths of approximately 150 feet.

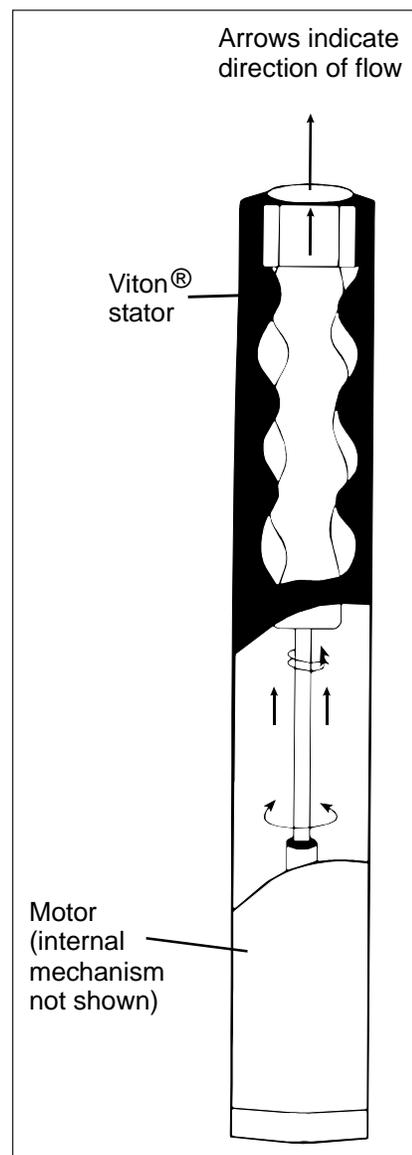


Figure 5.9 Progressive Cavity Pump. Illustration published with permission of Geotech Environmental Equipment, Inc.

Procedures for Use:

- i. Decontaminate pump, electrical leader and all associated fittings
- ii. For low-flow purging and sampling, attach precut tubing whose length has been predetermined based upon well-specific targeted zone of influence information. (See Chapter 6, *Sample Collection*, for specifics regarding low-flow procedures)
- iii. Initiate purge based on procedure selected
- iv. At end of purge, collect sample as specified in approved sampling plan.

Advantages:

- Positive-displacement
- Light weight
- Good variable speed control, especially at low rates
- Housing available in stainless steel construction with stator of highly inert material
- Acceptable for low-flow purging and sampling

Disadvantages:

- For portable sampling, many are designed with power supply molded into tubing, which is difficult to decontaminate and less appealing for portable sampling scenarios.

5.2.1.7 Reciprocating Piston Pump

A positive-displacement pump, this device utilizes a piston whose movement within a valved chamber draws, and then forces, water to the surface with minimal agitation (Figure 5.10). Driven by compressed air supplied at the surface, single piston pumps will operate to depths approaching 500 ft. (double piston pumps operate to depths up to 1000 ft.). Smaller 1.8 inch diameter models require 3/8" air supply and 1/2" air exhaust lines with a 1/2" diameter water discharge line. Restricting air supply controls flow rates. Air supply lines can be purchased either fused forming a single unit or as two separate lines. Tubing and flow control may be set up on a reel assembly. Pictured is a Bennett Pump (Figure 5.11).

Procedures for Use:

- i. Decontaminate pump, outside of air supply/exhaust lines, sample discharge line and all associated fittings
- ii. Dispense pump and all lines from reel
- iii. Lower pump slowly through water column wiping down tubing with DI saturated paper towel
- iv. For volume average sampling, set the pump either within three feet of the top of water column, or, immediately above the well screen depending on chosen method.
- v. For low-flow purging and sampling set pump at predetermined depth within well screened interval
- vi. Control air pressure via regulator and gauge to adjust sample flow rates
- vii. Air pressure supplied by portable air compressor (5.2 cfm @ 140 psi for 1.8" diameter model)

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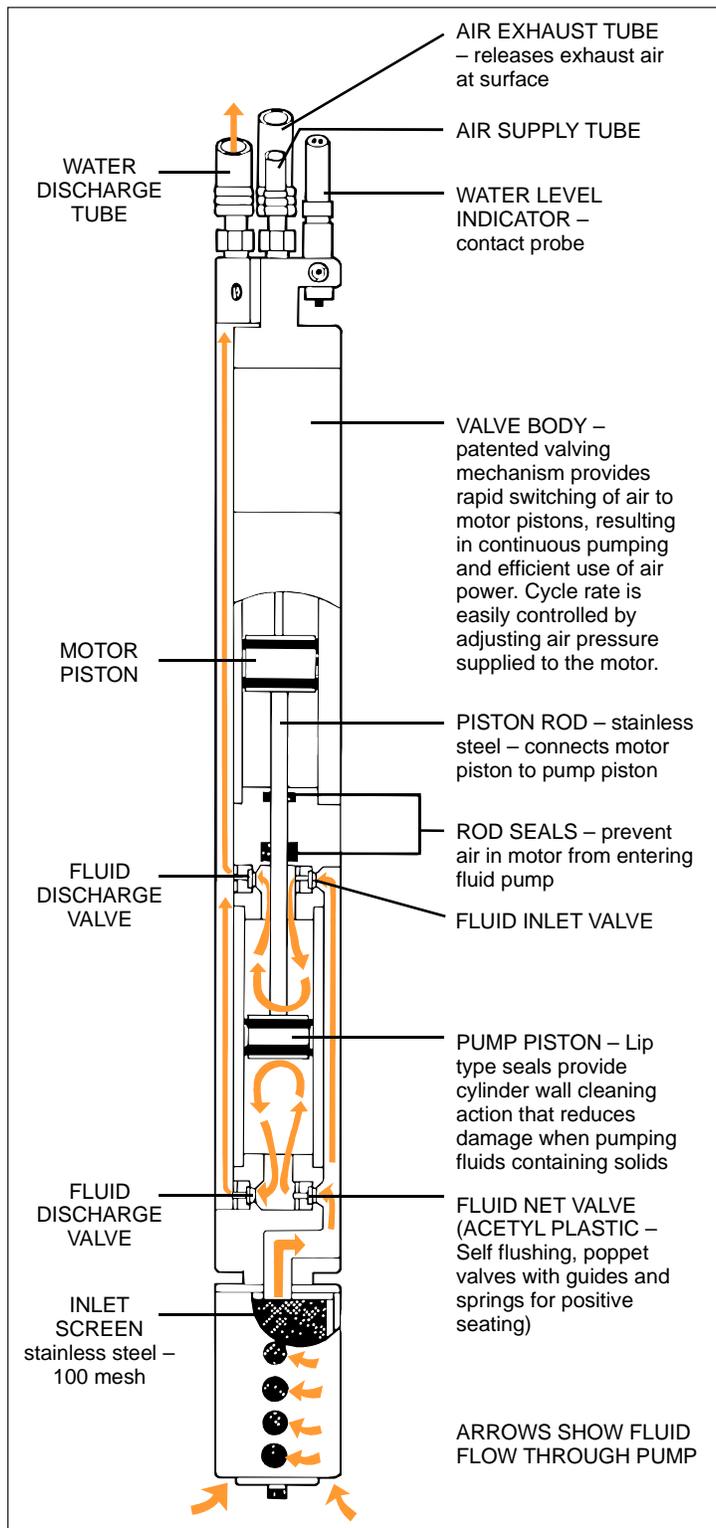


Figure 5.10 Reciprocating Piston Pump



Figure 5.11 Bennett Pump

Advantages:

- Stainless steel construction of pump body and piston.
- Variable speed control
- Positive-displacement
- Portable or dedicated sampling options
- Flow rates as low as 0.75 liters per minute
- Pump disassembly possible for decontamination purposes

Disadvantages:

- Large sample discharge ($\frac{1}{2}$ " diameter) on 1.8 inch diameter model
- Operation from reel in portable mode makes decontamination of tubing difficult
- Worn parts may allow compressed air to cross into sample or result in loss of pump efficiency

5.2.1.8 Inertial Pump

As the name implies, this pump works on the principle of inertia. The pump consists of polyethylene or Teflon[®] tubing with a foot or ball-check valve attached at one end (Figure 5.12). The foot or ball-check valve allows water to enter the tubing, but prevents water from draining out. Simply raising and lowering the tube over a short distance operates the pump. Movement on the downstroke forces the valve open allowing water to enter the tubing. On the upstroke, the valve closes trapping water inside the tubing. Continued up and down movement advances water upward due to inertia.

There is virtually no pressure gradient at the valve, however there may be considerable disturbance within the

well casing, which limits the value of the technique. Using this technique in wells established in silty geologic settings may produce sample results that are biased high for inorganic analysis. Sporadic non-laminar sample delivery into the container at the surface may bias volatile analysis low. The operation can be performed manually or automatically utilizing a power unit. The automatic mode does allow for some control on well disturbance and sample delivery. The technique does have favorable application for field screening of narrow diameter (>1 inch) temporary wells and field screening for vertical delineation of contaminant plumes utilizing direct push technology (Figure 5.13).

Procedures for Use:

- i. Attach decontaminated Teflon[®] foot check valve or stainless steel ball check valve to end of tubing



Figure 5.12 Waterra Pump. Illustration published with permission of Waterra.

- ii. Wipe tubing with paper towel and DI water as tubing is lowered into well
- iii. Begin up and down movement at desired depth avoiding disturbance of well casing to best ability



Figure 5.13 Two styles of foot check valves offered by Geoprobe® for narrow diameter temporary well points (Photograph by J. Schoenleber)

Advantages:

- Inexpensive
- Ease of operation
- Decontamination of valves relatively simple
- Best use limited to field screening of volatiles when utilizing direct push technology and narrow diameter temporary well points

Disadvantages:

- Manual use is labor intensive
- Use produces considerable agitation and turbid conditions
- Uneven sample delivery
- May cause VOC loss due to agitation
- Use in slow-recharge narrow-diameter temporary well points may cause the water level to drop significantly and result is aeration of the water column

5.2.1.9 Syringe Sampler

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Syringe samplers are specialized devices designed to capture and preserve in-situ ground water conditions by precluding sample aeration and pressure changes from sample degassing (escape of VOCs) or outgassing (escape of inorganic gases). Their use, while not widely applied to general monitor well sampling, does have application when attempting to collect a discrete, non-purged sample. Examples may include collecting an undisturbed aliquot of dense non-aqueous phase liquid from the very bottom of a well, or, targeting a zone for field analytical measurement.

Measurement of water quality indicator parameters made in discrete or nonpumped samples are more vulnerable to bias from changes in temperature, pressure, turbidity and concentrations of dissolved gases than measurements using a downhole or flow through-chamber system. As a result, subsamples can be used for conductivity, pH and alkalinity but should not be used for reported measurements of temperature, dissolved oxygen, Eh or turbidity.

The device shown in Figure 5.14, manufactured by General Oceanics (<http://www.generaloceanics.com/>), is constructed of stainless steel and glass components and is designed to universally accept standard off the shelf medical syringes of varying volumes. The stainless steel and glass construction allows for more thorough cleaning when sampling between monitor wells. Another model manufactured by General Oceanics is constructed of polycarbonate material and as a result can only be used on a one-time basis.

Advantages:

- Can sample at discrete depths
- Interior of sampler not exposed to water column
- Potential for use as a collection device for field screening techniques

Disadvantages

- Small sample volume renders comparison of duplicate and quality assurance samples inconclusive
- Not recommended for analysis of volatile organics from samples collected in monitor wells due to potential volatile loss
- Use of this no-purge device must be approved on a case by case basis.



Figure 5.14 Syringe Sampler. Illustration published with permission of General Oceanics, Inc.

5.2.1.10 Suction-lift Pumps

Suction-lift pumps (e.g., diaphragm, surface-centrifugal and peristaltic)

are pumps situated at the ground surface with tubing (polyethylene or flexible PVC) inserted into the well leading from the pump to the top of the water column. Diaphragm and surface-centrifugal pumps are used only to evacuate wells prior to sampling. Peristaltic pumps can be used to sample inorganic contaminants. All tubing must be new and dedicated to a particular monitor well. As the tubing is inserted into the well, it must be wiped down with paper towels and distilled/deionized water. Tubing associated with surface-centrifugal pumps should be equipped with a decontaminated foot check valve to avoid having aerated water within the pump fall back into the well prior to sampling. Should a check valve not be employed, then the pump must continue to operate during removal of tubing to avoid purged water remaining in the tubing and pump chamber from falling back into the well.

These evacuation only pumps are typically associated with volume-averaged sampling where three-to-five standing water volumes are removed from the well prior to sampling with a bailer. Again, ground water can not be collected through suction lift pumps for chemical analysis with the exception of inorganic analysis via peristaltic pumps. When using surface centrifugal pumps for purging, care must be taken to ensure that the entire pump impeller housing chamber is drained after use and then is thoroughly rinsed to remove build up of suspended materials.

The main limitation exhibited by these types of pumps is their inability to overcome the physical constraints imposed by one atmosphere of pressure. Generally, water within the well casing must be twenty-five feet from the ground surface or the pump's efficiency in pulling water to the surface diminishes dramatically. Note: If priming the pump is necessary, care must be taken as to the source of the water used. ONLY potable water is acceptable.

5.2.1.11 Passive Diffusion Bag Samplers (PDBs)

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5.2.1.11.1 Deployed In Monitor Wells

When confronted with sampling a monitor well that displays little or virtually no recharge capability during well evacuation (where historic data indicate drawdown exceeds 3 tenths of a foot while purging at flow rates that are equal to or below 100 ml per minute), the option to use this no-purge sampling technique may be justified. More appropriately, there may be instances where long term monitoring during the operation and maintenance phase of remediation justifies their use. Whatever the reason, use of passive diffusion bags must be granted prior approval, as there are well-defined limitations to this sampling technique that must be understood by the sampler, as well as the end user of data. Due to the limited number of contaminants PDB samplers are capable of detecting, these devices are not recommended for initial investigations where a more complete understanding of the contaminants of concern remains to be determined. In addition, PDB samplers are not recommended for sampling sentinel wells. For more information on NJDEP sampling policy and procedures related to this device consult Chapter 6, *Sample Collection*, Section 6.9, *Ground Water Sampling Procedures*, Subsection 6.9.2.5.1, *Passive Diffusion Bag Samplers*, before using PDBs.

PDB samplers are made of low-density polyethylene plastic tubing (typically 4 mil), filled with laboratory grade (ASTM Type II) deionized water and sealed at both ends (Figure 5.15). The samplers are typically about 18 to 20 inches in length and can hold from 220 ml to 350 ml of water. Vendors can usually modify the length and diameter of a sampler to meet specific sampling requirements.

Teflon[®] coated stainless-steel wire is preferable for deploying the samplers in the well. Teflon[®] coated stainless-steel wire can also be reused after proper decontamination. As an alternative to Teflon[®] coated stainless steel wire, synthetic rope may be



Figure 5.15 Eon PDB Sampler with accessories (Photograph by J. Schoenleber)

used as the deployment line for single-use applications if it is 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 sampler within the well screen or open hole of the well. Deployment lines consisting of material other than Teflon® coated stainless steel wire may not be used in another well and must be properly disposed of after a one-time use.

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. Many VOCs equilibrate within 48 to 72 hours, however, 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 sampler 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 samplers 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. Unfortunately, data are currently unavailable to support longer deployment periods (i.e., semi-annual or annual). Leaving samplers in a well for longer than 3 months is not recommended. If future data become available which demonstrate longer deployment timeframes are appropriate, this condition will be modified.

Advantages:

- Purge water associated with conventional sampling reduced or eliminated.
- The devices are relatively inexpensive.
- Simple deployment and recovery reduces the cost and the potential for operator error.
- Monitoring well stability parameters are not required which reduces associated cost.
- PDB samplers are disposable.
- The stainless steel weights and Teflon® coated wire are the only pieces of equipment needing decontamination.
- Quick deployment and recovery is a benefit when sampling in high traffic areas.
- Multiple PDB samplers can be deployed along the screened interval or open borehole to detect the presence of VOC contaminant stratification.
- Has been shown to deliver accurate dissolved oxygen measurement.
- Since alkalinity conditions in the well are not transferred across the membrane, effervescence associated with HCl preservation is avoided.

Limitations:

- PDB samplers provide a time-weighted VOC concentration that is based on the equilibration time of the particular compounds; usually that period is 2 to 3 days.

This is a limitation if sampling objectives are to identify contaminant concentrations at an exact moment the sample is collected. The time-weighted nature of the PDBs may be a factor in comparison with low-flow sampling if concentrations have been shown to be highly variable over time.

- PDB samplers have a limited detection capability.
- PDB samplers work best when there is unrestricted horizontal movement of ground water through the well-screen or open hole. If filter packs or screens are less permeable than the surrounding formation, ground water flow lines may not enter the well and PDB samples may not be able to provide a representative sample.
- As with low-flow samples, PDB samplers represent a point sample. Contamination migrating above or below the targeted depth interval will not be detected.
- Membrane limitations restrict accurate pH, specific conductance or temperature data.
- In some cases, heavy biofouling of the bag may inhibit sampler performance

5.2.1.11.2 Deployed in Lake, Stream, River or Estuarine Sediment

While the primary application of passive diffusion bag sampling is intended for monitor well investigation, the device can be modified for application in stream sediment when investigating ground water discharge areas. The same limitations regarding the physical chemistry of contaminant diffusion across polyethylene membranes apply to sediment settings. In addition, the lithology of the streambed, the “gaining” relationship between the stream and investigation area and the remedial phase pose further limitations that must be examined before approval of this adaptive PDB application can be granted. In “gaining” situations, transect deployment of PDBs over a two week period may indicate areas of concern that were previously overlooked. Since the nature of PDB construction does not lend itself to the rough handling and

deployment into sediments, a protective housing constructed of 2-inch diameter PVC slotted well screen material offers a means to deploy without damage to the bag (Figure 5.16). (Note: Air in bag artifact of long time storage.)

The slotted well screen serves as a protective barrier for the PDBs while allowing the free flow of



Figure 5.16 PDB for Sediments using bag provided by Columbia. (Photograph by J. Schoenleber)

ground water to come into contact with the sampler. A two-inch PVC cap can be placed on each end of the well screen. The bottom cap should be secured with a standard 5/16-inch zinc plated bolt to assure that the cap will stay in place. A smaller diameter through-hole can be drilled in the top cap and a short length of Teflon® coated stainless steel braided wire can be looped through the cap, creating a “handle” while holding the top cap securely in place.

Using a length (measurement based on need) of 4-inch diameter Schedule 80 PVC pipe, drive 18 to 24-inches into the sediment with a sledgehammer. This will form a barrier (cofferdam) from any standing or moving water. Use a 4-inch Teflon® bailer to remove the standing water within the coffer casing. This removal of water from the casing will facilitate the use of a 3-inch stainless steel bucket auger to begin the removal of sediment. Intermittently, the bailer may have to be used again to remove any water that infiltrates the casing during the removal of sediment. Once the desired depth into the sediment has been reached with the auger, the assembled PDB device can be lowered through the casing into the open hole. A 6-foot length of polyethylene line should be tied to the coated stainless steel braided wire to act as means to relocate and assist in pulling the device from the sediment when the time comes for retrieval. The auger can then be used again to ensure the device is resting at the bottom of the augured hole and to confirm the sampler’s depth.

A small amount of clean sorted coarse #2 sand should be poured from a stainless steel bucket into the casing. This will create a type of filter pack around the device and enhance contact with the surrounding formation. The sand also reduces the friction when it comes time to remove the device from the sediment. After enough sand is used to fill in the voids around the entire sample device, the native stream bed sediment that was originally removed from the hole must be placed back on the top of the device to complete the boring seal. The assembled device should be buried vertically to a depth that allows for approximately 6-inches of coverage by native sediment. Use extreme caution when removing the 6-inch casing as the PDB device may want to follow along with the casing’s removal. An exact record of the location of the sample device must be obtained using a global positioning satellite unit or measured triangulation.

5.2.1.12 Direct Push Technology

Use of direct push technology to obtain ground water samples via temporary well points has gained wide acceptance. The relative ease to collect minimally disturbed ground water samples depth plus the ability to provide other hydrogeological data has made this system attractive. While various manufacturers make and distribute their own ground water equipment and accessories, the same general principles still apply when collecting ground water samples. Chief among them is following NJDEP required decontamination procedures. When using direct push technology you must apply, at a minimum, the Cold Regions decontamination procedure discussed in Chapter 2, *Quality Assurance*, Section 2.4, *Decontamination Procedures*.

One of the special applications of direct push technology relative to ground water sampling is the ability to obtain vertical profile information while working the same bore hole. This process only further stresses the need to eliminate all possible sources of extraneous or cross contamination, especially when contaminant levels are on the order of only 1 or 2 parts per billion. High pressure, hot water (100° C) cleaning is the only acceptable means to decontaminate sampling equipment and maintain confidence that data is not influenced by unwanted variables. In

addition, equipment must be maintained in good working order to insure its performance. This means (but is not limited to) all rods used for boring advancement must have unworn O-rings at each connection and undamaged threads to insure that each connection can be drawn tight, all downhole equipment must be decontaminated between each use and sample collection tubing must not be reused. Operators must have boring certification in good standing from the Bureau of Water Systems and Well Permitting and all permit approvals must be on-site. Extreme caution must be taken to insure that communication between various water bearing zones within the same boring does not take place, therefore, all grouting must be tremied under pressure starting from the bottom of the boring and completed at the surface using grout of the required density. Finally, no boring work can begin without first contacting New Jersey One Call service to secure utility mark-outs

General guidance on the construction of temporary wells installed via direct push technology can be referenced through this manual, ASTM D6001-96, *Direct Push Water Sampling for Geoenvironmental Investigations*, and via the following Internet links:

<http://www.epa.gov/superfund/programs/dfa/dirtech.htm>,
<http://epa.gov/swerust1/pubs/esa-ch5.pdf>, <http://geoprobe.com>, and
<http://www.ams-samplers.com/main.shtm?PageName=welcome.shtm>.

5.2.1.13 Packers

Packers, an accessory deployed in conjunction with pumps designed for sample collection, are used to isolate portions of a well for sampling or other hydrogeological purposes. Expandable rubber bladders, arranged singularly or in pairs, are designed to allow discharge and power supply lines to pass through with the pump sandwiched in between. They deflate for vertical movement within the well and inflate when the desired depth is reached.

Under certain circumstances, ground water contamination in bedrock aquifers can migrate to significant depths. The presence of contaminants denser than water, high angle fractures, nearby pumping wells, or a downward hydraulic gradient within the aquifer can facilitate the downward migration of contaminants. Packers may be used to focus the investigation to a particular fracture. Present NJDEP policy limits the length of bedrock well open borehole or screen length to 25 feet.

To facilitate vertical contaminant delineation in bedrock aquifers, packer testing of a bedrock borehole is commonly performed. Packer testing of a bedrock borehole can be conducted in two different ways. The first method entails advancing the borehole to a pre-determined depth. Once the borehole has been completed, information generated from drilling such as: changes in borehole yield, changes in drilling rate, occurrence of weathered zones, presence of odors or sheens, and the occurrence of elevated PID/FID readings, are used to determine the intervals chosen for packer testing. Portions are then sectioned off using an upper and a lower packer. Conducting down-hole video work, down-hole caliper logging or vertical flow measurement may also be used to determine the borehole depths to set the packers.

The second method involves alternating the advancement of the borehole with packing off the bottom and collecting a sample. Only one packer is needed to create a barrier at the top of the newly drilled section (the bottom of the borehole completes the interval). Since the use of the packer is undertaken in an alternating fashion with advancement of the borehole, the length of the intervals is usually predetermined. This method is less prone to leakage but it is usually slower and more expensive than other methods.

Pumping of water from within the packed interval can be used to estimate yield of the selected zone, and the analysis of samples collected from each zone can be used to determine the vertical

extent of ground water contamination. If samples are to be collected for field screening or laboratory analysis, volume averaging or low-flow sampling techniques can be employed before sample collection. The resolution of the ground water quantity and quality within the borehole is based on the length of the bedrock borehole interval tested and usually does not exceed 20 feet in length.

If packers are not seated properly, water will leak around the system during the test. To determine if leakage around the packer 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 the interval is being pumped, it is likely that water leakage around the packer is occurring. Packers used in cored bedrock 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, leakage of water around the packer via the fracture may be unavoidable. For more information on packer application go to the following USGS web site: <http://toxics.usgs.gov/pubs/FS-075-01/#4>.

Procedures for Use:

- i. Packers are assembled at the surface with the selected pump sandwiched between individual bladders.
- ii. Assembled unit is lowered to a predetermined depth by cable.
- iii. Bladders are inflated from air-lines originating at the surface.

Advantages:

- isolates a portion of well for sampling at discrete transmission zones within an open borehole or long screen
- decreases purge volume of a well

Disadvantages:

- sampler must be aware of background regarding contaminants and other well characteristics
- packers are constructed of rubber and may deteriorate with time, releasing undesirable organics into the ground water
- should not be used for initial sampling episodes prior to identification of contaminants of concern
- sampler needs to know the stratigraphy and hydrology to be sure area packered is isolated from other water bearing zones
- the decontamination of packers is critical due to their multiple reuse from site to site
- packers used inside a well screen will not prevent water from flowing through the filter pack from above and below the packers.

5.2.2 Wastewater Sampling Equipment

Wastewater sampling equipment is typically designed to collect aqueous samples from influent and effluent sources at a treatment facility. Since large volumes of water are being monitored over time, their ability to composite samples makes them most suitable. These devices may also be adapted for characterizing mainstems of rivers, estuaries, coastal areas, lakes or impoundments.

Samples may be collected manually or with automatic samplers. Whichever technique is adopted, the success of the sampling program is directly related to the care exercised during sample collection. Optimum performance will be obtained by using trained personnel.

5.2.2.1 Manual Sampling

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There is minimal initial cost involved in manual sampling. The human element is the key to the success or failure of any manual-sampling program. It is well suited to the collection of a small number of samples, but is costly and time consuming for routine and large sampling programs

Advantages:

- low capital cost
- can compensate for various situations
- note unusual conditions
- no maintenance
- can collect extra samples in short time

Disadvantages:

- probability of increased variability due to sample handling
- inconsistency in collection
- high cost of labor when several samples are taken daily
- repetitious and monotonous task for personnel

5.2.2.2 Automatic Sampling

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Automatic samplers are favored because of their cost effectiveness, versatility, reliability, increased capabilities, greater sampling frequency and application to monitoring requirements specific to discharge permits. Automatic samplers are available with widely varying levels of sophistication, performance, mechanical reliability and cost. However, no single automatic sampling device is ideally suited for all situations. For each application, the following variables should be considered in selecting an automatic sampler:

- Variation of water or wastewater characteristics with time.
- Variation of flow rate with time.
- Specific gravity of liquid and concentrations of suspended solids.
- Presence of floating materials.

Selection of a unit should also be preceded by careful evaluation of the range of intended use, the skill level required for installation and the level of accuracy desired. There are usually five interrelated subsystems in the design of an automatic sampler to consider. These are the sample intake, gathering, transport, storage, and power subsystems.

The reliability of a sample intake subsystem can be measured in terms of: freedom from plugging or clogging; non-vulnerability to physical damage; minimum obstruction to flow; rigid intake tubing or facility to secure or anchor; multiple intakes; and construction materials compatible with analysis.

Commercial automatic samplers commonly use either a vacuum or a peristaltic pump. Figures 5.17 and 5.18 illustrate two versions of the ISCO® sampler for composite and sequential collection, respectively.

Most commercially available composite samplers have fairly small-diameter tubing in the sample train, which is vulnerable to plugging due to the buildup of fats, solids, and other

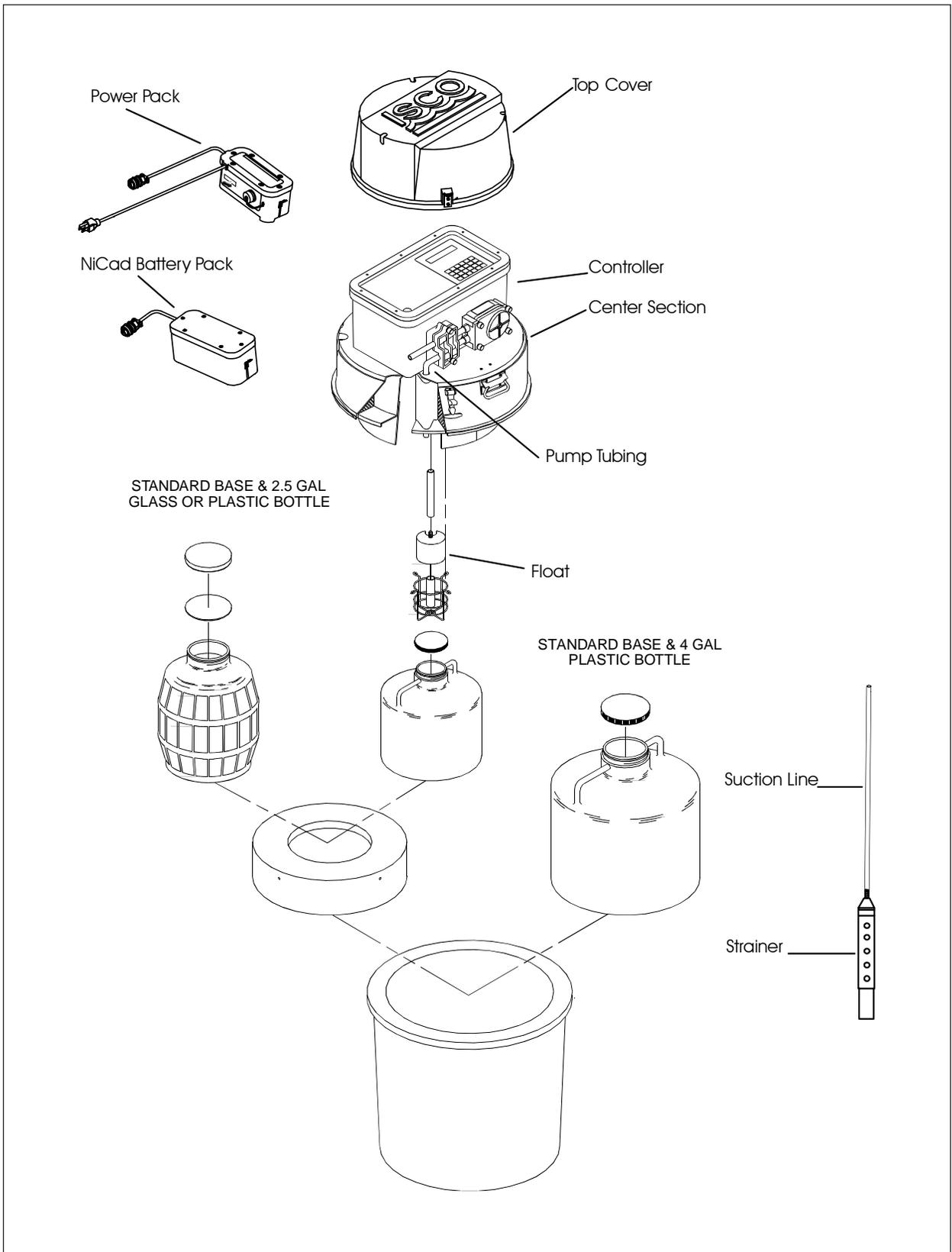


Figure 5.17 ISCO® 3700 Series Sampler for composite collection. Illustration published with permission of Teledyne ISCO.

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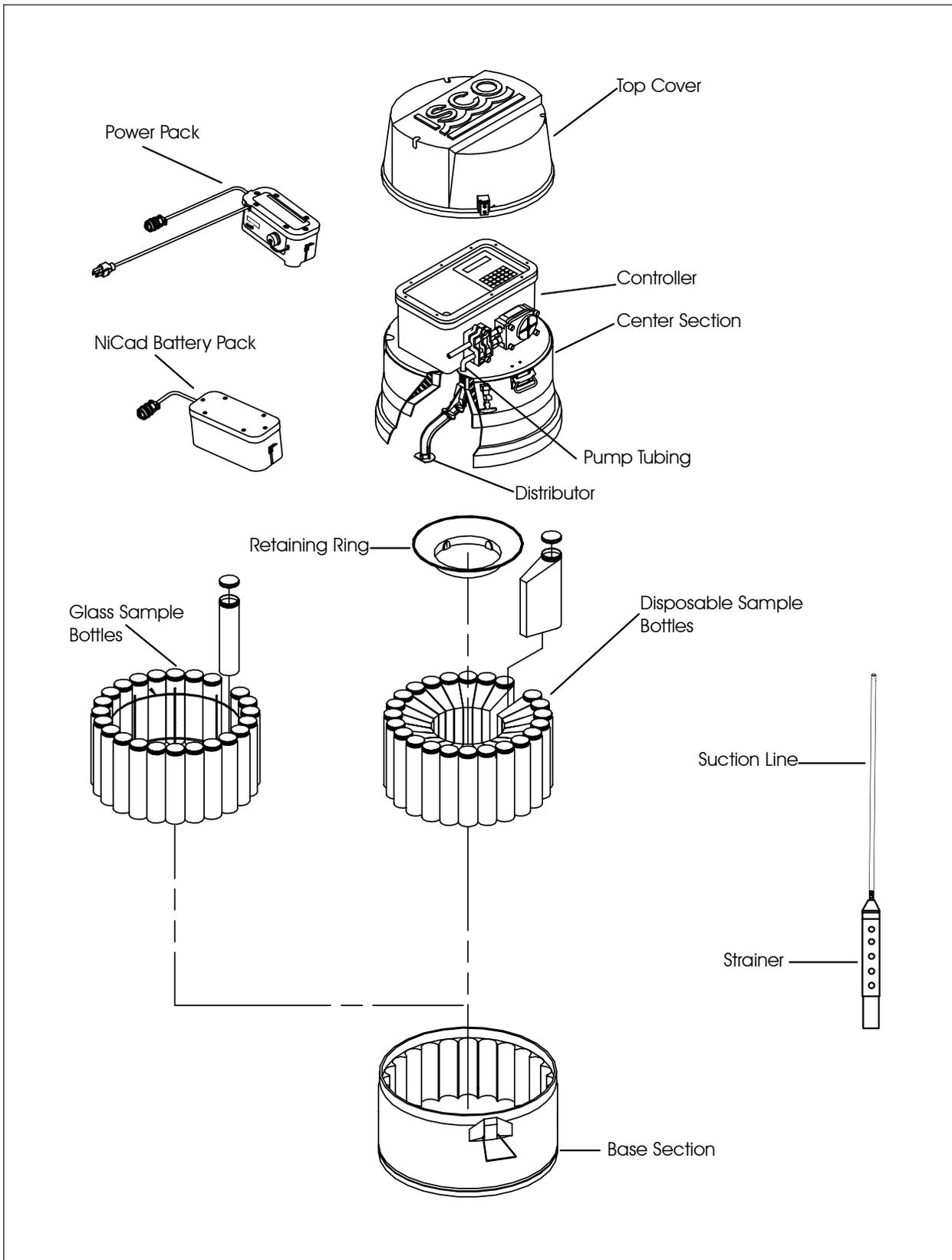


Figure 5.18 ISCO® 3700 Series Sampler for sequential collection. Illustration published with permission of Teledyne ISCO.

insoluble components. Adequate flow rates must be maintained throughout the sampling train to effectively transport suspended solids.

Discrete samples are subject to considerably more error introduced through sample handling, but provide opportunity for manual flow compositing and time history characterization of a waste stream during short period studies. The desired features of sample storage subsystems include flexibility of discrete sample collection with provision for a single composite container; minimum discrete sample container volume of 500 ml and a minimum composite container capacity of 7.5 liters. Storage capacity of at least 24 discrete samples, containers of conventional polyethylene or borosilicate glass of wide mouth construction, and adequate insulation for the sampler to be used in either warm or freezing ambient conditions.

Finally, various power and control features may be necessary depending upon whether the sampler is at a portable or a permanent installation. These include but may not be limited to: 1) capacity for either AC or DC operation; battery life for 2 to 3 days of reliable hourly sampling without recharging; 2) battery weight of less than 20 pounds and sealed so no leakage occurs; 3) solid-state logic and printed circuit boards; 4) timing and control systems contained in a water-proof compartment and protected from humidity; 5) controls directly linked to a flow meter to allow both flow-proportional sampling and periodic sampling at an adjustable interval from 10 minutes to 4 hours; 6) capability of multiplexing, (i.e., drawing more than one sample into a discrete sample bottle to allow a small composite over a short interval); 7) capability for filling more than one bottle with the same aliquot for addition of different preservatives; and 8) capability of adjusting sample size and ease in doing so.

Procedures for Use:

- i. All parts of the device, which come in contact with the sample, must be decontaminated following the eight-step decontamination procedure described in Chapter 2, Quality Assurance. A distilled water rinse may not be necessary between setups on the same sample waste stream.
- ii. When a sampler is installed in a manhole, secure it either in the manhole (e.g., to a rung above the high water line) or outside the manhole to an above ground stake by means of a rope.
- iii. Place the intake tubing vertically or at such a slope to ensure gravity drainage of the tubing between samples, avoiding loops or dips in the line.
- iv. Inspect the intake after each setup and clean, if necessary.
- v. Exercise care when placing the intake(s) in a stream containing suspended solids and run the first part of the sample to waste.
- vi. Maintain sufficient velocity of flow at all times to prevent deposition of solids.
- vii. When a single intake is to be used in a channel, place it at six-tenths of the channel's depth (point of average velocity). For wide or deep channels where stratification exists, set up a sampling grid.
- viii. Maintain electrical and mechanical parts according to the manufacturer's instructions.
- ix. Replace the desiccant as needed.
- x. If a wet-cell lead-acid battery is used, neutralize and clean up any spilled acid.

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- x. Position the intake in the stream facing upstream. Limit the head-on orientation of the intake 20 degrees on either side. Secure the intake by a rope at all times with no drag placed on the inlet tubing.
- xi. After the installation is complete, collect a trial sample to assure proper operation and sample collection. The sample device must give replicate samples of equal volume throughout the flow range. If the sampler imposes a reduced pressure on a waste stream containing suspended solids, run the first part of the sample to waste.
- xii. During winter operation place the unit below the freezing level or in an insulated box. When AC is available, use a light bulb or heat tape to warm device. Be certain to place the intake line vertically or at such a slope to ensure gravity drainage back to the source. Even with a back purge system, some liquid will remain in the line unless gravity drainage is provided. If an excess length of tubing exists cut it off. Keep all lines as short as possible. Do not use catalytic burners to prevent freezing since vapors can affect sample composition. When power is unavailable, use an well-insulated box containing the device, a battery and small light bulb to prevent freezing.
- xiii. Parameters requiring refrigeration to a specific temperature must be collected with an automatic compositor, which provides that refrigeration for the entire compositing period. This can be accomplished by packing the lower tub of the compositor with ice. Care must be taken to avoid flooding the tub with melted ice in warm months and freezing the samples during the cool months.

Advantages:

- consistent samples
- probability of decreased variability caused by sample handling
- minimal labor requirement
- has capability to collect multiple bottle samples for visual estimate of variability and analysis of individual bottles

Disadvantages:

- considerable maintenance for batteries and cleaning
- susceptible to plugging by solids
- restricted in size to the general specifications
- inflexibility
- sample contamination potential
- subject to damage by vandals

5.2.3 Surface Water and Liquid Sampling Equipment

Surface water sampling includes collection of samples from lakes, ponds, streams, and rivers. It may also be necessary to collect liquid samples from lagoons, surface impoundments, sewers, point source discharges, wastewater and leachate seeps.

Sampling situations encountered in the field vary greatly and therefore the sampling device to be chosen and procedures to be followed may be varied to best fit each situation. Safety concerns will play the primary role in determining which sampling device is most appropriate. That said, the

most important goal of surface water or liquid sampling is the collection of a sample representative of all the horizons or phases present. Selection of the proper equipment rests with these two factors. Additional information on liquid/sludge samplers can be found in Section 5.3, *Non-Aqueous Sampling Equipment*, Subsection 5.3.2, *Sediment and Sludge Sampling Equipment* of this chapter. Refer to Chapter 6, *Sample Collection*, Section 6.8, *Surface Water and Sediment Sampling*, for information related to the collection procedures associated with this matrix.

The USGS notes that the two primary types of surface water samplers are the isokinetic depth-integrating samplers and nonisokinetic samplers. Isokinetic depth-integrated samplers are designed to accumulate a representative water sample continuously and isokinetically (that is, stream water approaching and entering the sampler intake does not change in velocity) from a vertical section of a stream while transiting the vertical at a uniform rate. Isokinetic depth-integrated samples are divided into two groups based on the method of suspension: hand-held and cable-and-reel samplers. Discussed in detail, examples of the US DH-81, US D-77, US D-95 and D-77 samplers can be found in the US Geological Survey's Book 9, *Handbooks for Water Resources Investigations, National Field Manual for the Collection of Water-Quality Data*, Chapter A2, Section 2.1.1, *Surface-Water Sampling Equipment* at <http://water.usgs.gov/owq/FieldManual/>.

Nonisokinetic samplers include open-mouth samplers, thief samplers, single-stage samplers and automatic samplers and pumps. Discussed below are examples of open-mouth samplers. These include the laboratory cleaned sample bottle, pond sampler, weighted bottle sampler and the Wheaton-Dip sampler. Also discussed below are examples of the following thief samplers: the Kemmerer, Van-Dorn and double-check valve bailer. Discussion on automatic samplers and pumps can be found above in the wastewater sampling section. Finally, for discussion and examples of single-stage samplers, go to the US Geological Survey's Book 9, *Handbooks for Water-Resources Investigations, National Field Manual for the Collection of Water-Quality Data*, Chapter A2, Section 2.1.1, *Surface-Water Sampling Equipment* at <http://water.usgs.gov/owq/FieldManual/>.

5.2.3.1 Laboratory Cleaned Sample Bottle

The most widely used method for collection of surface water samples is simple immersion of the laboratory cleaned sample bottle. Using the sample bottle for actual sampling eliminates the need for other equipment. This method also reduces the risk of introducing other variables into a sampling event. A low-level contaminant metal sampling requires the usage of an acid-rinsed container as per USGS. To learn more, refer to the US Geological Survey's Book 9, *Handbooks for Water-Resources Investigations, National Field Manual for the Collection of Water-Quality Data*, Chapter A3, *Cleaning of Equipment for Water Sampling*, at <http://water.usgs.gov/owq/FieldManual/>.

Procedures for Use:

- i. Make sure bottles are intact with a good fitting lid.
- ii. Proceed to immerse bottle by hand into surface water and allow water to run slowly into bottle until full. (Collect samples for volatile organics analysis first to prevent loss of volatiles due to disturbance of the water. Fill vials to zero headspace.)
- iii. Use care not to create sediment disturbance, especially when trace metals sampling is included in the requested analysis.
- iv. Follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).

Advantages:

- easy hand operation
- no field decontamination necessary
- no other equipment needed
- eliminates need for a field blank

Disadvantages:

- outside of bottle comes in contact with sample
- labeling may be compromised due to submersion
- may not be possible when bottles are pre-preserved

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5.2.3.2 Pond Sampler

The commercially available pond sampler (a.k.a. Dipper) (Figure 5.19) is used to collect liquid waste samples from disposal ponds, pits, lagoons, and similar reservoirs.

The pond sampler may consist of an adjustable clamp attached to the end of a two or three piece telescoping aluminum tube that serves as the handle. The clamp is used to secure a sampling beaker. Other pond samplers may be a single molded polyethylene handle with a 500-ml Teflon® cup fixed on the end. The sampler is easily and inexpensively fabricated. The tubes can be readily purchased from most hardware or swimming pool supply stores. The adjustable clamp and sampling beaker (stainless steel or PTFE) can be obtained from most laboratory supply houses. The materials required to fabricate the sampler are given in Figure 5.20.



Figure 5.19 Pond Sampler (Photograph by J. Schoenleber)

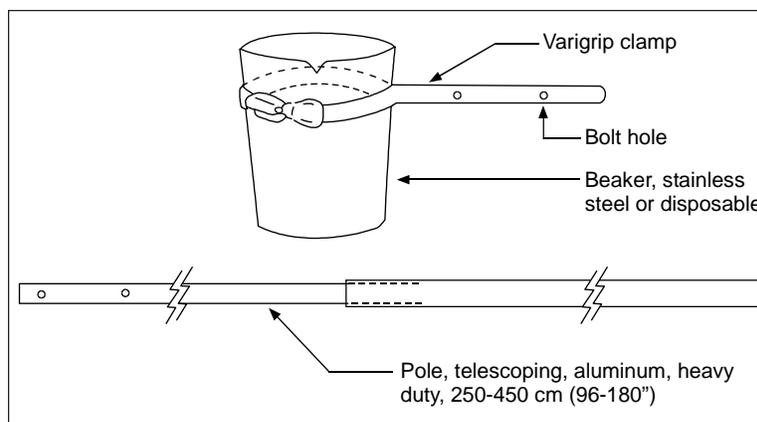


Figure 5.20 Fabricated Pond Sampler

Procedures for Use:

- i. Assemble the pond sampler. Make sure that the sampling beaker or sample bottle and the bolts and nuts that secure the clamp to the pole are tightened properly.

- ii. Slowly submerge the beaker with minimal surface disturbance.
- iii. Retrieve the pond sampler from the surface water with minimal disturbance.
- iv. Remove the cap from the sample bottle and slightly tilt the mouth of the bottle below the dipper/device edge.
- v. Empty the sampler slowly, allowing the stream to flow gently down the inside of the bottle with minimal entry turbulence. When applicable, always fill VOA vials first and fill to zero headspace.
- vi. Repeat steps ii - v until sufficient sample volume is acquired.
- vii. Follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).
- viii. Dismantle the sampler and store in plastic bags for subsequent decontamination.

Advantages:

- relatively inexpensive to fabricate
- can sample depths or distances up to 3.5m

Disadvantages:

- difficult to obtain representative samples in stratified liquids
- difficult to decontaminate when viscous liquids are encountered

5.2.3.3 Weighted Bottle Sampler

The weighted bottle sampler (Figure 5.21) can be used to sample liquids in storage tanks, wells, sumps, or other reservoirs that cannot be adequately sampled with another device. This sampler consists of a bottle, usually glass or plastic, a weight sinker, and a bottle stopper. Equal-depth and equal-width increment sampling procedures typically associated with ambient surface water data collection do not require a bottle stopper. To learn more see the US Geological Survey's Book 9, *Handbooks for Water-Resources Investigations, National Field Manual for the Collection of Water-Quality Data*, Chapter A4, *Collection of Water Samples*, at <http://water.usgs.gov/owq/FieldManual/>. Samplers used for trace element (metal) sampling should not be constructed of metal. Weighted bottle samplers can be constructed of polyvinyl chloride for this purpose. To learn more see the *National Field Manual for the Collection of Water-Quality Data*, Chapter A2, *Selection of Equipment for Water Sampling*, at <http://water.usgs.gov/owq/FieldManual/>.

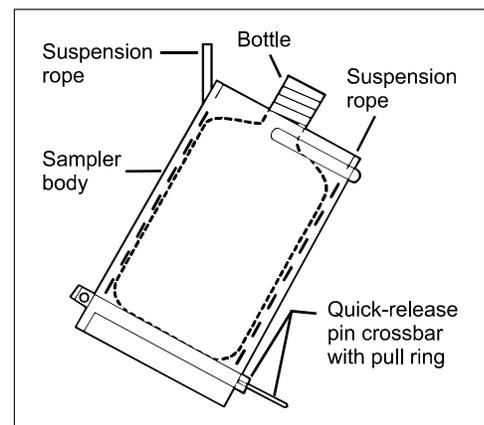


Figure 5.21 US WBH-96 Weighted Bottle Sampler. Illustration from Federal Interagency Sedimentation Project, Waterways Experiment Station, Vicksburg, Miss.

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Procedures for Use:

- i. Assemble the weighted bottle sampler.
- ii. Lower the sampling device to the predetermined depth.
- iii. When the sampler is at the required depth, pull out the bottle stopper with a sharp jerk of the sampler line and allow the bottle to fill completely. (This is usually evidenced by the cessation of air bubbles.)
- iv. Retrieve sampler.
- v. Transfer sample into laboratory cleaned sample bottles (if applicable, fill VOA vials first) or churn splitter and follow procedures for preservation and transport (see Chapter 2, *Quality Assurance*).
- vi. For equal-depth or equal-width increment sampling follow the procedures in found in the US Geological Survey's Book 9, *Handbooks for Water-Resources Investigations, National Field Manual for the Collection of Water-Quality Data*, Chapter A4, Collection of Water Samples, at <http://water.usgs.gov/owq/FieldManual/>.

Advantages:

- sampler remains unopened until at sampling depth (if equipped with a bottle stopper)
- samples can be taken from bridges when streams are inaccessible or too deep to wade

Disadvantages:

- cannot be used to collect liquids that are incompatible with the weight sinker, line or actual collection bottle
- laboratory supplied bottle may not fit into sampler, thus requiring additional equipment (constructed of PTFE or stainless steel)
- some mixing of sample may occur when retrieving the sampler from depth

5.2.3.4 Wheaton Dip Sampler

The Wheaton Dip Sampler (Figure 5.22) is useful for sampling liquids in shallow areas. It consists of a glass bottle mounted on a metal pole of fixed length. Attached to the bottle's screw cap is a suction cup mounted on another metal pole. When the sampler is lowered to the desired sampling depth, the bottle cap is released by turning the metal pole attached to the suction cup. When the bottle is full (usually evidenced by the cessation of air bubbles), the cap is screwed back on to seal the sampling container and the bottle is retrieved.



Figure 5.22 Wheaton Dip Sampler (Photograph by J. Schoenleber)

Procedures for Use:

- i. Assemble the sampler in accordance with the manufacturer's instruction.
- ii. Operate the sampler several times to ensure proper adjustment, tightness of the cap, etc.
- iii. Submerge sampler into liquid to be sampled.
- iv. When desired depth is reached, open sample bottle.
- v. Once sample is collected, close sample bottle.
- vi. Retrieve sampler
- vii. Transfer sample into laboratory cleaned sample bottles (if applicable). Note: volatile organic samples must be collected first. Follow procedures for preservation and transport (see Chapter 2, *Quality Assurance*).

Advantages:

- sample bottle is not opened until specified sampling depth is obtained
- sampler can be closed after sample is taken ensuring sample integrity
- ease of operation

Disadvantages:

- depth of sampling is limited by length of poles
- exterior of sample bottle (to be sent to lab) may come in contact with sample
- laboratory supplied sample bottle may not fit into the apparatus, thus requiring additional equipment (constructed of PTFE or stainless steel)

5.2.3.5 Kemmerer Depth Sampler

Aside from depth sampling in open bodies of water for macrophytes, the Kemmerer depth sampler (Figure 5.23) can be used to collect liquid waste samples in storage tanks, tank trailers, vacuum tanks, or other situations where collection depth prevents use of other sampling devices.



Figure 5.23 Kemmerer Depth Sampler (Photograph by J. Schoenleber)

This sampling device consists of an open tube with two sealing end pieces. These end pieces can be withdrawn from the tube and set in open position. These remain in this position until the sampler is at the required sampling depth and then a weighted messenger is sent down the line or cable, releasing the end pieces and trapping the sample within the tube.

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Procedures for Use:

- i. NOTE: The sampler described above may generally be operated from a boat launched onto the lake, pond, lagoon or surface impoundment with the sample collected at depth. If the lagoon or surface impoundment contains known or suspected hazardous substances, the need to collect samples vs. the potential risk to sampling personnel must be considered. If the sampling is determined to be necessary, appropriate protective measures (flat-bottomed boat for increased stability, life preservers, back-up team, etc.) must be implemented.
- ii. Set the sampling device so that the sealing end pieces are pulled away from the sampling tube, allowing the substance to pass through the tube.
- iii. Lower the pre-set sampling device to the predetermined depth.
- iv. When the sample is at the required depth, send down the messenger, closing the sampling device.
- v. Retrieve sampler.
- vi. Transfer sample into laboratory cleaned sample bottles (if applicable, fill VOA vials first) and follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).

Advantages:

- ability to sample at discrete depths
- ability to sample great depths

Disadvantages:

- open sampling tube is exposed while traveling down to sampling depth
- transfer of sample into sample bottle may be difficult

5.2.3.6 Van Dorn Sampler

The Van Dorn sampler (Figure 5.24) usually is the preferred sampler for standing crop, primary productivity and other quantitative plankton determinations because its design offers no inhibition to free flow of water through the cylinder. In deep-water situations, the Niskin bottle is preferred. It has the same design as the Van Dorn sampler except that the Niskin sampler can be cast in a series on a single line for simultaneous sampling at multiple depths with the use of auxiliary messengers. Because the triggering devices of these samplers are very sensitive, avoid rough handling. Always lower the sampler into the water; do not drop. Kemmerer and Van Dorn samplers have capacities of 0.5 L or more. Polyethylene or polyvinyl chloride sampling devices are preferred to metal samplers because the latter liberate metallic ions that may contaminate the sample. Use polyethylene or glass sample storage bottles. Metallic ion contamination can lead to significant errors when algal assays or productivity measurements are made.

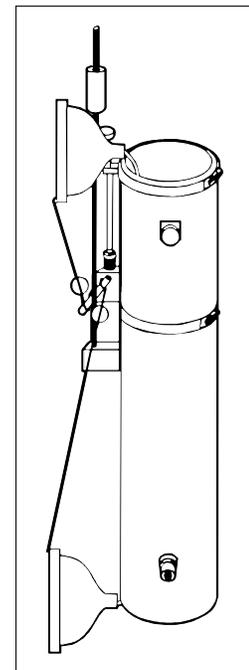


Figure 5.24 Van Dorn Sampler. Illustration from *Standard Methods for Examination of Water and Wastewater*, 20th Edition. Copyright 1992 by the American Public Health Association, the American Water Works Association and the Water Environment Federation.

Procedures for Use:

Similar to Kemmerer

5.2.3.7 Other Water Bottle Samplers

There are several variations of water bottle and trap samplers readily available on the market. Vertical and horizontal water bottle samplers come in various cylindrical dimensions ranging from 2 to 8 liters in volume. Materials of construction range from PVC to transparent acrylics. All are triggered by messengers. Their primary purpose is to measure physical (temperature), chemical (dissolved gases, nutrients, and metals) and biological (phyto- microzoo- and bacterio- plankton) constituents at depth. Check with the manufacturer on the combinations of construction materials to suite your sampling needs. Vertical samplers can be arranged in series or a carousel setup when the objective is multiple depth sampling. Horizontal samplers are designed to focus on narrow layers (e.g., thermoclines).

Juday and Schindler-Patalas are larger trap samplers that range in collection volume from 10 to 30 liters. These are preferred for zooplankters and larger copepods. These can be fitted with nets where qualitative data or large biomass is needed. Schindler-Patalas traps are typically transparent and have no mechanical closing mechanism making them convenient for cold-weather sampling.

5.2.3.8 VOC Sampler

This device, manufactured by Wildco for the USGS, is used to collect stream and open-water samples for VOC analysis (Figure 5.25). The device has been tested for analyte loss, reproducibility and contaminant carryover in the laboratory and under field conditions. Made of stainless steel and refrigeration-grade copper, it is designed to collect samples representative of environmental conditions in most



Figure 5.25 VOC Sampler. Illustration published with permission from Wildco®

streams. An important function of the sampler design is to evacuate air and other gases from the sampler before sample collection. The device weights 11 lbs. and can be suspended by hand from a short rope or chain while wading a stream. During periods of high flow, 10 lb. weights can be added to keep the sampler vertical when suspended from a bridge or cableway.

The sampler is designed to collect a sample at a single point in a stream or open body of water. The stainless-steel device holds four 40 ml vials. Copper tubes extend to the bottom of each vial from the inlet ports on the top of the sampler. The vials fill and overflow in to the sampler body, displacing the air in the vials and in the sampler through the exhaust tube. The total volume is eight times larger than the vials; therefore, the vials are flushed seven times before the final

volume is retained in the vial. The small (1/16th inch inside diameter) copper inlet ports results in a slow (3 - 4 minutes) filling time. This feature helps to produce a representative sample and allows sufficient time to place the sampler at the desired depth. The sampler begins to fill as soon as it enters the stream; however, the final sample is retained in the vial during the last 15 - 20 seconds of the filling process. A cover over the inlet ports prevents contamination from surface oil and debris when the sampler is removed from the stream.

A complete description can be found in the Open-File Report 97-401, *A Field Guide for Collecting Samplers for Analysis of Volatile Organic Compounds in Stream Water for the National Water-Quality Assessment Program*. (or visit <http://ca.water.usgs.gov/pnsp/pest.rep/voc.html>). This device is not designed for nor can it be applied to monitor well investigations.

Approval of a device of similar operation targeted for use in monitor wells is currently pending further evaluation to determine its appropriate application. Manufactured by SIBAK Industries, the Kabis sampler has undergone preliminary testing published by the USEPA and an unpublished review by the NJDEP. The USEPA Environmental Technology Verification Report (EPA/600/R-00/054) identified inconsistencies in sample analysis when the device passed through a dirty zone within a controlled water column. The report also identified a low analytical bias for certain contaminants. The NJDEP identified additional inconsistencies resulting in a lack of confidence in the device's ability to meet data quality objectives. Finally, the USACE, Cold Regions Research and Engineering Laboratory, has examined the Kabis and other discrete ground water sampling devices and their observations can be reviewed in (ERDC/CRREL TR-02-12).

5.2.3.9 Double Check Valve Bailer

Double check valve bailers (Figure 5.26) are similar in construction to bottom check valve bailers, but have the addition of a second check valve located at the top. The procedures for use are similar to that of the bottom fill bailer except when the dual check valve bailer is used as a modified point source sampler. In this case, the dual check valve bailer is lowered to the desired depth and the check valves automatically close upon retrieval allowing for sample collection at discrete depths. Aside from sampling surface waters at depth, the dual check valve bailer can be used to sample dense, non-aqueous phase liquids (DNAPLs) which can accumulate in the bottom of monitor wells. The same restrictions regarding dissolved oxygen and other air sensitive parameters that apply to single check valve bailers above apply to the dual check valve bailer as well.

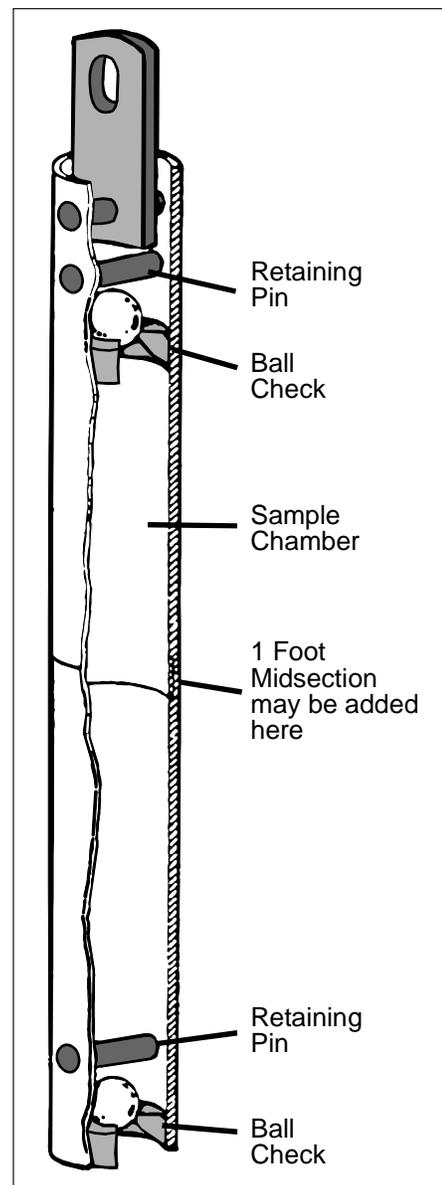


Figure 5.26
Double Check Valve Bailer

Procedures for Use:

- i. Unwrap laboratory-decontaminated bailer and connect to decontaminated PTFE coated leader/cable for lowering.
- ii. Lower the bailer slowly until the depth to be sampled is reached.
- iii. Slowly raise the bailer. The ball check valves will both close automatically as the bailer is lifted.
- iv. Tip the bailer to allow a slow discharge from the top gently down the side of the sample bottle to minimize turbulence. A bottom-emptying device may also be utilized and should be used when sampling for volatile organics. When applicable, always fill organic sample vials first, to zero headspace, with the first bailer full of water.
- v. Repeat steps iii. to v. until a sufficient sample volume is acquired.
- vi. Follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).
- vii. Place used bailer in bag for return to lab for decontamination.
- viii. Procure an additional lab decontaminated bailer and proceed to the next sampling location. Repeat procedure.

Advantages:

- measure the depth and thickness of DNAPL, if present.
- economical and convenient enough that a separate laboratory cleaned bailer may be utilized for each well therefore eliminating cross contamination
- available in PTFE or stainless steel construction
- relatively simple to use, lightweight

Disadvantages:

- aeration of sample as: 1) the sample is transferred from the bailer to the sample container over the top check valve, and 2) air becomes trapped between check valves when the bailer is turned upright causing agitation of the sample
- limited volume of sample collected
- field cleaning is not acceptable
- ball check valve function susceptible to wear, dimension distortion and silt buildup resulting in leakage. This leakage may aerate proceeding sample and may gather unwanted material by rinsing unwanted material from well casing.
- when used as a point source device, considerable mixing may occur
- representativeness of sample is operator dependent
- can not be used for well evacuation
- cannot provide reliable or reproducible data for air sensitive parameters e.g. dissolved oxygen, pH, carbon dioxide or iron and its associated forms. As a result, operator must submit to the Department a request for a variance from the Technical Requirement for Site Remediation Regulations (N.J.A.C. 7:26E-3.7), which requires the sampler to measure, record and submit well purging information associated with above parameters.

5.2.3.10 Bacon Bomb Sampler

The Bacon bomb sampler is a widely used, commercially available sampler, designed for sampling petroleum products. It is very useful for sampling large storage tanks because the internal collection chamber is not exposed to product until the sampler is triggered.

The Bacon bomb sampler (Figure 5.27) is constructed of brass or stainless steel and is available in two sizes: 1.5 inches or 3.5 inches in diameter. These range in volume from 4 oz.

up to 32 oz. It is equipped with a trigger, which is spring loaded. When opened, the trigger allows liquid to enter the collection chamber. When the trigger is released, liquid is prevented from flowing into or out of the collection chamber.



Figure 5.27 Bacon Bomb Sampler
(Photograph by J. Schoenleber)

Procedures for Use:

- i. Lower the Bacon bomb sampler carefully to the desired depth, allowing the line for the trigger to remain slack at all times. When the desired depth is reached, pull the trigger line until taut.
- ii. Release the trigger line and retrieve the sampler. Transfer the sample to the laboratory cleaned sample container by pulling upon the trigger. If applicable, fill VOA vials first.
- iii. Follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).

Advantages:

- sampler remains unopened until at sampling depth
- stainless steel construction facilitates proper decontamination

Disadvantages:

- difficult to decontaminate
- difficulties in transferring sample to container
- tends to aerate sample
- brass construction may not be appropriate in certain analysis

5.2.3.11 Continuous Water-Quality Monitors

A continuous water-quality monitor such as a data sonde is essentially a multi-meter, which is placed in a body of water for a prolonged period of time. The monitor is capable of taking continuous field measurements for a variety of parameters depending upon which probes it is equipped with e.g., pH, dissolved oxygen, specific conductance, turbidity, chlorophyll-a, etc. Continuous water-quality monitors are intensely more dynamic than simple flow-through cells used for monitoring well stability prior to sample collection. Use the URL below to gain a better understanding.

For more information regarding flow-through cells see Chapter 6, *Sample Collection*, Section 6.9, *Ground Water Sampling Procedures*, Subsection 6.9.2.2.4.5, *Flow-Through Cell*.

Procedures for Use

- See *Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Site Selection, Field Operation, Calibration, Record Computation, and Reporting*, USGS Water-Resources Investigations Report 00-4252 at <http://water.usgs.gov/pubs/wri/wri004252/>.

5.2.3.12 Churn Splitter

A churn splitter is essential for compositing surface water samples. It can be either an 8L, or, a 14L plastic container with a lid, spigot and churning paddle. See the US Geological Survey's Book 9, *Handbooks for Water-Resources Investigations, National Field Manual for the Collection of Water-Quality Data*, Chapter A2, *Selection of Equipment for Water Sampling*, Section 2.2.1.A, *Churn Splitter*, at <http://water.usgs.gov/owq/FieldManual/> for proper application. For proper cleaning when trace metal analysis is required see <http://water.usgs.gov/admin/memo/QW/qw97.03.html>. Should you experience water leakage at the spigot, go to <http://water.usgs.gov/owq/FieldManual/mastererrata.html#Chapter4> for tips on how to prevent.

Procedures for use:

- i. Clean churn using the appropriate method for the constituents which will be analyzed, e.g., trace element analysis requires an acid soak.
- ii. Churn should be kept double-bagged in clear plastic bags at all times after being cleaned including sample collection.
- iii. Rinse churn 3 times with 1 liter of sample water before collecting any samples. Be sure to allow the water to drain through the spigot each time.
- iv. Fill churn with the appropriate number of sub-samples. Be careful to keep lid on at all times except when depositing sub-samples.
- v. The contents of the churn should be composited by moving the paddle up and down at least 10 times prior to opening the spigot. A churning rate of 9 inches per second should be achieved before drawing off any samples. Once the rate is achieved, continue to churn the sample, open the spigot and collect raw samples. Filtered samples are taken directly from the churn's main compartment using a peristaltic pump and the appropriate tubing and filter.

5.2.3.13 Sample Collection and Preservation Chamber

A sample collection chamber is a containment system consisting of a white polyvinyl chloride framework with a clear plastic bag forming a barrier to ambient conditions. It is used create a clean environment in order to collect and preserve samples susceptible to contamination from ambient air deposition (i.e., affords protection to water quality samples in which constituents of concern occur at extremely low trace levels). Instructions from the USGS's Hydrologic Instrumentation Facility on how to construct your own sample and preservation chamber are available at the end of this chapter in Appendix 5.1, *Sample Collection and Preservation Chamber*. See the US Geological Survey's Book 9, *Handbooks for Water-Resources Investigations, National Field Manual for the Collection of Water-Quality Data*, Chapter A2, *Selection of Equipment for Water Sampling*, Section 2.2.2, *Processing and Preservation Chambers* for more information at <http://water.usgs.gov/owq/FieldManual/>.

5.2.4 Containerized Liquid Sampling Equipment

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One of the most difficult liquids to sample is that which is stored in a container. Several factors play an important role in determining the sampling method to be used. These include the location of the container, the location and size of the opening on the container, and the type of equipment that is available for sampling. Health and safety of sampling personnel also plays a key role in determining the choice of and which sampling tool will be used.

No matter what type of sampler is chosen, it must be utilized in such a manner that allows collection of all horizons present in the container. Rarely does a container hold a homogeneous mixture of material.

Sampling devices for containerized liquids and their procedures for use are presented below. Other sampling devices, which may be considered appropriate, include the Bacon Bomb, Kemmerer, or a Weighted Bottle Sampler, previously explained above in Section 5.2.3 of this chapter.

5.2.4.1 Coliwasa

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The Composite Liquid Waste Sampler, or COLIWASA, (Figure 5.28) is one of the most important liquid hazardous waste samplers. It permits the representative sampling of multiphase wastes of a wide range of viscosity, corrosivity, volatility, and suspended solids content. Its simple design makes it easy to use and allows for the rapid collection of samples, thus minimizing the exposure of the sample collector to potential hazards from the waste.

Three types of COLIWASA samplers are generally available based on materials of construction. These include those made of plastic, PTFE or glass. The plastic type consists of a translucent plastic sampling tube. This COLIWASA is used to sample most containerized liquid wastes except wastes that contain ketones, nitrobenzene, dimethylformamide, mesityl oxide, and tetrahydrofuran. The glass type uses a borosilicate glass plumbing pipe as the sampling tube and glass or PTFE for a stopper rod.

This type is used to sample all other containerized liquid wastes that cannot be sampled with the plastic COLIWASA except strong alkali and hydrofluoric acid solutions.

Procedures for Use:

- i. With the sampler in the open position, insert it into the material to be sampled.
- ii. Collect the sample at the desired depth by rotating the handle until one leg of the T is squarely perpendicular against the locking block.
- iii. Withdraw the sampler and transfer the sample(s) into laboratory cleaned sample bottles.
- iv. Follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).

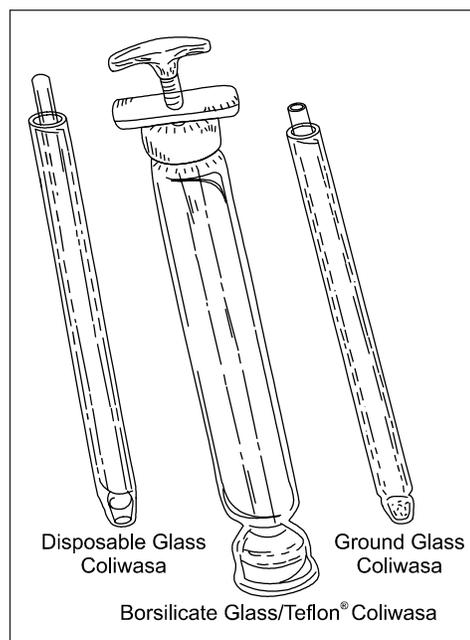


Figure 5.28 Coliwasa

Advantages:

- inexpensive
- simplicity of operation
- versatile

Disadvantages:

- problems encountered with fluids of very high viscosity
- difficulty in cleaning

5.2.4.2 Open Tube Thief Sampler

The open tube thief sampler (Figure 5.29) is basically a hollow glass or rigid plastic tube, which is anywhere from four to five feet in length. It generally has an inside diameter of 1/4" or 1/2". Choose a diameter based on the viscosity of the liquid to be sampled.

The plastic open tube sampler (Thief) is used to sample most containerized liquid wastes except waste that contains ketones, nitrobenzene, dimethylformamide, mesityl oxide, and tetrahydrofuran.

The glass open tube sampler (Thief) is used to sample all other containerized liquid waste that cannot be sampled with the plastic open tube sampler except strong alkali and hydrofluoric acid solutions.

Procedures for Use:

- Insert the sampler into the material to be sampled to the depth desired.
- Place gloved thumb securely over open end of tube and carefully withdraw the sampler.
- Transfer sample into laboratory cleaned sample bottles and follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).

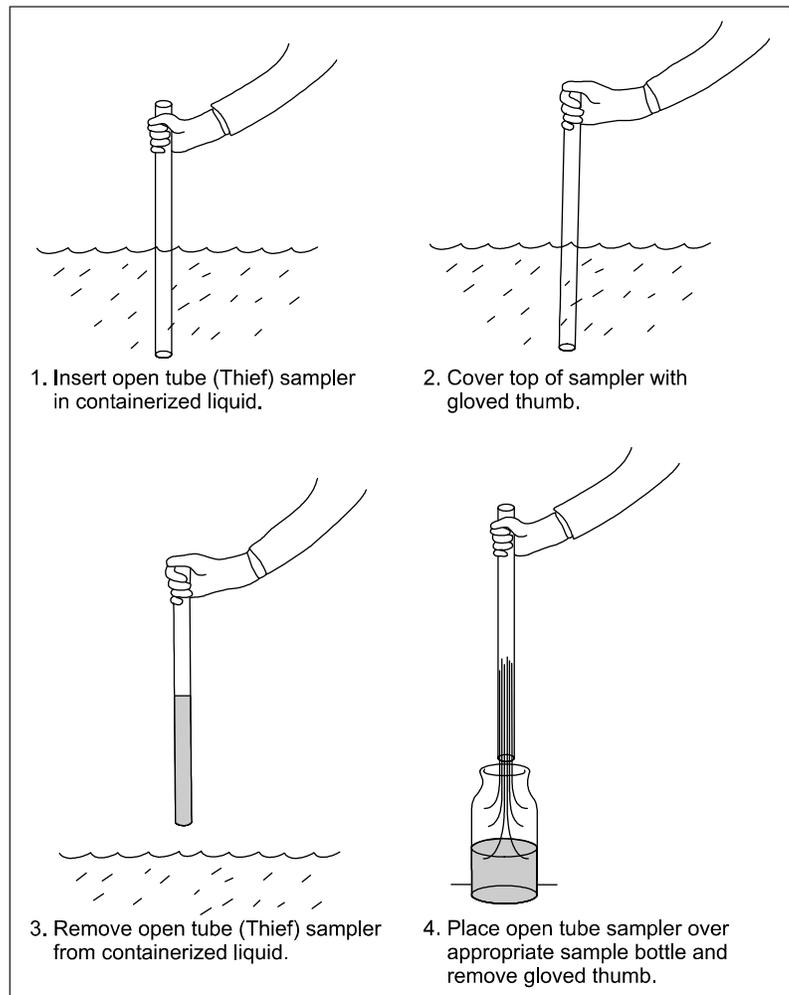


Figure 5.29 Open Tube Thief Sampler

Advantages:

- inexpensive
- simplicity of operation
- versatile, e.g. may be used to sample water from sump areas in homeowner basements
- disposable

Disadvantages:

- sample leakage
- small sample volume

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5.2.4.3 Stratified Thief Sampler

The stratified thief sampler (Figure 5.30) uses discs or wipers to hold stratified liquids in position while the tube is slipped past them. The wipers keep the inside of the tube from carrying portions of the upper fluid down into other layers.

The plastic stratified sample thief is used to sample most containerized liquid hazardous waste except waste that contains ketones, nitrobenzene, dimethylformamide, mesityl oxide, and tetrahydrofuran. It is particularly useful for highly viscous, stratified liquids.

Procedures for Use:

- Insert the sampler into the material to be sampled with the outer sheath raised to the open positions.
- When the desired depth is reached, slide outer sheath down over center section.
- Withdraw the sampler and transfer discrete samples into laboratory cleaned sample bottles.
- Follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).

Advantages:

- simplicity of operation
- representative sample obtained in viscous, stratified liquids

Disadvantages:

- plastic is not compatible with certain substances
- some difficulty in transferring sample to sample container

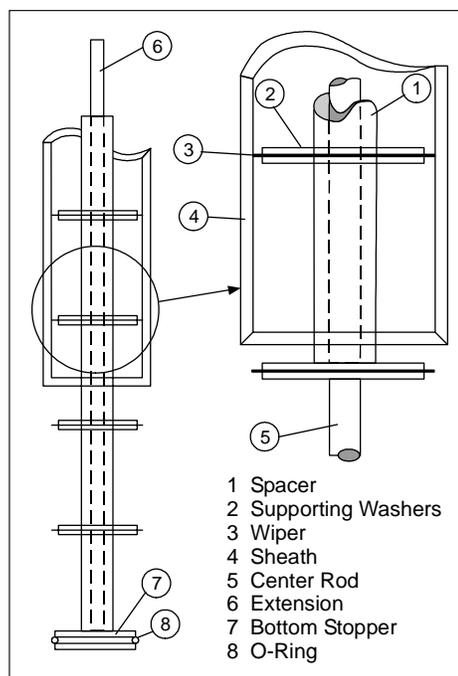


Figure 5.30 Stratified Thief Sampler

5.3 Non-aqueous Sampling Equipment

Sampling of non-aqueous matrices encompasses several different types of wastes, from solids in drums and containers to soil and sludge. There are many factors involved when choosing the proper sampling equipment for these materials.

The most important aspect of non-aqueous sampling is to retrieve a representative sample of all horizons present. An attempt must be made to maintain sample integrity by preserving its physical form and chemical composition. The proper use of appropriate sampling equipment lends to the accomplishment of these goals.

This portion of Chapter 5 is separated into three subparts: soil, sediment/sludge and containerized solids/waste piles. The three subparts deal with samplers designed for the specific materials involved. See Chapter 6, *Sample Collection*, Sections 6.1, *General Information Applicable to all Sampling Events*, 6.2, *Soil Sampling*, and 6.2.7, *VOC Sample Collection for Soils* for more information on the process of collecting soil samples.

5.3.1 Soil Sampling Equipment

Soil sampling is performed for a number of reasons. These include determination of soil contamination, identifying the horizontal and vertical extent of contamination and investigating the relationship between soil and ground water contamination. Soil can be sampled at the surface or below surface depending on the type of information required. Soil is typically divided by depth into two categories: surface and subsurface. Surface soils include the zone between ground level and 24 inches. Subsurface soils include any depth below 24 inches (please note that for radiological sampling, surface soils are considered to be in the top 6 inches, or 15 centimeters only). There are several different types of samplers that can be used to collect a soil sample at any depth.

5.3.1.1 Scoop/Trowel

The trowel or scoop (Figure 5.31) can be used to collect surface soil samples. They can also be used for homogenizing soil or for collecting a variety of other solid waste samples. A trowel looks like a small shovel. A laboratory scoop is similar to the trowel, but the blade is usually more curved and has a closed upper end to permit the containment of material. Scoops come in different sizes and makes. Some are coated with chrome paint, which can peel off and get into the sample: these are unacceptable. Stainless steel scoops are preferred however, scoops made from alternative materials may be applicable in certain instances (e.g., polyethylene for trace element sampling in sediments). The decision for equipment material of construction other than stainless steel will be made at the discretion of NJDEP. Samples can be put directly into sample containers or be processed through sieves to acquire the desired grain size. Stainless steel trowels and scoops can be purchased from scientific or environmental equipment supply houses.



Figure 5.31 Scoop/Trowel.
(Photograph by D. Dibblee)

Procedures for Use:

- i. At specified intervals, take small, equal portions of sample from the surface and immediately below the surface.

- ii. Transfer samples into laboratory cleaned sample bottles and follow procedures for preservation and transport (see Chapter 2., Appendix A., *Tables of Analytical Methods*).

Advantages:

- easy to use and clean

Disadvantages:

- can not be used to collect samples for volatile organic analysis.

5.3.1.2 Bucket Auger

[◀ Return to TOC](#)

The bucket auger (Figure 5.32 [Art's Manufacturing and Supply]) consists of a stainless steel cylindrical body with sharpened spiral blades on the bottom and a framework above allowing for extension rod and T-handle attachments. When the tool is rotated clockwise by its T-handle, it advances downward as it cuts into the soil and moves loosened soil upward where it is captured in the cylindrical body. Cutting diameters vary. The overall length of an auger is about 12 inches and extensions can extend the sample depth to several feet. There are three general types of augers available: sand, clay/mud, and augers for more typical mixed soils.



Figure 5.32 Bucket Augers (Photograph by D. Dibblee)

Depending on soil characteristics, choose the auger best suited for your needs. These tools can be purchased from scientific or forestry equipment supply houses.

The auger is particularly useful in collecting soil samples at depths greater than 8 cm (3 in.). However, this sampler destroys the cohesive structure of soil and clear distinction between soil collected near the surface or toward the bottom may not be readily apparent as a result of the mixing effect. It is not approved, therefore, when an undisturbed soil sample for volatile organics (VOA) is desired. It should be noted that this exception does not include analysis of other organics e.g., base neutrals, acid extractables, pesticides, PCBs, total petroleum hydrocarbons, and total organic carbon. Bucket augers are also perfectly acceptable for inorganic analysis.

Procedures for Use:

- i. Remove unnecessary rocks, twigs, and other non-soil materials from selected sampling point.

- ii. Attach the bucket and handle to an extension rod.
- iii. Begin turning the auger with a clockwise motion and continue until the desired sampling depth is obtained.
- iv. Use a second auger to collect the sample. The auger utilized for hole advancement is not acceptable for sample collection.
- v. Transfer the sample into laboratory cleaned sample containers using a clean decontaminated stainless steel spoon or trowel.
- vi. When collecting samples at depths greater than 12 inches, it is advisable to discard one-half inch of material in the top portion of the auger due to cave-in
- vii. Follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).

Advantages:

- relatively speedy operation for subsurface samples

Disadvantages:

- destroys soil horizons as it samples
- not approved for sampling soils for volatile organic analysis

5.3.1.3 Soil Coring Device

The soil-coring device (Figure 5.33 [Art's Manufacturing and Supply]) consists of a stainless steel, machined split-cylinder with threaded ends, cutting shoe and end cap with a slide hammer used for advancement into the soil. The cutting shoe and end caps of the corer are also constructed of stainless steel. Use of a plastic collection tube and soil-retaining basket is optional. Once the desired depth is reached, the slide hammer can be used to assist in pulling back the device. Caution should be used when back hammering so as not to loosen soil captured within the barrel if a liner/retaining basket is not used. This device may be used in conjunction with a soil auger if core analysis of depth profiles need to be performed.

Once opened and screened with a Photo or Flame Ionization Detector (PID or FID), a sub-sample of soil can be collected for volatile organic analysis soil using an En Core[®] or other sampler. See Chapter 6, *Sample Collection*, Sections 6.1, *General Information Applicable to all Sampling Events*, 6.2, *Soil Sampling*, and 6.2.7, *VOC Sample Collection for Soils* for more information on collection of soil samples.

Procedures for Use:

- i. Assemble the split barrel and screw on cutting shoe and end caps. Liner and basket retainers are optional.
- ii. Place the sampler in position with the bit touching the ground.
- iii. Drive with slide hammer until unit is completely advanced. Avoid sample compression
- iv. After reaching the required depth, use the slide hammer to back out device using caution so as not to lose sample.
- v. Remove both ends and tap barrel to break open split sections.
- vi. Use a utility hook knife to open plastic liner.



Figure 5.33 Soil Coring Device (Photograph by J. Schoenleber)

- vii. Field screen using a PID or FID.
- viii. Record visual observations in boring log.
- ix. For volatile organic analysis use an En Core[®] sampler to sample and preserve, or one of the devices discussed in Chapter 6, *Sample Collection*, to collect the sample prior to preservation.
- x. Follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).

Advantages:

- can be used in various substances
- core sample remains relatively intact
- bit is replaceable

Disadvantages:

- depth restrictions
- not useful in rocky or tightly packed soils
- only soil coring devices of stainless steel construction are recommended for collection of soils for chemical analysis

5.3.1.4 Split Spoon Sampler

[◀ Return to TOC](#)

A split spoon sampler (Figure 5.34) is utilized to collect representative soil samples at depth. The sampler itself is a length of carbon or stainless steel tubing split longitudinally and



Figure 5.34 Split Spoon Sampler (Photograph by D. Dibblee)

equipped with a drive shoe and a drive head. These are available in a variety of lengths and diameters and are typically advanced by blows of a 140-lb. hammer dropped 30 inches from a drill rig mast.

Procedures for Use:

- i. Assemble the sampler by aligning both sides of the barrel and then screwing the drive shoe with retainer on the bottom and the heavier headpiece on top.
- ii. Place the sampler in a perpendicular position on the material to be sampled.
- iii. Drive the tube utilizing a sledgehammer or well drilling rig if available. Do not drive past the bottom of the headpiece as this will result in compression of the sample.
- iv. Record the length of the tube that penetrated the material being sampled and the number of blows required obtaining this depth.
- v. Withdraw the sampler and open by unscrewing drive shoe and head and splitting barrel. If split samples are desired, a decontaminated stainless steel knife should be utilized to divide the tube contents in half longitudinally.
- vi. Collect volatile organic sample first per procedures discussed in Chapter 6, *Sample Collection*, Section 6.2.7, *VOC Sample Collection for Soils*.
- vii. Transfer sample into laboratory cleaned sample bottles, or, into bowl for homogenization for non-volatile analysis using a stainless steel scoop or trowel and follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).
- viii. When split tube sampling is performed in order to gain geologic information, all work should be performed in accordance with ASTM # D 1586-84 (re-approved 1974).

Advantages:

- easily available
- strong
- ideal for split sample collection

- preferred sampling device for volatile organic sample collection

Disadvantages:

- requires drilling or tripod for deeper samples

5.3.1.5 Shelby Tube Sampler

[◀ Return to TOC](#)

A Shelby tube is used mainly for obtaining geological information but may be used in obtaining samples for chemical analysis.

The Shelby tube consists of a thin walled tube with a tapered cutting head. This allows the sampler to penetrate the soil and aids in retaining the sample in the tube after the tube is advanced (without excessive force) to the desired depth.

Procedures for Use:

- Place the sampler in a perpendicular position on the material to be sampled.
- Push the tube into the soil by a continuous and rapid motion, without impact or twisting. In no instance should the tube be pushed further than the length provided for the soil sample.
- Let sit for a few minutes to allow soils to expand in the tube.
- Before pulling out the tube, rotate the tube at least two revolutions to shear off the sample at the bottom. If the sample is to be shipped for further geologic analysis, the tube must be appropriately prepared for shipment. Generally this is accomplished by sealing the ends of the tube with wax in order to preserve the moisture content. In such instances, the procedures and preparation for shipment shall be in accordance with ASTM # D 1586-83.

Advantages:

- inexpensive
- tube may be used to ship the sample without disturbing the sample
- provides core sample
- easily cleaned

Disadvantages:

- sometimes difficult to extract sample
- not durable encountering rocky soils

5.3.1.6 En Core® Sampler

The En Core® sampler (Figure 5.35) is the only approved soil sampling tool which can be used to collect a sub-sample from an intact soil core for volatile organic analysis and submitted directly to the laboratory. See Chapter 6, *Sample Collection*, Section 6.2.7, *VOC Sample Collection for Soils* for more specific information on collection procedures for volatile organics in soil.



Figure 5.35 En Core® Sampler with T Handle
(Photograph by C. Van Sciver)

Procedures for use:

- i. Open foil package containing 5-gram En Core® Sampler.
- ii. Insert 5-gram Teflon® sampler into En Core® T-handle.
- iii. DO NOT pull plunger back prior to use.
- iv. Set device aside on a clean surface.
- v. In controlled setting, open coring device and expose core for field screening with direct reading instrument.
- vi. Once a 6-inch increment for sampling is identified, carefully prepare soil core surface for sub-core sampling by scraping away a small portion of soil with a stainless steel spatula.
- vii. Position En Core® with T-handle squarely over the prepared surface and press into soil to a depth of approximately 5/8" to achieve 5-gram sample.
- viii. Remove and with a clean SS spatula eliminate any excessive soil from end of sampler that may interfere with obtaining a tight and complete seal when capped. Also remove any excess soil from outside surface of 5-gram sampler allowing O-ring inside the cap to secure seal.
- ix. Cap sampler.
- x. Remove sampler from T-handle and lock plunger by inserting plunger stem into the specially designed hole found on T-handle and give a 1/4 turn. If the stem does not turn, it's an indication that the plunger did not completely retract and a full 5 grams has not been collected.
- xi. Return to foil package, seal, label and cool to 4° C.
- xii. Ship to laboratory the same day as sample collection to ensure 48 hour holding time (time of sample collection to methanol extraction in the laboratory) is not exceeded.

Advantages:

- The only DEP approved device to collect a soil sample for volatile organic analysis that eliminates the need for field preservation.
- Engineered to maintain integrity of soil sample without loss of volatile organics.

Disadvantages:

- Plunger is designed to open as it is pressed into the soil core. Depending on the cohesive nature of the substrate being sampled, obtaining a full 5-gram sample in one movement may be difficult.
- Cores consisting of small rocks, shale, cobble or similar material can not be effectively sampled.

5.3.1.7 Power Auger

In and of itself, the power auger is not a tool for sample collection. Instead, a power auger is used in lieu of a bucket auger to reach the depth of a desired sample interval. The power auger is composed of a length of auger flight, usually three feet; attached to a power source which turns the auger either hydraulically or mechanically. Various sizes and types of power sources are available, from one man to truck mounted units. Additional auger flights can be used to increase the depth obtainable by the unit.

The power auger is used to bore just above the desired sampling depth. A bucket auger or coring device, smaller in diameter than the auger flight, is then used to obtain the sample.

Advantages:

- reduces sampling time
- samples at depth easily obtainable

Disadvantages:

- initial expense
- use of gasoline powered engine increases possibility of contamination of sample
- not useful in rocky soils
- Extensive decontamination procedure (high pressure, hot water cleaning of auger flights)

5.3.1.8 Direct Push Technology

[◀ Return to TOC](#)

Use of Direct Push technology to obtain soil samples has gained wide acceptance. The relative ease to collect minimally disturbed soil cores at the surface or at depth plus the ability to provide a wide array of geotechnical options has made this system attractive. While various manufacturers make and distribute their own 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 you must apply, at a minimum, the Cold Regions decontamination procedure discussed in Chapter 2, *Quality Assurance*, Section 2.4, *Decontamination Procedures*.

The Technical Requirements for Site Remediation N.J.A.C. 7:26E-3.6(a)4.(ii), instruct one to select a six-inch increment of soil for volatile organic laboratory analysis based on field screening (direct reading PID/FID) measurements of an exposed core using criteria relative to the instrument's initial background readings. If a boring is continuously cored to 20 feet below grade where ground water is first encountered, then 4 to 5 individual 48" - 60" soil core segments will have to be opened and screened before determination as to which six-inch increment is to be selected for sampling and analysis. Special attention must be paid to labeling and storage of individual core samples when continuous soil samples are collected from a single boring. In many instances soil cores can be produced faster than they can be opened, logged, screened and sampled by a technician. In those instances when a backlog of cores are being generated, care must be made to protect the cores from direct sunlight, excessive ambient temperatures and rain. 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. Proceeded carefully, but quickly when field screening. If necessary, log soils for lithology information *after* sample collection. Always calibrate the direct reading instrument at the start of each day.

Another other option is to select a six-inch increment from every individual core segment, collect a sample, and only submit the sample required for analysis as directed in 7:26E-3.6(a)4(ii). This option can be more costly as several En Core[®] samplers will have to be discarded at the end of the each boring. If other preservation techniques are used, several laboratory bottles with preservative will have to be discarded and if methanol is the preservative, then disposal could be an issue. Sampling every individual core first, prior to determining which increment to ship for laboratory analysis will also require additional labor. This particular option, to collect a representative six-inch incremental sample from every individual segment of

a continuous core with its associated cost, makes the first option to carefully protect and manage the cores to control the loss of volatile organics even more critical.

For more information related to direct push technology, see Sections 5.2.1.12, 6.4, 6.9.2.1, and Appendix 6.1 (A.6.1.3.3) or go to the following USEPA web site:

<http://www.epa.gov/superfund/programs/dfa/dirtech.htm#vendor>

5.3.2 Sediment and Sludge Sampling Equipment

Factors that contribute to the selection of a sediment/sludge sampler include the width, depth, flow, and the bed characteristics of the area or impoundment to be sampled. In collecting sediment/sludge samples from any source, care must be taken to minimize disturbance and sample washing as it is retrieved through the liquid column above. When retrieving a sample through a water column of 4-inches or more, and/or fast stream flow, it is necessary to use sampling equipment that is capable of capturing the sample with minimal loss of sediment fines. When cleaning, at a minimum, use the Three-Step or Cold Regions decontamination procedures described in Chapter 2, *Quality Assurance*, Subsections 2.4.2 and 2.4.3, respectively.

Several samplers, which are used for other types of non-aqueous sampling, may be adapted for use as sediment/sludge collection devices. These include the scoop/trowel, bucket auger, soil coring device, and split spoon sampler, which have all been previously described above. This section describes additional samplers that are specifically designed for sediment sample collection. For more information on sample collection and sediment see, Chapter 6, *Sample Collection*, Section 6.8, *Surface Water and Sediment Sampling* and Subsection 6.8.2, *Freshwater Biological Monitoring Program* and Table 5.2.

5.3.2.1 Benthic Grab Samplers

Benthic samplers can be divided into three general types based upon their mechanical action: center pivot grabs, clamshell pivot grabs and drags, sleds and scoops. While their primary use is for the collection of macroscopic bottom fauna, they can be used for the collection of bottom sediment for chemical analysis. Choosing the correct device requires a fore knowledge of the bottom's physical and flora condition. It requires a prior understanding of the analysis to be conducted and how the results will be used. It also depends upon the mechanical action and material of construction of the device (sample disturbance), and finally, correct selection depends on whether the device will be used in fast or slow moving, fresh or salt-water environments.

5.3.2.1.1 Ponar Dredge

The Ponar dredge (Figure 5.36) is an example of a center pivot device whose scoops keep disturbance of bottom sediments to a minimum. The shell is opened and latched in place and lowered to the bottom. When tension is released



Figure 5.36 Ponar Dredge. Illustration published with permission of Wildco®

on the lowering cable, the latch releases and the lifting action of the cable attached to the center pivot closes the device. Ponars are best suited for hard bottoms (sand, gravel, consolidated marl or clay) in fresh or salt water (stainless steel construction). They are available in a “Petite” version with a 232 square centimeter sample area that is light enough to be operated without a winch or crane. Penetration depths will usually not exceed several centimeters. Grab samplers, unlike corers, are not capable of collecting totally undisturbed samples. As a result, material in the first centimeter cannot be separated from that at lower depths. The sampling action of these devices causes agitation currents, which may temporarily suspend some settled solids. This disturbance can be minimized by slowly lowering the sampler the last half-meter and allowing a very slow contact with the bottom. Collection of sludge or sediment samples must be done after all overlying water samples have been obtained.

Procedures for Use:

- i. Attach a decontaminated stainless steel Ponar to the necessary length of sample line.
- ii. Measure and mark the distance to bottom on the sample line. A secondary mark, 1 meter shallower, will indicate proximity so that lowering rate can be reduced, thus preventing unnecessary bottom disturbance.
- iii. Open sampler jaws until latched. From this point on, support sampler by its lift line or the sampler will be tripped and the jaws will close.
- iv. Tie free end of sample line to fixed support to prevent accidental loss of sampler.
- v. Begin lowering the sampler until the proximity mark is reached.
- vi. Slow rate of descent through last meter until contact is felt.
- vii. Allow sample line to slack several centimeters. In strong currents more slack may be necessary to release mechanism.
- viii. Slowly raise dredge clear of surface.
- ix. Drain excess liquid through screen.
- x. Place dredge into a stainless steel or Teflon[®] tray and open.
- xi. Collect a suitable aliquot with stainless steel spoon or equivalent and place into the appropriate sample container. Care should be taken to collect material, which has not contacted the dredge's sides.
- xii. Transfer sample into laboratory cleaned sample bottles and follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).

Advantages:

- ability to sample most types of sludge and sediment from silts to granular material.
- light weight
- large sample can be obtained intact, permitting further intervals

Disadvantages:

- shock wave from descent may disturb fine sediments on the surface

- not capable of collecting undisturbed samples
- can lose possible contaminants when pulling samples through water column
- possible incomplete closure of jaws can result in sample loss

Other examples of center pivot samplers are the Ekman Grab, Shipek[®], and Box Corer.

5.3.2.1.2 Ekman Grab Sampler

The Ekman Grab sampler (Figure 5.37) is best suited for soft, finely divided, shallow, littoral trash-free bottoms with little current. Sticks, decayed leaves and mixtures of sand and stone may prevent the jaw from closing properly. Two thin, hinged overlapping lids on top open during descent to let water pass through. They close during retrieval and are held shut by water pressure to reduce washout. Ekman's can be purchased in various sizes by volume and with additional weights to accommodate sampling needs. Stainless steel construction allows for chemical analysis of sediments in both fresh and salt water.

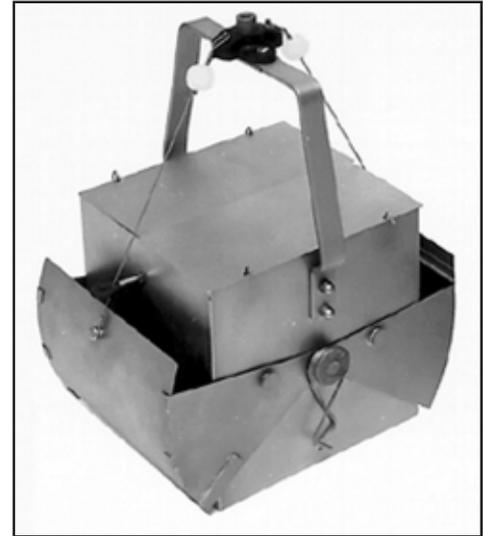


Figure 5.37 Ekman Grab Sampler. Illustration published with permission of Wildco[®]

5.3.2.1.3 Box Corer

The Box Corer (Figure 5.38), also an example of a center pivot scoop, is designed to work in hard bottoms of finely divided muck, clays, mud ooze, submerged marl or fine peaty materials without the use of spring powered grabs. This device can weight over 100 lbs. without the use of additional weights and over 200 lbs. with weights. Using the Box Corer requires the use of a winch. Options include acrylic liner and wash frame for sample separation on deck. Stainless steel construction allows for chemical analysis of sediments in both fresh and salt water.

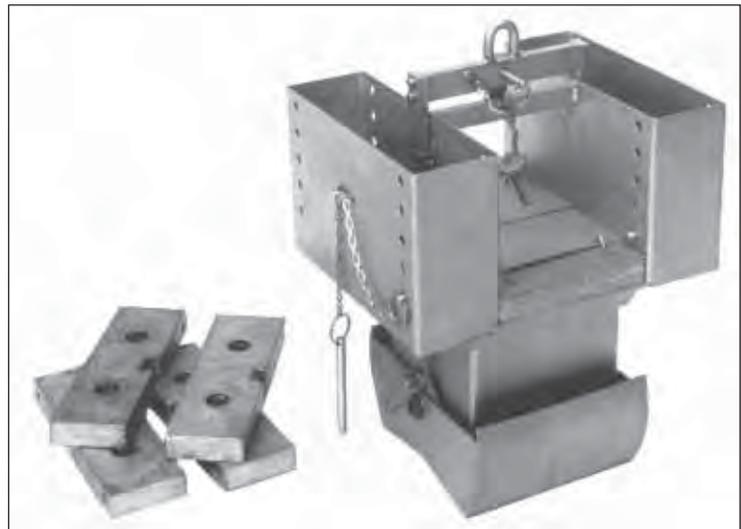


Figure 5.38 Box Corer. Illustration published with permission of Wildco[®]

5.3.2.1.4 Shipek[®]

The Shipek[®] (Figure 5.39) is yet another example of a center pivot grab sampler. This unusual looking device is designed to collect an undisturbed sample of unconsolidated sediment, from soft ooze to hard-packed silts. Sample volume

can range up to 3000 ml. It consists of two concentric half cylinders, one of which is fixed into the body of the device. A cocking wrench is used for winding the torsion springs. A safety hook prevents premature release. Cast into each end of the frame are large stabilizing handles which, along with its weight, hold the sampler upright

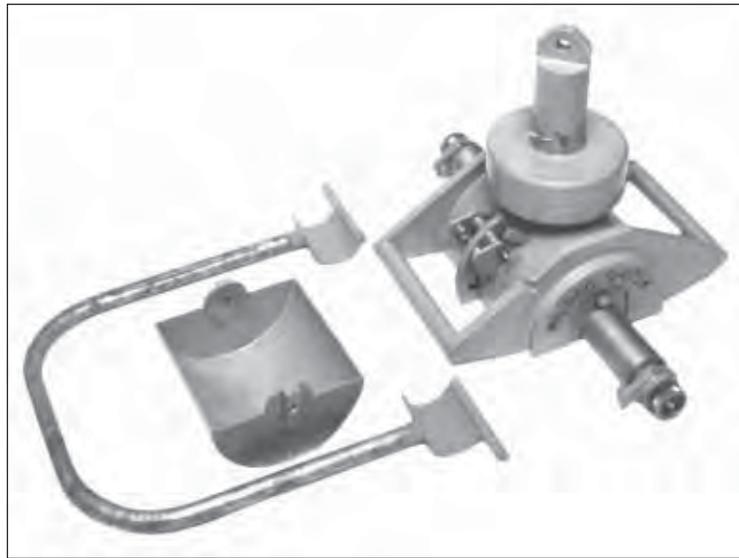


Figure 5.39 Shipek® Grab Sampler. Illustration published with permission of Wildco®

during descent. When the grab touches bottom, inertia from a self-contained weight releases a catch and helical springs rotate the inner half cylinder by 180°. Because the rotation of the half cylinder is extremely rapid, its shear strength is far greater than the sediment strength, thus cutting cleanly. After turning, the scoop remains closed preventing washout and thus provides an undisturbed sample. Because the Shipek is spring-loaded and its scoop is very dangerous when closing, use extreme caution. Operation needs 2 strong people due to its size and weight (134 lbs.). Its stainless steel construction allows for chemical analysis of sediments in both fresh and salt water.

5.3.2.1.5 Van Veen

An example of a clamshell pivot, the Van Veen grab (Figure 5.40) is lightweight and suited to take large samples in soft bottoms. The long lever arms allow it to cut deep into softer bottoms. The top is covered with a stainless steel screen for water to flow through during descent. The screen is covered with a neoprene rubber flap to prevent sample washout during retrieval.

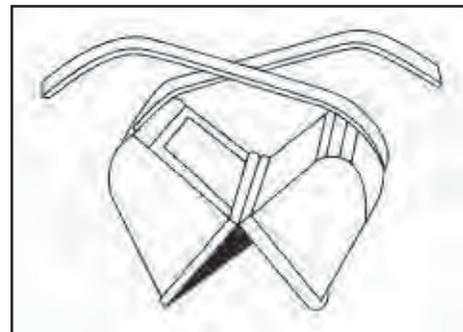


Figure 5.40 Van Veen Grab. Illustration published with permission of Wildco®

5.3.2.1.6 Petersen Grab

The Petersen grab (Figure 5.41), another clamshell pivot device, is typically used for fresh water qualitative or quantitative macroscopic fauna sampling in hard bottoms. Zinc plating on heavy steel construction prohibits the use of this device for sediments requiring chemical analysis. Since this device has been used for grab sampling sediment for over 70 years, it makes comparative study where other Petersen grab samplers have been used ideal.



Figure 5.41 Petersen Grab. Illustration published with permission of Wildco®

5.3.2.2 Sediment Core Samplers

Sediment corers differ from benthic grab samplers by their ability to retain the integrity of sediment horizons with minimal disturbance. This allows for discrete sampling of horizons or zones of interest. They are also capable of collecting samples at greater depths than grab samplers. They generally provide less sample volume than grab samplers and user degree-of-difficulty increases when samples are collected under several feet of water from a boat or barge. Various manufacturers provide a wide range of devices capable of collecting sediment cores from specific environments. Understanding your specific needs and the conditions of the medium will assist in choosing the proper tool. While more expensive than chrome or zinc plated devices, stainless steel corers can better withstand the rugged field handling and corrosive

environments and also compliment chemical analysis. As with grab samplers, when cleaning, at a minimum, use the Three-Step or Cold Regions decontamination procedures described in Chapter 2, *Quality Assurance*, Subsections 2.4.2 and 2.4.3, respectively.

5.3.2.2.1 Hand Corer

The Hand Corer (Figure 5.42), used for collecting sediment samples, has been modified from a standard single barrel soil core sampler by the addition of a handle to facilitate driving the core and a check valve on top to create a partial vacuum which prevents wash out during retrieval through overlying water. It should be noted,

however, that this device can be disruptive to the water/sediment interface and might cause significant alterations in sample integrity if extreme care is not taken. The hand corer is available in stainless steel construction allowing for chemical analysis of sediments in both fresh and salt water.



Figure 5.42 Hand Corer (Photograph by J. Schoenleber)

Hand corers can be used for sludges as well as sediments provided the water is shallow. Some hand corers can be fitted with extensions allowing collection of samples beneath a shallow layer of liquid (to about 15 feet). Most of the corers can be adapted to hold liners.

Wildco® Supply manufactures the Ogeechee™ Sand Corer for special-

ized hand coring in firm or sandy bottoms in fresh, salt or brackish swiftly moving waters. They also manufacture the K-B® Core Sampler which has a specially designed valve that is locked open during descent thus creating minimal frontal wave and minimal warning to fauna at the water/bottom interface. The Ogeechee™ Sand Corer can be used in fast moving waters as deep as 15 feet with the use of extensions. The K-B® Core Sampler can be used in water as deep as 300 ft. Both can be outfitted with stainless steel tube bodies allowing for the chemical analysis of sediments in both fresh and salt water.

Procedures for Use:

- i. Decontaminate prior to use.
- ii. Force corer in with a smooth, continuous motion.
- iii. Twist corer and withdraw in one motion.
- iv. Remove nosepiece and withdraw sample.
- v. Transfer sample into an appropriate sample bottle with a stainless steel spoon or equivalent.
- vi. Transfer sample into laboratory cleaned sample bottles and follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).

Advantages:

- easy to use
- minimal risk of contamination

Disadvantages:

- can disrupt water/sediment interface
- does not work well in sandy sediments

5.3.2.2.2 Russian Peat Borer

The Russian Peat Borer (Figure 5.43), manufactured by Aquatic Research Instruments, can be used for paleoecological analysis of bog and salt marsh sediments, collection of uncompressed core in poorly decomposed woody peat and in shallow water applications. One wall of the core tube is sharpened to longitudinally cut through sediments when sampler is turned clockwise while a solid Delrin® core head and bottom point support a stainless steel cover plate which freely rotates inside the core tube. The stainless steel cover plate is curved and sharpened to minimize disturbance when inserted into the sediment.

A complete Environmental Technology Verification (ETV) Program Report on the Russian Peat Borer (EPA/600/R-01/010, Dec. 1999) produced by the USEPA, can be obtained by going to http://www.epa.gov/etv/pdfs/vrvs/99_vr_ari_peat.pdf. This document contains “how to” information as well as advantages and limitations. A quality assurance/quality control comparison to reference sediment sampling devices rounds out a critical look as to the Russian Peat Borer’s effectiveness. The 134 page report indicates that, “Based on the demonstration results, the Russian Peat Borer can be operated by one person with minimal skills and training and does not require support equipment such as a winch and power source, even when collecting sediment

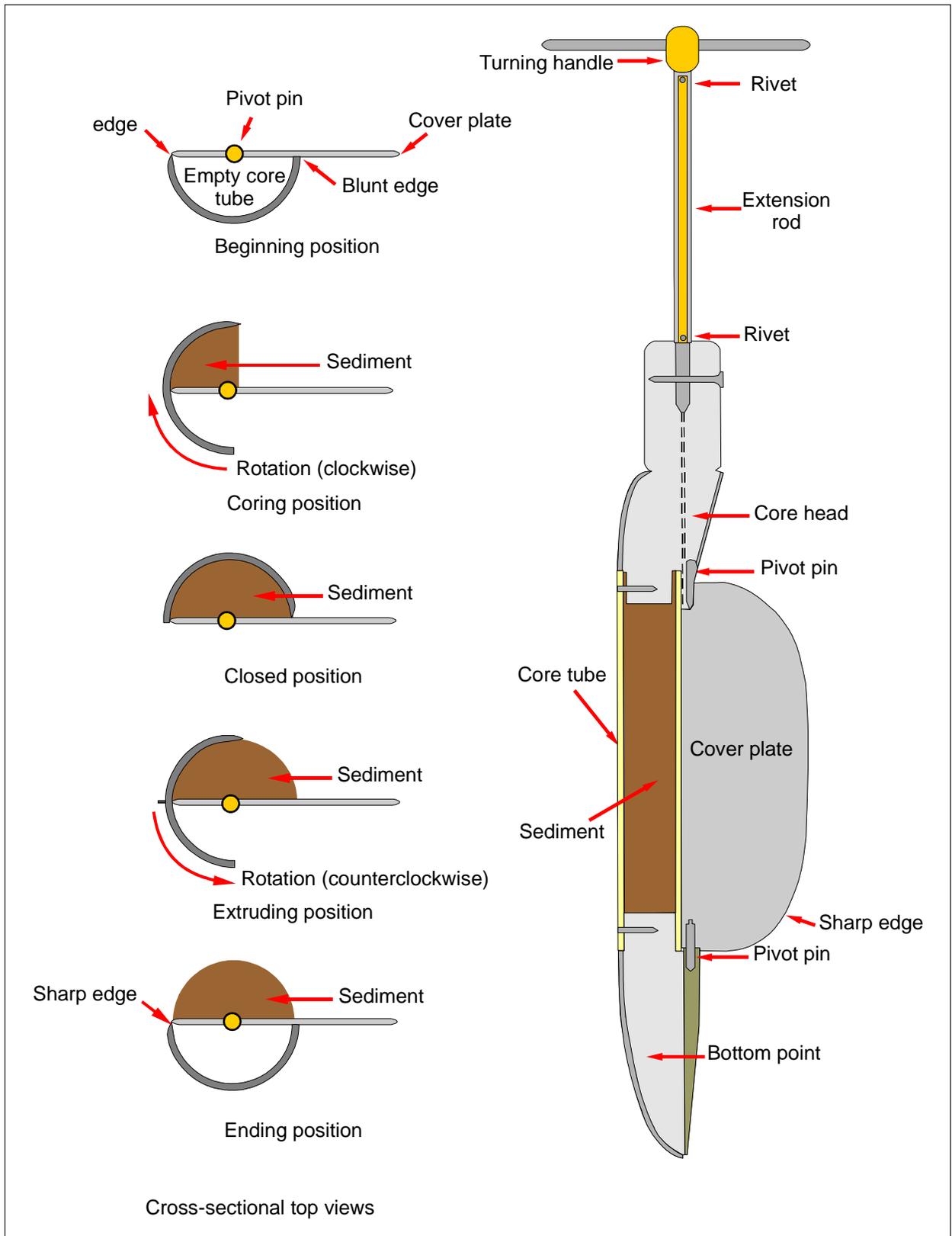


Figure 5.43 Russian Peat Borer. Illustration published with permission of Aquatic Research Instruments

samples at depths up to 11 feet below sediment surface. The sampler can collect representative and relatively uncompressed samples of consolidated sediment in discrete depth intervals. The sampler preserves sediment stratification in consolidated sediment samples, but sediment stratification may not be preserved in unconsolidated sediment samples. The Russian Peat Borer is a superior alternative to conventional sediment samplers, particularly for sampling consolidated sediment. As with any sampler selection, the user must determine the appropriate sampler for a given application based on project-specific data quality objectives.”

5.3.2.2.3 Split Core Sampler

The Split Core Sampler (Figure 5.44), manufactured by Art’s Manufacturing and Supply, is designed to collect sediment submerged under several feet of water. What separates this device from other core samplers is the ability to open the core longitudinally. This eliminates any complications that may arise when extruding sample from fixed core barrels. Joining like sections together end to end can extend the length of this core sampler up to 48 inches. Additionally, consideration has been made for the adaptive use of an electric hammer to provide a source of vibration to reduce friction during advancement into the sediment.

A complete Environmental Technology Verification (ETV) Program Report on the Split Core Sampler (EPA/600/R-01/009, Dec. 1999) produced by the USEPA, can be obtained by going to http://www.epa.gov/etv/pdfs/vrvs/99_vr_art_split.pdf. This document contains “how to” information as well as advantages and limitations. A quality assurance/quality control comparison to reference sediment sampling devices rounds out a critical look as to the Split Core Sampler’s effectiveness. The report indicates that, “Based on the demonstration results, the Split Core Sampler can be operated by one person with minimal skills and training. For more efficient recovery of samples, an electric hammer should be used to induce vibrations in the sampler. When more than two extension rods are used, a winch is recommended for sampler operation. The sampler is designed to collect sediment samples up to a maximum depth of 4-feet below sediment surface and based on visual observations, collects partially compressed samples of both consolidated and unconsolidated sediments from the sediment surface downward; sample representativeness

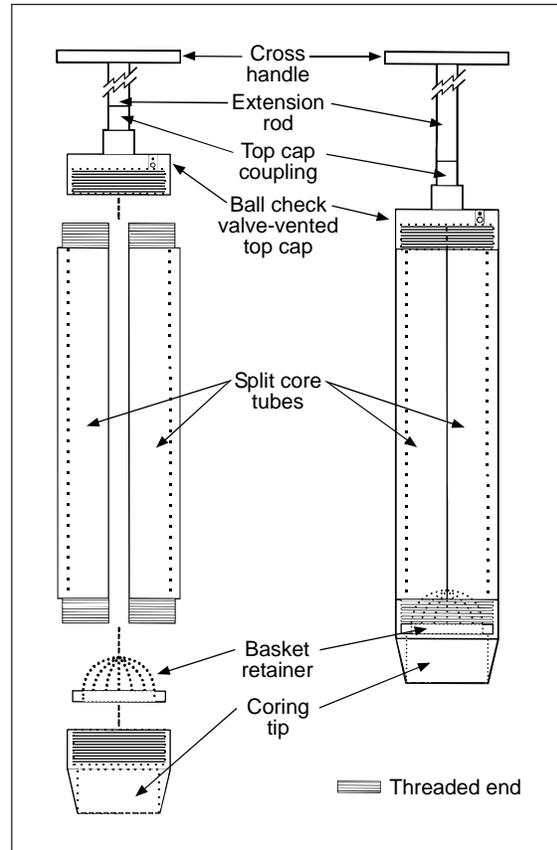


Figure 5.44 Split Core Sampler. Illustration published with permission by Art’s Manufacturing & Supply

may be questionable because of core shortening and core compression. The sampler preserves sediment stratification in both consolidated and unconsolidated sediment samples. The Split Core Sampler is a good alternative to conventional sediment samplers. As with any sampler selection, the user must determine the appropriate sampler for a given application based on project-specific data quality objectives.”

5.3.2.2.4 Gravity Corer

A gravity corer (Figure 5.45) is a weighted metal or rigid plastic tube with a replaceable tapered nosepiece on the bottom and a ball or other type of check valve on the top. The check valve allows water to pass through the corer on descent but prevents washout during recovery. Gravity corers are capable of collecting samples of most sludges and sediments. They collect essentially undisturbed samples at considerable depth, which represent the profile of strata that may develop in sediments and sludges during variations in the deposition process. The tapered nosepiece facilitates cutting



Figure 5.45 Gravity Corers. Illustration published with permission from Aquatic Research Instruments

and reduces core disturbance during penetration. What separates a gravity corer from a sediment corer are design features that allow the gravity corer to free fall through an unlimited water column, remain upright on contact and pierce the sediment with enough downward force to produce a core sample up to 30 inches or more. Density of the substrate and weight factor into penetration depths. Advanced designs take into consideration frontal wave reduction, additional weight and check valve anti-fouling

Care should be exercised when using gravity corers in vessels or lagoons that have liners since penetration depths could exceed that of substrate and result in damage to the liner material.

Aquatic Research Instruments also manufactures other sediment coring devices, among them a Gravity Corer which uses a polycarbonate core tube and a Piston Sediment Corer which is designed primarily for paleoecologic analysis. For more information on these devices go to

<http://www.aquaticresearch.com/>.

Procedures for Use:

- i. Attach decontaminated corer to the required length of sample line.
- ii. Secure the free end of the line to a fixed support to prevent accidental loss of the corer.
- iii. Allow corer to free fall through liquid to bottom.
- iv. Retrieve corer with a smooth, continuous lifting motion. Do not bump corer as this may result in some sample loss.
- v. Remove nosepiece from corner and slide sample out of corer into stainless steel or PTFE (e.g., Teflon®).

- vi. Transfer sample into appropriate sample bottle with a stainless steel lab spoon or equivalent.
- vii. Follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).
- viii. Decontaminate before use at next location.

Advantages:

- collects undisturbed samples

Disadvantages:

- may damage membrane liners in vessels or lagoons

5.3.2.2.5 Vibracorer

Vibracoring is a highly specialized form of sediment core sampling. While not a new tool in the sediment sampling arsenal (reportedly used in the 1950s), its advancement was slow due to the availability of vibrators that adapted easily to underwater use. Generally, there are three types of vibrators that can be applied to this system of sediment sampling: pneumatic, hydraulic and electric. While conceivably the least complicated and easiest to adapt, pneumatic vibracore systems have a considerable limitation, i.e., the deeper the application, the larger the volume of air is needed to overcome surrounding water pressure. Hydraulic vibrators do have a certain appeal, as there is some application of resonant drive capability, however, these systems along with pneumatic vibracores require an umbilical line to the surface and an independent power source at the surface either in the form of a hydraulic pump or large air compressor. Electric vibracores (Figure 5.46), the most versatile, generally rely on a readily available power system aboard a vessel and with today's safety features, the risks of using electrical current underwater have been reduced.

In the extreme, vibracores can collect samples at depths exceeding 4000 meters (over 2-miles) and retrieve a single continuous sediment core down to 35-feet below sediment surface. And while these applications serve a host of specialized needs worldwide, vibracoring on the small scale for more "localized" work in estuaries, lakes and rivers is quite common. Vibracoring requires the use of a working platform, an A-frame and winch and at least two people to operate. The typical weight of a fully equipped vibracorer, with vibrohead and core is about 150 lbs. Core tube dimensions generally range

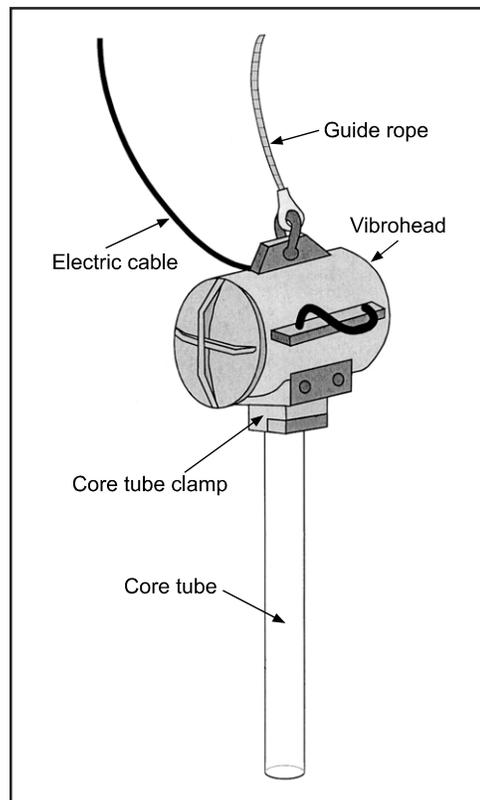


Figure 5.46 Vibracorer (Source USEPA, ETV Program Report)

from 4-inches in diameter by 15-feet in length to 3-inches in diameter by 20-feet in length. Once the vibracorer has been assembled and lowered to the sediment floor, the vibrating head creates the energy necessary to overcome the two forces opposing advancement: frontal resistance and wall friction. The energy from the vibrohead is transferred down the core and at the point of contact along the core tube sediment pore-pressure is raised and a thin layer of liquefaction is created. The check valve and core nose keep the sediment within the tube during retrieval and once on deck the tube can be opened with a saw or, if a tube liner is used, the sediment is removed from the tube in one long segment. To learn more about vibracores and their application, go to either ETV hyperlink listed above (EPA/600/R-01/009, Dec. 1999), as the vibracorer was one of the reference devices that the Russian Peat Sampler and Split Core Sampler were compared against or, go to <http://www.aquasurvey.com/Services/Vibracoring/vibracoring.html>

5.3.2.2.6 Sediment Sieve

Sediment sieves are used to process bottom material to a desired grain size (USGS recommends that sub-samples be processed through a maximum mesh size of 2.0 mm). Use the US Geological Survey's, Book 9, *Handbooks for Water-Resources Investigations, National Field Manual for the Collection of Water-Quality Data*, Chapter 8A, *Bottom Material Samples*, 8.3.1.B. *Sieves*, (<http://water.usgs.gov/owq/FieldManual/>) for additional information on sieving sediment. Sieves consist of a measured mesh screen and a collection pan and can be constructed of various materials. Stainless steel is preferred unless collecting samples for metals analysis. Such samples should be processed through polyethylene sieves, which have been acid rinsed.

Procedures for Use:

- i. Rinse equipment with water from the body of water from which the sediment will be collected.
- ii. Collect sediment subsamples with the appropriate scoop or trowel.
- iii. Process the samples through the mesh and into the collection pan
- iv. When the desired amount of subsamples are processed into the collection pan, mix the sediment to achieve a homogeneous sample.
- v. With the scoop or trowel, remove sediment from the collection pan and place it into the appropriate sample container.
- vi. Clean equipment using the recommended procedure (see Chapter 2, *Quality Assurance*).

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Table 5.2 General Characteristics of Selected Grab and Core Samplers

[Penetration depth, sample volume, and applications are presented in English units because equipment is constructed to English-unit specifications: 1 inch = 2.54 centimeters, 1 pound = 0.4536 kilogram, 1 foot = 0.3048 meter, D, diameter; L, length; W, width; PDC, plastic dip coated; *, trade name; I.D., inside diameter; na, not applicable; mm, millimeter; ft, feet, SS, stainless steel; PVC, polyvinyl chloride; ft/s, feet per second; <, less than]

Sampler designation	Sampler construction material	Sampler dimensions (inches)	Sampler weight (pounds)	Suspension	Penetration depth (inches)	Sample volume (cubic inches)	Application
Grab Samplers							
USBMH-53	SS body, brass piston	2 D x 8 L	7.5	46-inch-long rod	0-8	0-25	Wadable water, loosely consolidate material less than 0.063 mm.
USBMH-60	Cast aluminum body, SS rotary scoop, rubber gasket	8 x 4.5 x 22	32	Hand line or winch and cable	0-1.7	0-10.7	Wadable to water of slow velocity (<1 ft/s) and moderate depth; firm unconsolidated to loosely consolidated materials, less than 16 mm; PDC version available; sampler must be equipped with safety yoke.
USBMH-80	SS rotary scoop	2.75 D x 32.5 W	8	56-inch-long rod	0-1.75	0-10.7	Wadable water; unconsolidated to loosely consolidated material, less than 16 mm.
USBM-54	Cast steel body, SS rotary scoop, rubber gasket	8.5 x 7 x 22	100	Winch and cable	0-1.7	0-10.7	Water of moderate velocity and depth; firm unconsolidated to loosely consolidated material, less than 16 mm; PDC version available, sample must be equipped with safety yoke.
Ponar* (2 sizes)	SS body, zinc-plated steel weights and neoprene flaps	6x6 or 9x9	15-22 or 45-60	Hand line or winch and cable	0-4	0-146.4 or 0-500	Weight dependent; wadable to water of slow velocity (<1 ft/s) and moderate depth; unconsolidated loosely consolidate material, less than 16 mm; susceptible to loss of fines.
Petersen*	Zinc-plated steel	12 x 12	39-93	Hand line or winch and cable	0-12	600	Weight dependent; wadable to water of slow velocity and moderate depth; unconsolidated to consolidated material, less than 16 mm; susceptible to loss of fines
Birge-Ekman* (4 sizes)	SS or brass	6x6x6 or 6x6x9 or 9x9x9 or 12x12x12	16-25 or 21-35 or 47-68 or 100-150	Rod, hand line, or winch and cable	0-3 or 0-4 or 0-5 or 0-6	0-216 or 0-323 or 0-729 or 0-1,726	Wadable to water of slow velocity (<1 ft/s) and moderate depth; soft unconsolidated to consolidated material, less than 0.50 mm; susceptible to loss of fines' PDC version available

Table 5.2 General Characteristics of Selected Grab and Core Samplers (continued)

[Penetration depth, sample volume, and applications are presented in English units because equipment is constructed to English-unit specifications: 1 inch = 2.54 centimeters, 1 pound = 0.4536 kilogram, 1 foot = 0.3048 meter, D, diameter; L, length; W, width; PDC, plastic dip coated; *, trade name; I.D., inside diameter; na, not applicable; mm, millimeter; ft, feet, SS, stainless steel; PVC, polyvinyl chloride; ft/s, feet per second; <, less than]

Sampler designation	Sampler construction material	Sampler dimensions (inches)	Sampler weight (pounds)	Suspension	Penetration depth (inches)	Sample volume (cubic inches)	Application
Grab Samplers							
Shipek*	Cast alloy steel	4x6x6 or 18.6 x 25.1 x 17.4	11 or 135	Hand line or winch and cable	0-1.2 or 0-4	0-30.5 or 0-183	Wadable to water of moderate velocity and depth; unconsolidated to consolidated material, less than 0.50 mm; susceptible to loss of fines; PDC versions available.
Van Veen* (2 sizes)	SS body, zinc-plated steel chain, neoprene flaps	13.8 x 27.6 or 19.7 x 39.4	66-88 or 143-187	Cable	0-12	0-11 or 0-46	Wadable to water of moderate velocity and depth; soft unconsolidated material less than 0.25 mm.
Core Samplers							
Hand	SS or SS core tubes; Lexan* or SS nose piece and SS or plastic core catcher	2 I.D. 20-96L	10-60	Handle 0-15 ft. L	0-96	0-300	Wadable to diver application, water of slow velocity (<1 ft/s); soft to semi-firm unconsolidated material less than 0.25 mm; 2-inch core liners available in plastic and SS.
Ogeechee* (sand corer)	SS or SS core tubes; Lexan or SS nose piece and SS or plastic core catcher	2 I.D. 20-96 L	10-60	Hand corer	0-96	0-300	Wadable to diver application, water of slow velocity (<1 ft/s); soft to semi-firm unconsolidated material less than 0.25 mm; 2-inch core liners available in plastic and SS.
Kajak-Brinkhurst (K-B)* (gravity corer)	SS, Lexan, or SS core tubes; Lexan or SS nose piece, SS or plastic core catcher, neoprene valve	2 I.D. 20,30 L	15-48	Hand line or winch and cable	0-30	0-90	Water with very slow velocity (<1 ft/s); loosely consolidated material less than 0.063 mm; 2-inch core liners available in plastic and SS.

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Table 5.2 General Characteristics of Selected Grab and Core Samplers (continued)

[Penetration depth, sample volume, and applications are presented in English units because equipment is constructed to English-unit specifications: 1 inch = 2.54 centimeters, 1 pound = 0.4536 kilogram, 1 foot = 0.3048 meter, D, diameter; L, length; W, width; PDC, plastic dip coated; *, trade name; I.D., inside diameter; na, not applicable; mm, millimeter; ft, feet, SS, stainless steel; PVC, polyvinyl chloride; ft/s, feet per second; <, less than]

Sampler designation	Sampler construction material	Sampler dimensions (inches)	Sampler weight (pounds)	Suspension	Penetration depth (inches)	Sample volume (cubic inches)	Application
Core Samplers							
Phleger* (gravity corer)	SS core tube, nose piece, core catcher; neoprene valve	1.4 I.D. 20 L	17.6-33	Hand line or winch and cable	0-20	0-40	Water with a very slow velocity (<1 ft/s); soft to firm unconsolidated material less than 0.50 mm; core liners available in plastic.
Balchek* (gravity corer)	Bronze head, SS or PVC core tubes; Lexan* or SS nose piece and SS or plastic core catcher; plastic/polyurethane valve	2-5 I.D. 30-96 L	Variable depending on size and construction material	Hand line or winch and cable	0-96	0-750	Water with very slow velocity (<1 ft/s); loosely consolidated material, less than 0.063 mm; core liners available in plastic and SS.
Benthos* (gravity corer)	Steel core tube, nose piece, and core catcher	2.6 I.D. 120 L	55-320	Winch and cable	120	0-490	Water with very slow velocity (<1 ft/s); loosely consolidated material less than 0.063 mm; core liners available in plastic
Alpine* (gravity corer)	Steel core tube, nose piece, core catcher, and neoprene valve	1.6 I.D. 72 L	242-342	Winch and cable	72	0-180	Water with very slow velocity (<1 ft/s); loosely consolidated material less than 0.063 mm; core liners available in plastic; inconsistent vertical penetration.
Box	SS with optional acrylic box liner	6x6x9	31-100	Winch and cable	9	0-300	Water with very slow velocity (<1 ft/s); loosely consolidated material less than 0.25 mm.
Piston	SS or plastic core tubes; Lexan or SS nose piece; SS or plastic core catcher	1-5 I.D. 40-800 L	25-500	Hand line or winch and cable	0-80	0-6,200	Water with very slow velocity (<1 ft/s); loosely consolidated material less than 0.25 mm; core liners available in plastic.
Vibrator* (gravity corer)	Variable	2-3 I.D. 40-500 L	100-300	Frame	0-500	0-2,300	Water with very slow velocity (<1 ft/s); loosely consolidated material less than 16 mm; assembly might require scuba divers.

Table taken from US Geological Survey's, Book 9, *Handbooks for Water-Resources Investigations, National Field Manual for the Collection of Water-Quality Data*, Chapter 8A, *Bottom Material Samples*, (<http://water.usgs.gov/owq/FieldManual/>)

5.3.2.3 Sludge Samplers

Several of the sediment devices listed above may be used for the collection of sludge. Caution however, must be taken when using grab or coring samplers for sludge collection as these devices may puncture liners in controlled settings. Additionally, safety precautions must be considered when using the sludge sampling devices listed below as often times these samples are collected from manholes, tanks, lagoons, out-fall pipes and other areas prone to slip, trip or fall scenarios.

5.3.2.3.1 Lidded Sludge/Water Sampler

A lidded sludge/water sampler (Figure 5.47) can be used to collect viscous sludge or waste fluids from tanks, tank trucks or ponds at a specific depth. It can sample liquids, multi-layer liquid wastes and mixed-phase solid/liquid wastes. Sample volume can be up to 1 liter. It consists of a removable glass sample bottle situated inside a holder that is suspended gimbal-like within a stainless steel framework, which is attached to a rod and handle.

The conical shaped bottom allows the sampler to be lowered into the material being sampled. At the desired depth to the sample bottle is opened and closed by rotating the top handle. The device is then carefully retrieved from the material and the sample bottle removed by lifting it from the holder.

Procedures for Use:

- i. Place the sample bottle into the holder.
- ii. Lower the sampler to the desired depth.
- iii. Open the sample bottle using the handle, and allow the sample vessel to fill.
- iv. After the bottle has had time to fill, turn the handle again to close.
- v. Remove sampling device from sludge.
- vi. Remove sample bottle from holder and follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).

Advantages:

- can be used in heavy sludge
- can collect discrete samples at depth
- bag liner can be used with sampler
- easily decontaminated with steam cleaner or solvent wash

Disadvantages:

- heavy

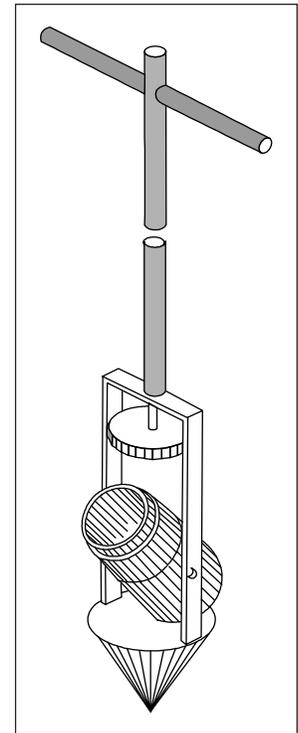


Figure 5.47 Lidded Sludge/Water Sampler (Source: USEPA RCRA Waste Sampling Draft Technical Guidance, August 2002)

5.3.2.3.2 Liquid Grab Sampler

A liquid grab sampler (Figure 5.48) can be used to collect sludge or slurry samples from surface impoundments, ponds, lagoons or containers. Grab samples can be obtained at discrete depths. The sampler is available for use with wide or narrow necked sample bottles and has large access port openings to allow the sample to enter the bottle. Sample volumes can range from 0.5 to 1.0 liters. The sample bottle is attached to the end of the 6-ft. long handle. The control valve is operated from the top of the handle once the sampler is at the desired depth.

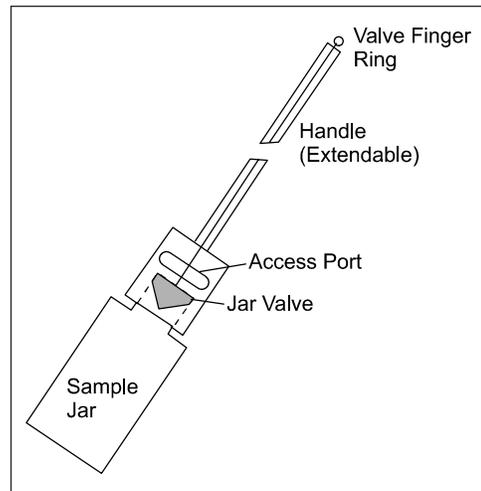


Figure 5.48 Liquid Grab Sampler (Source: USEPA RCRA Waste Sampling Draft Technical Guidance, August 2002)

Procedure for Use:

- i. Assemble the sampler.
- ii. Operate the sampler several times to ensure proper adjustment, tightness of the cap, etc.
- iii. Submerge sampler into liquid to be sampled.
- iv. When the desired depth is reached, pull valve finger ring to open control valve and allow sample to enter container.
- v. Retrieving sampler.closes valve.
- vi. Transfer sample into laboratory cleaned sample bottles and follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).

Advantages:

- allows discrete samples to be taken at depth

Disadvantages:

- depth of sampling is limited by length of pole
- not useful in very viscous sludges
- hard to decontaminate

5.3.2.3.3 Swing Jar Sampler

The swing jar sampler (Figure 5.49) is a surface sampler that may be used to collect liquids, powers, or small solids at a distance of up to 12 feet. It can be used in a variety of settings to collect samples from drums, surface impoundments, tanks, pipe/point source discharges, sampling ports and storage bins. Sample volume ranges from 0.5 to 1.0 liters. It is normally used with high-density polyethylene sample jars and has an extendable

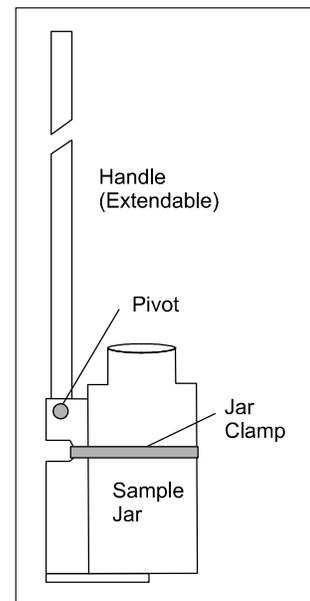


Figure 5.49 Swing Jar Sampler (Source: USEPA RCRA Waste Sampling Draft Technical Guidance, August 2002)

aluminum handle with a pivot at the juncture of the handle and jar holder. The jar is held in the holder with an adjustable clamp. The pivot allows samples to be collected at different angles.

Advantages:

- Easy to use
- Easily adaptable to samples with jars of different sizes and materials.

Disadvantages:

- Cannot collect discrete depth samples

5.3.2.3.4 A sludge judge (Figure 5.50) is useful for obtaining a core of sludge, or water and sludge. This may be useful in determining the physical state (% solids) of a tank's contents or its volume of sludge. However, this device is commonly constructed of PVC and its use is limited in hazardous waste sampling due to possible reactivity and quality assurance considerations. The sludge judge is a long narrow tube with a check valve on the bottom. Typically the device is sold in 3, 5-foot sections and one 3-foot section for a total combined length of 18 feet when fully assembled.

Procedures for Use:

- Slowly insert the sampler into the material being sampled.
- When the sampler has filled with material, pull back on the sampler to close the valve and retrieve the sample.
- Transfer the sample (by pouring from the top or a release valve from the bottom) into a laboratory cleaned sample bottle and follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).

Advantages:

- easy to use
- delineates amount of settled sludge or physical state of medium

Disadvantages:

- use is limited due to PVC construction
- hard to decontaminate
- not useful in thick sludges

5.3.3 Containerized Solids and Waste Pile Sampling Equipment

Waste materials are sometimes found on-site in containers or in waste piles. Sampling of containerized solids includes powdered, granular, or coarse materials in drums, barrels, or other similar

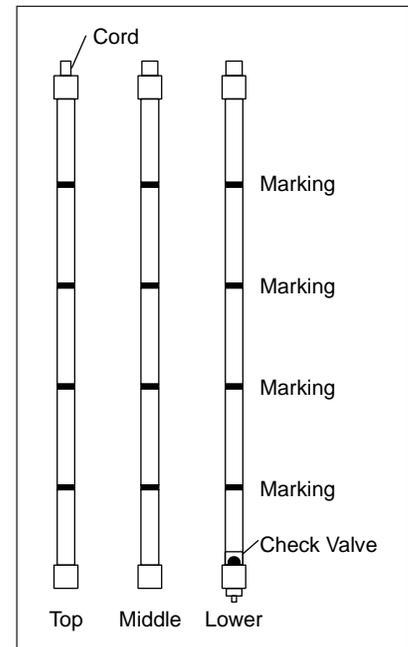


Figure 5.50 Sludge Judge
(Source: USEPA RCRA Waste Sampling Draft Technical Guidance, August 2002)

containers. Waste piles may be found in various sizes, shapes, structure and compactness.

The type of sampler chosen should be compatible with the waste so as to collect a representative material for proper analysis. Table 5.1 at the end of this chapter lists NJDEP recommended waste material samplers and their application.

In addition to the equipment and methodology presented below, scoops and trowels are commonly used when sampling containerized solids/waste piles.

5.3.3.1 Grain Sampler

The grain sampler (Figure 5.51) is used for sampling powdered or granular wastes or materials in bags, fiber drums, sacks, or similar containers. This sampler is most useful when the solids are no greater than 0.6 cm (1/4") in diameter.

This sampler consists of two slotted telescoping tubes, usually made of brass, stainless steel or high-density polyethylene. The outer tube has a conical, pointed tip on one end that permits the sampler to penetrate the material being sampled. The sampler is opened and closed by rotating the inner tube. Grain samplers are generally 61 to 100 cm (24 to 40 in.) long by 1.27 to 2.54 cm (1/2 to 1 in.) in diameter and they are commercially available at laboratory supply houses.

Procedures for Use:

- i. While the sampler is in the closed position, insert it into granular or powdered material or waste being sampled from a point near a top edge or corner, through the center, and to a point diagonally opposite the point of entry.
- ii. Rotate the inner tube of the sampler into the open position.
- iii. Wiggle the sampler a few times to allow materials to enter the open slots.
- iv. Place the sampler in the closed position and withdraw from the material being sampled.
- v. Place the sampler in a horizontal position with the slots facing upward.
- vi. Rotate and slide out the outer tube from the inner tube.
- vii. Transfer sample into laboratory cleaned sample bottles and follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).



Figure 5.51 Grain Sampler (Photograph by J. Schoenleber)

Advantages:

- ease of operation

Disadvantages:

- not desirable for moist or sticky samples
- provides a low volume

5.3.3.2 Waste Pile Sampler

The waste pile sampler (Figure 5.52) is used for sampling wastes in large heaps with cross-sectional diameters greater than 1 m (39.4 in.). It can also be used for sampling granular or powdered wastes or materials in large bins, barges, or soils where the grain sampler or sampling trier is not long enough.

This sampler is essentially a large sampling trier. It is commercially available but it can be easily fabricated from sheet metal or plastic pipe. A length of PVC pipe 1.52 m (5 ft.) long by 3.2 cm (1 1/4 in.) in diameter by 0.32 cm (1/8 in.) wall thickness is adequate. The pipe is sawed lengthwise (about 60/40 split) until the last 10 cm (4-in.). The narrower piece is sawed-off and hence forms a slot in the pipe. The edges of the slot and the tip of the pipe can be sharpened to permit the sampler to slide into the waste material being sampled. The unsplit length of the pipe serves as the handle. The plastic pipe can be purchased from hardware stores.

Procedures for Use:

- Insert the sampler into the waste material being sampled at 0° to 45° from horizontal.
- Rotate the sampler two or three times in order to cut a core of the material.
- Slowly withdraw the sampler, making sure that the slot is facing upward.
- Transfer the sample into a laboratory cleaned sample container with the aid of a spatula and/or brush.
- Follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).

Advantages:

- easily fabricated
- disposable
- inexpensive
- can be fabricated to site-specific needs

Disadvantages:

- does not collect representative samples when the diameters of the solid particles are greater than half the diameter of the tube.

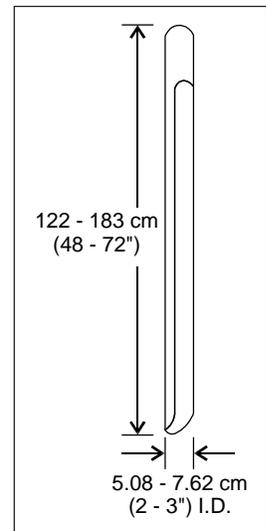


Figure 5.52 Waste Pile Sampler
(Source: USEPA RCRA Waste Sampling Draft Technical Guidance, August 2002)

5.3.3.3 Sampling Trier

A sampling trier (Figure 5.53) is used for sampling soils, powdered or granular wastes or materials in bags, fiber drums, sacks, or similar containers.

A typical sampling trier is a long tube with a slot that extends almost its entire length. The tip and edges of the tube slot are sharpened to allow the trier to cut a core of the material to be sampled when rotated after insertion into the material. A spiral attachment may be used to advance a hole when sampling at depth. Sampling triers are usually made of stainless steel with wooden handles. They are about 61 to 100 cm (24 to 40 in.) long and 1.27 to 2.54 cm (1/2 to 1 in.) in diameter. They can be purchased readily from laboratory or forestry supply houses

Procedures for Use:

- i. Insert the trier into the material to be sampled at a 0° to 45° angle from horizontal. This orientation minimizes the spillage of sample from the sampler. Extraction of samples might require tilting of the container.
- ii. Rotate the trier once or twice to cut a core of material.
- iii. Slowly withdraw the trier, making sure that the slot is facing upward.
- iv. Transfer the sample into a laboratory cleaned sample container with the aid of a spatula.
- v. Follow procedures for preservation and transport (see Chapter 2, Appendix 2.1, *Tables of Analytical Methods*).

Advantages:

- preferred for moist or sticky samples

Disadvantages:

- relatively difficult to use in stony, dry, or sandy soil
- if sample is excessively moist or loose and powdery, difficulty may be encountered when removing the sampler

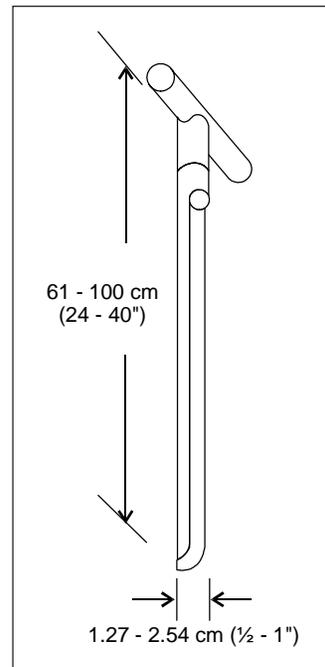


Figure 5.53 Sampling Trier (Source: USEPA RCRA Waste Sampling Draft Technical Guidance, August 2002)

Table 5.3 Samplers Recommended for Various Types of Waste		
Waste Type	Recommended Sampler	Limitations
Liquids, sludges, and slurries in drums, vacuum trucks, barrels and similar containers	COLIWASA Open Tube (Thief), Stratified sample (Thief)	Not for containers over 1.5 m (5 ft) deep
	a) Plastic	Not for wastes containing ketones, nitrobenzene, di-methylformamide, mesityl oxide, or tetrahydrofuran.
	b) Glass	Not for wastes containing hydrofluoric acid and concentrated alkali solutions
	c) PTFE	None
Liquids, sludges, and slurries in drums, vacuum trucks, barrels, and similar containers	Open tube	Not for containers 1.5 m (5 ft.) deep
	a) Plastic	Not for wastes containing ketones, nitrobenzene, di-methylformamide, mesityl oxide, or tetrahydrofuran.
	b) Glass	Not for wastes containing hydrofluoric acid and concentrated alkali solutions
Liquids and sludges in ponds, pits, lagoons, or treatment units	Pond	Cannot be used to collect samples beyond 3.5 m (11.5 ft.) Dip and retrieve sampler slowly to avoid bending the tubular aluminum handle.
Powdered or granular in bags, drums, barrels and similar containers	a) Grain sampler	Limited application for solids sampling of moist and sticky solids with a diameter over 0.6 cm (1/4 in.)
	b) Sampling trier	May incur difficulty in retaining core sample of very dry granular materials during sampling
Dry wastes in shallow containers and surface soil	Trowel or scoop	Not applicable to sampling deeper than 8 cm (3-in.). Difficult to obtain reproducible mass of samples
Waste piles	Waste pile sampler	Not applicable to sampling solid wastes with dimensions greater than half the diameter of the sampling tube
Solid deeper than 8-cm (3-in)	a) Soil auger	Does not collect undisturbed core sample
	b) Sampling trier	Difficult to use on stoney, rocky, or very wet soil
Wastes in storage tanks	a) Weighted bottle sampler	May be difficult to use on very viscous liquids
	b) Bacon Bomb	Volume restriction 1 L maximum
	c) Kemmerer sampler	May need extra weight

(Adapted from USEPA document EPA 600/2-80-018 *Samplers and Sampling Procedures for Hazardous Waste Streams*, 1980).

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Appendix 5.1 – Sample Collection And Preservation Chamber

Purpose: To collect water samples in a clean environment.

Consisting of: Two sections.

- Section 1: sample-wetted parts.
- Section 2: the chamber framework, field fabricated PVC or CPVC tube frame

Section 1: Sample wetted parts.

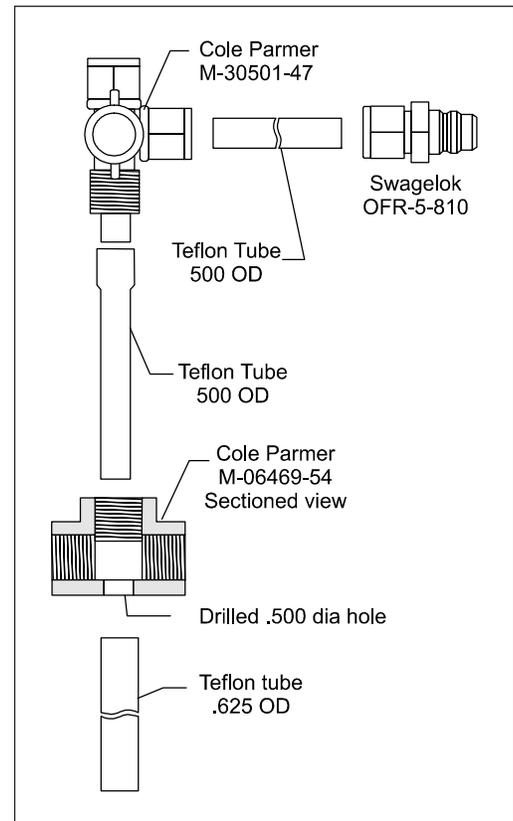
Consisting of: Teflon valve, Teflon Tee, Teflon rubbing (.500 and .625 OD sizes)

Item Description	Unit	Quantity
1 Valve, Teflon, Three-Way Stopcock to fit .500 OD tube to fit .500 OD tube Cole-Parmer P/N M-30501-47	ea	1
2 Flaring tool required to assemble tube to valve: Cole-Parmer P/N M-07148-47 NOTE: One flaring tool is required to assemble the tube to the valve.	ea	1
3 Tee, Teflon, Cole-Parmer P/N M-06469-54	ea	1
4 Tubing, Teflon, smooth wall .500 OD x .062 wall (.375 ID) x 42" long Cole-Parmer #06375-07	ea	1
5 Tubing, Teflon, smooth wall .625 OD x .062 wall (.500 ID)	ft	1
6 Quick-Connect Stem, SS, Full-Flow type (No shutoffs either end) with Swagelok fitting to fit .500 OD tube Swagelok P/N SS-QF8-S-810	ea	1
7 Nylon tie straps, .140 wide x 8 (nominal) long Thomas & Betts P/N TY-5242M Package of 10	pkg	1

Assembly Procedure**Section 1: Sample-wetted parts****Fabrication and Assembly Required:**

1. Drill a .500-diameter hole through the back of the Teflon tee.
Do this by running the drill bit straight down the branch of the Tee, then drilling through the opposite site (back) of the Tee.
NOTE: Do not damage the threads in the branch of the tee.
2. Cut a 4-inch-long piece of .500 OD Teflon tube, and flare one end.
Ensure that the free end of the tube has a clean, 90 degree cut end.
Remove the nut from one of the run fittings of the valve, and slide the flared end of the tube onto the valve.

3. Insert the free end of the tube from step 2 into the branch of the Tee until the tube extends through the hole drilled in the rear of the Tee, and the threads on the valve engage the threads in the branch of the Tee. Thread the valve into the Tee until snug.
4. Cut a piece of .625 OD Teflon tube, 5 inches long.
5. Slide the .625 OD Teflon tube over .500 OD tube extending through the drilled hole in the Tee. Push the .625 tube until it gets tight or until it bottoms against the tee.
6. Flare one end of the remaining 36" piece of .500 OD Teflon tube.
7. Assemble the flared end of the .500 OD x 36: long Teflon tube to the branch fitting of the valve.
8. Assemble the Swagelok quick-connect stem to the free end of .500 OD x 36: tube



Section 2: Framework.

Consisting of: ½-inch schedule 40 CPVC pipe, elbows and tees:

All parts (except item 5) are readily available at most hardware stores, and are to be obtained locally.

Item Description	Unit	Quantity
1 Pipe, CPVC, ½-inch schedule 40, 21 feet long (stock length-can be cut for transport)	ea	1
2 Elbow, CPVC, ½-inch schedule 40 ‘Slip’ style for assembly with PVC primer and cement	ea	8
3 Tee, CPVC, ½-inch schedule 40 ‘Slip’ style for assembly with PVC primer and cement	ea	4
4 Male adapter, CPCX, ½-inch schedule 40 ‘Slip’ style one end, ½-NPT male threads other end.	ea	2
5 Teflon Tee, (from Assembly #8, section 1) “sample-wetted parts”, with ½-NPT female threads.	ea	1
6 PVC/CPVC pipe primer		
7 PVC/CPVC pipe cement		

Note: If primer and cement are used, then the glued frame should be cured several days in a warm, well-ventilated area away from other sampling equipment. After curing, do a liquinox/tap water wash, tap-water rinse(3x) to remove detergent solution, DI-water rinse to remove tap-water residue, air

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dry in a clean environment, and bag for storage before use. When storage bag is re-opened check to ensure no glue residue aroma can be detected.

Assembly Procedure

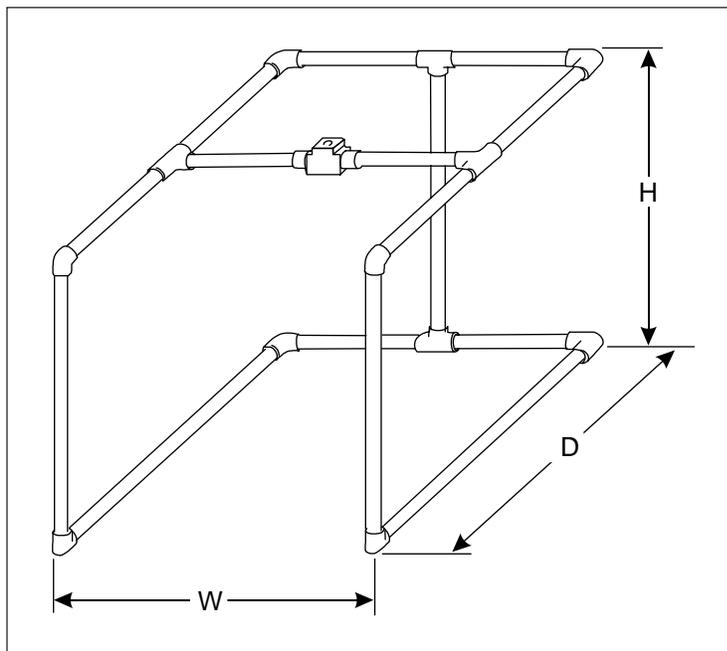
Section 2: Framework

Fabrication and Assembly Required:

Cut and glue* the CPVC pipe and fittings together to make the assembly shown in the sketch. Suggested overall dimensions are 16W x 16H x 16D. This will allow this frame to be ‘nested’ with the three frames of Assembly #12 for ease to transport.

Note that the male adapters should be assembled to the threaded Tee before the short cross-bar Pipes are glued to the adapters. There is considerable flexibility in the order in which the frame assembly can be glued together, but **be sure that you DO NOT leave installing the threaded Tee for last!**

*Some sampling units prefer to not glue the frame together. This allows them to ‘knock-down’ the frame for transport.



This appendix is taken directly from the U.S. Geological Survey’s Hydrologic Instrumentation Facility (HIF) at the Stennis Space Center, MS. <http://www.hif.er.usgs.gov/>

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References

USGS Links of Interest

USEPA Links of Interest

Other URLs of Interest

- Soil Science
- Soil Classification
- Sediments
- Manufacturers/Vendors of Environmental Sampling Equipment
- General

Chapter 6

Sample Collection

6.1 General Information Applicable To All Sampling Events

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.

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 re-done 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 2 and properly prepared for transport to the site. Care must be taken in transporting and storing cleaned sampling equipment. Equipment should never be stored or transported in the same vehicle used to transport generators, gasoline or decontamination solvents. Under such conditions cross-contamination is likely to occur.

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. 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 must be collected and provisions made for their proper disposal.

When decontaminating equipment in the field, extra care must be taken to assure thorough cleaning. Because of the difficulty encountered in cleaning bailers, field decontamination is not allowed for this piece of equipment. Bailers must be 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:

- Lab-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).
- Bound field logbook, 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 4°C.
- Portable instrumentation (e.g., Geiger counter, explosimeter, oxygen level monitor, photoionization detector, flame ionization detector, flow through cell).
- 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.
- 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.

Finally, one must plan for all other equipment needed to meet specified requirements in the sampling plan and the Technical Requirements for Site Remediation. Examples include equipment used to determine the depth of sample, pH, temperature, and dissolved oxygen content of aqueous samples, or the instrumentation necessary to determine the geographically referenced location of any sample.

6.1.2 Type of Samples

6.1.2.1 Environmental and Waste Samples

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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 man-made 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 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 points. 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, the detection limits for each individual sample may be raised proportionally by the number of samples added to the composite. For instance, if a sampler wishes to composite two discrete samples into one and the method detection limit for a target compound were 330 ppb, the detection limit for the target compound does not change for the composite. However, the detection limit for the compound in the individual samples, which make up the composite is two times the normal detection limit or $2 \times 330 = 660$ ppb. This is important to keep in mind because if a contaminant were present in only one of the two composited samples, and if it were at a level between 330 and 660 ppb, that contaminant would not be quantified or possibly even identified due to the effective dilution of the contaminant concentration in 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 is collected. It is advisable that if a positive identification is made in the course of 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 Program, grab sampling should be the chosen method. While composite samples may have merit when performed for specific purposes 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 D6051-96 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. 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

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The analytical needs associated with the collection of samples should be clearly defined in the site-specific sampling plan. Important information regarding the data quality objectives, analytical methods to be employed, turnaround times, deliverables, and funds available must be specified. When choosing a lab, these factors act as a guide. Additional considerations include:

- whether the lab has maintained the required certifications and approvals for specific parameters for which samples are to be analyzed.
- whether the lab is available to perform the analysis requested.
- whether the lab has the capacity to handle all the samples that will be delivered.
- whether the lab can perform the analysis within the time frame specified (if applicable).
- the lab's proximity to the site or capability to pick up and deliver as needed.
- whether the lab provides DOT/IATA shipping containers and packaging materials.

6.1.4 Quality Assurance Samples

When advising the chosen laboratory of the required analyses, specifications regarding quality control samples should be relayed. The lab 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 lab 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 a sampling plan or quality assurance project plan be developed per regulatory authority requirements. As stated in Chapter 2, all regulatory programs require the submittal to and approval by the Department of a QAPP 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 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 in an effort to clean it. Rather, if necessary, a clean paper towel moistened with distilled and deionized water may be used.

The sample should be preserved immediately (4°C 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 logbook. 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.

6.2 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 chapters in order 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*. Finally, effective soil sampling can not be complete without reference to The Technical Requirements for Site Remediation (N.J.A.C. 7:26E, <http://www.state.nj.us/dep/srp/regs/techrule/>).

6.2.1 Selection of Sampling Equipment

New Jersey's soil types range from the principally unconsolidated sandy soils of the southern coastal plain to the more heterogeneous soils in the north. Particular attention should be paid to the soil type being investigated in order to select the most appropriate sampling device. 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 must 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 device's type and style of construction. Specifically, the sensitive chemical/physical nature displayed by the volatile organic fraction requires special consideration in sample equipment selection. Some sampling devices (e.g., bucket auger) may churn or otherwise alter or destroy certain physical attributes (e.g., pore space, ped formation, horizon delineation, color, etc.) and aerate the soil. This can cause an unwanted loss of volatiles from the sample. These devices can not be used for volatile organic sample collection. The recommended device (e.g., soil corer or split spoon) should produce a relatively undisturbed soil core, which will minimize the loss of VOCs and the destruction of soil characteristics (i.e., silt/clay). 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., PID/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. For further clarification, advanced discussion with the regulatory authority is recommended before proceeding. Correct selection of sampling equipment will not only save time and expense, but will allow for collection of the most representative sample possible.

Typical soil sampling devices and accessories include but are not limited to the following:

- scoop or trowel*
- bucket/hand auger*
- soil coring device
- waste pile sampler
- split spoon sampler
- Shelby tube sampler
- mixing bowl or tray*
- spatula*

*Not acceptable for use when sampling VOCs

All of the above devices must be of stainless steel construction. In certain pre-approved circumstances, scoops or trowels constructed of rigid polyvinyl or polyethylenes are acceptable, but their reuse limited to a particular site and/or excessive wear. Another exception to this rule is the split spoon sampler, which is commonly constructed of carbon steel.

6.2.2 Equipment Preparation

After selection of the proper device, consideration must be given to equipment decontamination. When the decontamination procedure is properly performed (see Chapter 2), the potential for cross contamination can be significantly reduced. Care must 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 must be decontaminated prior to use and in between sample locations. Once the equipment has been cleaned, it must 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 must 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 must also be decontaminated if the equipment will directly contact the sample. Similar to the treatment of heavy equipment, decontamination of sampling equipment must 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 can not be overstated that costly and lengthy cleanup or permit decisions are based on the outcome of soil samples collected in relatively short order. Therefore, initial attention to equipment selection and its preparation can offer a significant reduction in oversight expense while providing the most professional results.

6.2.3 Soil Logs

Pursuant to N.J.A.C. 7:26E-3.6(a)2, a profile of subsurface conditions is required for investigations concerning soil contamination. Soil logs must be prepared to document soil types, field instrument measurements, depth to groundwater, soil mottling, presence of odors, vapors, soil discoloration, or the presence of free and/or residual product. Information obtained by performing the Standard Penetration Test (SPT, ASTM Method 1586-84) must also be included on the soil boring logs. Similar information must also be recorded when installing monitor wells, pursuant to N.J.A.C. 7:26E-4.4(g)4.

Important! Soil logs must 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.

Soil logs should include a description of texture, moisture content, color, stratification, fabric and structure. 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. Soil color descriptions should 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 must 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 23 to assist field personnel in recording observed soil data.

6.2.3.1 Wentworth Scale

The Wentworth scale was developed in 1922 and is based on the work of Udden. It is the generally accepted standard used by geologists and sedimentologists in North America (Pettijohn, 1975). It 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, 1975.			
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 was developed for the US Army Corps of Engineers and Bureau of Reclamation for classifying soils for engineering purposes based on laboratory determination of particle size, liquid limit and plasticity index. It was first used to judge a soil's suitability as a subgrade for roads and airfields, but it is used today for most engineering applications of soil. It 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.

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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.

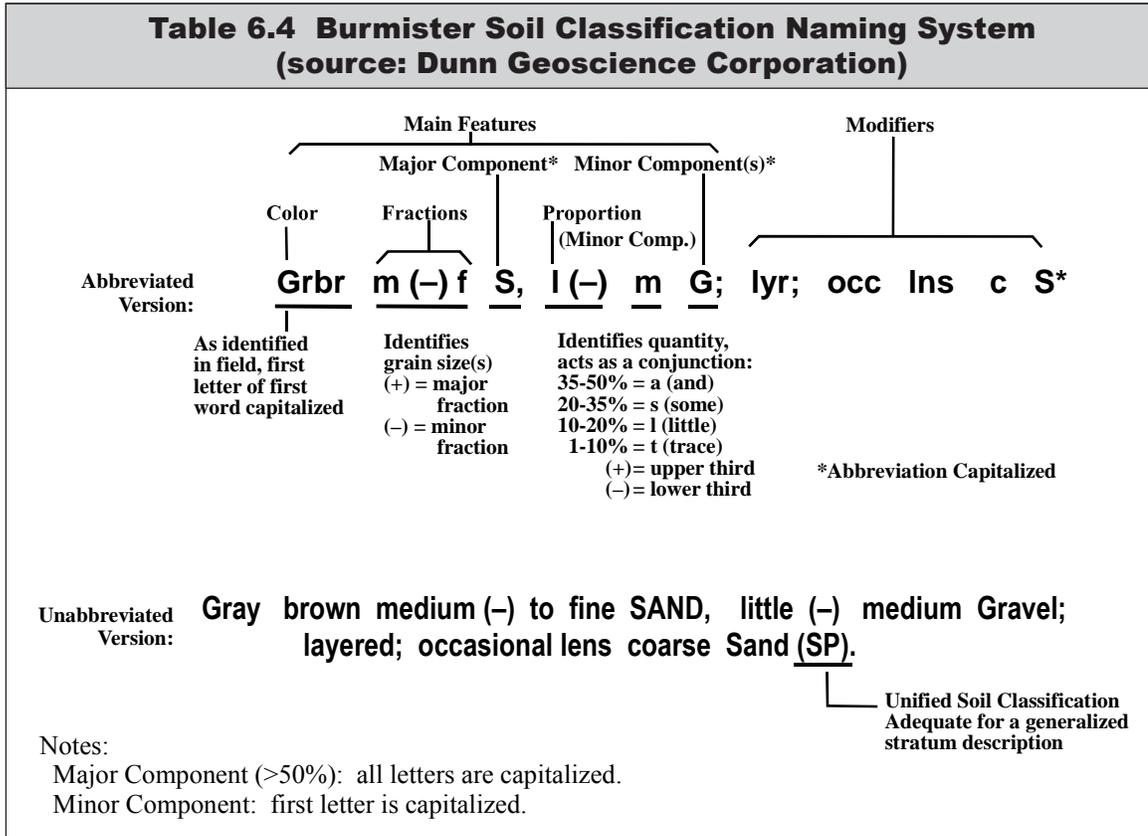


Table 6.5 Burmister Soil Classification System Coarse-Grained Soils, Gradation of Components		
Coarse to fine	cf	All sizes
Coarse to medium	cm	Less than 10% fine
Medium to fine	mf	Less than 10% coarse
Coarse	c	Less than 10% medium and fine
Medium	m	Less than 10% coarse and fine
Fine	f	Less than 10% coarse 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 was developed primarily in order to organize soils into established groups, identify their best uses and allow for estimates of their agricultural productivity (Dragun, 1988). 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. 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 qualified geologist or soil scientist should perform logging of soils and sediments. A recommended soil-boring log is provided following Table 6.9.

6.2.4 Field Log Books

In addition to soil logs, accurate field books are essential to the evaluation and interpretation of analytical results after sampling is complete. Information compiled in the field log book or soil logs for each sampling point should include:

- date/time/weather
- sampler/geologist/soil scientist name(s)
- 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	cobble	4026		No. 5+				
				2048						
				1024						
				512						
cobble		cobble		256	10.08					
				128	2.52					
v. coarse		coarse gravel		coarse gravel			medium gravel	64	1.26	
					32					
	coarse pebble gravel	medium gravel	fine gravel	fine gravel	16		0.63			
					8					
medium fine	fine gravel	coarse sand		4	0.31					
				2		0.16				
gran. (vf) gravel							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		medium sand	0.25	0.01	No. 35-60				
fine sand			fine sand	0.125	0.005	No. 60-120				
v. fine sand	fine sand	fine sand	v. fine sand	0.031	0.002	No. 120- No. 230				
							coarse silt	silts & clays	silt	0.0625
coarse silt	fine silt	silt								
			0.0156							
			0.0078							
			0.0039	0.0002						
v. fine silt										
clay		clay	<0.0039	<0.0002						

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 book 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 Determination of Soil Sample Location

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 to 3.6). Sample locations should also be chosen based on Area Specific Requirements pursuant to N.J.A.C. 7:26E-3.9 such as sampling in and around above and below ground storage tanks, impoundments, septic tanks, etc.

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 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 zero to 6 inches 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.

Soil samples shall be collected from discrete six-inch intervals. Deviations from this requirement due to poor sample recovery or logistical problems should be noted in the soil log and field logbook. Composite sampling is not allowed except in the case of waste characterization analysis for proper disposal. 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 must 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 must 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

The advancement of any downhole large-diameter sampling device must follow ASTM #D1586-84 for disturbed (split spoon) samples, or, ASTM #D1586-83 for undisturbed (Shelby tube) samples. In addition, all borings must be performed in accordance with the procedures and regulatory requirements pursuant to the Subsurface and Percolating Water Act, N.J.S.A. 58:4A-4.1 et. seq. Soil boring permits are required for borings greater than 50 feet in depth. 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/sand in pursuant to NJAC7:9D-3.4. However, NJDEP recommends that contaminated soils should not be returned to the borehole. If the contaminated soils are returned back to the borehole, the responsible party shall address the presence of this contamination in the remedial action workplan in pursuant to NJAC 7:26E-3.6.

Subsurface soil samples can be collected via a standard drill rig or direct push drilling by advancing a dedicated or decontaminated large-diameter sampling device (e.g., split spoon, Shelby tube or soil corer) in the borehole. A decontaminated split spoon retaining basket should be used to prevent loss of the soil back into the borehole while raising the split spoon sampling device to the surface. Upon retrieval to the surface, the large-diameter sampling device (e.g. split spoon, soil corer or Shelby tube) should be handled and transported in such a way to prevent loss while opening or during shipment preparation. The split spoon or 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 the large-diameter sampling device can not 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 should be opened and screened with a direct reading instrument (DRI) to determine the sample interval of interest. Soil samples shall be collected from discrete six-inch intervals. Deviations from this requirement due to poor sample recovery or logistical problems should be noted in the field logbook. 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 and biodegradation, and cross contamination due to excessive handling of the soil.

Shelby tubes are typically used to collect undisturbed solid soil cores for laboratory analysis such as geotechnical parameters. Shelby tubes, once collected, should not be open 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.

Soil samples collected for VOC analysis must be handled in a manner that will minimize losses due to volatilization and biodegradation. See section 6.2.6., *VOC Sample Collection for Soils*, for appropriate sample collection procedures.

Soil samples collected for analytical parameters other than VOCs must 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.

6.2.6 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).

To obtain the most representative monitor reading, use a decontaminated stainless steel spoon, knife or other appropriately constructed device and make a longitudinal score deep enough to expose a porous surface the length of the core. Or optionally, make very small divots at six-inch intervals to expose a porous surface. 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.) should be discussed with the appropriate regulatory authority for approval before sample collection.

The Technical Requirements for Site Remediation N.J.A.C. 7:26E-3.6(a)4.(ii), instruct one to select a six-inch increment of soil for volatile organic laboratory analysis based on field screening with a DRI. If a boring is continuously cored to 20 feet below grade where ground water is first encountered, then 4 to 5 individual 48" - 60" soil core segments will have to be opened and screened before determination as to which six-inch increment is to be selected for sampling and analysis. Special attention must be paid to labeling and storage of individual core samples when continuous soil samples are collected from a single boring. In many instances soil cores can be produced faster than they can be opened, logged, screened and sampled by a technician. In those instances when a backlog of cores are being generated, care must be made to protect the cores from direct sunlight, excessive ambient temperatures and rain. 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. If necessary, log soils for lithology information *after* sample collection. Always calibrate the DRI at the start of each day.

Another option is to select (using the DRI), and sample (using a small diameter coring device), a six-inch increment from every individual core segment, and only submit the sample required from that particular boring for analysis as directed in 7:26E-3.6(a)4(ii). This option can be more costly as several sample containers will have to be discarded at the end of the each boring. If chemical preservation is used (methanol), proper disposal could be an issue. Sampling every individual core first, prior to determining which increment to ship for laboratory analysis will also require additional labor. This particular option, to collect a representative six-inch incremental sample from every individual segment of a continuous core with its associated cost, makes the first option to carefully protect and manage the cores to control the loss of volatile organics even more critical.

6.2.7 VOCs Sample Collection for Soils

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.

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, it has been the acts of collection and storage that subject a sample to numerous variables that can alter VOC concentration. These variables 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 must 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 VOC Soil Sample Depth Selection

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 all soil and non-aqueous samples for VOC analysis must be as follows:

The collection of samples for VOC analysis must 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 sampling 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 must 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.

***Important!* Soil samples for VOC analysis must be collected immediately (within minutes) to reduce loss of VOCs to volatilization and biodegradation.**

Using the field-screening data, select samples for VOC analysis using the following criteria:

If field-screening measurements are detected above background:

- Extend the boring from ground surface until either background readings are achieved, ground water is encountered or bedrock is encountered; and

- Collect a soil sample from the six (6) inch interval registering the highest value on the DRI, at a minimum, using the appropriate sample collection method and device as specified in N.J.A.C. 7:26E-2.1(a)4 and
- Collect any additional samples as necessary based on DRI readings or laboratory data to delineate VOC contamination pursuant to the requirements specified in N.J.A.C. 7:26E-4.1 and 4.3.

If all intervals register the same measurement from the DRI or if all measurements do not exceed background:

- Extend the boring to ground water, bedrock, or 10 feet, whichever is encountered first, and;
- Collect an undisturbed sample from the six-inch interval at the bottom of the soil boring, at a minimum, using the appropriate sampling sample collection method and device as specified in N.J.A.C. 7:26E-2.1(a)4.
- Collect additional samples as necessary based on DRI readings or laboratory data to delineate VOC contamination pursuant to the requirements specified in N.J.A.C. 7:26E-4.1 and 4.3.

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.

6.2.7.2 VOC Soil Sample Collection Devices - Small Diameter Core Samplers

***Important!* Soil samples for VOC analysis must be collected immediately (within minutes) to reduce loss of VOCs to volatilization and biodegradation.**

Soil to be collected for laboratory analysis **can not** 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 **can not** 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, splitspoons, covered liners or intermediate containers will lead to VOC losses and thus yield poor quality data. See Section 6.2.6., *Field Screening Soil Samples*, for more information.

Sub-sampling of the large-diameter sampling device for VOCs must be performed with the use of a dedicated or decontaminated small-diameter core sampler. The small-diameter core sampler must be capable of collecting the required amount of sample from the large-diameter sampling device (e.g., split spoon or soil corer) or from freshly exposed soils. The small-diameter core sampler must be capable of delivering the sample quickly and directly into the sample container without disturbing the native soil structure.

It is important that the small-diameter core sampler provide the required mass of sample material. As such, a **test sample** (of similar matrix to be sampled) should be collected and weighed to determine the amount of soil needed to obtain the required mass of sample material for each type of small-diameter core sampler and analytical method. Using a small electronic portable scale with an accuracy of 0.1grams, weigh the empty small-diameter core sampler (e.g., disposal syringe) to the nearest 0.1grams. The scale must be calibrated before use and intermittently checked during the day to ensure accurate weight measurement. Calibration information must be recorded in the field logbook. A translucent cover can be placed over the scale during the weighing process to negate variations caused by wind. Push the small-diameter core sampler

test sample into the matrix to collect the required mass of material (3cm³ should yield approximately 5-grams of sample [wet weight]). Wipe clean any soil adhering to the outside of the small-diameter core sampler before weighing. If the weight is above the required amount, excessive soil can be removed by extruding a small portion of the core and cutting it away with a decontaminated trowel or spatula. If the weight is below the weight limit, obtain additional soil by reinserting the small-diameter core sampler into the soil core. Reweigh after each addition or removal of sample from the small-diameter core sampler until the target weight is attained. Note the sample volume and amount in the small-diameter core sampler. **Discard the test sample.** Use this volume when collecting soil of similar matrix. Additional test samples should be weighed whenever a change in the matrix is observed.

All small-diameter core samplers used in the collection of samples for VOCs must 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 ridged 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.

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 must be able to deliver a minimum of 5-gram sample ($\approx 3\text{cm}^3$ of sample assuming a density of 1.7g/cm³) 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 must 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 cm³ 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 cannot be decontaminated.

The disposable syringe can not be used for storage or shipment to the laboratory. The soil sample must be transferred into appropriate sample containers immediately upon sample collection for proper preservation.

6.2.7.2.2 Easy-Draw Syringe and Power-Stop Handle

The Easy-Draw Syringe[®] and Power-Stop Handle[®] is a 5-gram volumetric coring system for sample collection 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® can not be used for storage or shipment to the laboratory. The soil sample must 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 to 10 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® can not be used for storage or shipment to the laboratory. The soil sample must 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 must be flush with the bottom of the coring body before 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 must be extruded from the En Core® sampler and preserved by the laboratory within 48 hours of sample collection.

The En Core^a 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 can not 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 core samplers 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 must 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 must 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 manufacturers 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 ziplock bags to help avoid cross contamination. The laboratory sample number or field sample identification number may be placed on the bag and crossed 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 must 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 preferred sample preservation method 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 maybe 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 must 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 (\pm 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 (\pm 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-way 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, un-preserved 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 must 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 must be taken when placing the soil in the vial to limit loss of soil. Each vial must 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) must 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 bound logbook, 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 [\pm 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 [\pm 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 must 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.

Disadvantages

- 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 ($\pm 2^{\circ}\text{C}$) 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, un-preserved 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 must 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 must 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) must 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 must 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 bound logbook, 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 [\pm 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 [\pm 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 must 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.

Disadvantages

- 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 (\pm 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 must 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 must 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 [\pm 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 must 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 must 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 **can 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 must 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.

Disadvantages

- The En Core® sampler cannot 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 must have a plunger to allow for proper mechanical dispensing at the laboratory, and must be approved for use by NJDEP.
- A 48 hour holding time for non-chemically preserved, soil samples cooled to 4°C (\pm 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 must 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 un-preserved 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 must 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 must 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) must 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 must 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 bound logbook, 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]) 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 circumstances:

- 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 must 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.

Disadvantages

- Sodium bisulfate can 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 must 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 must 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) must 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 must 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 bound logbook, 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 associate 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 must 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 re-classification of the sample as a hazardous waste. This hazardous waste classification results in increased shipping and disposal costs.

Pre-preserved sample containers must 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.

Disadvantages

- Methanol preservation is applicable to medium and high level analysis only. Low-level concentrations 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 un-preserved-glass sample containers with a PTFE-lined screw cap. A minimum of two 4-oz glass containers must 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 must 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 ($\pm 2^\circ\text{C}$) for later shipment to the laboratory. The holding time for non-chemically preserved, cooled to 4°C ($\pm 2^\circ\text{C}$) 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 must 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 must 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. Re-sampling of potential impact areas may be required using approved preservation procedures after the emergency has been mitigated.

Sample containers must 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.

Disadvantages:

- 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 ($\pm 2^\circ\text{C}$) 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 must be provided to the laboratory from each sample location. The additional sample aliquot must be collected using a decontaminated stainless steel trowel or spatula and place into an un-preserved sample container, usually a 60-ml wide mouth PTFE-lined glass container. This sample is not chemically preserved. The sample must be obtained from the same interval and location as the sample for VOC analysis. The sample container must be completely filled with sample to minimize headspace and loss of

VOCs. The laboratory must 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 clean or paper towel. 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 must be placed and shipped on ice at 4°C (± 2°C).

6.2.7.6 Commercial Equipment Suppliers

A partial listing of equipment suppliers for sampling equipment is included in Table 6.10. This listing of equipment suppliers is not an endorsement by the New Jersey Department of Environmental Protection; it is supplied for information purposes only.

Table 6.10 Discrete Soil Sampler Suppliers	
Discrete Soil Sampler	Supplier
Purge and Trap Soil Sampler®	Associated Design and Mfg. Co. 814 N. Henry St. Alexandria, VA 22314-1619 703-549-5999
En Core® Sampler Terra Core Sampler® Easy-Draw Syringe® and Power Stop Handle	En Novative Technologies 1241 Bellevue St. Green Bay, WI 54302 1-888-411-0757
10-cc Syringes	J&H Berge, Inc. 4111 South Clinton Ave. South Plainfield, NJ 07080 1-908-561-1234 VWR Scientific Products P.O. Box 369 405 Heron Drive Swedesboro NJ 08085 856-467-2600 Thomas Scientific 99 High Hill Road @I-295 P.O. Box 99 Swedesboro, NJ 08085 856-467-2000

6.2.8 Non-VOC Sample Collection for Soils

Contaminants such as semivolatile organic compounds (SVOCs), pesticides, PCBs, metals or cyanide that cannot be detected with field screening instrumentation must 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 logbook any information noted during sampling activities that

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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 may be 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 is collected for VOC analysis as well as other non-VOC parameters, the soil for VOC analysis must 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 must 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 must 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 return the container to an iced cooler in an upright position. Sample containers from different sample locations should be placed in separate ziplock 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 crossed 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 must 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 must be provided to the Department.

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 must 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 must be performed quickly to prevent a loss of VOCs. A small funnel can be used to channel the sample into the container. The funnel must 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 must be used with caution. Loss of VOCs may occur when sampling this matrix due to the increase 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 must 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 must 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 must 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 excavation. 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 must be taken in working near the backhoe. All personnel must 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 must 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 must 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 must 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 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

The Technical Requirements for Site Remediation require, if appropriate, that rock cores be collected during the drilling of bedrock monitoring wells, piezometers and other borings [N.J.A.C., 7:26E-4.4(g)5].

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.

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.

6.3.2 Coring Tools

6.3.2.1 Tube-Type Coring Tools

Tube-type coring tools can be either a single or double-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) (Figure 6.1). 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.

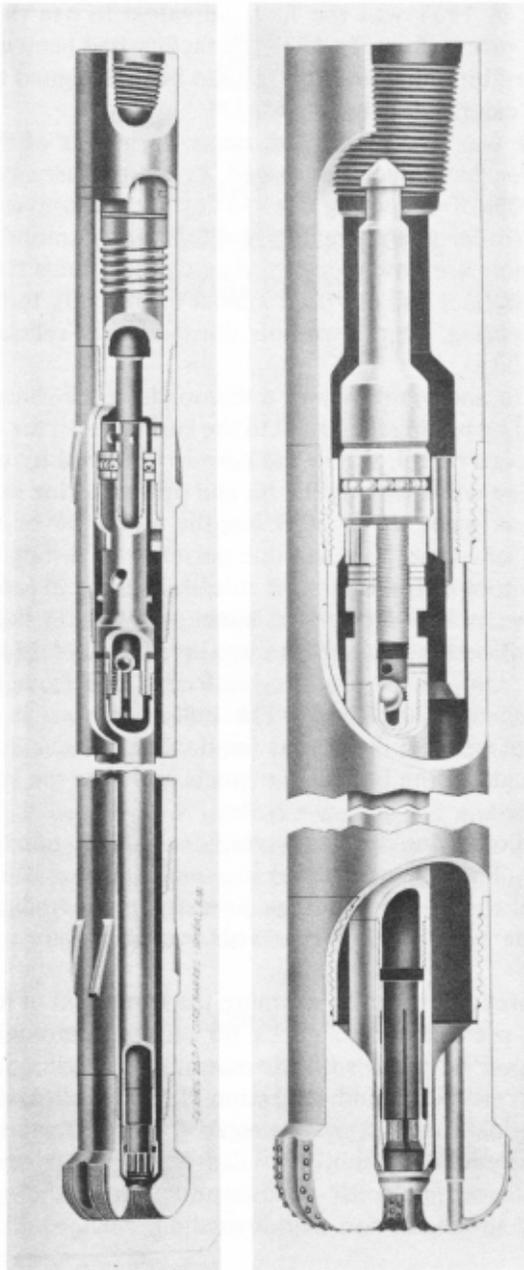


Figure 6.1 Double tube coring tool. Anderson, 1975, printed with permission.



Figure 6.2 Impregnated diamond bit. Acker, 1974, printed with permission.

Descriptions of specifications for various types of tube-type tools can be found in the ASTM standard practice reference designation D 2113-83, “Practice for Diamond Core Drilling for Site Investigation.”

Most conventional coring tools are fitted with a circular diamond core bit (Figure 6.2). 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.

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 (PSE&G SOP 310,1997):

- 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.
- In order to prevent possible damage to a core sample, a full core run should not be drilled if it is 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.

6.3.4 Rock Core Logging

A field log of each core must be completed and maintained by the project geologist. Table 6.11 lists and describes the information that is required for entry into each core log. The necessary information should be recorded on an appropriate rock core log form. An example of a rock core log form is illustrated in Table 6.10.

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 (PSE&G SOP 311,1997).

Wooden blocks should be placed in the storage boxes between each core run sample. The blocks shall 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

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Table 6.11 Rock Coring Requirements	
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 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. $RQD = (r/l) \times 100$ 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 must be noted including elevated air monitoring instrument readings, odors, visual observations, and the presence of NAPL, etc.

- 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

6.4 Direct Push Technology

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 you must apply, at a minimum, the Cold Regions decontamination procedure discussed in Chapter 2, *Quality Assurance*, Section 2.4., *Decontamination Procedures*.

One of the special applications of direct push technology relative to soil sampling is the ability to obtain vertical profile contaminant information while working 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 the only acceptable means to decontaminate direct push sampling equipment and maintain confidence that data is not influenced by unwanted variables. In addition, equipment must be maintained in good working order to insure its performance. This means (but is not limited to) all rods used for boring advancement must have unworn O-rings (if applicable) at each connection and undamaged threads to insure that each connection can be drawn tight. All downhole equipment must be decontaminated between each use. Operators must have boring certification in good standing from the Bureau of Water Allocation and all permit approvals must be on-site. Extreme caution must be taken to insure that communication between various water bearing zones within the same boring does not take place therefore, all grouting must be tremied under pressure starting from the bottom of the boring and completed at the surface using grout of the required density. Finally, no boring work can begin without first contacting New Jersey One Call service to secure utility mark-outs.

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-97-001. 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: <http://epa.gov/swerust1/pubs/esa-ch5.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 D6001-96, *Direct Push Water Sampling for Geoenvironmental Investigations*, and via the following vendor Internet links: <http://geoprobe.com>, and <http://www.ams-samplers.com/main.shtm?PageName=welcome.shtm>.

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. Quality assurance requirements will be determined on a site by site basis by a NJDEP representative.

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 logbook 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.

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.

Next, the containers should be marked with an identification number for present and future reference. Enamel spray paint is often suitable for this purpose. Again, photographs of the numbered containers can prove valuable in documenting the containers' condition.

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 employed 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 logbook.

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 decontaminated sampling device into the center of the material to be sampled. Retrieve the sample and immediately transfer it into the

sample bottle. If the sampling device is disposable, it may be left in the container sampled. Otherwise, decontaminate the device thoroughly before collecting the next sample. 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
- stratified sample thief (multiple liquid layer sampling)
- liquid/sludge sampler

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. If the sampling device is disposable, leave it in the container sampled. Otherwise decontaminate the device thoroughly before collecting the next sample. 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.

6.5.2 Tanks, Vacuum Trucks, Process Vessels and Similar Large 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 logbook 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. Each container should be marked with an identification number for present and future reference. Enamel spray paint is often suitable for this purpose. 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 must be considered to assure personal health and safety. Accessing storage tanks requires a great deal of manual dexterity. It usually requires climbing to the top of the tank through a narrow vertical or spiral stairway while wearing protective gear and carrying sampling equipment. At least two persons must always perform the sampling: One to open the hatch and/or collect the actual samples, and the other to stand back, usually at the head of the stairway and observe, ready to assist or call for help.

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 logbook.

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 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.

Upon retrieval, immediately transfer the sample into the sample bottle. If the sampling device is disposable, it may be left in the container sampled. Otherwise the device must be thoroughly decontaminated before collecting the next sample.

6.5.3 Transformers

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 pole mounted transformers a power operated scissors lift or cherry picker may be needed. In other cases the transformer may be in an underground cell.

The toxic nature and degree of hazard posed by PCBs 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 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 of the transformer can be removed with hand tools. A sample of the dielectric fluid is most efficiently obtained with a disposable glass COLIWASA.

In order to obtain a representative sample, lower this device at a rate that allows the levels of the fluid inside and outside the sampler to remain the same. When the sampler reaches the bottom of the transformer, close it and as it is retrieved, wipe the COLIWASA with a disposable absorbent pad. Transfer the sample directly into the sample bottle. If a disposable sampling device is used, and if the transformer is out of service, it may be possible to leave the used sampler in the sampled materials. However this should only be done after consultation with the responsible authorities. Otherwise the sampler should be drummed along with protective clothing, sheeting and absorbent pads, and disposed of at a pre-determined approved location.

The transformer drain valve should never be utilized for sample collection for several reasons. The integrity of these valves cannot be assured. The valve may be rusty, may break or may become

jammed in the open position resulting in the uncontrolled release of the transformer's contents. Secondly, it is likely that transformer contents may have stratified. Since PCBs are heavier than other insulating oils this stratification may prevent the collection of representative samples. Samples obtained from the valve near the bottom of the transformer might reveal higher PCB concentrations than the true concentration of the total dielectric fluid.

6.6 Waste Pile Sampling

This recommended protocol outlines general procedures for collecting samples from waste piles and other waste materials, equipment necessary for sampling, and the adequate representation of the material. Also presented will be necessary factors for consideration when formulating a sampling plan. Because of the variables involved in waste material sampling, including shape and size of piles; size, compactness and structure of the waste material; and make-up throughout the material, exact procedures cannot be outlined for every sampling situation. Considerations must be made for the above mentioned variables, the purpose of sampling, and the intended use of the data to help determine correct sampling methodology.

6.6.1 Considerations for the Sampling Plan

The physical and chemical make-up of the waste pile and the purpose of sampling should be considered in planning for the sampling event. 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 waste material and waste piles may vary greatly in a real 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 are being represented.

6.6.1.2.2 Chemical Stability

Waste 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.

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. However, for verification of that information, or when no information is available about the nature of the material, the involved Site Remediation Program in NJDEP will direct the first round of sampling for analysis of the waste. 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.

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.

After the waste has been classified as hazardous, additional sample points and analysis for a wide range of parameters is usually required. The sampling scheme should address delineation of the extent of hazardous material exceeding clean-up criteria. It should characterize waste with contaminant concentrations above a specific, significant level but below removal criteria which may be removed to another approved facility, remain on site after risk assessment, or undergo some other form of remediation such as on-site treatment.

6.6.2 Sampling Procedures

As with soil sampling, waste 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, waste pile samplers or grain samplers may be used.

Waste pile sampling is generally accomplished through the use of one of the following samplers:

- scoop or trowel
- waste pile sampler
- sampling trier
- soil auger

- grain sampler
- split spoon sampler
- soil coring device

6.6.2.1 Surface

At the desired location, clear surface debris. Collect the adequate volume of waste from a depth of 0-6 inches using a trowel, scoop or auger. For a core sample from the surface use the waste pile sampler, trier, or other 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 may be utilized with a split spoon for sample collection. Upon retrieval the split spoon should be opened, its contents logged if necessary, and immediately transferred into a sample bottle using a decontaminated spatula or spoon.

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.state.nj.us/dep/dshw/rrtp/index.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 include RCRA characteristics, total petroleum hydrocarbons (TPHC) content and total polychlorinated biphenyl (PCB) content. 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 detection limits must 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 3rd (or most recent) Edition must be submitted along with analytical results.

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.

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 materials to be characterized are excavated soils, a guidance document entitled *Guidance Document for the Remediation of Contaminated Soils* can be obtained from the NJDEP Maps and Publications office at 609-777-1038. This document provides guidance on the evaluation of soils in order to determine their regulatory status and recommends appropriate sampling in support of the determinations.

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. For Beneficial Use Determinations (BUD), the material must normally be sampled at a rate of one sample per five hundred (500) cubic yards of the material. To obtain a representative sample, the material must be divided into grids and each grid must represent no more than twenty (20) cubic yards of material.

6.7 Surficial Sampling

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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.

6.7.1 Wipe Samples

This method of monitoring surficial contamination is intended for non-volatile species of analytes (e.g., PCB, TCDD, and TCDF) 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).

To collect a wipe sample the following equipment is needed:

- a ruler or measuring tape to measure out the area being wiped
- disposable surgical gloves, to be changed prior to handling clean gauze, sample container or solvent
- sterile, wrapped gauze pad (3 in. x 3 in.)
- appropriate pesticide grade solvent or distilled and deionized water

To facilitate the collection of a wipe sample, 3 in. x 3-in. gauze should be utilized. The use of filter paper for wipe sampling is not recommended. Filter paper will tend to rip and crumble if the surface wiped is slightly rough. If filter paper is to be used, it should be four-inch diameter heavy gauge paper, such as Whatman #4 Filter Paper.

The solvent of choice may change based upon the analytes of interest and surface being sampled. Gauze pads for semi-volatiles, pesticide and PCB samples should be moistened in a 1:4 acetone/hexane mixture and those for metals with distilled and deionized water. The gauze pad should be soaked and excess squeezed out immediately before the collection of each sample. Use of pre-soaked pads is not acceptable. Alternate solvents may be acceptable for certain parameters, however, their approval for use will be at the discretion of NJDEP.

Occasionally samples are desired from painted or waxed surfaces. Since hexane may degrade the finish or pick up interfering substances, an alternate solvent should be used. In this case, methanol or distilled/deionized water for semi-volatiles, pesticides and PCB's and distilled and deionized water alone for metals should be used. Surface interference should be recorded in the field log-book.

Once the sample location has been determined, sample collection can begin. It is recommended that an area be premeasured (e.g. 25 cm x 25 cm) to allow for easier calculation of final results. However, this is not always feasible and may be done after area is wiped. Wearing a new pair of disposable surgical gloves, remove the gauze pad from its sterile wrapping and soak it with the appropriate solvent. Wipe entire area to be sampled once in the horizontal direction and once in the vertical direction, applying moderate pressure. Wipe the entire area so that all the sample material is picked up. Place the gauze pad into the sample container.

A blank must always be collected for each wipe-sampling episode in order to ensure the quality of the data. This blank will help to identify potential introduction of contaminants from the pad, solvent, sample container or ambient air conditions. To perform a wipe blank, start by wearing new gloves, then wet a gauze pad with the solvent or water (for each collection parameter) and place the pad directly into the sample bottle.

When samples are submitted for analysis, the laboratory should be told to rinse the sample jars with the appropriate extraction or digestion solvent, depending on the analysis to be performed, when transferring sample to the extraction glassware. This will ensure that the entire sample has been removed from the container.

6.7.2 Chip Samples

This method of monitoring surficial contamination is intended for non-volatile species of analytes (e.g., PCB, TCDD, and TCDF) on porous surfaces (e.g., cement, 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 is received, the area sampled should be measured. To collect a chip sample, the following equipment is needed:

- a ruler, or measuring tape to measure out area to be sampled
- disposable surgical gloves, to be changed prior to collection of each sample

- decontaminated chisel of borosilicate construction and hammer or electric hammer
- dedicated natural bristle brush and a dust pan lined with aluminum foil or one that is dedicated, decontaminated and constructed of a pre-approved material which will not interfere with the contaminants of concern
- container for sample

Once the sample location has been determined and marked off, sample collection can begin. Wearing a new pair of disposable gloves, and using a decontaminated chisel and hammer, break up the surface to be sampled. An effort should be made to avoid scattering pieces out of the sampling area boundary. Any pieces that fall outside the sampling area should not be used. The area should be chipped to less than one-quarter inch (preferably 1/8 in.). Record how deep chips were taken. Collect the chipped pieces using a dedicated, decontaminated dustpan and natural bristle brush and transfer the sample directly into the bottle.

6.7.3 Sweep Samples

This method of monitoring surficial contamination is intended for non-volatile species of analytes (e.g., PCB, TCDD, TCDF) 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 wipe sample to be easily collected.

To collect a sweep sample the following equipment is needed:

- dedicated natural bristle brush
- decontaminated stainless steel spatula and/or a dustpan lined with aluminum foil, or one that is dedicated, decontaminated and constructed of a pre-approved material which will not interfere with the contaminants of concern
- disposable dedicated surgical gloves to be changed prior to collection of each sample.
- container for sample

Once the sample location has been determined, sample collection can begin. Wearing a new pair of disposable gloves, sweep all residue in the area to be sampled onto a decontaminated or dedicated dustpan or directly into the sample container. A decontaminated or dedicated spatula may be used to aid in transferring the sample into the sample bottle.

6.7.4 Rinsate Samples

This method of sampling is utilized to determine if surfaces contain hazardous waste residual after being cleaned. It is normally associated with drum storage pads, floors of buildings and the inside of waste tanks.

Collecting the water from the last rinse when cleaning a tank or surface area constitutes the Rinsate sample. This water, which is normally potable water, is then analyzed and compared against a blank consisting of the same type of water.

6.8 Surface Water And Sediment Sampling

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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 groundwater seeps.

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. Personnel safety associated with surface water and sediment 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. Chapter 4, *Site Entry Activities*, offers additional considerations, especially when sampling at sites associated with the Site Remediation and Waste Management Program.

If the sampling plan calls for the samples to be collected from a stream, use the USGS rule of thumb: Do not wade into flowing water when the product of depth (in feet) and velocity (in feet per second) equals 10 or greater. This rule varies among individuals according to their weight and stature and to the conditions of the streambed. If the sampling plan calls for the samples to be collected from the shore of a water body or impoundment, the person collecting the sample should be fitted with a safety harness with a rope secured to an immobile object on shore. Backup personnel must be available to assist in collection and shall be prepared and able to pull the sampler to safety if unstable banks are encountered. If the banks are not sloped, the sampling personnel may be able to collect the liquid directly into the sample bottle. In some instances where the liquid to be sampled cannot be reached, a pond sampler, by virtue of its extension capabilities, may offer an option. In this case, assemble the pond sampler ensuring adequate extension to obtain the sample without placing the sampling personnel in danger of falling into the water body impoundment being sampled.

Samples may need to be collected away from the shoreline, via boat, barge or bridge, often at various depths. If the content of the channel or impoundment is suspected to be highly hazardous, the risk to sampling personnel must be weighed against the need to collect the sample. Again, each person on the barge or in the boat must be equipped with a life preserver and/or lifeline. Sampling from a bridge may require consideration for vehicular traffic.

Wastewater sampling has its own set of safety issues. Access to sample locations within a working treatment facility or its associated outfalls requires that one follow the safety rules applicable to working within an industrial setting. Wastewater sampling, especially in manholes and enclosed spaces, may involve exposures to vapors of oxygen-depleted atmosphere, requiring suitable precautions.

6.8.1.2 Physical Characteristics and Water Quality Measurements for Ambient Monitoring

Prior to sample collection, water body characteristics (e.g., size, depth, and flow) should be recorded in the field logbook. Water quality measurements shall include temperature, pH, total

hardness (as CaCO₃), alkalinity (as CaCO₃), salinity (parts per thousand, 0/00), conductivity (as umhos/cm), and dissolved oxygen (mg/l). These measurements must be properly documented as per Chapter 10, *Documentation*. Non-aqueous data must be accompanied by laboratory-analyzed total organic carbon (TOC) and particle grain size for each sample.

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 sampling 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, therefore, to always be clear of 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. Consideration should be given to NJDEP program requirements for sampling at varied tidal stages.

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. For selection of appropriate sampling apparatus, refer to Chapter 5, *Sampling Equipment*.

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6.8.1.7.1 Aqueous – The collection of surface water samples is generally accomplished through the use of the following samplers:

- Laboratory Cleaned Sample Bottle
- Pond Sampler
- Weighted Bottle Sampler
- Wheaton Dip Sampler
- Kemmerer Depth sampler
- Bacon Bomb Sampler
- Water Bottle Sampler
- ISCO Manual or Automatic sampler

6.8.1.7.2 Non-Aqueous – The sampling of sediments/sludges is generally accomplished through the use of one of the following stainless steel or PTFE samplers:

- Scoop or Trowel
- Sampling Trier
- Bucket Auger
- Soil Coring Device
- Waste Pile Sampler
- Split Spoon Sampler
- Ponar Dredge
- Box Corer
- Ekman Dredge
- Shipek
- Van Veen Grab
- Russian Peat Sampler
- Hand corer
- Gravity Corer

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 or a vessel. Refer to Chapter 5, *Sampling Equipment*, for further information.

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 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 wastestream for purposes of obtaining a permit, the determination should be based on the inspector 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 wastestreams.

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 wastestream'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. The following general guidelines apply when taking samples:

- Take samples at the site specified in the permit or at the site selected by the inspector to yield a representative sample if the site has not yet been specified by in permit.
- 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 inspector should avoid skimming the surface of the wastestream 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 inspector deems most appropriate if the method has not yet been specified in a permit). Note that in 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.
- Fill the container completely if the sample is to be analyzed for purgeable organics, dissolved oxygen, 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 wastestream. 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 samples collected depends on the type and number of analyses needed. The parameters to be measured and the method requirements guiding the analytical laboratory will determine this. 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 completing all analyses, since the lab is in the best position to estimate the necessary volume of sample. Individual, minimum composite portions should be 100-ml with a total composite volume of 2-4 gallons. Larger volumes may be necessary if samples are to be separated into aliquots or if bioassay tests are to be conducted.

6.8.2 Freshwater and Biological Monitoring Program

6.8.2.1 Sampling Objectives

The objectives of the surface water 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; and
- sample in segments of the river determined to be representative of larger segments.

6.8.2.2 Aqueous Samples

6.8.2.2.1 Stream/Flowing Water

For a stream, channel, river, etc., collect the sample from mid-depth. Once the sample is obtained, transfer it directly into the sample bottle. Decontaminate the sampling device before taking the next sample. If the liquid has stratified, a sample at each strata 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. After collection, decontaminate the sampling device before taking the next sample.

6.8.2.2.2 Composite 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. If collecting samples for trace elements, be sure to use acid rinsed sample containers and churn splitters. 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.

Before the start of sampling, the churn splitter must be rinsed three times using 1L of sample water per rinse. Be sure to allow rinse water to completely drain from the spigot each time. It's important to store the churn splitter in double-bagged clear polyethylene bags prior to use in order to reduce air deposition contamination.

The number of individual samples in a composite varies with the width of the stream being sampled. Horizontal intervals should be at least one foot wide. Determine the number of stream intervals by using a tag line, bridge markers or visual inspection. At the interval (or vertical) of apparent maximum discharge determine the equal transit rates (or constant rates of speed) at which the sampling apparatus is to be lowered and then raised at all succeeding verticals. Lower and raise the sampling apparatus at a rate which, when all the verticals through the water column are sampled, will provide an adequate sample volume. Contact with the streambed should be avoided to decrease the possibility of suspended material entering the sample container. The contents of the sample container are then emptied into the churn splitter for rinsing of the churn.

The transit rate, number of verticals and the number of passes at each vertical are influenced by the volume of water required for the parameters to be analyzed and the mixing characteristics of the stream. A narrow or shallow stream may require each vertical to be sampled more than once, but all verticals must be sampled the same number of times. The compositing of the verticals in the churn splitter creates a single cross-sectional representation of the stream. The composited sample must now be split into the necessary subsamples as explained below. Samples collected for organic analysis, organic carbon, pesticides, herbicides and bacteria should not be composited in the churn splitter nor collected in any plastic device because of the potential for contamination. These parameters require glass samplers and containers. Bacteriological samples can be collected in auto-claved plastic containers.

The *Churn Splitter* is a 1/4-inch thick, white polyethylene cylinder. Currently, there are two types in use. One has an 8 3/16-inch inside diameter, a depth of 10 3/4-

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inches, holds a volume of 8.6 liters and has a white polyethylene lid. The valve and spout are white polypropylene. The stirring disc is a 3/8 in. thick, white polypropylene disc 8 inches diameter with 16 apertures; 9 as scallops in the outer edge, and 8 in a inner circle. The handle, a 3/4-inch diameter by 14-in. long white polypropylene rod, is welded perpendicular to the center of the disc and supported by four ribs. A small “notch” on the disc aligns the disc with a guide rib and maintains the correct alignment with the valve. The valve is a screw type, also made of white polyethylene. The second type of churn splitter is constructed in the same way but holds approximately 14 liters. It has a 10 1/8-inch inside diameter, and is 11 3/4-inch deep. The stirring disc is 10 inches in diameter with an attached 1-inch rod, 16 3/4-inches long. All other aspects of this churn splitter are the same as the smaller version except for the valve. The valve on the larger version is a push button type with a metal string inserted. The model should be avoided when sampling for trace metals.

The *Sample Splitting Procedure* requires a total sample volume of 3 to 8 liters of which 1 to 6 liters are suitable for composited water column subsamples. The remaining two or more liters may be used for filtered subsamples if required by the analytical schedule. If not, they may be discarded. This size churn splitter does not reliably produce representative composited water column subsamples when it contains less than 2 liters. Before collection of the representative sample of the stream flow, determine the total volume needed. Add to this volume at least 10% to cover filter losses and rinse water. Collect approximately one liter of water and thoroughly rinse the churn splitter.

When the required volume plus 10% for waste is collected in the splitter, place all subsample containers within easy reach so that once started, the stirring can be continuous. The sample should be stirred at a uniform rate of approximately 9 inches per second. If faster or slower churning rates are used, maximum errors of 45% to 65% are possible. As the volume of sample in the splitter decreases the round trip frequency should be increased so that the churning disc velocity is constant. The disc should touch bottom, and every stroke length should be as long as possible without breaking the water surface. If the stroke length, and or disc velocity, is increased beyond the recommended rate, there is a sudden change of sound and churning effort which is accompanied by the introduction of excessive air into the mixture. This is undesirable because excessive air may tend to change the dissolved gases, bicarbonate, pH and other characteristics. On the other hand, inadequate stirring may result in non-representative subsamples. The sample in the splitter shall be stirred at the uniform churning rate for about 10 strokes prior to the first withdrawal to establish the desired churning rate of 9 inches per second and to insure uniform dispersion of suspended matter. The sample containers are to be rinsed with churned sample water prior to filling them. (See the *USGS National Field Manual for the Collection of Water-Quality Data, Techniques of Water-Resources Investigations, Book 9 Chapter A5* at <http://water.usgs.gov/owq/FieldManual/>)

When all composited water column subsamples have been obtained, the remaining portion of sample is used for filtered samples. Rinse the bottles for filtered samples with filtered water first. When all of the necessary filtered subsamples have been obtained, the mixing tank, churning disk and filtered apparatus shall be rinsed thoroughly with distilled/deionized water.

Note: The churn splitter lid should be kept on at all times except when pouring samples, in order to protect samples from dust contamination.

Note: Acid-rinsed bottles for trace metals and hexane-acetone rinsed bottles for pesticide analyses should be rinsed with sample water prior to sample collection. These containers are appropriately preserved following sample collection. Bottles that are pre-preserved by the laboratory and whose data are not directly related to ambient surface water programs should not be pre-rinsed for the obvious reasons

6.8.2.2.3 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) non-representative samples are desired. Pre-rinse the sample container with water from the site. 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.

6.8.2.2.4 Point Sampling

Point 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 point samples or placed directly into the sample containers pre-rinsed with water from the same point in the water column. A point 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.

6.8.2.2.5 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 more shallow standing water bodies, collect the sample from just below the surface or at mid-depth. If temperature recordings at varied depths 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.

6.8.2.2.6 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 and only after the turbulence from the wake has subsided. The site should be approached from downstream.

6.8.2.2.7 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.

6.8.2.2.8 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).

6.8.2.3 Non-Aqueous Samples

6.8.2.3.1 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 goals of sediment sampling are: 1) identify areas of highest contamination/impact; 2) to 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 Characteristics 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.

6.8.2.3.1.1 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/>)

6.8.2.3.1.2 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 both the corer and dredge and the trowel before collecting the next sample.

6.8.2.3.1.3 General Procedures

Sediment samples must 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 and using brown borosilicate glass containers with Teflon[®] lined lids for organics.

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 affect 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 4° Celsius and in the appropriate containers.

6.8.2.3.2 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.

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

For sludge sample preservation, samples generally should not be 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 4° 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 Department 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 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.

6.8.2.4 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.

6.8.2.4.1 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 an 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.

6.8.2.4.2 Open-Channel Flow Meters

6.8.2.4.2.1 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 Palmer-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 down-

stream 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 farther 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.

6.8.2.4.2.2 Parshall Flumes

A Parshall flume operates on the same principle as the Palmer-Bowlus flume. The measuring point for this flume located in the converging section at a distance of $2/3A$ upstream from the beginning of the throat of the flume. The distance A is the length of the converging section measured along the wall, rather than along the centerline of the 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.

6.8.2.4.3 Weirs

Weirs differ from flumes in that a weir is essentially a dam across the flow, as compared to reshaping the channel. 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.

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.

6.8.2.4.3.1 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 $Q=2.49H^{2.48}$.

6.8.2.4.3.2 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 nappe is achieved by installing vent pipes beneath the nappe. 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:

$$Q = 3.33 LH^{1.5}$$

The formula for contracted rectangular weirs is usually given as:

$$Q = 3.33 (L - 0.2H)H^{1.5}$$

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:

$$Q = 3.367LH^{1.5}$$

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.

6.8.2.4.3.3 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 Kennison nozzle and the parabolix nozzle and also occasionally used to measure flow.

6.8.2.4.4 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 is 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.

6.8.2.4.5 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.

6.8.2.4.6 Types of Meters, Methods and Systems

6.8.2.4.6.1 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.

6.8.2.4.6.2 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.

6.8.2.4.6.3 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:

$$V = a + bN, \text{ where}$$

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 6.3 shows the propeller current meter, which is typical of a horizontal-axis current meter with vanes. Figure 6.4 shows the Price current meter, which is typical of a vertical-axis rotor current meter with cups.

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.

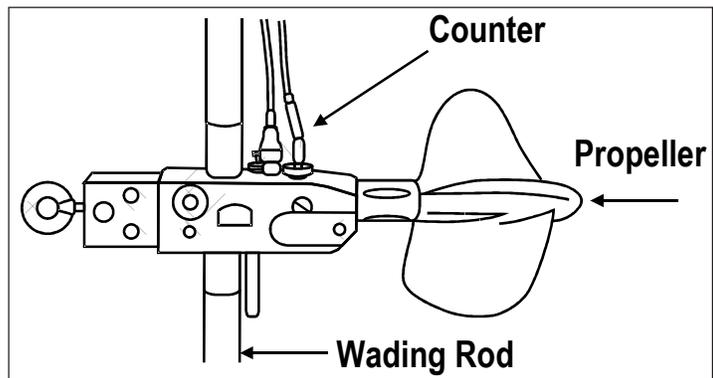


Figure 6.3 Propeller Current Meter

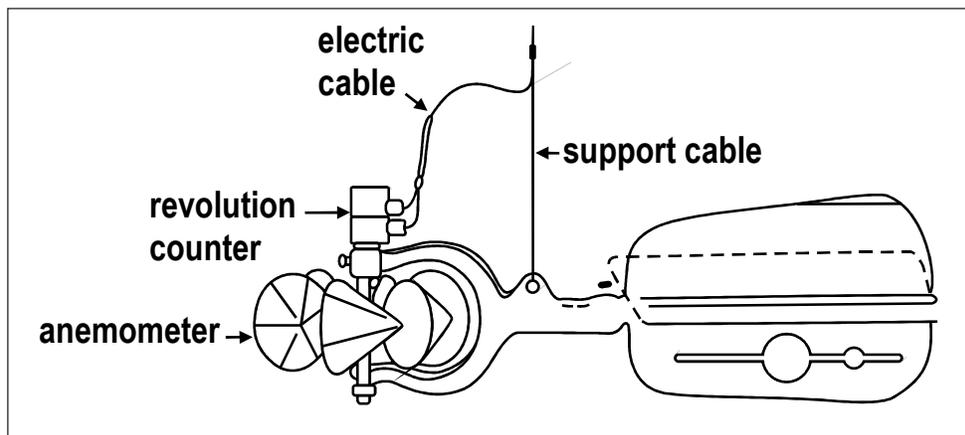


Figure 6.4 Price Current Meter

6.8.2.4.6.4 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.

6.8.2.4.6.5 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.

6.8.2.4.6.6 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.

6.8.2.4.6.7 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.

6.8.2.4.6.8 Floats

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:

$$Q = \frac{D(L_2-L_1)}{t_2-t_1}$$

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.

6.8.2.4.6.9 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. Sodium chloride and lithium chloride are commonly used. The basic procedure is as follows:

- Install two pairs of conductivity electrodes downstream from the salt injection point at known distances and sufficiently far apart in the stretch of the channel.
- Connect the recording galvanometer to the electrodes.
- Inject the slug of salt solution.
- The time for salt solution to pass from the upstream to the downstream electrodes, in seconds, is determined by the distance on the graph between the centers of gravity of the peak areas.
- calculate the discharge using the formula:

$$Q = AL / T, \text{ where}$$

Q = discharge in cubic meters per second

A = cross sectional area of flow, square meters

L = distance between electrodes, meters

T = recorder time for salt solution to travel the distance between electrodes, seconds.

6.8.2.4.6.10 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. Commercially stable dyes (see Part C.3) or potassium permanganate may be used as the coloring matter. The color velocity is computed from the observation of the travel time associated with the center of mass of colored liquid for the instant the slug of dye is poured at the upstream station to the instant it passes the downstream station, which is at a known distance from the upstream station.

With fluorescent dyes, the use of a fluorometer to detect the center of the colored mass will enhance the accuracy of the results.

6.8.2.4.6.11 Discharge

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

6.8.2.4.7 Miscellaneous Flow Measurement Methods

6.8.2.4.7.1 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 overlooked. These changes may be due to water actually consumed in the process, for example, cement manufacturing, conversion of quick lime to slaked lime.

6.8.2.4.7.2 Measure Level Changes in Tank

In some instances the level change in a tank can be used to estimate flow. To accomplish this, 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 6.5 gives the relationship of depth to the stationary volume of a liquid in a horizontal cylinder.

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

$$\text{Volume} = \frac{\alpha}{360} \alpha R^2 - 2 \left[\frac{1}{2} h_2 (R^2 - h_2^2)^{1/2} \right] L$$

Where: R = Tank Radius

h_1 is less than R:

h_1 is greater than R:

$$\alpha = 2 \cos^{-1} \frac{h_2}{R}$$

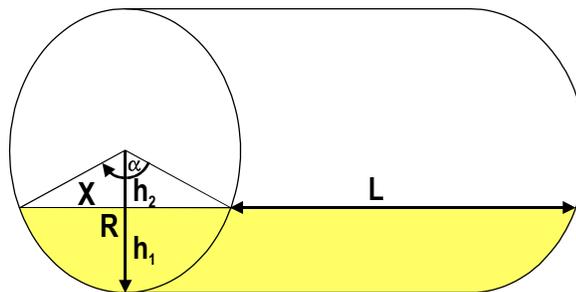
$$\alpha = 360 - 2 \cos^{-1} \frac{h_2}{R}$$

$h_2 = R - \text{depth of liquid}$
or h_1

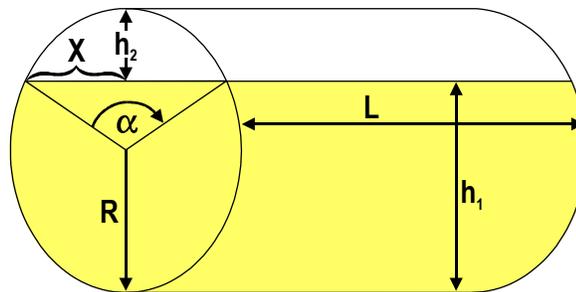
$h_2 = \text{Tank Diameter} -$
depth of liquid or h_1

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

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



Partially filled horizontal cylinder where h_1 is less than R



Partially filled horizontal cylinder where h_1 is greater than R

Figure 6.5 Stationary Volume of Liquid in Horizontal Cylinders

6.8.3 Site Remediation and Waste Management Program

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 preliminary assessment 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 investiga-

Table 6.12 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	$\frac{V_{0.2}+V_{0.8}}{2}$	Observed velocity is the mean velocity	$V_{mean} = C \times V_{0.2}$ C = Coefficient obtained from vertical-velocity curve at that vertical for flow depth	$V_{mean} = \frac{\{V_{0.2}+V_{0.8}\}+V_{0.6}}{2}$	$V_{mean} = C \times V$ 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						

tion 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-3.8 and 4.5. Samples shall be collected in accordance with procedures outlined below with exceptions and additions noted as follows:

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, groundwater, and soil. Surface water body and wetland samples are generally discreet 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, *Guidance for Sediment Quality Investigations*, November 1998.

6.8.3.1.2 Reference Sample Location

When investigating surface water, sediment, or wetland soil contamination in order 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 in order to assess local ambient conditions. At a minimum, upgradient and local reference samples shall receive the same chemical analyses as site-related samples.

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 3.8 and 4.5. 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 discreet (not composited) and biased to detect contamination from the suspected sources under investigation (for example, point source discharges, non-point/ sheet flow runoff, dis-

charge 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 groundwater 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.

6.8.3.3 Non-Aqueous Samples

Samples shall be collected pursuant to N.J.A.C. 7:26E 3.8 and 4.5 and NJDEP's *Guidance for Sediment Quality Evaluation*, November 1998. Procedures in Section 6.8.2.1 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 insure 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.).

6.8.3.4 Use of Passive Diffusion Bag Samplers

Passive Diffusion Bag (PDB) samplers are currently being deployed in monitor wells as a no-purge option when prior approval for their use has been granted by the overseeing agency. Interest in PDB application to sediment/surface water sampling has been growing and research is being conducted by those first responsible for conducting the PDB monitor well research. At this time PDB sampling is an approved sampling technique on a case by case basis for deployment in stream sediments where “gaining” situations can be demonstrated. See Chapter 5, Section 5.2.1.11 and 6.9.2.5.1 for more information on PDB sampling equipment and Chapter 6 for PDB sample collection policy.

6.9 Ground Water Sampling Procedures

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6.9.1 Scope

These procedures describe recommended methods as well as minimally acceptable methods for obtaining representative ground water samples for organic, inorganic, residue, nutrient, bacteriological and other general chemical analyses. Ground water monitor wells, homeowners' 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. The procedures described herein are to be followed by Department personnel, state-approved contract vendors, contractor personnel or anyone submitting ground water data to the NJDEP. Samples obtained in a way that does not meet these minimum criteria will not be considered as representative ground water samples and will not be accepted. In the case of state-approved vendors, unrepresentative sample collection may form the basis of non-payment for services rendered.

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., their implementing regulations (N.J.A.C. 7:9D-1.1 et seq.) and any NJDEP approved changes to these specifications including repeals, new rules and amendments. The Department's Bureau of Water Allocation administers the above Act and oversees all related licensing and permitting activities. Any deviations to the well construction or well decommissioning standards must be approved by the Bureau of Water Allocation prior to the initiation of said activities. Monitor well specifications for Bedrock Formations, Unconsolidated Formations, and Confined Formations are provided in Appendix 6.1 of this section. General guidance on the construction of temporary wells installed via direct push technology can be referenced through this manual, ASTM D6001-96 *Direct Push Water Sampling for Geoenvironmental Investigations*, and via the following Internet links: <http://www.epa.gov/superfund/programs/dfa/dirtech.htm>, <http://epa.gov/swrust1/pubs/esa-ch5.pdf>, <http://geoprobe.com>, and <http://www.ams-samplers.com/main.shtm?PageName=welcome.shtm>.

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. 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 in order to identify and mark out any ancillary underground utilities falling under their jurisdiction.

Additional regulations that must be complied with prior to collection of ground water samples and respective data submission to the Department include the 'Technical Requirements for Site Remediation', N.J.A.C. 7:26E and Laboratory Certification N.J.A.C. 7:18. Respectively, these regulations require: 1) purge and sample water derived from a well be monitored for pH, dissolved oxygen, temperature and specific conductance (7:26E-3.13(c) 7i., ii., iii. & iv.); 2) before **ANY** field analysis of those water quality parameters classified as "analyze immediately," those firms using LFPS instrumentation must first be certified by the Office of Quality Assurance (N.J.A.C. 7:18).

Finally, it is the policy of the Department of Environmental Protection that a sampling plan be submitted for approval before the initiation of ANY low-flow purging and sampling event.

6.9.2 Means of Sample Collection

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)
- Slot size of screen, screen type and length of screen
- Zones of infiltration
- Expected recharge rate of well
- Sampling objectives (field screening, remedial investigation, quarterly sampling, No Further Action [NFA] closeout, Monitored Natural Attenuation sampling, or filtered samples)

Based on the above considerations, the options chosen to evacuate ground water and collect a sample can generally fall into one of the five categories:

- Temporary well point/Direct Push - Ground water purged and sampled *without regard** to monitoring “stabilization.”
- Low-flow purging and sampling (LFPS) - Ground water purged and sampled **within** the screened/borehole interval *with regard* to monitoring “stabilization”
- Low-Yield, Low-flow purging and sampling - Ground water purged and sampled **within** the screened/borehole interval in a well displaying uncontrollable drawdown necessitating sample collection *without regard** to monitoring “stabilization”
- Volume-averaged sample - Ground water purged and sampled **above** the well screen *without regard** to monitoring “stabilization”
- Point source grab sample - Ground water obtained as a grab sample from **within** the screened interval *without regard** to monitoring stabilization.

Refined further, below are the types of equipment associated with each of the five general categories:

- Temporary well point /Direct Push
 - * Bailer^b
 - * Bladder pump^c
 - * Inertial pump^c
 - * Peristaltic pump^d
- LFPS in the screened/borehole interval utilizing a **variable-speed**, positive-displacement pump including:
 - * Bladder pump^f
 - * Gear pump^f
 - * Reciprocating piston pump^f

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-] Progressive cavity pump^f
-] Submersible centrifugal pump^f
- Low-yield LFPS in the screened/borehole interval of a well displaying uncontrollable drawdown utilizing a **variable-speed**, positive-displacement pump including:
 -] Bladder pump^g
 -] Gear pump^g
 -] Progressive cavity pump^g
 -] Reciprocating piston pump^g
 -] Submersible centrifugal pump^g
- Volume-averaged sample
 - ◊ Pump intake positioned immediately above the well screen at a depth of less than 25 feet utilizing a **variable-speed**, suction-lift or positive-displacement pump including:
 -] Bailer^b
 -] Bladder pump^e
 -] Gear pump^e
 -] Peristaltic pump^d
 -] Progressive cavity pump^e
 -] Reciprocating piston pump^e
 -] Submersible centrifugal pump^e
 -] Surface centrifugal pump^a
 - ◊ Pump intake positioned immediately above the well screen at a depth greater than 25 feet utilizing a **variable-speed**, positive-displacement pump including:
 -] Bladder pump^e
 -] Gear pump^e
 -] Progressive cavity pump^e
 -] Reciprocating piston pump^e
 -] Submersible centrifugal pump^e
 - ◊ Pump intake positioned at the top of the water column at a depth of less than 25 feet utilizing a **variable-speed**, suction-lift or positive-displacement pump including:
 -] Bladder pump^e
 -] Gear pump^e
 -] Peristaltic pump^d
 -] Progressive cavity pump^e
 -] Reciprocating piston pump^e
 -] Submersible centrifugal pump^e
 -] Surface centrifugal pump^a
 - ◊ Pump intake positioned at the top of the water column at a depth greater than 25 feet utilizing a **variable-speed**, positive-displacement pump including:
 -] Bladder pump^e
 -] Gear pump^e
 -] Reciprocating piston pump^e
 -] Submersible centrifugal pump^e
 -] Progressive cavity pump^e
- Point source grab sample
 -] Passive diffusion bag sampler^h

- * Gore Sorberⁱ
- * Syringe sampler^j

^apurge only

^bsample from top of water column only

^cpurge and sample for volatile organics only, limited to field screening

^dpurging acceptable for all contaminants however, sampling restricted to metals, Pesticides and PCBs

^epurge and sample for all contaminants

^fpurge and sample for all contaminants including water quality indicators

^gpurge and sample for all contaminants based upon sufficient sample volume within the well to operate pump and fill all sample containers.

^hsample for select volatiles only

ⁱsample for select contaminants in coordination with manufacturer’s analysis, limited to field screening

^jsample for volatiles only, limited to field screening

**without regard* – This category of sampling technique is not conducive to accurate measurement of WQIP for determining stabilization. If collecting samples for programs regulated by Technical Requirements for Site Remediation, a variance from the requirement to provide pH, dissolved oxygen, specific conductance and temperature (N.J.A.C. 7:26E-3.13(c)7i.,ii.,iii. & iv.) must first be attained before sampling can commence.

The order in which analytical samples should be collected is as follows:

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/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

When several wells will be sampled of known or suspected contamination, the least contaminated well should be sampled first, and the wells then sampled in order of increasing contaminant

concentrations. 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. Attention to decontamination procedures must be strictly followed.

Surgical gloves must be changed between each sample location. 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.

6.9.2.1 Temporary Well Points and Direct Push Technology

The Alternative Ground Water Sampling Techniques (AGWST) Guide is now incorporated herein. Use of the techniques listed in the 1994 version, with the exception of the screened auger (Method AGWST 1.00), remain viable alternatives to sampling ground water when “field screening” is the sampling objective. Issues of contaminant carryover downhole using Method AGWST 1.00 have rendered this alternative unacceptable. In addition, other sampling methods are available (e.g., narrow-diameter “mini” bailers) for sampling the miniature drive point. (Method AGWST2.00), therefore, sampling them with peristaltic pumps is no longer acceptable unless specifically approved on a case-by-case basis. Access to the complete guide can be attained using the following URL: <http://www.state.nj.us/dep/srp/regs/agws>. When referring to the 1994 AGWST Guide, all construction, decontamination, purging and sampling techniques must follow this or subsequent editions of the *Field Sampling Procedures Manual* in effect. The phrase “temporary well” is used here figuratively to consolidate the five acceptable techniques described in the AGWST Guide. They include use of a Miniature Drive Point, a Well Point, a Passively Place Narrow Diameter Point, a Direct Push Point, and use of a HydroPunch® sampler. Other commercially available devices, which have similar design and function capabilities, may be deemed acceptable for use with prior approval.

Temporary wells are typically, narrow-diameter wells, with short screens, installed by hand (shallow), drill rig, or hydraulic direct push. If the casing/screen are removed and the borehole is properly decommissioned within 48 hours of their installation, they are considered to be Category 5 Geotechnical Wells, pursuant to N.J.A.C. 7:9D-2.1(a)5. Any well remaining in the ground for more than 48 hours will be classified as a permanent well and thus will be subject to all the regulations regarding monitor 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.).

Temporary wells may be used for both horizontal and vertical delineation of contamination under certain circumstances; (e.g., if the sampling method does not impact sample quality and vertical profiling using direct push methods does not cause cross-contamination of samples during advancement in the same borehole). Determination of whether temporary well points may be used for delineation is made on a case-by-case basis by the SRP case team.

Direct push samplers typically cause turbid samples since there is no filter pack and the formation interval of interest is not fully developed. As such, analytical results for total metals may be biased high. Application of samplers designed with pre-attached filter packs offers a means to reduce turbidity, however, there is no guarantee turbidity will be completely eliminated. Generally, since volatile organic contaminant concentrations are not typically influenced by the presence of suspended material, the VOC values derived from this technique provide reliable field-screening data.

Temporary well points and direct push samplers typically have short screens. Therefore, the sampler will focus on a narrow zone in the aquifer. Examples of the use of temporary well points are those used to characterize a groundwater contaminant plume through vertical profiling using screening-level data. 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 monitor wells and plume delineation. In addition, advancement in direct push technology now allows for the generation of extended geophysical and hydrogeological data once strictly associated with monitor well installation and observation.

The American Society for Testing Materials discusses general technique issues in ASTM D6001-96, *Direct Push Water Sampling for Geoenvironmental Investigations*. Additional information can be found on the Internet at the following USEPA and vendor URLs:

<http://www.epa.gov/superfund/programs/dfa/dirtech.htm>,

<http://www.epa.gov/swrust1/pubs/esa-ch5.pdf>

http://www.geoprobe.com/products/tools/tools_menu.htm, and

<http://www.geinsightonline.com>

<http://www.ams-samplers.com/main.shtm?PageName=welcome.shtm>

6.9.2.2 Low-Flow Purging and Sampling

6.9.2.2.1 Method Summary and Application

The purpose of Low-Flow Purging and Sampling (LFPS) is to collect groundwater samples from monitor wells that are representative of ambient groundwater conditions in the aquifer. This is accomplished by setting the intake velocity of the sampling pump to a flow rate that limits drawdown inside the well. 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 minimizes aeration of the groundwater during sample collection. Third, the amount of groundwater purged from a well is usually reduced as compared to conventional groundwater purging and sampling methods.

Because the method allows collection of groundwater samples with low turbidity, it was originally used for collecting samples for inorganics analysis. The method typically allows the collection of samples for total metals analysis and eliminates the need to filter the samples for dissolved metals analysis. In addition, since the method minimizes aeration of the samples, it can be used to collect samples for analysis of volatile and semi-volatile organic compounds (VOCs and SVOCs), provided that appropriate pumps are used in sample collection, as discussed below.

Advantages of LFPS are:

- Groundwater samples tend to be more representative of actual aquifer conditions with respect to mobile contaminants and turbidity
- It causes minimal disturbance of the formation adjacent to the screened interval
- It is generally less prone to sampling variability compared to other groundwater sampling techniques (e.g., bailers)
- Smaller purge volumes and associated disposal expense

- Increased sample consistency from dedicated systems and reproducibility of data due to reduced operator variability

Disadvantages of LFPS are:

- Misconceptions regarding reduced purging and sampling time
- Sampling from non-dedicated systems requires greater set-up time
- Sampling from dedicated systems requires higher initial capital expenses
- Increased technical complexity
- Increased training needs for sampling personnel
- Attractiveness of advantages may lead to improper and inconsistent application
- Typically not a “first round” sampling option
- Not recommended for wells with long screen intervals unless multiple samples are collected

6.9.2.2.2 Introduction

The following procedures are specific to LFPS of monitor wells in New Jersey. These procedures were developed in consideration of the USEPA-Region I guidance document dated July 30, 1996 (<http://www.epa.gov/region01/measure/well/lowflow8.pdf>) and the USEPA-Region II guidance document dated March 16, 1998 (<http://www.epa.gov/Region2/desa/hsw/lowflow.txt>). 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. The procedures provided in the USEPA and USGS guidance must be followed except where they differ from the information provided below. Finally, three forms are provided herein to assist the sampler in recording low-flow stabilization data, calibration information and pump intake depth placement. They can be found on pages 109, 110, and 111 respectively.

6.9.2.2.3 Low Flow Policy

In the event that a responsible party is conducting a Remedial Investigation without Departmental oversight, submittal of a sampling plan is not required. However, it is *highly recommended* that the responsible party seek approval for any deviations from this guidance prior to conducting LFPS. In the event that a responsible party decides to use LFPS without submitting a sampling plan and receiving approval, it must be recognized that any deviations from this guidance may result in rejection of the data. In addition, when submitting the results of the LFPS event, the responsible party must include specific details of the LFPS techniques used which demonstrate that they were consistent with the guidance specified below. The responsible party shall also provide adequate rationale justifying any deviations from this guidance whether or not they were previously approved by the Department.

It is also Departmental policy that LFPS is not an acceptable method for any wells with screened or open borehole intervals greater than 5 feet in length **unless:** 1) multiple locations at five-foot intervals along the screen/borehole are sampled, or 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

specific zones where sufficient geophysical (e.g., heat-pulse flowmeter, caliper and temperature logs, etc.) and hydrogeological information (e.g., tracer tests) or other evidence (e.g., stained soils or fractures noted on boring logs) that **clearly** identifies the depth(s) at which contaminants are entering the well screen or open borehole.

Once the collection of multiple samples (vertical profiling) in a well has been completed, long-term sampling of the well may require LFPS at fewer 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 groundwater (e.g., LNAPL, DNAPL, etc).

6.9.2.2.4 Laboratory Certification (N.J.A.C. 7:18)

N.J.A.C. 7:18 requires that any environmental laboratory* submitting analytical data to the Department, regardless of quality level, must be certified by the Office of Quality Assurance. This applies to those firms using LFPS instruments associated with the “analyze immediately” category of water quality indicator parameters (WQIPs) including pH, temperature, and dissolved oxygen. Regardless of whether or not the equipment in question is rented or privately owned the requirement for certification can not be ignored. All certification documentation must accompany the instrument into the field and accompany all WQIP data submitted to the Department. (*Environmental laboratory is defined as any laboratory, facility, consulting firm, government or private agency, business entity or other person that the Department 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 Departmental regulatory program).

6.9.2.2.5 Specific LFPS Considerations

6.9.2.2.5.1 Pump Intake Location

When LFPS is performed correctly, the data being collected should be a snapshot of a narrow zone along a length of well screen or fracture in an open borehole. For these reasons, it is important to place the pump intake in the zone of highest contaminant concentration or contaminant flux along the screened/open-hole interval. This is particularly important in wells constructed with more than 5 feet of well screen.

Information to be considered when selecting the pump intake depth should include: 1) evidence of soil/sediment contamination from boring logs; 2) soil/sediment sampling analytical results; 3) vertical profiles of groundwater and soil contamination developed from direct-push sampling and field-screening techniques; and; 4) lithology/stratigraphy, particularly the permeability of the aquifer materials.

Typically, the most permeable zones are selected for the pump intake location since the majority of contaminant mass will be transported through them, particularly as the plume migrates downgradient of the source area. Identification of these zones may be made from borehole geophysical data, (e.g., resistivity, fluid conductance, or natural gamma logging, etc.) and hydraulic conductivity data or grain-size analyses. The use of a series of passive-diffusion-bag samplers in a well may also help to identify the zone of highest VOC contamination. The physical/chemical behavior of the contaminants of concern should 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 may need to be sampled, each from a discrete sampling interval.

As discussed above, LFPS is not an option in wells with screened intervals that exceed 5 feet in length, **unless** multiple sample locations at five-foot intervals along the screen/borehole are investigated. Monitor wells screened across zones of significant geologic heterogeneity or open boreholes in fractured rock may be subject to significant vertical flow. Under those conditions, use of packers to isolate specific zones should be considered.

6.9.2.2.5.2 Water Quality Indicator Parameters (WQIPs)

For groundwater investigations in New Jersey utilizing LFPS, the following parameters must be measured in order to determine when well stability has been achieved prior to sampling. Their respective measurements must fall within the stated range for three consecutive readings. 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 must be restarted. If, after four hours, stability has not been achieved for the parameters listed below, follow the recommendations in Section 3 below.

Water Level Drawdown	< 0.3 ft*
pH	± 0.1 unit
Specific Conductance	± 3%
Temperature	± 3%
Dissolved Oxygen	± 10%
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.

In wells with short screens (i.e., 5 to 10 ft long) or when sampling for gasoline constituents at the water table, it is much more important to limit the drawdown to less than 0.3 ft, for example, than a well with 15 ft of screen being sampled for metals only with the pump intake set in a permeable zone 5 ft or more below the water table. When sampling groundwater for VOCs and SVOCs, aerating the water by allowing it to cascade down the inside of the well should be avoided. Therefore, drawdown should not expose the screen more than 0.3 ft below the static water level in the well.

Measurements should be taken once every 5 to 6 minutes. This interval is 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. 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 document should be used to record drawdown and the WQIPs.

WQIP measurements must be collected in a manner that will insure integrity of the data being collected. To insure consistency of the data, consideration of the following must be made: 1) tubing diameter, length, and material of construction;

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2) flow-through cell design, capacity, decontamination, and “purge-train” set-up; 3) pump selection and plumbing fittings; 4) calibration of flow-through cell probes; 5) purge rate; and, 6) water-level-measurement technique.

6.9.2.2.5.3 Purge Volume vs. Stabilization Time

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 **FOUR** hours of purging: 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 WQIPs do not stabilize, the sampler must document that LFPS could not be performed and document in the report how the samples were collected.

While every effort should be taken to assure that all of 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 groundwater is aerobic or anaerobic). In addition to providing information on the effectiveness of LFPS, 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 impact on VOC concentrations in water samples.

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 samples may be collected. However, any WQIPs that are affected by field conditions or instrument malfunction, must be discussed in the text of the report in order to alert the end-user of potential data bias. If questions arise regarding when stabilization occurs, the sampler should contact the Department’s assigned case manager for the site, if any, either prior to (preferably) or when performing LFPS.

6.9.2.2.5.4 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 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. Therefore, tubing must be completely full of water at all times.

If the sampling plan calls for multiple sample locations 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 must be protected from ambient conditions and the ground surface, in order to avoid impact to the WQIPs and sample data.

The tubing's material of construction must be either Teflon[®] or Teflon[®]-lined polyethylene up to the flow-through cell. This is consistent with collection of any groundwater sample. 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.

Tubing “reuse” is not recommended when sampling well to well since decontamination of tubing is difficult and time consuming. If tubing is to be reused, it must undergo a rigorous decontamination procedure, which must 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*, must be considered: 1) Collect additional field blanks if VOC concentrations in the last sample collected through the tubing are greater than 500 µg/L, or 2) The tubing should be replaced, rather than cleaned, if VOC concentrations in the last sample exceed 700 µg/L.

6.9.2.2.5.5 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 in order to “see” the physical condition of the purge water or air bubbles passing through the system. Highly turbid or iron bacteria-laden water can be visually monitored for change as the purge progresses. The cell must 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 must be small (300-1,000 ml) in order to maintain a desirable turnover rate of water coming into the cell to ensure real-time data integrity. The in-line design must 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.

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 draw-down, stabilize the flow rate and prevent fouling of probes by bacteria, sediment, or NAPL. Once drawdown measurements indicate that the flow rate has been controlled 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 monitor 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 NOT normally 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 must be collected ahead of the flow cell. When two cells are used in series, the dissolved oxygen probe must be located in the first 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 in order to minimize the length of tubing needed between the well head and flow-through cell. The flow-through cell must be protected from ambient conditions and the ground surface. See Figure 6.6.

6.9.2.2.5.6 Pump Selection

Pumps used for monitoring WQIPs must 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 must be fitted appropriately to receive either 1/4 or 3/8-inch inside-diameter (ID) Teflon® or Teflon®-lined polyethylene tubing.

Peristaltic pumps are suction-lift pumps, which can create a negative pressure gradient. Therefore, their use is not appropriate when collecting groundwater samples for analysis of organic compounds. However, peristaltic pumps may be used for the collection of groundwater samples for analysis of inorganic compounds. It should be kept in mind, however, that sampling with peristaltic pumps may affect the stabilization 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 these data are to be used to evaluate the effectiveness of Monitored Natural Attenuation of groundwater.

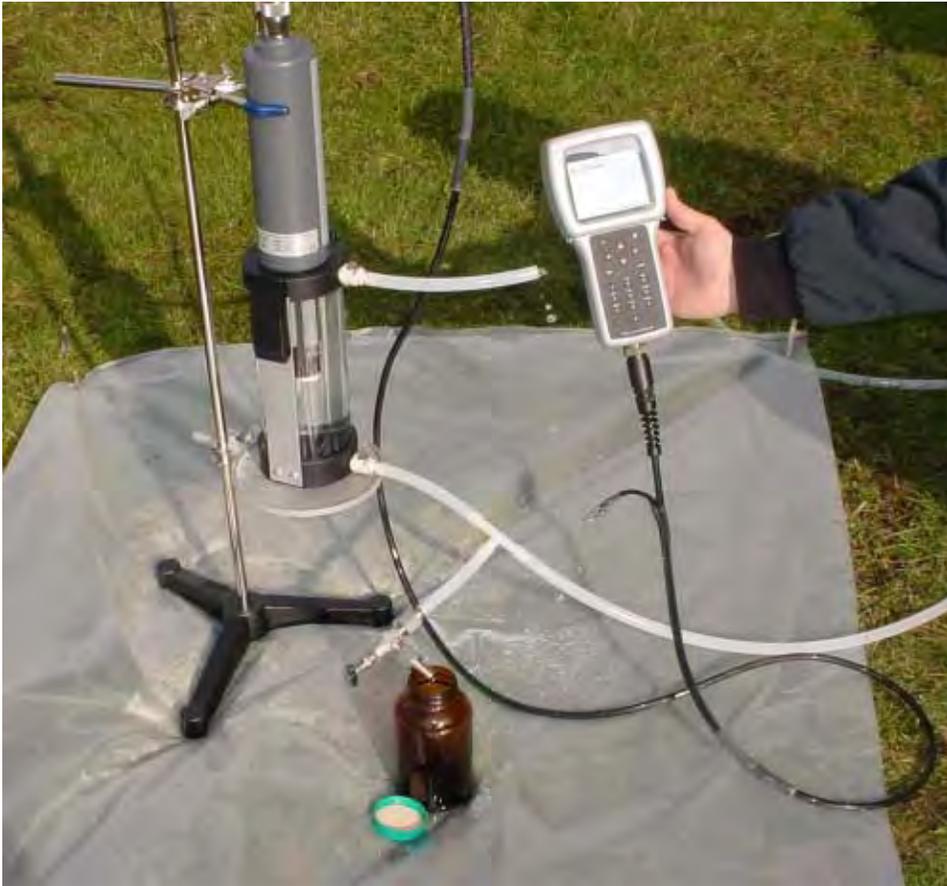


Figure 6.6 Illustration of Flow Cell with stand. (Photograph by J. Schoenleber)

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 unacceptable plastic parts, are 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.

6.9.2.2.5.7 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. In order 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 must 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]) must 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” must be decontaminated before use at any well. See Figure 6.7.



Figure 6.7 Closeup of Needle Valve.
(Photograph by D. Dibblee)

6.9.2.2.5.8 Calibration of Probes

Calibration of the probes used to monitor water quality indicator parameters must take place **in the field prior** to the day’s events. The Office of Quality Assurance must certify the *environmental laboratory* (see Section 6.9.2.2.4) using probes for pH, dissolved oxygen and temperature measurement.

There are no exceptions to these rules. Probe calibration is critical to the accurate and precise measurement of WQIPs.

For warranty purposes, **all** manufacturers’ instructions for proper care and calibration must be followed. Solutions for probe calibration must be held to the temperature of the liquid (groundwater) being measured as temperature correlation is critical in calculating conductivity, dissolved oxygen and pH. Tables and equations to compensate for the difference between ambient groundwater 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 groundwater 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 must be maintained at the temperature of groundwater during calibration. All efforts made to account for proper temperature control of solutions during calibration must be reported to the end user. All steps must be recorded in the field notes. No sampling shall commence until all instruments are calibrated and operating properly. See the “Tips” section below for further discussion on Temperature of Calibration Solutions.

6.9.2.2.5.9 Water Level Measurements

The depth to the top of the water column must 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 must never 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 at the point at which drawdown is equivalent to a 0.3-foot drop. Record water levels simultaneously with WQIP measurements 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 acceptable.

6.9.2.2.5.10 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 pump on a portable or well-to-well basis. 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 not always practical, especially when site security can not 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 monitor wells are open.

Pumps must be installed in such a manner as to insure 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 must be predetermined. Under no circumstance should the pump make contact with, or be “bounced” off, the bottom of the well.

One helpful method to insure proper intake location is to accurately measure and pre-cut the tubing for each individual well prior to site activity. A mark can be made on the tubing, which coincides, with the top of the well. Cutting the tubing off-site in a controlled setting is most desirable. Tubing can be wiped down with paper towels, moistened with distilled/ deionized water, labeled and then sealed into plastic bags until needed. If this practice is used, be sure to allow enough tubing to account for the distance from the top of the well casing to the flow cell.

6.9.2.2.5.11 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 location, 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 in the range of 100 to 500 ml/min. Pump the initial purge water to waste in order 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 pump speed must remain constant such that flow rates never exceed 500 ml/min and, once stabilized, the flow rate must not be varied, even during sample collection. If drawdown continues to exceed 0.3 ft., reduce the pump speed until the drawdown has stabilized but do not adjust pump speed to a flow rate below 100 ml/min. Flow rates below this level may induce pump stalling and undo the effort to reach stabilization. If drawdown does not come under control at 100 ml/min, then a field decision should be rendered as to how far to allow drawdown to continue until sample collection. At no time should evacuation allow any portion of the well screen to be exposed (for wells screened below the water table) or bring the well to dryness.

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 every 5 minutes. Once stability has been attained and recorded, begin sample collection

6.9.2.2.5.12 Sampling

Once WQIPs have stabilized, or a 4-hour time decision has been rendered, sampling can proceed. Do not adjust the flow rate; maintain the same pumping rate during sampling that was used to purge the well. 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. Any exceptions to this technique must first be approved in writing from the NJDEP on a case-by-case basis before commencing sampling operations.

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.

6.9.2.2.5.13 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 an option for LFPS well-to-well consideration because of their limited ability to be decontaminated thoroughly.**

Most bladder pumps can not 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, 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 6.8). Care must be taken upon reassembly to insure 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.

6.9.2.2.5.14 Field Blank Collection

When employing LFPS techniques, collection of the field blank must follow the same general rules for all groundwater sampling equipment. This includes the requirement that “all” sampling equipment, which comes in contact with the sample, must also come into contact with the field blank water. To overcome some of the difficulties that manual field blank collection through the inside of a pumping system creates, the following procedure is strongly recommended. Fill a 1000-ml decontaminated, graduated glass cylinder with method 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 method 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 can not be practically satisfied when using LFSP. The identical bottle-to-bottle field blank requirement is waived for this sampling technique procedure only.



Figure 6.8 Grundfos® Pump being prepared for decontamination (Photograph by J. Schoenleber)

6.9.2.2.6 Tips

6.9.2.2.6.1 Temperature Measurement and Submersible Pumps

Variable-speed submersible pumps such as the Grundfos Redi Flo 2^â 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, two (2)- or four (4)- inch-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 eventually exceeds 40% of the initial recorded temperature (Celsius) 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. Higher temperatures may also reduce the concentrations of volatile organic compounds in groundwater samples due to their relatively high Henry's Law constants. If sampling with submersible pumps continues to result in elevated water temperature, other sampling alternatives should be discussed with the appropriate regulatory program.

When using some submersible pumps in large-diameter wells (six inch 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 shrouds may overcome this condition.

6.9.2.2.6.2 Control of Pump Speed

In order 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. Then, if a check valve has been installed, 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.

6.9.2.2.6.3 pH

Monitoring for stabilization of pH in groundwater is relatively straightforward and rarely requires serious troubleshooting. When calibrating for pH, do a two-point calibration, at a minimum. The calibration range should bracket the anticipated pH. If the pH is unknown, then a three-point calibration must be made. The temperature of the buffer solutions should be as close to the temperature of the groundwater as possible. If the probe does not calibrate properly, check to make sure that the probe’s electrical contact points are dry. 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. Overnight storage generally requires placement of the probe into a 2-molar (M) solution of potassium chloride. This solution may cause an unwanted build up of salt, therefore, frequent rinsing may be necessary.

6.9.2.2.6.4 Temperature of Calibration Solutions

Correct field measurement of dissolved oxygen, conductivity and pH requires tight control over calibration solution temperature. Proper calibration calls for solution temperatures of these parameters to be the same as the groundwater being measured (<http://water.usgs.gov/owq/FieldManual/Chapter6/6.2.1.html#HDR6.2.1.CAL1>). This may be difficult to achieve when field sampling well to well as groundwater 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 solutions to groundwater temperature at the point of pump intake without first installing the pump, collecting purge water and allowing sufficient time to bring calibration solutions to appropriate temperatures.

For the purposes of LFPS in New Jersey, calibration solution temperatures and the flow-through cell itself must be maintained at approximately 54° F (12° C ± 2° C) during calibration. When ambient conditions warrant, this will 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.

Field Instrument and Calibration Data Sheet

Site: _____		
Field Personnel: _____		
Date: _____	Start Time: _____	Stop: _____

Meter (make/model)	Probe
DO _____	_____
pH _____	_____
Spec. Cond. _____	_____
ORP _____	_____
Turbidity _____	_____

Dissolved Oxygen	Turbidity	ORP
	Standard Reading	
Water Temp _____	D.I. Water _____	Standard Temp. _____
Baro. Pres. _____	_____	Standard Conc. _____
Saturation _____	_____	Initial Reading _____
Init. Mtr. Rd. _____	_____	Meter reset to _____
Mtr. reset to _____	_____	
O ₂ Satur. % _____	_____	

Specific Conductance				
Conc.	Initial Reading	Reset to	Temperature	Lot # and Exp. Date
Standard #1 _____	_____	_____	_____	_____
Standard #2 _____	_____	_____	_____	_____
Standard #3 _____	_____	_____	_____	_____
Standard #4 _____	_____	_____	_____	_____

pH Calibration					
Buffer	Temperature	Initial Reading	mV	Meter Reset To	Lot # and Exp. Date
4	_____	_____	_____	_____	_____
7	_____	_____	_____	_____	_____
10	_____	_____	_____	_____	_____

During the purge phase, record the difference between the stabilized temperature and the temperature of the calibration solutions. This information must be presented to the end user. If the sampling event is extended for two or more days, appropriate adjustments can then be made to more accurately reflect the groundwater temperature during calibration.

6.9.2.3 Low-flow Purging and Sampling for Low-Yielding Wells

The principal focus of water supply well installation is well-yield. In contrast, the principal focus of monitor well installation is water quality; well-yield is of secondary importance. In an attempt to locate and delineate ground water contamination, monitor wells are frequently installed in low-yielding water-bearing zones.

Low-yield wells present challenges with respect to representative ground water sample collection. The removal of water by bailers draws down the water-level in the well in slug-type increments. Peristaltic pumps draw water out of the well by vacuum (negative pressure) which may result in degassing and VOC loss. The operation of variable-speed submersible pumps at low-flow rates may result in heating of the sample as it flows around and through the pump, which may also lead to degassing and VOC loss.

Wells that yield less than 0.1 Lpm (100ml/min) frequently incur significant drawdown during well purging. If drawdown occurs across the screened interval or open borehole of a well, VOC loss may result. The increased stress on a well caused by significant drawdown may also result in an increase in well water turbidity. NJDEP recognizes that the use of sampling methods for LFPS discussed above may be impractical if drawdown cannot be limited. In an effort to facilitate the collection of a representative ground water sample from low-yielding wells, NJDEP will allow special sampling procedures to be used. This may include sample collection without regard to monitoring water quality indicator parameters associated with well stabilization.

At a minimum, water quality data, well construction data, water-level data, and accurate well-yield data for each low yielding well will need to be submitted to the Department prior to the formulation of an acceptable sampling procedure. Since sample collection may begin almost as soon as purging is initiated, it is imperative that the exact interval where the sample will be collected along the screen be predetermined. Aside from the considerations for monitoring drawdown and WQIP, all other aspects of LFPS may be found in the section above. The owner of the well shall also propose possible explanations for the low-yield of the well(s). Once the aforementioned information has been received, the Department will work with the well owner to formulate an acceptable sampling plan. The sampling plans will be approved on a case-by-case basis and will be well specific. Implementation of any special sampling procedure shall not be undertaken without prior NJDEP approval.

6.9.2.4 Volume-Averaged Purging and Sample Collection

Application of water supply well construction practices to remedial investigations often resulted in monitor wells with open boreholes or screens of up to twenty-five feet in length. Previous NJDEP guidance specified that the standard well purging procedure was to calculate, in gallons, one volume of standing water within a monitor well and purge three to five times that amount. Over the past decade, much information has shown that this procedure may have produced data of questionable value. Today, the general consensus is that ground water contaminants in a heterogeneous subsurface often flow within thin or narrow zones of higher permeability. Purging large volumes of water from wells with long screens situated in a heterogeneous aquifer

creates a situation where ground water in the contaminant-bearing zone may be diluted by uncontaminated water entering the well from one or more “clean” zones. Utilizing poor well development techniques following well construction may exacerbate this dilution process in wells with long screens. The resulting condition is responsible for what is now acknowledged as a volume-averaged sample.

It should be noted that data generated from volume-averaged sampling can provide useful information regarding the contamination present in ground water. Indeed, volume-averaged sampling has been considered to be a conventional method of sampling monitor wells for years. If contaminant concentrations are not diluted below method detection limits, use of the method allows identification of the contaminants present in the ground water. A properly executed remedial investigation using this method can be used to monitor plume movement. The information generated, however, may fall short when evaluating the extent of a plume, true contaminant loads and, ultimately, the information needed to design a remedial action. Another example, where data generated under volume-averaged conditions remains valid, is potable sampling used for contaminant identification during homeowner/residential well investigations. This sampling method is a cost-effective means of determining whether contaminants have impacted potable wells and, if so, the potential level of risk to the well owners.

Sample collection equipment and the procedures for their use, when employing volume-averaging methods, are discussed in Chapter 5.

Because volume-averaged sampling involves purging a specified volume of water (i.e., 3 to 5 well volumes) and does not involve setting a pump intake in a specific screened or open bore-hole interval, there is no basis to justify the recording of any water quality indicator parameters typically monitored during LFPS. During a volume-averaged sampling event, the pump intake location can be set either immediately above the well screen or at the top of the water column. If the intake location is immediately above the well screen, and there is more than three feet of standing water above the pump, then the pump must be a positive-displacement pump since the sample will have to be collected through the pump. If the intake location is at the top of the water column and the depth of 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 purging, samples must be collected by another means, typically via bailer.

Not all wells respond similarly to purging. Thus, the five ground water sampling categories listed at the beginning of this section were developed to match the best sampling technique to the well's design and the sampling objectives. Generally, **every** reasonable effort must be made to keep pumping rates low to avoid over-pumping or pumping the well to dryness. To accomplish this, pump rates may be adjusted and pumping times extended in order to remove the desired volume of water. Samples should be collected within two hours of purging. In no case should the time of sampling exceed 24 hours after purging. The evacuation rate of a monitor well should never exceed that of the rate used to develop the well to avoid altering the hydrogeological properties of the aquifer in the vicinity of the well. When sampling for VOCs, purging the well to dryness is unacceptable.

In some volume-averaged situations, evacuation of three-to-five well volumes may not be practical in wells with slow water-level recovery rates. If a well has been pumped to near dryness at a rate less than 0.5 gallons per minute, the well should be allowed to recover completely before sampling. If necessary, sampling within the two-hour limit may be exceeded to allow the well to recover sufficiently for sampling. In no case should the time of sampling exceed 24 hours after purging.

There are several reasons why the well should not be pumped below the level at which the ground water enters the well. First, 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, thus resulting in the loss of volatile organic compounds. Secondly, pumping to dryness can cause dehydration of the saturated zone; again, volatiles may be lost due to aeration within this zone. Additionally, other contaminants may adsorb to formation materials where a dehydrated zone is created. Finally, exposure of the filter pack to atmospheric conditions may have long term effects. As a result, samples collected upon the recharge of a well pumped to dryness may not accurately characterize ground water quality due to one or more of these effects.

There are many methods that may be used for well evacuation. Not all methods are acceptable under all conditions. The depth to the water table usually dictates the selection of an evacuation method. The preferred and most commonly used methods involve the use of a surface centrifugal or peristaltic pump when the depth to water is less than twenty-five feet, and, a submersible centrifugal pump when the depth to water is greater than twenty-five feet.

It is paramount to ensure that the evacuation procedure does not cause cross contamination from one well to the next. Therefore, the preferred method employs dedicated tubing and pumps. Since in many cases it may not be practical to dedicate a pump to a specific well, it is permissible to decontaminate this equipment between wells, if approved methods are used (refer to Chapter 2 of this manual). Tubing should always be dedicated to each 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.

Prior to evacuation, check the well for floating product. The disposal or discharge of floating product or hydrocarbons, and the discharge of highly contaminated water may require special purge water collection and disposal procedures. During evacuation, drawdown should be kept to a minimum to avoid “overpumping” the well. However, if volume-averaged sampling is the objective, the pump intake or tubing shall be lowered if the water level drops and to ensure that all static water will be removed from the well prior to sampling. Regardless of the evacuation procedure used, the evacuation rate should not exceed that of well development. Overpumping will cause a “redevelopment” of the well resulting in collection of a turbid sample.

6.9.2.5 Point Source (No-Purge) Sampling

Point source sampling is a technique that utilizes a device specifically designed to obtain a grab sample of limited volume within the screened interval without the aid of, or disturbance caused by, well purging prior to sample collection. There are very few of these devices that are available on the market today, and the few that are must first be approved for use through an approved sampling plan. This is mainly due to their inherent design or function limitations, which restricts their broad application. Generically, these devices are only approved for use once the contaminants of concern have all been identified and the specific zone of contaminant flow in the screened interval/open borehole of the well has also been positively identified. This implies that these devices are more likely to be approved for operation and maintenance sampling where point source quarterly sampling supplements annual sampling performed using a pump for confirmation purposes. There may, however, be instances where deployment of multiple passive diffusion bag samplers in one well may be instrumental in determining the zone of contaminant flow. See below for a description of those devices approved for this technique and their associated advantages and disadvantages.

6.9.2.5.1 Passive Diffusion Bag Samplers (PDBS)

6.9.2.5.1.1 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:

1. “*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,
2. “*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)

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. Both of 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>

Once it has been demonstrated that PDBS are appropriate for the intended application (see the discussion under “Theory” below), and regulatory approval has been granted, PDBS may replace the existing sampling method used for long term monitoring applications. Due to potential variations in lithology, well construction, and contaminant distribution, the use of PDBS must be evaluated and approved on a well-by-well basis (i.e. approval to use samplers at one well does not imply it is appropriate or acceptable for all wells at the site). The use of PDBS has been approved by the NJDEP at sites within NJ, and generated data may be used for compliance monitoring and/or to demonstrate that clean-up objectives have been achieved for site closure. When data are needed to document site closure, it is necessary to document that the PDBS interval used during the sampling program is still appropriate, and that data being submitted to close the site represents a worst-case scenario. This shall be accomplished by re-profiling the well using PDBS. A less desirable but acceptable alternative would be to take a conventional ground water sample to document that ground water contaminant concentrations within the well have decreased to levels that are acceptable for site closure.

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 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 is 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.

6.9.2.5.1.2 Limitations And Concerns

- PDBS provide a time-weighted VOC concentration that is based on the equilibration time of the particular compounds, usually 1 to 4 days. 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.
- PDBS have a limited detection capability (only VOCs).
- PDBS work best when there is unrestricted horizontal movement of ground water through the well-screen or open hole. Due to improper well construction and/or inadequate well development, the filter pack and/or screen of a well could be less permeable than the surrounding formation. Under ambient flow conditions, ground water flow through the well would be restricted and PDBS may not be able to provide a representative sample. In such cases, a conventional pumped sample may better represent ground water quality in the formation.
- PDBS represent a point sample within the well/open borehole. Contamination, migrating horizontally above or below the targeted depth interval, may not be detected by the sampler.
- Membrane limitations restrict accurate pH, specific conductance and temperature data.
- 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.

6.9.2.5.1.3 Theory

PDBS have proven effective in detecting 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. All proposals to use PDBS must include an evaluation of these factors, which are discussed in greater detail in the following sections of this guidance. In addition, it also may be necessary to evaluate how PDBS results compare to results from more conventional ground water sampling techniques to determine if the method is appropriate for the well. More conventional ground water sampling techniques would include purging 3-5 well volumes and sampling with a bailer, or low flow ground water purging and sampling.

6.9.2.5.1.4 PDBS Construction

PDBS are made of 4-mil. low-density polyethylene (LDPE) flat tubing that is filled with laboratory grade (ASTM Type II) deionized water and sealed at the ends. Samplers range in length from about 18 to 20 inches and hold up to 350 ml of water. 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 PDBS available. One sampler is **pre-filled** by the vendor and shipped to the sampling location for deployment. The second type is shipped **unfilled** to the sampling location and must be filled in the field with ASTM Type II distilled water prior to deployment. Vendors can usually modify the length and width of a sampler to meet specific sampling requirements. A list of equipment vendors for PDBS can be found at the USEPA Internet Website “reachit” <http://www.epareachit.org>. The PDBS are suspended in the screened interval of a well at a pre-determined depth via Teflon® -coated stainless steel wire or low-stretch braided, polyester rope (please see “Deployment” section for additional requirements regarding the use of braided polyester rope). 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 re-used.

6.9.2.5.1.5 Contaminant Detection Capabilities

PDBS are capable of detecting 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 lab tests (i.e., greater than 11% difference between concentrations inside and outside the PDBS). For that reason, use of PDBS is not recommended for sampling ground water where those parameters are the contaminants of concern. Parameters showing good correlation in lab tests and recommended for sampling with PDBS are identified in Table 6.13. 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 be used at a site *after* the contaminants of concern

have been thoroughly documented and are determined to be compatible for their use.

Table 6-13. Passive Diffusion Bag Samplers (PDBS)		
Lab Tested VOCs that Displayed Good Correlation (i.e. less than 11% difference between concentrations inside and outside the PDBS)		
Benzene	BDC Methane	Bromoform
Chlorobenzene	Carbon Tetrachloride	Chloroethane
Chloroform	Chloromethane	2-Chlorovinylether
DibromoChloromethane	DibromoMethane	1,2-DiChlorobenzene
1,3-DiChlorobenzene	1,4-DiChlorobenzene	Dichlorofluoromethane
1,2-Dichloroethane	1,1-Dichloroethene	cis-1,2-Dichloroethene
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 within the aquifer at the location of deployment. Historic sampling data (from the wells where the use of PDBS is being proposed) must be submitted along with a discussion regarding the ability of the PDBS to detect contaminants of concern.

Note: Compounds that displayed poor correlation in testing and are not recommended for sampling with PDBS include MTBE, Acetone, Styrene and MIBK.

6.9.2.5.1.6 Well Construction Considerations

PDBS work best when there is horizontal movement of ground water through the well-screen or open hole. As such, well construction has 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 will be diverted around the well resulting in well water that may not be representative of formation water. Inadequate or inappropriate well development could create a similar condition, which diminishes the ability of PDBS 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.) must be submitted with any proposal to help evaluate the appropriateness of using PDBS in a well. Since it is common for proposed well installation specifications to be modified in the field due to drilling difficulties, borehole cave-in or lack of desired well construction materials, it is necessary to use “as built” well diagrams to help assess the appropriate depth for PDBS deployment. 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 PDBS position in the well.

6.9.2.5.1.7 Contaminant Stratification/Multiple Sampler Deployment

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 chemical variability along the vertical portion of even a 10-foot well screen. A sample from PDBS represent a point sample from the section of screened interval or open borehole where the sampler is positioned. Because of this, PDBS have the ability to detect contaminant stratification. If multiple samplers are deployed along the screened interval or open borehole of the well, they can provide valuable information on the vertical stratification of contaminants within the well. Contaminant stratification within a well may indicate the presence of preferential flow zones in an aquifer. Identifying zones of preferential flow and contaminant transport in an aquifer can be useful when refining a site conceptual model, modeling contaminant fate and transport, or optimizing the performance of remedial systems. Since use of PDBS does not require well purging, field parameters such as pH, dissolved oxygen, temperature, and specific conductance are not measured to assess the adequacy of purging, however, these parameters may still provide useful information. In some cases the Department may still require field parameter data to be collected. It should also be noted that the *New Jersey Technical Requirements for Site Remediation* (N.J.A.C. 7:26E-3.13(c)7) requires field parameter data to be collected and submitted and with all ground water sampling data. Therefore, if PDBS sampling data is submitted without collecting field parameter data, a variance must be requested to obtain relief from these reporting requirements. Procedures for requesting a variance from requirements of the *New Jersey Technical Requirements for Site Remediation* are described in N.J.A.C. 7:26E-1.6(d).

If contaminants are migrating through the aquifer above or below the depth where the sampler is positioned, the PDBS may not detect them. It is, therefore, necessary to vertically profile a well using multiple PDBS to identify the presence of contaminant stratification and to document the most appropriate depth interval for future sampler deployment. Initially, any well having greater than 5 feet of well screen or open borehole must deploy multiple PDBS at the midpoint of every 5 feet of saturated screen or open hole to evaluate the potential for contaminant stratification. For example, a 10-foot well-screen or open borehole would have one sampler set at the midpoint of the upper 5 feet of screen/open hole and one sampler set at the midpoint of the lower 5-feet of screen/open hole. Although vertical profiling is only required on the initial sampling round, it must be recognized that for long-term monitoring applications it should be conducted periodically to document that conditions have not changed and that the sampling interval remains appropriate. The frequency of confirmation should be negotiated with the NJDEP Case Team for individual sites and will be based on the length of the monitoring program, historic data trends, fluctuations in ground water elevation, contaminant distribution, and fate and transport factors. In applicable instances, appropriate field

screening techniques at a Data Quality Level 2 (see Chapter 7, *Field Analysis*) may be substituted for fixed laboratory data in reaffirming the original vertical profile.

6.9.2.5.1.8 Vertical Flow Within the Well

As previously mentioned, 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 VOC concentration in PDBS will be more representative of the water flowing vertically past it from another portion of the aquifer rather than from ground water quality in the adjacent formation. If vertical profiling is conducted in a well using multiple PDBS and the results indicate all samplers have similar concentrations regardless of depth, the presence of vertical flow within the well should be suspected. In these cases, it is necessary to know where the water is coming from and where it is going. This can be accomplished by using a borehole 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.

6.9.2.5.1.9 Comparison of PDBS Results with Conventional Sampling Methods

When evaluating the appropriateness of PDBS use at a particular well, a common approach is to do a side-by-side comparison with a conventional sampling method. However, it must be kept in mind that no sampling method currently available is without faults or biases. When pumping a well during sampling, conditions within the well are immediately modified. This action could clearly bias a sample since contaminants could be drawn into the well from locations that would not naturally flow into the well. As such, results from pumped samples and passive samples could differ significantly. If results from PDBS do not correlate well with results from pumped samples, it does not necessarily mean the bags are inappropriate for the intended application. Poor correlation between sampling methods means that additional work needs 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 PDBS and historical sampling results may provide enough information to determine whether PDBS are 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) would be more appropriate to ensure the data reflect the same sampling conditions.

6.9.2.5.1.10 Use of PDBS in Sentinel Wells

PDBS are not recommended for monitoring sentinel wells if the saturated length of well screen exceeds five feet unless multiple 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 PDBS is positioned above or below a discrete zone where the contaminants are migrating, the impact may not be detected. To avoid missing the contaminant impact, sentinel wells with saturated screens/open boreholes in excess of five feet must be vertically profiled every sampling round. This would involve deploying one PDBS at the midpoint of every five feet of saturated screen or open borehole.

6.9.2.5.1.11 Procedures for PDBS 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 PDBS must be filled with laboratory grade ASTM Type II distilled 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 PDBS must be prepared and deployed for an additional 2-week equilibration period. A list of vendors can be “searched” for using the USEPA “reachit” website (<http://www.epareachit.org>.)

6.9.2.5.1.11.1 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. Weight construction must be stainless steel, which can be reused after thorough decontamination per acceptable decontamination procedures (See Chapter 2, *Quality Assurance*). Teflon® coated stainless-steel wire is preferable for deploying the samplers in the well. Teflon® coated stainless-steel wire can also be reused after proper decontamination. As an alternative to Teflon® coated stainless steel wire, synthetic rope may be used as the deployment line for single-use applications if it is 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 PDBS within the well screen or open hole of the well. Deployment lines consisting of material other than Teflon® coated stainless steel wire may not be used in another well and must be properly disposed of after a one-time use. The deployment line and PDBS must 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. Under no circumstances can PDBS be re-used.

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 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. 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 location within the screened interval. As previously mentioned, sufficient weight must be added to the PDBS deployment line to counterbalance the buoyancy of the PDBS. This is particularly important when deploying multiple PDBS. If there is uncertainty regarding the length or depth of the well screen/open borehole, an independent method of confirmation must be employed, such as video imaging.

6.9.2.5.1.11.2 Measuring and Attaching the PDBS to the Deployment Line

It is usually easier to measure the placement of the PDBS on the deployment line from the bottom of well. In this case, calculate the distance from the bottom of the well (or top of the sediment) up to the desired interval in the well where the PDBS will be suspended. For example, a well having 5 feet of screen may deploy a single bag positioned at the midpoint of the saturated-screened interval or open borehole. If the top of the well screen is 55 feet below the top of casing (btoc), and the measured total depth of the well is 59 feet btoc, then the bottom of the well has been filled with 1 foot of sediment. In this case, the middle of the PDBS should be set at 57-feet or 2-feet from the bottom of the well. Measure up 2 feet from the bottom of the weighted deployment line and position the midpoint of the sampler there. Provide attachment points in the deployment using loops in the line at appropriate points or movable clamps with rings. Attach the PDBS 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 PDBS punctures or tears.

For wells that are screened across the water table, PDBS must be placed at least 2 feet below the water column in the well. Extreme care must 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 PDBS, VOCs from ground water that diffuse into the bag could diffuse out of the top of the bag into ambient air. If this condition were observed prior to retrieval of the PDBS, it would be necessary to re-suspend 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 must be reviewed to determine the appropriate depth to set the PDBS so it will not be exposed to ambient air during the equilibration period.

If the well screen or open borehole intersects zones of varying hydraulic head and /or variable contaminant concentrations, vertical flow may occur in the well.

Under these conditions, VOC concentrations in the PDBS may not be representative of ground water quality in the formation immediately adjacent to the sampling interval. Sample concentrations may reflect the concentration of VOCs flowing vertically past the sampler from other parts of the formation, which could provide misleading information. In this case, use of a borehole flow meter in combination with vertical profiling of the well would be needed to define the zones where contaminated ground water is entering and exiting the well.

6.9.2.5.1.11.3 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. Many VOCs equilibrate within 48 to 72 hours; however, 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 PDBS 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 PDBS 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. Unfortunately, data are currently unavailable to support longer deployment periods (i.e., semi-annual or annual). Leaving samplers in a well for longer than 3 months is not recommended. If future data become available which demonstrate longer deployment timeframes are appropriate, this condition will be re-evaluated.

6.9.2.5.1.11.4 Sample Retrieval

After the appropriate equilibration period (discussed above), the PDBS is/are 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 field-sampling logbook. When retrieving multiple samplers from a single well, only one PDBS 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 must be immediately transferred into appropriate pre-labeled, VOC vials. All sampling information (e.g. site, well designation, sample ID, date and time of collection, depth interval, etc.) must be recorded before removing the next PDBS from the deployment line. If a protective outer covering is used during deployment, remove the PDBS bag and dry excess water from the bag using a lab wipe. PDBS water can be transferred to VOC sample vials using several available options depending on the equipment vendor and selected materials. One option is to carefully cut the PDBS bag at the top corner using decontaminated scissors or razor blade and carefully decant the sample into the VOC vials. Some PDBS models are equipped with a removable end cap that can be removed to allow the sample to be gently poured into VOC sample vials. Other equipment options include a small lab-cleaned straw that has a sharpened end. The straw is used to pierce the bag at the bottom and the sample is decanted through 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 **al-ready** full of ice or ice packs such that samples are **immediately** chilled and stored at a temperature of 4°C, in accordance with existing NJDEP ground water sampling protocols.

6.9.2.5.1.11.5 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 lab 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 lab 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 Lab 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 must be contacted to ensure they are comfortable with the approach.)

6.9.2.5.1.11.5.1 Blanks for Lab filled PDBS

For PDBS that are filled in a lab and shipped to the site, a modified PDBS trip/equipment blank must 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* PDBS, 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. Throughout the deployment event, the “extra” PDBS must travel in the same container as the other samplers that are being deployed. Once all samplers have been deployed, a sample must then be taken from the *extra* PDBS. Open this PDBS 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 must be processed (i.e. if appropriate, preserved, and properly labeled) and immediately chilled/stored in a sample cooler at 4° Celsius and sent to a NJ-certified lab 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. This type of blank must 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* PDBS) must be taken for each sampler container.

6.9.2.5.1.11.5.2 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 must be filled with ASTM Type II deionized water. It is also necessary to take a *modified trip/equipment blank* for this type of sampler. This blank is intended to detect any sample bias due to the quality of the fill water, PDBS 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 must 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 must then be taken from the *extra* PDBS. Open this PDBS 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 must be processed (i.e. if appropriate, preserved, and properly labeled) and immediately chilled/stored in a sample cooler at 4° Celsius and sent to a NJ-certified lab 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. This type of blank must 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* PDBS) must be taken for each sample container.

6.9.2.5.1.12 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 PDBS Data Checklist (see page 126) must be completed for each well where PDBS are deployed. This checklist must be submitted with the analytical results for each sampling round. In addition, a narrative must that describes the site, the well, and procedures that were used to deploy and retrieve PDBS must accompany the checklist and submitted analytical data. The narrative should also include any problems encountered during PDBS deployment and retrieval and the steps taken to address the problems.

6.9.3 Sampling Private Homeowner Wells (a.k.a. Public Non-Community/Non-Public/Domestic Wells)

Domestic wells usually provide only limited useful information for ground water investigations. This is due to the fact that adequate geological information relative to the well's placement and construction is not available. Also, domestic wells usually have long well screens, which may cause dilution of the contaminants being investigated (volume-averaged sample). However, domestic 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 by-pass such treatment systems. Always collect sample from the cold water faucet with the aerator removed. Should a raw water sample be desired, 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 Monitor 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 homeowner 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.

6.9.4 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 in order 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.

6.9.5 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.

6.9.6 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 a number of 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. 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 or 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 at all 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 by the use of 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 2, *Quality Assurance*). It is preferable to collect samples directly into the containers in which they will be submitted for analysis, if at all 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 at all 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 overstressed. 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 6.14 to be helpful:

6.9.7 Public Community 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.

6.9.7.1 Source Sample (Raw Water)

6.9.7.1.1 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

Table 6.14 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

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.

6.9.7.1.2 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.

6.9.7.2 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.

6.9.7.3 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.

6.9.7.4 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. 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.

6.9.8 Ground Water-Level Measurements

Pursuant to N.J.A.C. 7:26E-3.7(e)3, if ground water contamination is confirmed, a ground water remedial investigation must be performed. The person responsible for conducting the investigation

must collect a minimum of two rounds of synoptic static ground water-levels at a minimum of thirty (30) calendar days apart, pursuant to N.J.A.C. 7:26E-4.4(h)3ii2. By measuring the depth to ground water in networked monitoring wells or piezometers, the direction of ground water flow can be determined.

Various measuring devices and methods can be used to determine well depths, depths to ground water, as well as product thickness, if any. 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 must 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 must be marked for future reference. 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). 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 tape. The following is a discussion of some of the equipment and techniques used to measure ground water-levels in monitoring wells and piezometers.

6.9.8.1 Steel Tapes

Ground water-level measurements can be obtained using a steel tape. Tapes are typically a quarter-of-an-inch-wide steel band mounted to a hand-wound reel. Measurements are obtained by first applying either water indicator paste or chalk to the bottom two feet of the tape and then lowering the tape to a predetermined depth close to the anticipated ground water depth. The referenced stopping point should be recorded and the tape brought back to the ground surface. The difference between this point and the area on the tape where the paste/chalk has been washed off is the depth to ground water from the surveyed reference point at the top of the inner well casing. The tape can only be lowered to the predetermined stopping point and then retrieved. If the tape is lowered past this point and then retrieved, it will result in a false ground water-level measurement. For this reason, and the fact that the chalk or paste may impact ground water quality analyses, the Department does not recommend the use of this method in monitor wells.

6.9.8.2 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, meter 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 monitor well. Occasionally, the cable may need to be raised and lowered a few times in order to obtain an accurate reading. Not all electronic ground water-level indicators are incremented every 0.01 feet, as some older cables may be incremented every 5 feet, every foot or every tenth of a foot. If the cable is not marked in hundredths of a foot, an engineering ruler that is marked every hundredth of a foot must be used to take the measurement.

6.9.8.3 Helpful Hints

The accuracy of ground water-level measurements collected from electronic ground water-level indicators 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. As such, 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. Alternative solvents may be used upon approval of a Site Remediation Program Case/Site Manager.

Once a well has been located and properly identified, the field measurements listed below should be noted in a field logbook. 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 Observations

- 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 floating product, 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.
- Calculation of the water table elevation in the well by subtracting the depth to ground water from the top-of-casing elevation.

Note: 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.

6.9.8.4 Ground Water Level and Non-Aqueous Phase Liquid (NAPL) 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 (CD) 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 free product / 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.

6.9.8.4.1 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 bailer. The bailer is raised and the product thickness measured. Once the 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. However, due to difficulties associated with the Interface Probe, use of the clear bailer is the preferred method to identify and estimate thickness of floating product in monitor wells.

6.9.8.4.2 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 hydro-

carbon 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.

Experience has determined that the optical sensor on Interface Probes may become damaged if solvents are used to clean product from the probes. Additionally, the optical sensor may become smeared when used to measure product, rendering pin-point accuracy to an estimate at best. In either case, close attention to decontamination procedures will improve accuracy, operational life and reduce the risk of cross contamination with other wells.

6.9.9 New Well Construction and Stabilization

After well construction and development, the length of time for ground water conditions to become representative of aquifer conditions at and near the monitor well (the stabilization period) will vary depending on site hydrogeologic conditions and the drilling, construction and development methods. Ground water flow velocities are typically less than one foot per day and natural flushing rates are generally slow. If a monitor well is drilled, installed and developed so that a 14-foot radius around the well was impacted by drilling fluids, for example, and a natural ground water flow rate was one foot per day, it would take 14 days for unaffected ground water to reach the well. Sampling a monitor well immediately after development will generally not be representative of the static ground water quality conditions at the horizontal and vertical location of the monitor well's intake interval. Therefore, all newly constructed and developed, or redeveloped monitor wells must be allowed to stabilize and equilibrate with the aquifer for a minimum of two weeks prior to sampling.

6.9.9.1 Well Development

Following construction, well development is necessary to remove drilling fluid and construction residues remaining in the borehole or surrounding aquifer and restore the hydraulic properties of the formation immediately surrounding the screened interval. 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].

Installation and construction of monitor wells may themselves alter the quality of ground water in the surrounding aquifer. Site-specific subsurface conditions should be used to determine the appropriate well development techniques. Many times, a combination of the techniques mentioned below will be necessary to produce a properly developed monitor well. Also discussed are certain outcomes inherent to the well development techniques that can be mitigated by following the 14-day stabilization period.

Since construction of monitor wells is merely an extension of water supply well construction techniques, the chosen well development technique is not often given appropriate weight in the overall decision process. This miscalculation can be compounded when constructing a well in a low-yield hydrogeological setting. More often than not, a submersible pump is lowered into a well and pumping is continued until the well water clears. This one-directional, high-stress flow is not effective in proper well development since overpumping 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. Effec-

tive 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 6.9 below.

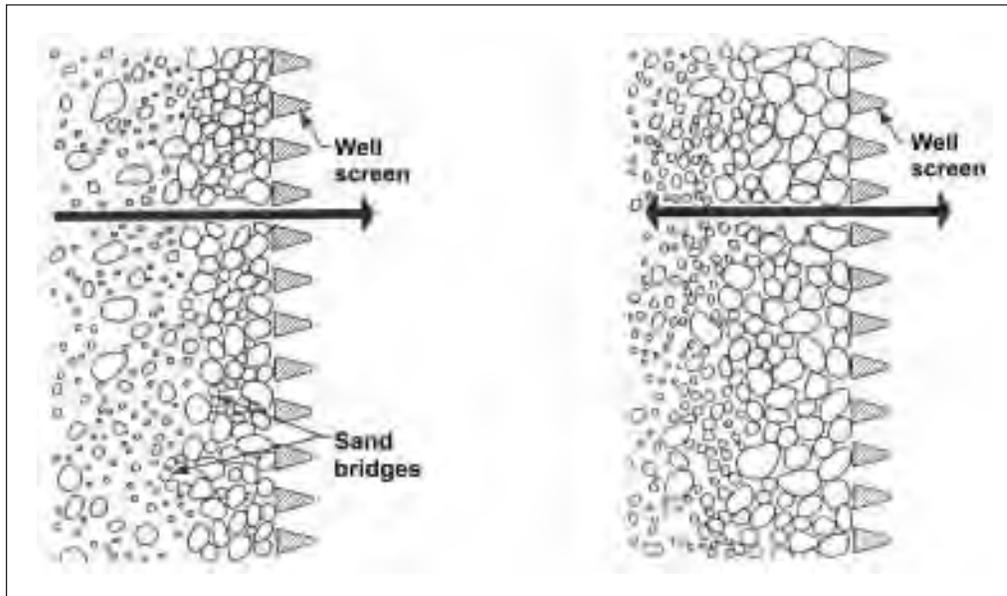


Figure 6.9. On the left, overpumping has formed sand bridges, which eventually collapse reducing the permeability of the filter pack. On the right, bi-directional flow through the screen and filter pack removes the bridges (illustration published with permission of Johnson Screens, from *Groundwater and Wells*).

In the screened portion of the well there may exist an area that, relative to other areas across the screen, has higher permeability. Once pumping is commenced, this particular area begins to yield water, thus reducing the influence of pumping on other areas in the screened interval. This condition or

pipng effect, as it has sometimes been termed, can be minimized if more attention is given to 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 *pipng effect*, and create a monitor well capable of delivering a better ground water sample.

6.9.9.2 Other Considerations

- High-velocity air jetting or air-lift development methods may introduce air into the aquifer surrounding the monitor 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 are not acceptable in wells installed with screens and filter packs.
- Over-pumping of a monitor well for development may draw ground water to the monitor well from considerable distances and draw ground water of quality not representative of the horizontal and vertical location of the monitor 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 of ground water samples for up to 100 days after completion of development. The Department only approves the use of organic drilling fluids on a case-by-case basis.

- Non-aqueous phase liquid contaminants may be pushed away or drawn to a monitor well location during development depending on the development method selected. The process may smear soil and sediment, thus permanently undermining the intention of obtaining representative ground water samples.
- Suspended, construction-induced 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 monitor well's design, construction and development, and aquifer characteristics is necessary in order to properly interpret analytical results.

6.9.10 Filtering Ground Water Samples

In order to assure the quality of data generated from the analysis of ground water samples, critical sample handling procedures must be addressed. An important consideration is sample filtration. However, because the objectives of specific monitoring programs may vary, it is difficult to establish a standard for filtering that will apply to all situations.

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. 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 larger) data is needed for evaluation against the NJDEP and USEPA surface water quality criteria for discharge of ground water to surface water. Otherwise, filtration should only be allowed after approval of the sampling objectives, method, filter type and size by the NJDEP under an approved oversight document. There are numerous articles in the scientific literature discussing the various problems with sample filtration relative to obtaining accurate, representative samples.

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 case demands consideration of dissolved metals, both filtered and unfiltered samples should be collected for analysis. The regulatory document, i.e., NJPDES permit, ACO, or approved quality assurance project plan (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 will be based on the physical quality of the samples, the objective of the monitoring program and the policy of the Program within the NJDEP controlling the specific event. If filtering is allowed and chosen, it is imperative that it be per-

formed in a manner that will preserve the integrity of the sample and allow consistent reproduction of the technique.

6.9.10.1 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) and the National Secondary Drinking Water Standards (NSDWS) for metals are based on total metals concentration. An assessment of water quality must 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 is dispersed through a second. In ground water, colloidal particles are generally smaller than ten micrometers (10 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, or 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 the aquifer (i.e., pH decrease) that would cause adsorbed ions to become dissolved, thereby raising the total metals concentration.

Note: Unfiltered sample results should be reported as total metals. Acidification of an unfiltered sample will dissolve some particulate matter, thereby raising the original metals content by releasing adsorbed metals into solution.

6.9.10.2 Trace Metals Sampling

The following guidelines will apply to samples collected for trace metal analysis of ground water:

- For new investigations, that is, when ground water quality is uncertain, samples must be unfiltered for the initial round of samples. As stated above, the SRP recommends sampling for total (unfiltered) metals analysis using LFPS methods. Unfiltered samples will represent “worst case” with respect to metal content. Thus, if no significant concentrations are detected, further sampling for metals normally will not be required.
- If metal concentrations significantly above ground water standards are confirmed, two samples may then be collected from each well: one sample filtered according to the NJDEP procedures and a second unfiltered sample.

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

6.9.10.3 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 (i.e., 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 is not permitted.

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 and the filter itself may leach inorganic compounds, raising the concentration in a 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 must be field filtered immediately after sampling and prior to preservation.

6.9.10.4 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 must be collected for this apparatus.

When filtration is performed, it must be done immediately upon sample collection and prior to preservation. The sample may not be transported to the laboratory for filtration and preservation nor may 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 equipped with an ungridded, 0.45-micron pore-diameter filter. 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, dissolved metals analysis of samples filtered with a 0.45-micron filter may also bias the sample results. Some investigations show that use of a 0.1-micron filter is more appropriate for determining the concentrations of dissolved metals.

6.9.11 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 product (LNAPL) is suspected to be floating on the water table, all shallow wells installed in the area under investigation must 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 greater than water are the contaminants of concern or if contaminants are suspected in more than one stratified layer in the well column, sampling procedures must 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 a water indicator paste/gel with a weighted steel tape to determine the depth to the top of the floating layer and to the water surface. 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.

6.9.12 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) must be performed prior to purging (evacuating) the well. Measurement of the DNAPL may be accomplished by using a water indicator paste/gel with a weighted steel tape (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.

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Prior to purging a monitor 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.

6.10 Biological Sampling Procedures

6.10.1 Phytoplankton 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 pollution source or major tributary. Stations should also be set up on either side of the river so as to account for unequal lateral mixing. Slow moving sections of streams generally contain more phytoplankton than slower 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 so as 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 of the main basin. In tidal areas, the effects of tidal oscillation should also be taken into account when determining sampling frequency. When locating stations for a *red tide* survey in estuarine or coastal waters, note where and when the blooms tend to occur.

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 deeper 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 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; larger sample volumes of at least one liter are needed because these waters are typically low in productivity.

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.

If analysis is limited to species composition clear polyethylene or glass bottles may be used. If chlorophyll analyses is requested, amber bottles are recommended. Clear or translucent glass or plastic bottles may be used provided they are covered with aluminum foil so as to shield out light.

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 adding more periodically to maintain the color of weak tea. In special studies glutaraldehyde may be used (6-drops/25 ml of sample). All preserved samples should be stored in the dark immedi-

ately so as to prevent the degradation of the phytoplankton, or the preservative if Lugol's solution is used.

All species composition phytoplankton samples should be fixed (preserved) 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 °C (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 out of direct sunlight, in an ice chest, with some of the ambient water. 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.

Samples collected for Chlorophyll analysis shall not be fixed preserved. Chlorophyll samples shall be preserved by chilling to 4°C. 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 heavy brass slug or 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 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 and list the date 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.

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 at all 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 in order 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 in order 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
- Mason Jars
- 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-cm² 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 continues until the exposed area of substrate and toothbrush are clean. Approximately 20-30 ml of 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 (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 lotic waters (i.e., streams and rivers). * from USEPA 1999, *Rapid Bioassessment Protocols for Use in Streams and Rivers*, Second Edition. EPA 841-B-99-002. Washington, D.C.

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.

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 2m² 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 m² 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 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 from 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 from 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.

6.11 Toxicological Sampling (Toxicity Test or Bioassay)

6.11.1 Dilution Water Sample Collection and Handling:

Dilution water is acceptable for use in a bioassay provided healthy test organisms survive in it through the acclimation period without showing any signs of stress, including but not limited to, abnormal behavior or discoloration.

Dilution water samples shall be representative of the receiving water system which the effluent is discharged into. Samples shall be collected in the following manner:

In non-tidal waters, dilution water samples shall be collected from a location as close as possible to, but upstream of, the effluent-mixing zone.

In estuarine waters, dilution water samples shall be collected from a location as close as possible to, but upstream of, the effluent mixing zone. Samples shall also be collected during the outgoing tide up to and during low slack tide.

In marine waters (that is, tidal saltwater), dilution water samples shall be collected from a location outside the influence of the effluent being tested.

The sampling location shall be such that the salinity of the sample shall be within the salinity range for receiving water immediately outside of the effluent mixing zone.

When samples are collected from streams or rivers, an integrated sample shall be collected. This is a sample that is collected from bottom to top of the water column so that the sample collected is proportional to 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 units, then the dilution water samples shall be adjusted to pH 5.0 prior to their use in test organism acclimation and/or toxicity test.

If the receiving water is influenced immediately upstream of the effluent outfall 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 sample(s) shall be 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 of preference:

Another surface water or ground water having a natural quality similar to that of the receiving water prior to its pollution may be used; or

Reconstituted or artificial freshwater or saltwater having a natural quality similar to that of the receiving water prior to its pollution may be used; and

Substitute dilution water shall have a total hardness, total 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 5.0 units.

Alteration of dilution water samples shall be limited to the following:

Filtration is conducted through screening made of a non-toxic material. This screening shall have a mesh of 2 mm or larger if sample is to be used for fish testing or 0.45 microns or larger for zooplankton and macrocrustacean testing.

Adjustment of the salinity of dilution water samples shall only by either the addition of laboratory pure water to lower the salinity or by the addition either a hypersaline brine or artificial sea salts to raise the salinity made in accordance with N.J.A.C. 7:18 9.5(a)6.

Sample collection and transport containers shall meet the requirements listed in Appendix 3-1. Prior to sample collection, containers shall be pre-rinsed with the dilution water and then filled so that there is little or no air in the container neck or cap.

Dilution water sample storage shall be in covered containers constructed of non-toxic materials as specified in N.J.A.C. 7:18-7.3(a)13.

Dilution water samples shall not be stored for more than 150 hours and should be collected as close as possible to the time of testing.

6.11.2 Effluent Samples Shall be Collected and Handled in the Following Manner.

Unless otherwise specified by the Department, the effluent sampling location shall be the same as that specified in the applicable permit. The Department may specify an alternate sampling location when the following conditions prevail:

- When there is better access to the effluent at a point located between the final treatment and the discharge outfall. That point shall be the sampling point, or
- When the chlorinated effluent is dechlorinated prior to discharge and the purpose of the test is to determine the toxicity levels of the dechlorinated effluent. The sampling point shall be located after dechlorination.

The following sampling procedures shall be adhered in order to insure a representative effluent sample:

If the facility discharges wastewater continuously, the following procedures shall be used: Twenty-four hour composite samples consisting of equal volumes collected at least once every hour or a flow proportionate 24 hour composite sample shall be collected and used to set up a single toxicity test. This procedure is repeated for the duration of toxicity tests or; the effluent shall be pumped directly and continuously into the dilutor system of the toxicity test, for the duration of the test.

If the facility discharges wastewater intermittently, one of the following procedures shall be used:

When the effluent is discharged continuously only during a single work shift, or two successive work shifts, at least one composite sample, of sufficient volume to set up the toxicity test, shall be collected;

When a facility retains the wastewater during a work shift, then treats and releases it in a batch discharge, a grab sample shall be collected during the discharge period. Sufficient volume of sample shall be collected for the set up and renewal of the toxicity test during the hours intervening between effluent discharges. Use caution when collecting these samples as wastewater sampling, especially in manholes and enclosed spaces, may involve exposures to vapors of oxygen-depleted atmosphere, requiring suitable precautions.

When a facility discharges wastewater to an estuary only during an outgoing tide, a single grab sample or composite sample (as specified by the Department in the NJPDES permit), of sufficient

volume to set up the toxicity test shall be collected on the outgoing tide. This procedure is repeated for the duration of the toxicity test.

Effluent samples shall be chilled during or immediately after collection for transport to the lab.

Alteration of samples shall be limited to:

Filtration through Teflon® or No. 316 stainless steel screening having a mesh of 2mm or larger. Screening constructed of unplasticized polyethylene or polypropylene may be substituted provided the screens are discarded upon the completion of a bioassay.

Introduction of dry artificial sea salts or hypersaline brine for the purpose of adjusting the effluent test concentration.

Using a dechlorinating agent to reduce the level of chlorine in an effluent sample. Any adjustments made shall be consistent with N.J.A.C. 7:18-9.5(b)6.

All sampling equipment shall be constructed of approved materials in accordance with N.J.A.C. 7:18-7.3 and cleaned in using the methodology in accordance with N.J.A.C. 7:18-7.4(c). Prior to sample collection, containers shall be pre-rinsed with the effluent and then filled, using the specified procedures, so that there is no air space in either the neck or cap.

Unless the purpose of the bioassay is to ascertain the persistence of the toxicity of an effluent, testing shall begin within 24 hours of the collection of an effluent.

6.11.3 The Following Chain of Custody Procedures Shall be Employed in Collecting and Handling Composite or Grab Samples:

Only clean or new containers, previously rinsed with the material being sampled shall be used for taking composite or grab samples.

Tie-on affixed labels with an identification number shall be used for labeling all samples.

After a sample has been collected, the appropriate information as to identity of the sample shall be written on the label and the label affixed. The label shall remain affixed until the test has begun and the surplus has been discarded.

Immediately upon delivery of a sample to the laboratory, the sample collector shall complete the appropriate chain of custody section of the sample report form or chain of custody form.

The chain of custody form shall list at a minimum the following information:

- 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 (if the sample was collected by a person other than laboratory personnel);
- Identity of person accepting custody (if the sample was collected by a person other than laboratory personnel);

Date and time of initiation of analysis. Identity of person performing analysis; and Name of the laboratory performing the analyses.

Appendix 6.1

Monitor Well Construction and Installation

A.6.1.1 Introduction

Monitor wells are installed to collect groundwater 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 Resource Evaluation Wells which include monitoring wells, air-sparging wells, soil vapor extraction (SVE) wells, recovery wells and temporary wells installed for environmental remediation projects (see N.J.A.C. 7:9D-2.1(a)3). Category 5 Geotechnical Wells include test borings, probe holes and borings involving use of direct-push methods (see N.J.A.C. 7:9D-2.1(a)5).

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 monitor 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 (BWA, 609-292-2957), 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 BWA, 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 encountered and well installation details must be recorded on logs, preferably by a qualified geologist and submitted with the completed well record to the Bureau of Water Allocation. The information recorded must include that specified at N.J.A.C. 7:26E-3.6(a)2, at a minimum, and 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* and Section 6.2.3.5, *Soil Classification*.

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, the casing and screen are placed inside the HSAs and the flights are individually removed while the annular space around the well is filled with the filter pack and 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 installation of monitor 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) 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 groundwater 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 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 dragging of contamination into deeper zones since the drill cuttings are re-circulated in 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.

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 must be advanced 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 with air and which 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.

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. As stated above, split spoons used to collect soil samples can become contaminated when they are advanced down a mud-filled borehole.

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. Logging of rock core should be consistent with N.J.A.C. 7:26E-4.4(g)5. See the section on coring in Chapter 6, Section 6.3.4, *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. The source of the potable water used during the installation (and development) of monitor 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 groundwater 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). Therefore, use of polymer-based drilling muds is not acceptable unless specific approval is first obtained from the SRP case/site manager or geologist.

A.6.1.3 Specialized Drilling Methods

A.6.1.3.1 Sonic Drilling

A resurrected and fastly becoming popular drilling technology used in the environmental field is sonic drilling, which is sometimes called roto-sonic drilling. The 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 core barrel used and range from 3 to 12 inches. The use of multiple over-ride casings of increasing diameter allow 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 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:

- 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 override 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 override 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 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. Acrylic 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, acrylic liners must be used.

Sonic drilling has been approved for:

- geologic profiling through the production of soil cores;
- collection of insitu ground water grab samples during borehole installation;
- well installation and;
- sampling of the soil core for metals, PCBs, and pesticides.

Sampling of the soil core for VOCs or SVOCs must be approved on a case by case basis. Proposals for VOC or SVOC soil core sampling must include provisions to minimize core fragmentation and heat generation, such as:

- the use of acetate 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 acetate 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 discrete depth groundwater 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 monitor wells without drilling a borehole. However, knowledge of the local stratigraphy (depth of confining layers, etc.) and depth to water should be known before the wells are installed. Therefore, soil sampling using sonic methods or other, conventional, methods (e.g., split-spoon sampling) should be performed prior to installing wells using the sonic method. This method does not allow or require installation of filter pack and grout filling of annular space. Approval to install wells in this manner should first be obtained from the SRP case/site manager or geologist.

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 monitor 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 6.10). 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. (The Department does not allow installation of permanent casing in monitor wells using this method.) It

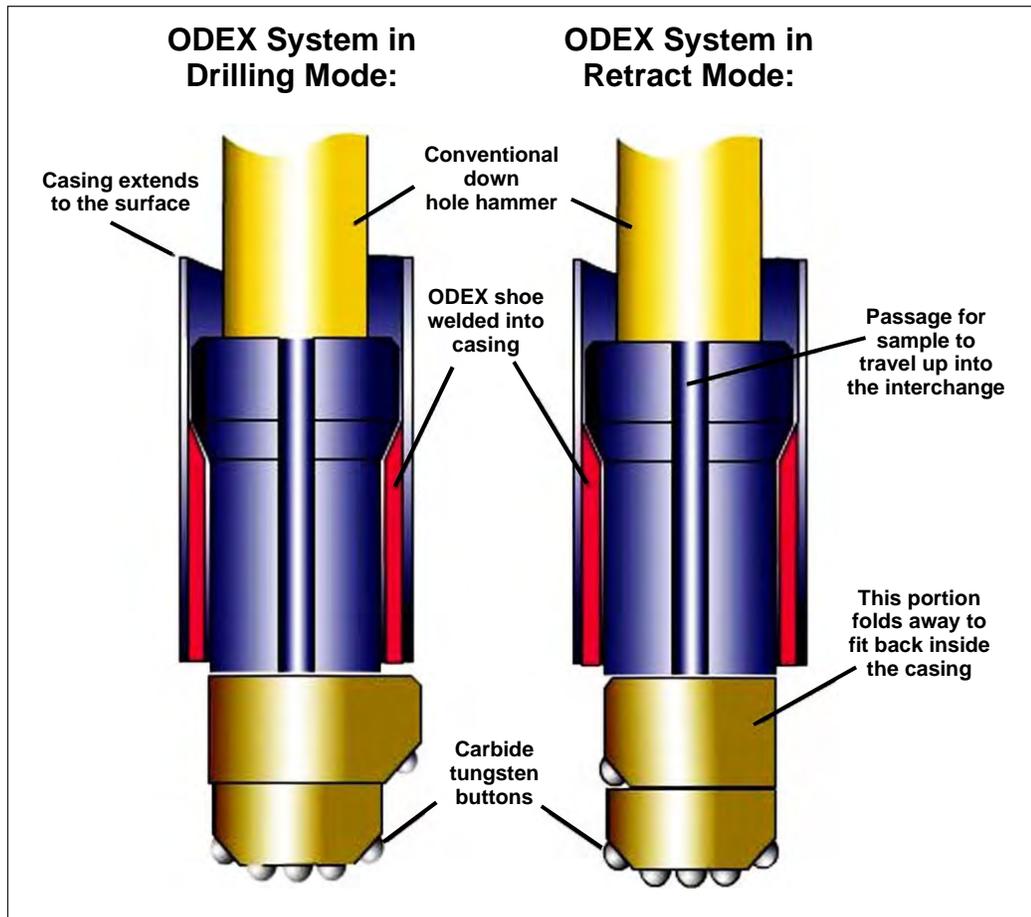


Figure 6.10 ODEX® System. Source: http://www.midnightsundrilling.com/ODEX_system.html

cannot be grouted in place. This means that conventional methods must be used to install and grout outer casing when installing monitor wells in confined aquifers. Another disadvantage of the method is the potential for rock cuttings to jam the bit and not allow it to be retracted and, therefore, retrieved through the casing.

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 groundwater without collecting actual soil samples and 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), 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 method involves hydraulically pushing hollow rods into the subsurface for the purpose of collecting soil and/or groundwater samples (e.g., Geoprobe®). The method can be used

to install small-diameter wells used to collect groundwater samples. These wells are usually installed for temporary use and subsequently retrieved. (i.e., Category 5 *Geotechnical Wells*). Wells installed to a depth of 50 feet or less and that remain in place 48 hours or less do not require boring permits. Wells installed to depths greater than 50 feet or that remain in place longer than 48 (i.e., Category 3 *Resource Evaluation Wells*) hours require well drilling permits and completion of well abandonment reports when decommissioned; these wells must be decommissioned using an approved grout material.

Advantages of the direct-push method include the relatively quick collection of groundwater 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 monitor wells.

Disadvantages of the method include the fact that the data quality achieved are often 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 groundwater 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 must be qualified accordingly. For this reason, use of the peristaltic pump for collecting groundwater samples for VOC analysis is not recommended and approval for its use should first be obtained from the SRP case/site manager or geologist.

Another disadvantage of using direct-push technology for collecting groundwater samples is the potential to breach confining units. To prevent this, 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 Monitor 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 (resource evaluation wells including monitoring wells, air sparging wells, soil vapor extraction wells, recovery wells, and wells or well points installed for environmental projects) and Category 5 wells (geotechnical borings including test borings, probe holes and those involving direct-push technologies). Requirements for the construction and maintenance of all Category 3 wells are provided at N.J.A.C. 7:9D-2.4. Specific requirements for the installation of Category 5 geotechnical borings are provided at N.J.A.C. 7:9D-2.6. Any proposed deviations from these construction standards must be approved by the BWA, pursuant to N.J.A.C. 7:9D-2.8.

The following is a discussion of different aspects of monitor well construction.

A.6.1.4.1 Well Diameter

Well construction varies depending on the intended use of the wells. Most permanent, overburden monitor 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 groundwater (e.g., recovery wells), well diameters may need to be larger (e.g., six inches or greater) to accommodate submersible pumps.

The Site Remediation Program does not ordinarily allow use of permanent monitor wells with a diameter of less than two inches unless they are used for the sole purpose of obtaining water-level measurements (i.e., piezometers). The use of piezometers to collect groundwater samples may be approved by the Site Remediation Program provided they meet the monitor well construction requirements.

In all cases where wells are installed in oversize boreholes, 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 monitor 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 and it is likely to cause failure of the well, 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. Other construction materials (e.g., PTFE) must be approved by the SRP case/site manager or geologist prior to use.

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 Monitor 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). If the borehole diameter is 6-inches, then the casing and screen diameter should be 2-inches.

A.6.1.4.3 Screen Length

The maximum length of well screen (or open borehole in bedrock wells) for monitor wells is 25 feet. The purpose of this limitation is to minimize the potential to cross-contaminate uncontaminated aquifers. In most cases, screen length should be minimized (e.g., 5 to 10 feet of screen) if sufficient well yield is available to allow sampling of the well. In cases where low-flow sampling is intended in newly installed monitor wells, the wells should be installed with no more than five feet of screen (see Section 6.9.2.2, *Low-Flow Purging and Sampling*).

In cases where a well will be used for groundwater 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. However, approval must be obtained from the SRP case/site manager or geologist prior to installing such wells.

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. No more than five feet of filter pack should 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 in wells must be sealed to prevent the borehole from acting as a conduit for 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. All grouting materials should be installed as slurry using a side-discharge tremie pipe in order to prevent invasion of the grout into the filter pack. Examples of material include Portland cement, high-grade bentonite and Portland cement/high-grade bentonite mixtures. *The installation of a bentonite seal above the filter pack using bentonite pellets is not permitted.* Proposals for their use must be submitted as a deviation request to BWA, pursuant to N.J.A.C. 7:9D-2.8(a).

A.6.1.4.6 Well Depth

Pursuant to the Technical Requirements for Site Remediation, groundwater contamination must be delineated both horizontally and vertically (see N.J.A.C. 7:26E-4.4(h)3i). This may require installation of wells in clusters at various depths (see also Multi-screened Wells below). The well clusters not only provide information on water quality with respect to depth but also provide information with respect to horizontal and vertical hydraulic gradients in the aquifers which is required to properly characterize 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 (wall thickness 0.218 inches), rather than Schedule 40 (wall thickness 0.154 inches), PVC since it is more rigid.

A.6.1.4.7 Multi-Screened Wells

Where groundwater 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. The installation of such wells must be performed as prescribed by the manufacturer and must first be approved by the Department, pursuant to N.J.A.C. 7:9D-2.8. Examples of such wells include the Waterloo Multilevel Groundwater Monitoring System® and the FLUTE® method. (This should not be construed to represent an official Department endorsement of these methods; this discussion is for informational purposes only.) Seals installed between well intake zones should be at least two feet thick.

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. No packers are used to separate sample ports; packers can fail or not seal properly.

Likewise, well clusters, where wells are installed in separate boreholes, may be more appropriate than well nests in which multiple wells share the same 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 multiple-level devices are: 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., see URL below) system involves the use of a flexible liner that can be used to temporarily seal a boring in unconsolidated sediments or bedrock wells. The liners can also be used to sample borings and wells at specific depths through dedicated tubing 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 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.

Use of the FLUTE™ method (<http://www.flut.com/systems.htm>) and multi-screened wells requires specific approval from the SRP case/site manager or geologist and from BWA. Specific approval for installing bedrock wells with more than 25 feet of open borehole must be obtained from both SRP and BWA. For boreholes left open for more than 48 hours, or that are deeper than 50 feet, a well drilling permit must be obtained from BWA; a well record and well abandonment report must also be provided to BWA.

A.6.1.4.8 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.6.1.4.9 Horizontal Wells

Horizontal wells must be installed by a New Jersey-licensed well driller who must obtain a well permit from BWA. All proposals for installation of horizontal wells must first be approved by the Department. Installation of horizontal wells may include well screens longer than 25 feet provided that appropriate justification is submitted to the Department. All proposals for installation of horizontal wells must include the purpose of the well (e.g., monitor 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, the grouting procedures and the specific sampling method(s) that will be used.

A.6.1.4.10 Wells Used to Investigate LNAPL and DNAPL

Any well installed to detect floating product, or light, non-aqueous-phase liquid (LNAPL), must 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 must 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 of 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 may extend into the confining unit in order to create a sump for the DNAPL to accumulate in, provided that specific approval is first obtained from the Site Remediation Program and the Bureau of Water Allocation for constructing wells in this manner, pursuant to N.J.A.C. 7:9D-2.8. Care must be taken to prevent the well from completely penetrating the confining unit.

Wells installed in bedrock must meet the construction requirements provided in this Appendix and in N.J.A.C. 7:9D-2.4. These requirements include drilling the borehole used to case off the overburden a minimum of 10 feet into competent bedrock. However, if DNAPL and/or dissolved contamination is suspected or likely to be present in the weathered bedrock, the ten-foot casing requirement will hide the DNAPL from detection. In this case, an overburden well (with casing and screen) should be installed in the weathered bedrock and an outer steel casing installed ten feet into bedrock would not be required. Likewise, if the weathered bedrock is found to be contaminated, a well may need to be installed within the upper 10 feet of competent bedrock. If the well will be constructed with an open hole in the bedrock, an outer steel casing should be installed in the top two feet of competent bedrock to case off the overburden and weathered bedrock aquifers. If casing and screen will be installed in the bedrock aquifer, then installation of the outer steel casing may not be required. In any event, specific approval must first be obtained from the BWA for constructing wells in these situations, pursuant to N.J.A.C. 7:9D-2.8.

A.6.1.4.11 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 5 wells, pursuant to N.J.A.C. 7:9D-2.1(a)5, and must be installed and decommissioned accordingly, pursuant to N.J.A.C. 7:9D-2.6 and N.J.A.C. 7:9D-3, 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 monitor well is to provide a representative sample of water as it exists in the formation. Therefore, well development must restore the area adjacent to the well to its indigenous condition by correcting damage done to the formation during the drilling process. Monitor well development is required to: remove drilling fluid residues remaining in the borehole or surrounding aquifer; remove imported drilling water lost to the aquifer during the drilling procedure; restore the hydraulic properties of the formation immediately surrounding the monitor well, and; sort the filter pack material to allow ground water to freely flow to the monitor well.

There are three primary factors that influence the development of a monitor 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 during, well development.

Acceptable well development methods include: bailing, overpumping, 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 6.9) (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/overpumping/backwashing, and surging with a surge block or a combination of these methods. Following the use of these methods, the wells must be pumped to remove the fines from the wells. The use of chemicals (e.g., detergents, chlorine, acids, or other chemicals) to increase or restore the yield of monitor wells is not acceptable. However, their use in recovery and/or injection wells may be acceptable with prior approval from the Department.

Air-lift methods may be used to effectively develop wells installed in permeable formations. However, they may introduce air into the aquifer surrounding the monitor well, and this air has the potential for altering groundwater 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.

Overpumping 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, overpumping alone does not effectively develop monitor 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, overpumping of a monitor well during development may draw groundwater to the monitor well from considerable distances and draw groundwater of quality not representative of the immediate vicinity of the monitor well, especially in anisotropic and/or bedrock aquifers.

Well yields determined during the development of monitor 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. Well development should 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 Maintenance of Wells

Over time wells may become silted up. This may be the result of poor well design (e.g., inappropriate filter pack materials or screen slot size) or cases where wells are installed in fine-grained sediments (e.g., silt). When this occurs, part of the well screen can no longer yield a sufficient volume of water for sampling and/or it may prevent water from the most contaminated zone from entering the well. This requires that the well be redeveloped. Acceptable well development methods are discussed above (see 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 groundwater. 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 water tight (i.e., lid and gasket are present).

A.6.1.5.3 Well Decommissioning Requirements

All Category 3 monitor 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). A Well Abandonment Report must be submitted to BWA within 90 days of decommissioning a Category 3 well. All Category 5 wells and geotechnical borings must be sealed in accordance with N.J.A.C. 7:9D-3.4. Borings 25 feet or less in depth may be decommissioned by back-filling with cuttings, pursuant to N.J.A.C. 7:9D-3.4(b). 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.

However, the Site Remediation Program also requires that where NAPL is present or is likely to be present and/or confining layers are or may be present, the borehole must be sealed with an acceptable grout (see N.J.A.C. 7:9D-3.1 for acceptable grouting materials). Where the boreholes are 25 feet or less in depth, and no NAPL is present and/or no confining layers have been breached, then the boreholes may be back-filled with native materials.

Upon sealing a monitor 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-3.1(l).

A.6.1.5.4 Flush Mount Wells

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 with road boxes specifically manufactured for wells. The road box must be of the type with bolt-down lids, waterproof and able to withstand vehicular traffic. The lid must be clearly labeled as a monitor well. The road box must be firmly anchored to, or embedded in, a concrete surface seal. The concrete seal must be sloped away from the box, providing drainage for water and easy vehicular traffic. The road box shall 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 water-tight. 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 6.11).

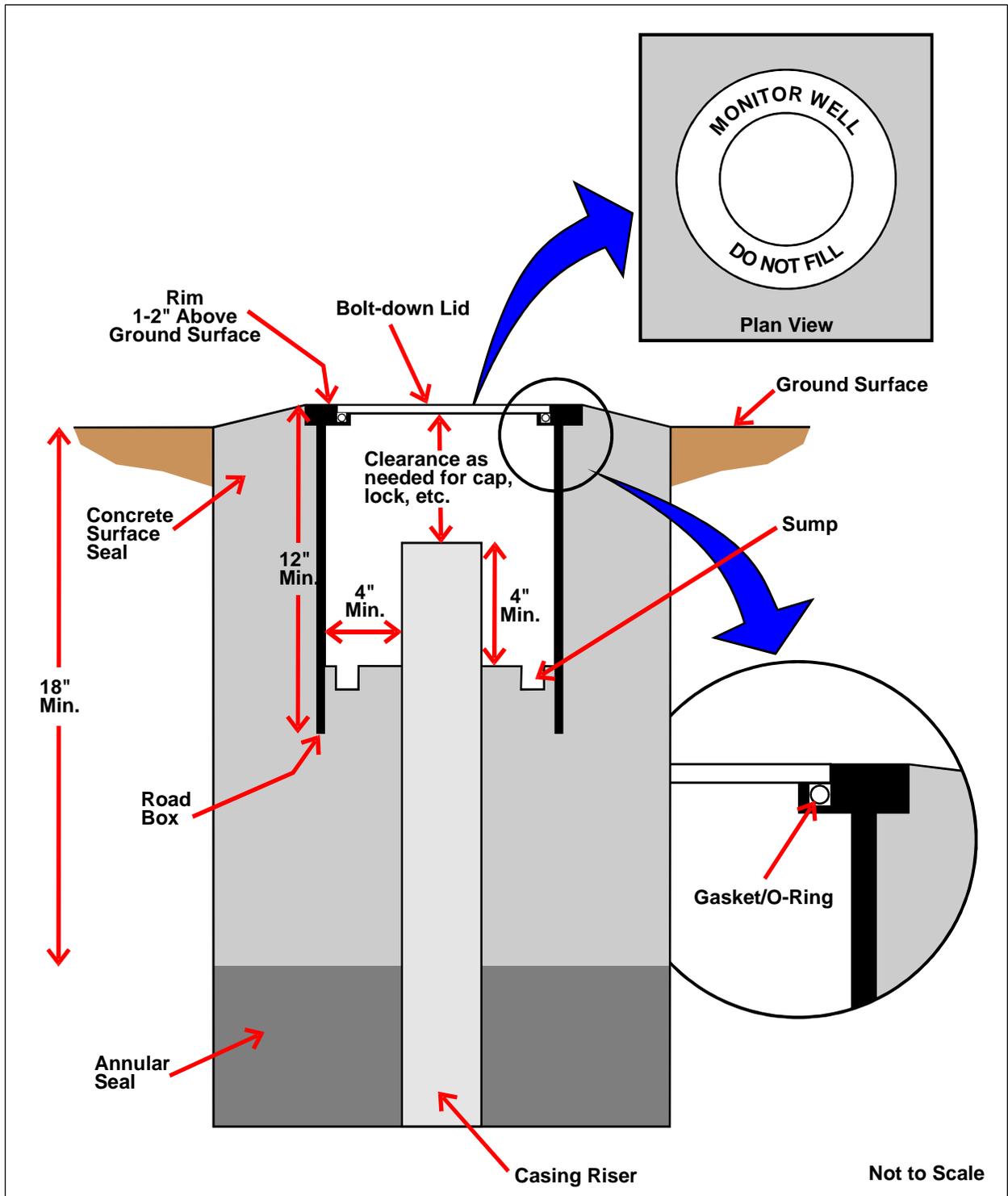


Figure 6.11 Typical Flush-Mount Completion. Illustration by M. Romanell.

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 must 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 Department's well permit number.

A.6.1.5.5 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 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.

Appendix 6.2

NJDEP Monitor Well Specifications for Bedrock, Unconsolidated and Confined Aquifers

A.6.2.1 Monitoring Well Requirements For Bedrock Formation (See Figure 6.12)

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.

Notice is Hereby Given of the Following:

The Department 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 Department.

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.

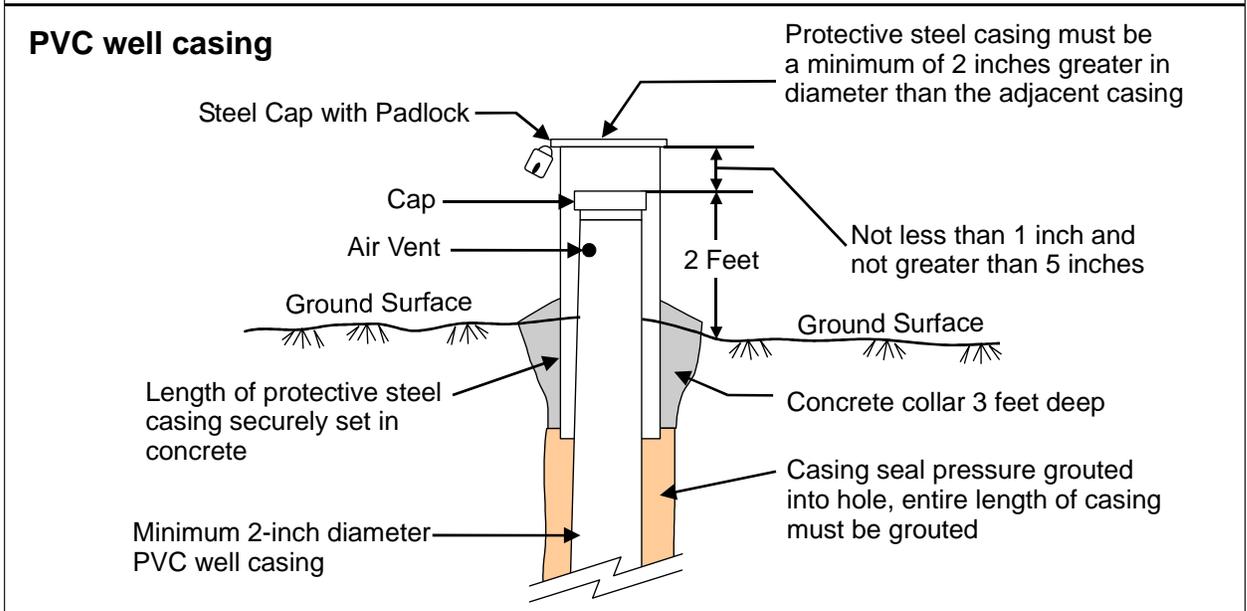
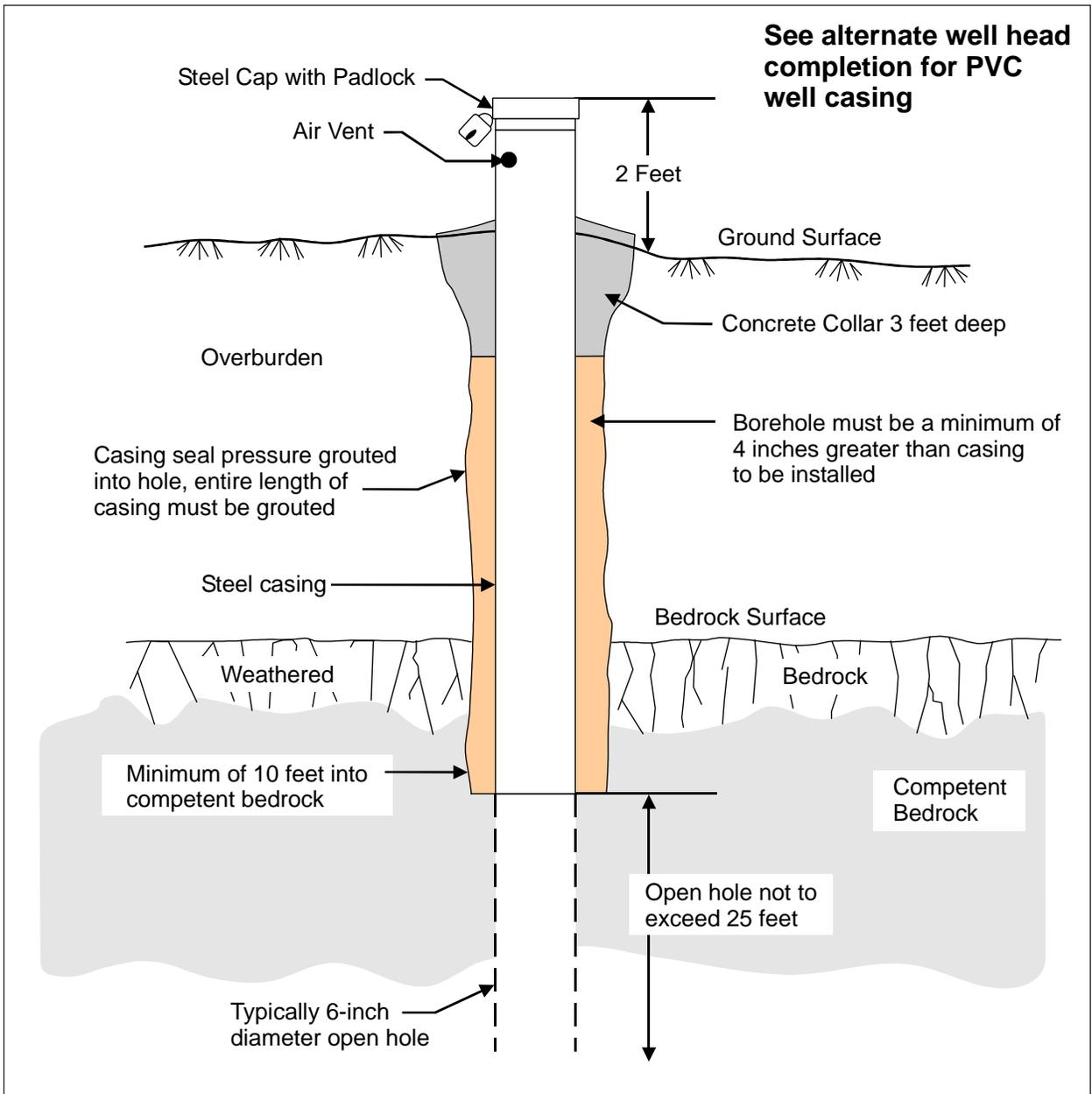


Figure 6.12 Bedrock Formation Well

A.6.2.2 Monitor Well Requirements For Unconsolidated Aquifers (See Figure 6.13)

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. In order 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 Department 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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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.

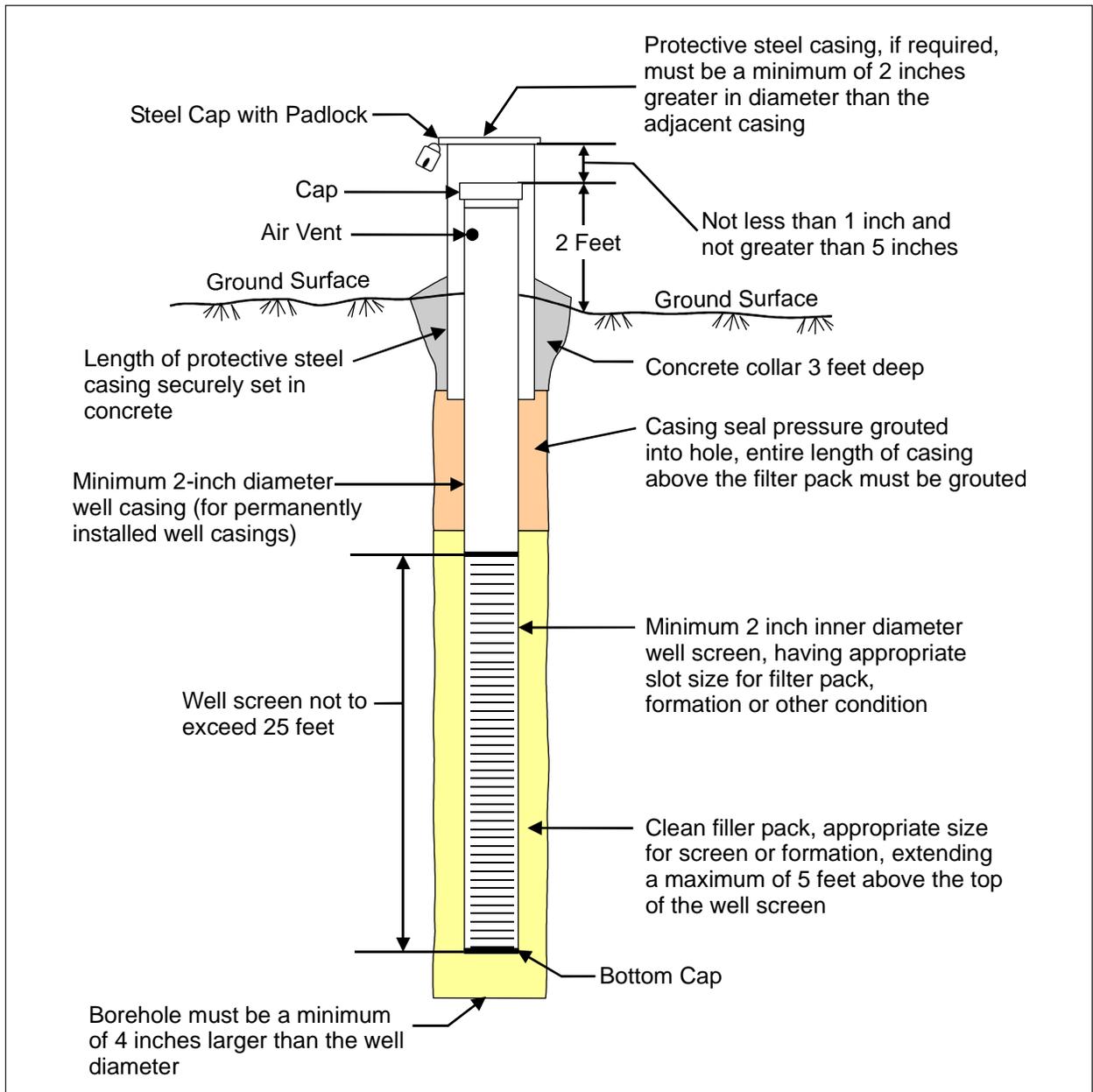


Figure 6.13 Unconsolidated Aquifer Well

A.6.2.3 Monitor Well Requirements For Confined Unconsolidated Aquifers (See Figure 6.14)

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. In order 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 Department 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 Department.

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.

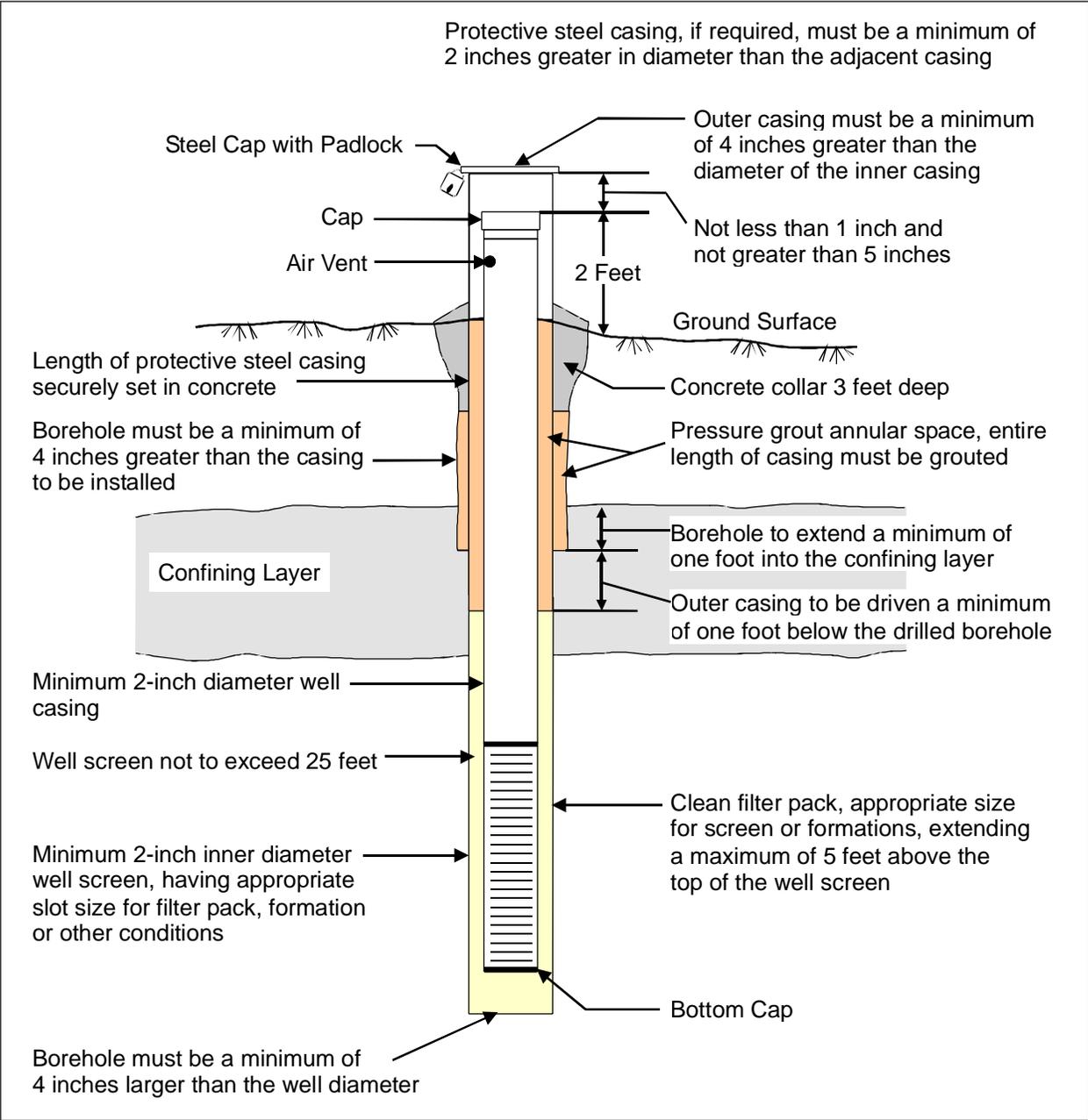


Figure 6.14 Confined Unconsolidated Aquifer Well

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USGS information on packer application

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Chapter 7

Field Analysis

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Chapter 7

Field Analysis

7.1 Introduction

The New Jersey Department of Environmental Protection (NJDEP) is committed to streamlining the site investigation and remediation process at contaminated sites. This chapter of the Field Sampling and Procedures Manual was developed primarily in an effort to expedite the delineation phases of site investigation by providing a means for improving the quality of field analytical data. One way to implement expedited site investigation is through the use of the Triad approach, and more information on this process may be found in Chapter 1.2 of this Manual.

The site investigation shall follow the Technical Requirements for Site Remediation, N.J.A.C. 7:26E, which places emphasis on laboratory analytical methods. However, field analytical methods may be employed if sufficient documentation can be provided to the NJDEP to support the proper application of the method. Persons wishing to use a field analytical method shall submit the proposal to the project team for approval.

With incorporation of the Field Analysis Manual (1994) into the Field Sampling Procedures Manual, field analytical methods are no longer included; however, this section now incorporates by reference several services for finding appropriate field analytical methods.

7.2 Application of Field Analytical Methods

Field-portable instrumentation provides useful information for critical decisions in the field. Typical application of field analytical methods include the following:

- Emergency response, Health, Safety and Industrial Hygiene, and Fence Line Monitoring to determine possible exposure of the community and of personnel
- Source/Process Monitoring – determines regulatory compliance-related monitoring of stack emissions or effluent discharge
- Odor Investigation – a portable gas chromatograph/mass spectrometer (GC/MS) will permit a full analysis for unknowns and leak detection (source detection), a portable gas chromatograph (GC) will permit analysis of suspected contaminants
- Site Characterization/Remediation/Brownfields – Field portable instrumentation/method is well suited to implement dynamic sampling plans in which the goal is to perform a rapid characterization with only a few mobilizations

Almost all projects require screening or semi-quantitative data during the field-screening phase of the site investigation. For example, headspace gas chromatography (GC) can be simple and fast for the analysis of VOCs in soil and water samples during underground storage tank removal or well installation and monitoring. Enzyme kits can provide rapid detection of polychlorinated biphenyls (PCBs) or explosives during site characterization.

Many advances have been and are continuing to be made in the development of field-portable instrumentation. Many of these instruments are hand-held, rugged, and offer very rapid results in the field. Field portable instruments include GCs, micro-GCs, GC/mass spectrometers (MS), extractive Fourier transform infrared (FTIR) spectrometers, filter-based and other infrared (IR) spectrometers, X-ray fluorescence (XRF) spectrometers, and selective monitors in addition to continuous flame ionization detectors (FIDs) and photoionization detectors (PIDs).

7.3 Field Analytical Techniques

Field analyses can be divided into two categories: real time and “near” real-time measurements. Real-time measurements provide instantaneous analysis without the need for sample treatment. Examples include ion-selective electrodes, fiber optic sensors, hand-held gas monitors, direct measuring GCs and portable in-situ XRF instruments.

Near real-time measurements typically include some sample pretreatment prior to analysis of samples. These techniques include wet chemical and enzyme immunoassay kits; GC with a variety of non-specific detectors such as PID and FID; class-selective detectors such as electron capture (ECD for PCBs and chlorinated pesticides) and; compound-specific detections by mass spectroscopy (MS for identification of individual organic compounds). Total petroleum hydrocarbon (TPH) analyzers; inductively coupled plasma/optical emission spectroscopy (ICP/OES); ex-situ XRF; and anodic stripping voltammetry for metals analysis round out examples of these instruments/techniques. The size and experimental operating features determine whether they are classified as field portable or transportable (laboratory-grade) instruments. For example, portable GCs are typically small in size, can use batteries but may not have temperature programming (therefore, operates isothermally) or have slow temperature program ramps from ambient to 200 degrees centigrade. In either case, these GCs are best suited to qualitative analysis of VOCs. In contrast, laboratory-grade GC/MS instruments require a generator or a line voltage power source but can produce quantitative analysis of VOCs and semi-VOCs in the field. Field GC/MS can provide the necessary measurement sensitivity, precision, and accuracy to meet most site-specific data quality objectives (DQOs). However, in many instances, rapid screening GC with ECD/FID or MS is sufficient for VOC soil and water analyses to determine vadose zone and ground water contamination profiles.

7.4 Specific Advantages of Field Analysis

The main advantage of field analysis is that it allows for the performance of rapid characterization with only a few mobilizations via a dynamic sampling plan.

An unique advantage that is offered by field analysis is dedicated analysis of the field samples with the associated QC samples. Often in a batch of 20 samples in a laboratory, a small number of samples (e.g. three samples) from the site of interest are processed with other unrelated samples and the QC samples (e.g. matrix spike samples) may not be one of the site samples. Therefore, the DQO that requires the quality assurance project plan (QAPP) to be based on the very specific needs of each site is served well or often better by dedicated field analysis. Also, due to a rapid turn-around time, the sample integrity of a properly collected and stored one-hour-old sample is often better than that of a sample held for 14 days.

7.5 Selection of a Field Analysis Method

The selected field analysis method must demonstrate method detection limits below the action level or levels of concern (e.g. EPA’s soil screening level or NJDEP’s soil cleanup criteria) for the medium. To insure that the field analytical instrumentation and methods selected are amenable to a given site, site-specific method detection limit studies using soil from the site is recommended. This will help to determine whether matrix interferences or target compounds mask (e.g. portable GC) or cross-react (e.g. enzyme kits) with targeted organics. For further information, please refer to the section titled, *Choosing Appropriate Field Analytical Methods for Contaminant Investigation*.

7.6 Factors To Be Considered For Field Analyses

To be “effective,” the field data generated must be of sufficient quality, with respect to measurement precision or reproducibility, accuracy, sensitivity, and have good correlation with the standard laboratory methods to support the objective of the site investigation or cleanup and the DQO. Several factors to be considered before mobilization include the following (the factors are not intended to be all inclusive):

- The action levels for field decisions shall be established as part of the DQOs.
- The project objective shall permit screening and semi-quantitative data in addition to quantitative data to meet DQO.
- The percentage of samples to be analyzed in the field as well as sent off-site for laboratory confirmation shall be determined.
- The methodology to compare field and laboratory data shall be established, for example using duplicate (field duplicate samples) and/or performance evaluation samples in addition to initial and daily calibrations.
- For the field instrument or the analytical method, the measurement selectivity, sensitivity, precision, accuracy, representativeness and action levels shall be determined.
- The standard operating procedures and method detection limit studies are completed before mobilization to evaluate matrix interferences that might be associated with a particular field technology.
- If applicable, the field technician performing the analyses shall have proof of training by the manufacturer/vendor of the test method.
- If sample preservation is required, samples shall be preserved in the field immediately after collection according to the method specific table in chapter two of this document.

7.7 Role of Field Screening/Analytical Methods According to the NJDEP Technical Requirements For Site Remediation, N.J.A.C. 7:26E

The field analytical methods for expedited site characterization (ESC) shall operate within the framework of existing regulatory programs of NJDEP. Therefore, screening quality data, e.g., enzyme kits, shall be verified by more quantitative analytical data.

A site characterization and/or investigation shall follow the Technical Requirements for Site Remediation, N.J.A.C. 7:26E. The role of field screening methods defined by N.J.A.C. 7:26E, section 2.1(b) is as follows:

- For delineation when the contaminant identity is known or if there is reasonable certainty that a specific contaminant may be present (for example, benzene, toluene, ethylbenzene, xylene in the case of sampling for a gasoline release); or
- To bias sample location to the location of greatest suspected contamination.

Laboratory data is not one hundred percent accurate, but currently represents the best estimate of the true concentration of a contaminant in an environmental sample. Therefore, a comparison of field and laboratory data is required to provide some guidance on the validity of the field data.

According to N.J.A.C. 7:26E 2.1 (b), field screening methods shall not be used to determine contaminant identity or clean zones. However, if satisfactory technical justification is provided, a variance may be approved on a case by case basis. For example, where ten or more samples are required for

initial characterization for an area of concern (AOC), field screening methods may be used to document that up to fifty percent of the sampling points are not contaminated i.e., “clean” or below the cleanup criteria. Any person responsible for conducting characterization and/or remediation may petition the Department for a variance from the frequency requirements in accordance with N.J.A.C. 7:26E-1.6(d). These variance petitions shall provide technical justification and will be evaluated by the Department on a case-by-case basis.

For a variance application, technical justification may include: knowledge of the contaminant, lack of or minimal matrix effect, lack of or minimal interfering constituents, capability to produce qualitative and quantitative data using standard calibration and QA/QC practices (e.g. using a Field GC/MS), project-specific audits where a NJDEP staff visits the site during the field sampling/analyses to verify that the standard operating procedure (SOP) and QAPP is followed, and the field strategy has been accepted as an ASTM Standard Practice or the technology has been independently verified.

When volatile organic contamination is suspected in soils, initial characterization for soils during preliminary assessment and site investigation, for both field and laboratory analyses shall be performed according to N.J.A.C. 7:26E-3.6.

The number of sampling locations at each contaminated and/or non contaminated area as well as depth of the samples at each location shall be determined and reported for all contaminants of concerns (COCs).

7.8 Regulatory Initiative For Development of Field Analyses

New third party technology verification programs are involved in evaluating, reviewing, or endorsing new and innovative field testing technologies. One such technology verification program is the EPA’s Environmental Technology Verification (ETV) program. Related programs include the EPA Site Characterization and Monitoring Technology, also known as the Consortium for Site Characterization Technology (CSCT), and Cal/EPA’s Certification Program.

Interstate initiatives such as the Interstate Technology & Regulatory Cooperation (ITRC, which currently has 43 member states) are in place to review and promote innovative technologies. The ITRC group publishes guidance documents on new technologies for environmental applications. The ITRC/ASTM partnership for accelerated site characterization, in Appendix G of their FY-97 summary report, delineated detailed guidelines on *Practice for Expedited Site Characterization of Vadose Zone and Ground Water Contamination at Hazardous Waste Contamination Sites*.

Several new characterization and assessment strategies have been cited in a recent EPA publication *Summary of Recent Improvements in Methods for the Study of Contaminated and Potentially Contaminated Sites*, published by the Technology Innovation Office (TIO). The strategies endorse the use of field methods for quick turnaround information for on-site decision making.

All of the above programs/agencies provide test results and report on a technology’s performance or permitting protocols. However, any new technology selected or adopted shall follow good QA/QC practices for verification.

Individual training programs such as DOE’s ESC Training Course, Argonne National Laboratory’s Quick Site™ Course and EPA’s Field-Based Site Characterization Technologies and Strategies for Field-Based Analytical and Sampling Technologies Courses are available. These as well as vendor provided courses offer information to keep abreast on the developments in this expedited site characterization area.

Currently, the following two strategies have been accepted as ASTM Standard Practices: Accelerated Site Characterization for Confirmed or Suspected Petroleum Releases (PS3-95) and ESC of Hazardous Waste Contaminated Sites (D6235-98). In the future, as sophisticated analytical instruments are being miniaturized, more field-based technologies are likely to become standard practices.

7.9 Choosing Appropriate Field Analytical Methods For Contaminant Investigation

The universe of field analytical methods has grown significantly and the accuracy of the methods has increased dramatically since the NJDEP initially developed the *Field Analysis Manual* in 1994. The NJDEP determined that inclusion of individual field analytical methods in this chapter of the Field Sampling Procedures Manual is not practical and not necessary considering the number of useful web sites dedicated to field analytical methods. Therefore, this section provides a guide to using web sites to identify appropriate field analytical methods, gather information regarding these methods and present this information to the NJDEP in an acceptable format.

7.9.1 Considerations Prior To Researching Field Analytical Methods

Field analytical methods can provide accurate results instantaneously or within a short period of time; however, the field analytical method chosen must be appropriate for the analytes of concern and site conditions. When choosing a field analytical method, the first consideration should be to determine what analytes of concern are present on the site (i.e. PAHs, PCBs, metals, etc.) and what level of detection (i.e. low ppb, mid ppm, etc.) must be achieved in order to reach the goals established in the QAPP. Most web sites will provide a search engine allowing for a search of methods specific to an analyte or group of analytes or will provide information indicating which methods are appropriate for an analyte or set of analytes. These web sites will generally also provide typical detection limits for each method.

7.9.1.1 Matrix Effects: The matrix or matrices (i.e. soil type, sediment, water, etc.) may cause one field analytical method to be preferable to another, or may cause interference in an analytical method. An example of matrix effects is extremely fine clays, which may cause an immunoassay test to be biased low. Another example of matrix effects is the presence of large pebbles, which may render it difficult to use an XRF efficiently, as a flat, relatively uniform, surface is required for analysis (this problem may be solved by sieving the soil prior to analysis). Some field analytical methods require extraction or other sample preparation methods and therefore, are not amenable to using with certain matrices. Knowledge of the unique characteristics of the site matrices will permit identification of potential interferences due to matrix effects. Concentrations of elements in different types of soil or matrices might change, causing interferences (i.e. between arsenic and lead). Site-specific calibration can compensate for some of those effects.

7.9.1.2 Analyte(s) of Concern: The field analytical method chosen must be capable of detecting the analyte or analytes of concern at the site. Unlike most laboratory methods, which detect suites of analytes providing quantitation for each of the individual analytes, many field analytical methods detect only individual analytes or groups of analytes, without providing quantitation for each of the individual analytes. Several field analytical methods (i.e. XRF, Field GC, etc.) can analyze a suite of analytes and provide quantitation for each individual analyte; however, these methods must be calibrated for each analyte of concern. Several field analytical methods can be used in conjunction to determine an array of analytes or cross-reference a common analyte. The objectives in the QAPP will determine which field analytical methods

will be employed at the site. If a number of similar analytes are present at a site, it may be difficult to quantify certain analytes accurately because interference may create false positive results. Results obtained by some field analytical methods (i.e. indicator tubes) are qualitative to semi-quantitative at best. The minimum detection limits for some field analytical methods are influenced by factors such as water vapor and chemical interference.

- 7.9.1.3 **Interfering Constituents:** Another item to consider, prior to researching a field analytical method, are other constituents present on the site. Other constituents, even those not regulated or below regulatory limits, may cause interference with the chosen field analytical method. An example of interference is high iron levels, which are below regulatory levels, may raise the detection limit for other metals with low regulatory limits when using an XRF for field analysis. Familiarity with other site constituents prior to researching a field analytical method will permit quick identification of possible interference. Some field analytical methods (i.e. field GC) may experience coelution of analytes which may cause biased high results, false positives or make quantification difficult or impossible.
- 7.9.1.4 **Limitations:** All analytical methods (fixed laboratory methods, field analytical methods, etc.) have limitations. Understanding these limitations will help to apply the technology properly to generate data that meets the needs of the project. Some methods may not perform well for certain groups of analytes (i.e. petroleum hydrocarbon [immunoassay] methods may not perform well for motor oil or grease, or for highly degraded petroleum fuels) and therefore, these methods may have a potential for false negative results. Some reagents may require refrigeration and, therefore, it may be necessary to have a cooler or refrigerator on site. While analysis with some field analytical methods can be accomplished quickly, it can be time-consuming to perform analyses with other field analytical methods. Certain instrumentation operation (i.e. field GC) requires a higher degree of expertise than most other field analytical methods. Some field analytical methods may require judgement made by the operator (i.e. color comparison to a chart) which can lead to inaccurate results. Some field analytical methods may require that the specific analyte to be tested must be known, so that the method can be calibrated correctly. Some field analytical methods may have no true field-portability, with a mobile laboratory setup required or an electrical power source required. Some field analytical methods may be cost prohibitive on small-scale projects, or a specific license may be required to operate certain instruments (i.e. XRF).
- 7.9.1.5 **Physical Conditions:** Physical conditions on site may cause logistical problem with certain field Physical analytical methods (i.e. space limitations, flat surfaces, dry surfaces, etc.) or may cause interference with the field analytical methods (i.e. heat, cold, excessive sunlight, etc.). Examples of logistical problem would be providing enough room with a relatively flat surface in an up wind location for a field GC. Extreme temperatures will effect most field analytical methods and excessive sunlight may cause some reagents to break down. Familiarity with the site conditions will permit a determination of whether a given field analytical method is viable at a particular site.

7.9.2 Searching the Websites

Once the analyte(s) of concern are determined, other constituents present at the site have been ascertained and the site matrix (matrices) and physical conditions are known, an internet search to determine an appropriate field analytical method can be performed. Several Internet sites including <http://fate.clu-in.org/index.htm>, <http://www.epareachit.org/index3.html>, <http://www.frtr.gov/> and <http://www.clu-in.org> are good references to begin determination of what field analytical method(s) will be appropriate. In addition, many vendors provide web sites

for their products. Whereas vendor web sites are good sources of information, research from an independent review of the field analytical method is advisable. Each Internet site has a unique way to begin a search.

7.9.2.1 FATE: The Field Analytical Technologies Encyclopedia (FATE) site lists field analytical methods by method. The web site then details under each method the list of appropriate analytes and matrices, what interferences and limitations are associated with the method, typical detection limits, and physical limitations of the field analytical method as well as links to other related web sites.

7.9.2.2 EPAREACHIT: The EPA REmediation And CHaracterization Innovation Technologies (EPAREACHIT) site provides a search engine to select analytes or groups of analytes, matrices and whether the technology has previously been used at a pilot scale, full scale or bench scale. The site then provides detailed information about the technology and links to other related sites.

7.9.2.3 FRTR: The Federal Remediation Technologies Roundtable (frtr) site provides case studies where site characterization technologies were used. The site lists advantages of the methods employed as well as a section on lessons learned during the case study. The site includes the *Field Sampling and Analysis Technologies Matrix and Reference Guide*.

7.9.2.4 CLU-IN: The clu-in site includes the Vendor Field Analytical and Characterization Technologies System (Vendor FACTS). This website has links to relevant “performance based” site characterization and clean up information. Vendor FACTS is a Windows™ based database of innovative technologies for site characterization available for registered users.

When utilizing one of these web sites or any other web site, it is important to identify as many different field analytical methods applicable to the site as possible along with the advantages and disadvantages of each in order to determine which method will best meet the objectives identified in the QAPP. Links to vender sites are useful, but while providing worthwhile information, may impart a bias to a particular method or instrument. When considering the advantages of a field analytical method, it is always important to consider the site matrices, analytes of concern, potential interferences and limitations of the field analytical methods. In addition, practicality and cost of the field analytical method should be considered for each phase of the site work. A field analytical method may be practical and cost effective for the delineation phase, but may not be practical or cost effective for the remedial phase if laboratory analysis will be required for a percentage of the sample points.

7.9.3 Listing Limitations and Interferences for Selected Field Analytical Methods

All analytical techniques have limitations and interferences, including methods used at a fixed laboratory; however, limitations and interferences do not preclude these methods from providing useful information. A thorough understanding of the field analytical method’s limitations and interferences as related to the site can define the usefulness of the method and data produced by that method. The limitations and interferences should be presented to NJDEP when initially requesting approval for the use of a field analytical method. In addition to listing the limitations and interferences, ways of compensating for these limitations and interferences or reasons why they will not interfere with the objectives of the QAPP for a given phase of the investigation of the site should be listed.

7.9.3.1 Matrix Effects: Sample matrix interference may not be easily resolved, dependant on the method of interference caused by the matrix (i.e. difficulty extracting from large pebbles); however, sometimes the method will provide a way of correcting the interference through site

specific calibration or altering the sample preparation method. When there is no method to compensate for matrix interference, then the field analytical method may be rendered useless at the site or may only be useful for gross contaminant delineation. When the method; however, can be adjusted or adapted to compensate for matrix effects, then, with NJDEP approval, the field analytical method can be used for finer delineation dependant on the objectives of the QAPP. When requesting use of field analytical methods for delineation at a site, all possible matrix interferences should be listed along with methods for compensating for the matrix interference, if applicable.

7.9.3.2 Analytes: Some field analytical methods analyze for general classes of analytes, while others analyze for specific contaminants. Several field analytical methods can be used to test for more than one analyte. Some field analytical methods are designed for classes of analytes (i.e. PAHs, carcinogenic PAHs, BTEX, etc.), and will provide a concentration of the total class of analytes, but will not indicate the concentrations of individual analytes. Some field analytical methods that analyze for one analyte also will respond in various degrees to other related analytes (i.e. immunoassay for PCP will respond to other chlorophenols). Some field analytical methods may provide quantitative results, semi-quantitative results, or qualitative results. Dependant on the objectives specified in the QAPP, any of these types of results may be acceptable for certain phases of the project. All analytes, groups of analytes and detection limits should be listed with an explanation of how these results will satisfy the objectives in the QAPP for each phase of the investigation.

7.9.3.3 Interfering Constituents: When interfering constituents are present on the site, generally the method cannot be altered to compensate for the interference. When the interfering constituent still allows analysis of the analyte of concern to be performed, but with a higher detection limit, then the field analytical method may still be valid for the site, but in a limited capacity. Although the field analytical method may not be appropriate for site closure purposes or final delineation, the field analytical method may still be a valuable tool in early delineation rounds of gross contamination. The way in which the field analytical method will be employed at the site will determine whether interfering constituents preclude the method's use at a given site. A list of interfering constituents, their effect on the analyte(s) of concern, and how this relates to the objectives of the QAPP should be presented.

7.9.3.4 Limitations: Some field analytical methods may not perform well for certain groups of analytes, may have a potential for false negative results, require refrigeration, be time-consuming, require a high degree of expertise, require judgement made by the operator, have no true field-portability, or may be cost prohibitive on small-scale projects. These limitations should be listed along with an explanation of how they relate to the objectives specified in the QAPP.

7.9.3.5 Physical Conditions: If the site is not amenable to conditions needed for a field analytical method, then the method cannot be utilized at the site. However, if an adjacent property provides the right physical conditions and can be utilized and the samples can be collected on the site and transported to the adjacent property, then the method may be viable for the site. A site building or a vehicle brought on to the site may often be utilized to provide the right site conditions such as controlling the amount of sunlight, temperature, humidity, etc. or by providing a space free of site vapors and dusts with large flat work surfaces. Generally physical constraints can be overcome; however, the cost and practicality may preclude this from being a viable option. The restricting physical conditions should be listed along with the resolution of these conditions and how they relate to the objectives specified in the QAPP.

7.10 Quality Assurance Project Plan (QAPP) For Implementation of Field Analytical Methods

This section defines the NJDEP Site Remediation Program’s Data Quality Levels for contaminant investigation. The type of data required depends on the decision to be made. There are four types of data that can be used to support different types of decisions. To guide in the selection of field analysis methods, a contaminant investigation plan shall meet the minimum data quality standards prior to receiving approval. The project team is responsible for the review and revision of all field analytical proposals.

- Preliminary or Field Screening Data – (Data Quality Objective Level 1): These data are described as screening data. The analyses use field portable instruments. Results often are not compound specific and not quantitative, but results are available real time. The key feature is that additional confirmatory analysis of the same samples is usually required with respect to the decision to be made.
- Effective Data or Field Analysis Data – (Data Quality Objective Level 2): These data are generated by more sophisticated portable analytical instruments and the instruments are capable of generating effective data. The term effective or acceptable data quality is meaningful only when the intended uses for the data are established. Therefore, the goal is to generate the quality data required to accomplish the DQO of the project. Depending on the objective that may or may not mean laboratory quality data. The quality of the data depends on the use of suitable calibration standards, reference material, and sample preparation equipment and the training of the operator. Results are available real time or within several hours.

The data is “effective” also when a portion (10 percent or more) of the results are substantiated or verified by off-site analysis using EPA-approved methods. The effective data are adequate or effective for the intended use (usually because associated quality control is sufficient to inspire confidence). For example, a site has been characterized well enough that the identities of the contaminants are known, and “yes or no” decisions about categorizing waste piles must be made. The analytical tool selected may be known to cross-react with a range of analytes, but, because it is known (from previous confirmatory investigation) that those interferences are not present, the tool is acceptable for support of the “yes or no” decision without confirmatory analysis by another method.

The field analytical methods shall provide data of sufficient quality to meet the data quality objectives. Supporting quality assurance (QA) and quality control (QC) procedures shall be provided to document data quality (please refer to the QA and QC sections for details).

As previously stated, according to N.J.A.C. 7:26E-2.1(b), field screening methods are generally not to be used to determine contaminant identity or clean zones. However, where ten or more samples are required for initial characterization for an area of concern and a variance is approved by the NJDEP, field analytical methods (as opposed to field screening methods) may be used to document that up to fifty percent of the sampling points are not contaminated.

- Meticulous or Definitive Data – (Data Quality Objective Level 3): These data are generated by a method that determines the identity and the concentration of the analyte with “reasonable” certainty. These data can stand on their own with respect to the vast majority of possible decisions.

The meticulous or definitive data are generated from an approved laboratory method and contain QA/QC deliverables as required in N.J.A.C. 7:26E, Appendix A. These data can be used for clean zone confirmation and for delineation during the remedial investigation.

- State-of-the-Art” Data: Special “state-of-the-art” methods may be developed specifically for a particular site, and would be approved on a case by case basis.

7.11 Quality Assurance Requirements

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7.11.1 Preliminary or Field Screening Data (Data Quality Level 1)(See Table 7.1.)

- 7.11.1.1 Field screening data are intended to be used for Health & Safety, initial contaminant screening and/or contaminant delineation (i.e. approximation of contaminated zone).
- 7.11.1.2 Instruments used for field screening data include PID survey instruments, FID survey instruments and XRF with remote probe (x-met). Methods used for Field screening data include hydrophobic dye test, colorimetric analysis and headspace analysis.
- 7.11.1.3 The data produced by field screening shall only be considered an indicator of contamination. Quality control procedures and deliverable requirements are limited to a brief method review, instrument calibration, maintenance logs, field logs, reported data values and background levels.
- 7.11.1.4 Field screening data are real-time, but are semi-qualitative and semi-quantitative, and measurements may be erratic. Therefore, data shall only be used for health and safety and to guide sample placement for analysis by higher level methods.
- 7.11.1.5 Since relatively few quality control procedures are employed compared to higher-level field methods, data quality is very much a function of sample handling techniques and analyst skill.

7.11.2 Effective Data or Field Analysis Data (Data Quality Level 2)

- 7.11.2.1 Effective Data or Field Analysis Data are intended to be effective for the end use and to provide reliable, rapid, contaminant delineation.
- 7.11.2.2 Effective Data or Field Analysis Data can achieve a high degree of reproducibility when required QA/QC procedures are employed.
- 7.11.2.3 Field analysis methods are typically laboratory methods, which have been adapted for field use (i.e. field GC, portable XRF, field IR).

In addition to screening data requirements, quality assurance (QA) deliverables shall include:

- Initial calibration curves
- Continuing calibration curves (1 per 10 samples)
- Field Duplicates (1 per 20 samples)
- Background/Blank data
- Analyses Run Log
- Raw data submission (i.e. chromatograms, recorded instrument readouts, etc.)
- Chain of Custody Documentation (or field sample tracking sheets)
- Non-conformance summary listing all deviations from the approved SOP and QA/QC parameters outside control limits. The non-conformance summary shall include an analyst certification statement.

- Laboratory confirmation data shall be submitted along with the field analytical data. At a minimum, if a variance is approved, 10% of all Field analysis data shall be laboratory confirmed (both clean and contaminated samples). As stated before, N.J.A.C. 7:26E-2.1(b) require that 50% of all “clean” samples be laboratory confirmed during the site investigation and 100% of all “clean zone” samples be laboratory analyzed/confirmed during the remedial investigation. A variance from these requirements may be requested pursuant to N.J.A.C. 7:26E-1.6(d) with technical justification.
- The laboratory performing the confirmation analyses using a standard method (e.g. a SW846 method or a CLP method) must be certified to perform the analyses.
- Results of analyst competency tests (i.e. performance evaluation tests and proof of training) are required.
- Matrix Spike Recovery (case-by-case)
- Surrogate Analyte Analysis (case-by-case)
- Method Blank Analysis (case-by-case)
- Quality Control Check Sample Analysis (case-by-case)

7.11.2.4 Field analysis data may be semi-quantitative (i.e. providing an estimated value) and semi-qualitative or class specific (definitive contaminant identification is not provided).

7.11.2.5 Environmental samples frequently contain contaminants of unknown identity and concentration. Laboratory data, although not one hundred percent accurate, currently represents the best estimate of the true concentration of a contaminant in an environmental sample. Therefore, a comparison of field and laboratory data can help to provide some guidance on the validity of the field data.

A laboratory-field correlation of Field Analysis data has two components and can be calculated by the following regression analysis equation:

$$L = xF + y$$

where:

L = the reported laboratory concentration of a contaminant

F = the reported field concentration of the same contaminant

x = the slope of the correlation of field and laboratory data

y = the intercept of the field and laboratory data (constant)

R squared = fit of equation

The two components of the laboratory-field correlation are: 1) the fit (R squared) and 2) the intercept (y). Given the lack of homogeneity of environmental samples, variation in sample handling and variations inherent in both field and laboratory data, the fit of the equation is not expected to be perfect (i.e. in most cases, R squared \neq 100%); however, R squared and a plot of the scatter graph shall be developed by the data reviewer and submitted to the Department. An examination of the R squared and scatter graph shall be made to determine the usefulness of the field data. Professional judgement shall be used when determining whether field data shall be used for delineation and/or clean samples (with an approved variance).

The intercept (y) is important due to differences in concentrations determined in field verses laboratory data. During the remedial investigation (RI), field based contaminant zone delineation levels may be adjusted per the following equation:

$$C_f = C + y$$

where:

C_f = contamination zone delineation criteria for field generated data

C = cleanup criteria for laboratory data

y = the intercept of the field and laboratory data correlation equation

7.11.2.6 Field Analytical methods also include published laboratory methods such as USEPA SW-846 laboratory methods, which are highly reproducible; however, field analytical data are generally documented using only limited quality assurance deliverables.

7.11.2.7 The quality or effectiveness of Field Analytical data generated using published (laboratory) methods with limited deliverables is a function of sample handling, storage and preservation procedures, and analytical instrument maintenance. These data shall be reliable if proper sampling, analytical, and QC procedures are followed.

7.11.3 Meticulous or Definitive Data (Data Quality Level 3)

7.11.3.1 Final remediation shall be based on the site-specific cleanup criteria using Meticulous or Definitive Data because this type of data is intended to generate the most reliable data practicable.

7.11.3.2 Meticulous or Definitive Data are highly reproducible and can provide the end user with complete QA/QC documentation in accordance with N.J.A.C. 7:26E, Appendix A.

7.11.3.3 Methods that generate Meticulous or Definitive Data are generally the same published laboratory methods as Field Analytical Data but are supported with full laboratory data deliverables or reduced laboratory data deliverables in accordance with subchapter 2 and Appendix A of N.J.A.C. 7:26E.

7.11.3.4 Meticulous or Definitive Data can only be generated by a certified or otherwise approved laboratory pursuant to N.J.A.C. 7:26E section 2.1.

7.11.4 “State-of-the-Art” Data:

7.11.4.1 Generally “State-of-the-Art” methods are developed specifically for a particular site or contaminant.

7.11.4.2 “State-of-the-Art” methods are used when standard laboratory methods are either unavailable or impractical.

7.11.4.3 Data generated using a “State-of-the-Art” method may have variable deliverable requirements. These requirements will be proposed by the laboratory or person performing the analysis and evaluated by the Department for each method proposed. If the method and the deliverables requirements are approved, the data produced by methods conforming to these requirements will be acceptable for their intended use.

7.11.4.4 “State-of-the-Art” methods may be accepted to delineate a contaminant, define a “clean zone” or confirm field data per Item 7.11.4.3, above.

7.11.4.5 Generation of “State-of-the-Art” data may necessitate use of a laboratory, which specializes in methods development.

Table 7.1 Overview of Data Quality Classifications

Data Quality Level	Purpose of Sample	Example Methods or Instruments
Screening Data	Health & Safety, Field use when excavating, Contaminant Screening & Delineation	Portable PID, Portable FID, Colorimetric Analysis, XRF with a remote probe (x-met), Headspace Analysis, Hydrophobic Dye Test
Field Analytical Data	Field use when excavating, Contaminant Delineation, Clean Sample Confirmation during SI	Portable GC, Portable IR, Portable XRF with Si(Li), Portable AA, Immunoassay, USEPA SW-846 Field Screening Methods Laboratory Analyzed Samples with Limited QA/QC requirements, {i.e. USEPA SW-846 Laboratory Methods (most recent edition)}
Definitive Data	Delineation, Clean Zone Confirmation	Laboratory Analyzed Samples, with full QA/QC documentation, {i.e. USEPA SW-846 Laboratory Methods (most recent edition)}
State-of-the-art Data	Non-standard method analysis	Laboratory Special Services, Mobile Laboratory

7.12 Field Data Deliverables Format

The following requirements can be incorporated into a dynamic workplan and to establish standard operating procedures (SOPs) and the QAPP. SOPs for sample collection and analysis shall be developed with other SOPs required to answer site-specific questions (e.g. geophysical and hydrogeological surveys, etc.). In addition, please refer to the sections on the QAPP and Quality Assurance Requirements of this chapter, and subchapter 2 and Appendix A of N.J.A.C 7:26E.

7.12.1 Field-Screening Data – QA/QC Requirements

The following represents the minimum data deliverables required for field screening data. The “Data Deliverables” section of each method will provide specific requirements:

7.12.1.1 A brief method review shall be provided.

7.12.1.2 A single point calibration shall be conducted prior to any field activities using site-specific standards.

7.12.1.3 Calibration checks shall be performed at a minimum of twice daily bracketing the sample analyses. If a calibration check falls outside the manufacturer’s suggested range, then a complete multi-point calibration is required.

7.12.1.4 A baseline or blank scan (i.e. “clean air,” “clean water” or “clean soil” as appropriate) shall be run each day prior to analyzing any site samples.

7.12.1.5 An instrument log shall be maintained and submitted (where appropriate). This log shall include instrument maintenance, blank, and calibration information, *including date, time, analyst’s name, calibration standard compounds, the concentrations and readings of the calibration standards.*

7.12.1.6 Field logs shall document sample ID#, date, time, location, depth, matrix (i.e. soil type, water, air), soil moisture (qualitative estimate where appropriate), and the reading and concentration/result of the analysis.

7.12.1.7 A non-conformance summary shall state all data inconsistencies and all divergences from the approved sampling/analysis program. The implication of all non-conformances shall be clearly explained and quantified (if possible).

7.12.2 Effective Data or Field Analysis Data – QA/QC Requirements

In addition to the requirements listed for the field screening data, the following represents the minimum data deliverables required for field analysis Data. The “Data Deliverables” section of each method will provide specific requirements:

7.12.2.1 Each project team that uses a field analysis method is required to operate a formal quality control program. The minimum requirements of this program consist of an initial demonstration of capability and an ongoing analysis of calibration standards. To establish the ability to generate acceptable accuracy and precision, the analyst shall perform the following operations:

7.12.2.1.1 A soil quality control (QC) check sample. The QC check sample shall be prepared by the laboratory using stock standards prepared independently from those used for calibration.

7.12.2.1.2 An aqueous QC sample, prepared in the same fashion as the soil QC sample, is also required.

7.12.2.1.3 Analyze four aliquots of each of the well-mixed QC check samples according to standard procedures.

7.12.2.1.4 Calculate the average recovery mean (X) and the standard deviation of the recovery (s) for each parameter of interest in each matrix using the four results.

7.12.2.1.5 For each compound, X shall be between 60% and 140% of the true value. Additionally, s shall be $\pm 40\%$ of X.

7.12.2.2 Method blanks (i.e. syringe blanks, equipment blanks, and instrument blanks) shall be run at the beginning and during each workday or after a sample when carry-over is anticipated. A higher frequency of blank analyses may be required depending upon equipment use and results.

7.12.2.3 Instrument shall be calibrated each month with 3-point or 3-level (minimum) laboratory certified standards and shall also be calibrated daily with 1-mid point or 1-mid level laboratory certified standards. The standard analytes and concentrations shall be chosen based on known site contamination and encompass the range of expected concentrations. Surrogate compounds shall also be included. Matrix-specific minimum detection limits shall be determined and reported for all site-specific compounds.

7.12.2.4 If standard curves remain linear over the entire analysis range, only one midpoint standard shall be analyzed at a frequency of 1 per 10 samples. If standard curves are not linear over the entire analysis range, a minimum of two (2) calibration standards, one low level and one high level standard shall be analyzed at a frequency of 1 per every 10 samples.

7.12.2.5 Matrix Spike and Matrix Spike Duplicate samples may be required at a rate of one per every 20 samples. The project team shall determine if MS/MSD samples are required on a case-by-case basis.

7.12.2.6 Chain of custody or sample tracking documentation shall be generated for all samples collected and analyzed. This documentation shall include a statement certifying that all data were generated following proper procedures.

7.12.2.7 Proof of training for the technician performing the analyses is required.

7.13 Data Management Plan

The ability to manage and easily use all of the data produced in the field is critical to the success of the field analysis technologies. Protocols for sample logging, analysis, data reduction, and site mapping shall be established. The data management plan shall be established prior to mobilization for the collection, processing, and presentation of the field generated data. Sample logging information and the results of the analysis can be managed through a Laboratory Information Management System or through the use of spreadsheets. The data can then be downloaded to a computer containing site visualization software for conceptual model update and review.

References/Resources

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Glossary

Accelerated Site Characterization (ASC) – A process for characterizing vadose zone and ground water contaminated sites using primarily professional judgement-based sampling and measurements by an integrated, multidisciplinary core technical team. The team operates within the framework of a dynamic work plan that gives flexibility and responsibility to select the type and location of measurements to optimize data collection activities during a limited number of field mobilizations.

Accuracy – the ability of a technique to detect the true concentration of the analyte.

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Calibration – the process by which data can be made to correlate with known standards.

Certified Laboratory – a laboratory that is currently certified pursuant to N.J.A.C. 7:18, the Regulations Governing Laboratory Certification and Standards of Performance, to perform laboratory analysis for a specific certification category and a specific parameter within the certification categories.

Clean Zone – a series of contiguous samples collected at a frequency consistent with the requirements of the Technical Requirements for Site Remediation, N.J.A.C. 7:26E, which are analyzed and determined to be below the cleanup criteria (a single sample may constitute a clean zone for small contaminated areas).

Contaminant – as defined in N.J.A.C. 7:26E, currently: any hazardous substance, hazardous constituent, hazardous waste or pollutant discharged by any individual or entity.

Contaminant Delineation – the systematic collection and analysis of samples from a point of known contamination to determine the vertical and horizontal extent of contamination.

Contaminant Screening – the analysis of environmental media by non-selective instrumentation or methods to gain a preliminary estimate of contaminant extent.

Corrected Results – the results obtained when instrumental results are adjusted to account for laboratory confirmation values and/or other quality control criteria.

Expedited site characterization (ESC) – A process for characterizing vadose zone and groundwater contaminated sites using primarily professional judgement, base sampling and measurements by an integrated, multidisciplinary core technical team. The team operates within the framework of a dynamic work plan that gives flexibility and responsibility to select the type and location of measurements to optimize data collection activities during a limited number of field mobilizations.

Dynamic work plan – A site characterization work plan including a technical program that identifies the suite of field investigation methods and measurements that may be necessary to characterize a specific site, with the actual methods used and the locations of measurements and sampling points based on on-site technical decision making.

Field Portable – an instrument that is durable and relatively simple to move between facilities for on-site analysis.

Full Laboratory Data Deliverables – the data deliverables as required in N.J.A.C. 7:26E section 1.8 and Appendix A.

Instrument Log – a manual that documents all instruments outputs, calibration, and maintenance.

Isoconcentration – more than one sample point exhibiting the same analyte concentration.

Isopleth – the line or area represented by an isoconcentration.

Limited Laboratory Data Deliverables – data deliverables with less QA/QC documentation than those required under Appendix A of N.J.A.C. 7:26E.

MDL (method detection limit) – the minimum concentration of a substance that can be measured and reported with a 99 percent confidence that the analyte concentration is greater than zero and is determined from the analysis of a sample in a given matrix containing the analyte.

PQL (practical quantitation level) – the lowest quantitation level of a given analyte that can be reliably achieved among laboratories within the specified limits of precision and accuracy of a given analytical method during routine operating conditions.

Precision – the ability of a method to provide reproducible results from sample to sample.

Quality Assurance (QA) – documentation designed to assure that proper sampling and/or analysis protocol are being followed. Measures taken to independently check and verify that the quality control procedures specified in the QA/QC plan are being carried out.

Quality Assurance Project Plan – a document which presents in specific terms the policies, organization, objectives, functional activities and specific quality assurance/quality control activities designed to achieve the data quality goals or objectives of a specific project or operation.

Quality Control (QC) – the implementation of protocols designed to assure that the final sampling or analytical results are reliable. QC is the process of ensuring the quality of data during their collection, measurement, integration, interpretation, and archiving, through the application of defined procedures.

Reduced Laboratory Data Deliverables – the data deliverables as required in N.J.A.C. 7:26E section 1.8 and Appendix A.

Response Factor (Relative Response Factor) – a measure of the relative response of the instrument detector to an analyte compared to an internal or external standard. Relative Response Factors are determined by the analysis of standards and are used to calculate the concentrations of analytes in samples.

Semi-Qualitative – identification of a compound by class rather than identification of the specific compound (i.e. semi-qualitative would identify aromatic hydrocarbons whereas qualitative would identify benzene).

Semi-Quantitative – numeric values which only approximate the true concentration of the analytes.

Site Screening – rapidly surveying a site, possibly employing some chemical analysis instrumentation or methods, in an effort to estimate worst case environmental conditions.

Site-similar material – material containing the same chemical and physical characteristics of native material found on-site and shall include actual site material used for the prescribed purpose.

Survey Instrument – an instrument which detects compounds with little or no selectivity.

Total Recoverable – the amount of a contaminant that is extracted from the sample.

Traditional Site Evaluation – the initial characterization, delineation and clean zone confirmation of a site by collection and analysis of samples by certified methods with appropriate data deliverables.

Chapter 8

Geophysical Techniques

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Chapter 8

Geophysical Techniques

8.1 Introduction

The use of various geophysical techniques for the investigation of hazardous waste and ground water pollution sites is often a rapid, cost-effective means of preliminary evaluation. The information obtained from a geophysical investigation can be used to determine the subsurface conditions at, and in the vicinity of, a site. Various geophysical techniques reveal physical properties of the subsurface which can be used to determine hydrostratigraphic framework, depth to bedrock, extent of concentrated ground water contaminant plumes, the location of voids, faults or fractures, and the presence of buried materials, such as steel drums or tanks.

Geophysical investigations are most effective when used in conjunction with a drilling or boring program, and should not be considered a substitute for such programs. The information gained from a surface geophysical survey can be used to choose optimal locations for the placement of boreholes, monitor wells or test pits, as well as to correlate geology between wells and boreholes. The information derived from a geophysical survey can also be used to reduce the risk of drilling into buried drums or tanks.

The use of geophysical methods at hazardous waste and ground water pollution sites is a fairly recent development. In the past, many of these techniques were used in the mineral, geothermal and petroleum exploration industries. In recent years, the need to conduct ground water pollution investigations has coincided with improvements in the resolution, acquisition and interpretation of geophysical data. This process is ongoing; therefore, outlines of geophysical techniques and procedures are subject to revision as improvements are made in the instrumentation and interpretation algorithms.

Each geophysical method has its advantages and limitations. The combination of two or more techniques in an integrated interpretation results in a reduction of the degree of ambiguity. A comprehensive knowledge of the local geology and site conditions is necessary in order to select an effective geophysical method or methods, to plan a survey, and to interpret the data.

In some instances, site conditions may preclude the successful use of most or all geophysical techniques. These conditions include the presence of factors that degrade the ability of the geophysical instruments to measure various physical parameters. For instance, the presence of strong electromagnetic fields at site may preclude the use of some geophysical techniques. Under such instances the use of geophysics may not be recommended. However, the application of geophysical methods should not be entirely dismissed until an experienced geophysicist evaluates the site. Although geophysical techniques may not be directly applicable on-site, a geophysical survey of the area surrounding the site may be useful to assist in the understanding of the hydrogeology of the impacted area.

Each site must be considered unique. The project geophysicist should therefore evaluate all material at his or her disposal prior to the implementation of a geophysical survey plan. In addition to visiting the site, an examination of aerial photographs, geologic maps, well data, and other information is recommended. A “generic” approach to work plans should be avoided. Another practice that should be avoided is attempting to apply geophysical methods when inappropriate, merely because a poorly written proposal states that a geophysical survey must be performed to satisfy contractual obligations.

Performance guidelines for a total of eight surface geophysical techniques, in addition to borehole methods, are presented in this chapter. The surface methods include ground penetrating radar (GPR), magnetic, gravity, electrical resistivity, induced polarization (IP), electromagnetic (EM), very-low

frequency electromagnetics (VLF), and seismic methods. Other methods, not widely used in ground water pollution investigations, are not in this Chapter; these include spontaneous or self-potential (SP), controlled source audio-magnetotellurics (CSAMT), infrared (IR), and airborne geophysical methods. The reader should consult the literature for more information on these methods.

Metal detectors are not included in this Chapter because most are essentially electromagnetic systems whose response is an audio or visual feedback that is rarely recorded. These instruments may be useful immediately prior to excavation to relocate some anomalous areas. Although radiometric devices (scintillation counters and Geiger counters) and organic vapor analyzers can technically be considered geophysical instruments, they are more commonly referred to as health and safety monitoring devices, and are therefore not included in this chapter.

The reader is advised to consult the literature if additional information on a particular method is needed. The use of new geophysical techniques or algorithms is encouraged if the investigation addresses the problem and the work plan is within budgetary constraints.

The expertise of the Geophysics Section of the New Jersey Geological Survey is available to other State or Federal agencies. Assistance can be given in the following areas: preparation of Requests for Proposals, review of proposals, field quality control, and review of reports. Geophysical surveys may be performed on a case-by-case basis. A reasonable lead-time is a necessary courtesy required on all requests.

Requests for assistance should include all pertinent information, including a project activity code, and be sent in writing to the State Geologist, New Jersey Geological Survey, NJDEP.

8.2 Ground Penetrating Radar

8.2.1 Fundamentals

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The ground penetrating radar (GPR) method has been used for a variety of civil engineering, ground water evaluation and hazardous waste site applications. Of all geophysical techniques available, it is one of the most highly used and successful. It provides subsurface information ranging in depth from several tens of meters to only a fraction of a meter. A basic understanding of the function of the GPR instrument, together with knowledge of the geology and mineralogy of the site, can help determine if GPR will be successful in the site assessment. When possible, the GPR technique should be integrated with other geophysical and geologic data to provide the most comprehensive site assessment.

The GPR method uses a transmitter that emits pulses of high-frequency electromagnetic waves into the subsurface. The transmitter is either moved slowly across the ground surface or moved at fixed station intervals. The penetrating electromagnetic waves are scattered at changes in the complex dielectric permittivity, which is a property of the subsurface material dependent primarily upon the bulk density, clay content and water content of the subsurface (Olhoeft, 1984). The electromagnetic energy is reflected back to the surface-receiving antenna and is recorded as a function of time.

Depth penetration of GPR is severely limited by attenuation and/or absorption of the transmitted electromagnetic (radar) waves into the ground. Generally, penetration of radar waves is reduced by a shallow water table, high clay content of the subsurface, and in areas where the electrical resistivity of the subsurface is less than 30 ohm-meters (Olhoeft, 1986). Ground penetrating radar works best in dry sandy soil where a deep water table exists. Under optimal conditions, depth penetration is between one and ten meters (Benson, 1982).

The plot produced by most GPR systems is analogous to a seismic reflection profile; that is, the data are usually presented with the horizontal axis as distance units (feet or meters) along the GPR traverse and the vertical axis as time units (nanoseconds). The GPR profile should not be confused with a geologic cross section, which shows data as a function of horizontal distance versus depth. Some of the digital systems will present the data as a depth profile. Caution must be exercised when viewing data in this fashion as the equipment operator usually inputs conversion factors to view the data as a depth profile. Very high resolution (as great as + 0.1 meter) is possible using GPR. It is necessary to calibrate the recorded features with actual depth measurements from boreholes or from the results of other geophysical investigations for accurate depth determinations.

Under optimal conditions, GPR data can resolve changes in soil horizons, bedrock fractures, water-insoluble contaminants, geological features, man-made buried objects, voids, and hydrologic features such as water table depth and wetting fronts.

8.2.2 Advantages

Most GPR systems can provide a continuous display of data along a traverse, which can often be interpreted qualitatively in the field. GPR is capable of providing high-resolution data under favorable site conditions. The real-time capability of GPR results in a rapid turnaround, and allows the geophysicist to quickly evaluate subsurface site conditions.

8.2.3 Limitations

One of the major limitations of GPR is the site-specific nature of the technique. Another limitation is the cost of site preparation necessary prior to performing the survey. Most GPR units are towed across the ground surface. Ideally, the ground surface should be flat, dry, and clear of any brush or debris. The quality of the data can be degraded by a variety of factors such as an uneven ground surface or various cultural noise sources (such as strong electromagnetic fields). For these reasons, it is mandatory that the project geophysicists visit the site before a GPR investigation is proposed. The geophysicist should also evaluate all stratigraphic information available, such as borehole data and information on the depth to water table, clay layers, and so on in the survey area.

8.2.4 Instrumentation

There are several manufacturers of commercially available GPR systems. The specifications of the instrument should be documented or referenced in the investigation report. The frequency of the transmitting antenna can be selected to achieve either greater depth penetration using a lower frequency antenna, or increased resolution using a higher frequency antenna. Although most commercial antennas have some flexibility of frequency range, a reasonable estimation can eliminate the added cost of using additional transmitter units. Because GPR systems can be so diverse and complex in construction, a detailed description of the instrumentation is not practical in the context of this review. The reader is advised to consult the literature if a more detailed description is needed.

8.2.5 Survey Design, Procedure and Quality Assurance

GPR traverses should be positioned appropriately to resolve and locate the target. Depending upon the nature of the survey, a network of intersecting traverse lines (grid pattern) or reconnaissance traverse lines can be employed. The traverse data should note fixed positions, intersections with other traverses and objects on the surface. Beginning and end points of traverses must be surveyed from a known location, which can be recovered at a future date. The minimum requirements for this surveying can be accomplished using a Brunton-type compass and a measuring chain. Fea-

tures such as buildings, monitor wells, property lines, and sources of cultural interference should also be noted on the GPR profile and/or map. There should be a redundancy of data with parallel or intersecting traverses. The detection of a target should not rest solely on the interpretation of one traverse.

Continuous recording GPR systems permit high lateral resolution by moving the transmitter/receiver unit at different rates along the ground surface. Back-scattered interference of electromagnetic waves by objects near the transmitter/receiver units may preclude the use of vehicles or all-terrain vehicles to tow the instrument. If vehicles are used, it should be justified in the documentation and a comparison traverse (towed by hand versus by vehicle) should be conducted at the site.

Rough terrain along traverse lines can cause the antenna unit to transmit signals at deflecting angles, causing inaccuracies and interference. Because of this, the ground surface should be smooth along the traverse. Using unshielded antennas makes above ground interference more apparent in the data record.

Interference can be caused by electromagnetic transmissions from power lines and radio transmitters, or by the presence of other objects above the ground surface, including trees. A shielded antenna should be used when such objects exist at the site. Sources of interference should be noted on the traverse profile and in the report.

8.2.6 Data Reduction and Interpretation

Most of the systems today are digital and various numerical processing operations, similar to the processing of seismic reflection data, may be employed. These include, but are not limited to, digital filtering, velocity filtering, deconvolution, brute stack, and automatic gain-control scaling. However, there are analog systems in use and processing of analog-recorded (usually found on the older systems) data is mostly limited to playback of the recorded data at different frequency bandwidths using analog filters.

GPR profiles are often qualitatively evaluated, although it is also possible to make depth estimates as stated previously. A skilled geophysicist can often define shallow stratigraphy, soil horizons, and the water table when examining the profiles. Fill areas and other regions of overburden disturbance can also be inferred, as can buried man-made features such as drums, tanks, and pipelines. Non-metallic structures, such as concrete vaults, voids or concrete and ceramic pipes can also be identified, although differentiating between steel drums and similar reflectors is difficult.

8.2.7 Presentation of Results

Traverse sections included in the report should be detailed showing fix positions, labeled interpretations, surface landmarks intersected by the traverse, areas of poor data quality, and a vertical time/depth scale. The site map should be equally detailed and surveyed showing permanent landmarks for later inspection of the site. The report should also contain information pertinent to the instrumentation, field operations, and data reduction and interpretation techniques used in the investigation. Digital systems can be used to process and manipulate the data; therefore, all processing procedures should be noted on the profiles or elsewhere in a report.

8.3 Magnetics

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8.3.1 Fundamentals

A magnetometer is an instrument which measures magnetic field strength in units of gammas or nanoteslas (1 gammas = 1 nanotesla = 0.00001 gauss). Local variations, or anomalies, in the

earth's magnetic field are the result of disturbances caused mostly by variations in concentrations of ferromagnetic material in the vicinity of the magnetometer's sensor. A buried ferrous object, such as a steel drum or tank, locally distorts the earth's magnetic field and results in a magnetic anomaly. The common objective of conducting a magnetic survey at a hazardous waste or ground water pollution site is to map these anomalies and delineate the area of burial of the sources of these anomalies.

Analysis of magnetic data can allow an experienced geophysicist to estimate the regional extent of buried ferrous targets, such as a steel tank, canister or drum. Often, areas of burial can be prioritized upon examination of the data, with high priority areas indicating a near certainty of buried ferrous material. In some instances, estimates of depth of burial can be made from the data. Most of these depth estimates are graphical methods of interpretation, such as slope techniques and half-width rules, as described by Nettleton (1976). The accuracy of these methods is dependent upon the quality of the data and the skill of the interpreting geophysicist.

The magnetic method may also be used at a site to map various geologic features, such as igneous intrusions, faults, and some geologic contacts that may play an important role in the hydrogeology of a ground water pollution site.

8.3.2 Advantages

Advantages of using the magnetic method for the initial assessment of hazardous waste sites are the relatively low costs of conducting the survey, and the relative ease of completing a survey in a short amount of time. Little, if any, site preparation is necessary. Surveying requirements are not as stringent as for other methods, and may be completed with a transit or Brunton-type pocket transit and non-metallic measuring tape. Very often, a magnetic investigation is a very cost-effective method for the initial assessment of a hazardous waste site where steel drums or tanks are suspected of being buried.

8.3.3 Limitations

There are certain limitations in the magnetic method. One limitation is the problem of "cultural noise" in certain areas. Man-made structures that are constructed using ferrous material, such as steel, have a detrimental effect on the quality of the data. Features to be avoided include steel structures, power lines, metal fences, steel reinforced concrete, surface metal, pipelines and underground utilities. When these features cannot be avoided, their locations should be noted in a field notebook and on the site map.

Another limitation of the magnetic method is the inability of the interpretation methods to differentiate between various steel objects. For example, it is not possible to determine if an anomaly is the result of a group of steel drums or old washing machines. Also, the magnetic method does not allow the interpreter to determine the contents of a buried tank or drum.

8.3.4 Instrumentation

Several types of magnetometers are commonly used in hazardous waste site investigations. These include the total-field proton-precession magnetometer, the fluxgate magnetometer, and the magnetic gradiometer. The specific operation and construction of these various instruments may be found in the literature.

The type of magnetometer most commonly used in hazardous waste site investigations is the total-field proton-precession magnetometer. The quantity measured by this instrument is a scalar quantity consisting of the sum of the earth's field, the anomaly caused by the magnetic source, if any, and the variations of the field caused by diurnal drift, magnetic storms and micropulsations.

There is no instrument drift associated with this type of magnetometer. The sensor must be oriented with one side towards the North and it must be held stationary when the reading is being taken. The major advantages of the proton precession magnetometer are the ease of operation and the rapid cycling rate of the instrument. This rapid cycling rate allows the operator to take a reading of the magnetic field strength in about one to two seconds. Modern proton precession magnetometers have digital readouts and electronic data storage.

The fluxgate magnetometer is another type of magnetometer that may be used to locate buried ferrous objects. When used by a skilled operator, the fluxgate magnetometer can define the boundaries of regions of buried steel objects more precisely than the proton precession magnetometer. The fluxgate magnetometer can also be used in instances when a continuous record is needed. A fluxgate magnetometer can also be used to acquire readings at discrete locations. Unlike the proton precession magnetometer, the fluxgate magnetometer does not measure the absolute value of the earth's magnetic field. Also, the fluxgate magnetometer requires an exact orientation of the instrument and physically leveling the instrument requires more time and skill on the part of the operator. An additional disadvantage of the fluxgate is that it is subject to instrument drift.

Vertical magnetic gradiometers are magnetometers, which measure the vertical gradient, or difference, of the earth's total magnetic field. This differential magnetometer is usually a proton precession magnetometer with two or more sensors mounted on a staff. A constant distance vertically separates these sensors, usually one or one-half meter. A true gradiometer takes simultaneous readings from both sensors. Some instruments take readings from the upper and lower sensors sequentially. It is important that the sensor be held stationary during the cycling period.

Gradient measurements enhance the anomalies resulting from shallow magnetic sources. This feature may be important when conducting a survey in an area where steel drums are expected to be buried in a region underlain by ferromagnetically rich bedrock. Examples include igneous or certain types of metamorphic rocks. However, it is important that the site have little or no ferrous debris lying on the ground surface, because the signal from these surface features will also be amplified. The tendency of the gradiometer to enhance the effects of surface metal should be considered at sites where there is an abundance of surface metal which cannot be removed prior to the investigation.

8.3.5 Survey Design, Procedure and Quality Assurance

The importance of survey planning cannot be overemphasized. Often, the difference between a successful investigation and a disastrous one lies in the care given to the proper planning and design of the survey.

Magnetic data can be acquired in two configurations: 1) a rectangular grid pattern, or 2) along a traverse. Grid data consists of readings taken at the nodes of a rectangular grid; traverse data is acquired at fixed intervals along a line. Each configuration has its advantages and disadvantages, which are dependent upon variables such as the site conditions, size and orientation of the target, and financial resources. The survey configuration should be selected on a site-specific basis.

In both traverse and grid configurations, the station spacing, or distance between magnetic readings, is important. "Single-point" or erroneous anomalies are more easily recognized on surveys that utilize small station spacing. If large areas of buried drums or large steel tanks are the targets, the station spacing can be large, sometimes as much as 20 to 25 feet. If the target is a single 55-gallon steel drum, a small steel canister, or a steel munitions container, smaller station spacing is needed. In such instances, a station spacing of five to 10 feet is suggested.

In most instances involving the initial assessment of a site where drum burial is suspected, optimum station spacing is 10 to 15 feet. For a cost-effective initial assessment, magnetic data be acquired in a traverse configuration with a station spacing of approximately 15 feet and a distance between traverses of 25, 50, or even as much as 100 feet, depending on site conditions. If an anomaly is encountered, additional traverses can be placed between the existing traverses. Traverses are sometimes aligned in a northerly orientation in order to define the asymmetric anomaly usually associated with buried ferromagnetic material.

Grid or traverse coordinates must be surveyed from a known location, such as a property corner, building, or other point that can be recovered at a future date. In addition to features such as buildings, roads, monitoring wells, and property lines, sources of potential cultural interference should be noted on the map. Non-magnetic survey markers should be used to mark grid or traverse coordinates.

Provisions should be made for monitoring and/or correcting for diurnal variations. Various methods include recording the diurnal data with a base station monitor, or looping back to a base location or base line. The magnetometer base station or loop reference point should be located in an area that is free from cultural interference and away from any known ferrous material.

In the looping method, magnetic readings are taken at a base location with the field magnetometer during the course of the survey. Because these readings are repeated at the same location, the magnetic readings should be relatively consistent over a short period of time. These readings represent the normal diurnal variation of the earth's magnetic field. The diurnal correction assumes that the variation between the base location readings is linear. The magnetic survey data is corrected to the interpolations made from the base location readings. When the looping method is chosen instead of operating a base station magnetometer, effort should be made to loop back to a base location approximately every 30 minutes or less.

When a base station magnetometer is used, the diurnal is monitored more closely. The monitor can be programmed to record readings for various time intervals. Time intervals between readings can range from one to several minutes. The magnetic survey data is corrected for diurnal drift in a method similar to the looping method, except that the time interval between readings is usually less for the base station method. Thus, the base station method tends to allow for a more accurate correction.

Although the amplitude of typical diurnal variations do not approach the amplitude of anomalies associated with shallowly buried steel drums, monitoring the diurnal is a necessary quality assurance procedure. Large variations between readings taken at a base location may be indicative of magnetic storms, micropulsations, or instrument malfunctions. In such instances, the project geophysicist should recommend that the survey be suspended until the cause of the variations can be identified and eliminated.

The presence of cultural interference and surface metal, which cannot be removed from the site prior to the investigation, should be noted in the operator's field notes. Evaluation of the field notes by the geophysicist during the interpretation allows for a qualitative compensation for the effects of these features.

8.3.6 Data Reduction and Interpretation

The data should be corrected for diurnal variations, if necessary. If the diurnal does not vary more than approximately 15 to 20 gammas over a one-hour period, corrections may not be necessary.

However, this variation must be approximately linear over time and should not show any extreme fluctuations.

After the data has been corrected for diurnal, the record should be plotted in profile form. Extraneous points that coincide with surface metal or cultural features must be noted. The geophysicist may decide to remove these extraneous data points from the record before producing a contour map.

After examination of the profile and contour map data, the geophysicist will outline areas of probable ferrous material burial. Examples of the typical magnetic response of a target source can be found in Redford (1964) and Breiner (1973).

It is sometimes possible to determine the approximate depth of burial of the material based on the magnetic data. Graphical and computer-modeling techniques for estimating the depth of burial can be found in the literature.

The geophysicist should indicate which anomalies might be the result of features other than buried ferrous material. The remaining anomalies should then be prioritized, with high priority anomalies representing areas most probable of containing buried steel objects. Test pits and/or boring locations can then be chosen to confirm the presence of buried ferrous material.

8.3.7 Presentation of Results

The final results will be presented in profile and contour map form. Profiles are usually presented in a north-south orientation, although this is not mandatory. The orientation of the traverses must be indicated on the plots. Areas of probable ferrous material burial, indicating a high, low or medium priority will be indicated on the contour map, together with physical and cultural features. A listing of the magnetic data, including the diurnal monitor or looping data should be included in the report. The report must also contain information pertinent to the instrumentation, field operations, and data reduction and interpretation techniques used in the investigation.

8.4 Gravity

8.4.1 Fundamentals

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The gravity method involves measuring the acceleration due to the earth's gravitational field. These measurements are normally made on the earth's surface. A gravity meter or gravimeter is used to measure variations in the earth's true gravitational field at a given location. These variations in gravity depend upon lateral changes in the density of the subsurface in the vicinity of the measuring point. Because density variations are very small and uniform, the instruments used are very sensitive. The acceleration due to the earth's gravity is approximately 980,000 milligal (the unit of measurement commonly used in gravity surveys). Many gravity meters have a sensitivity of 0.01 milligal. This allows the detection of a change of one part in 100 million of the earth's gravitational field. The gravity method is useful in delineating buried valleys, bedrock topography, geologic structure and voids.

8.4.2 Advantages

An advantage of using the gravity method for site assessment is that gravity measurements are not as susceptible to cultural noise and hence data can be acquired in heavily populated areas. The main source of interference or noise that may effect gravity data are vibrations, which may be caused by vehicular traffic, heavy equipment, low flying aircraft and wind. Nevertheless, gravity readings can be taken in virtually any location, even indoors.

8.4.3 Limitations

A disadvantage of the gravity method is that each station has to be precisely surveyed for elevation and latitude control. This could be costly and time consuming, especially in surveys covering large areas. The accuracy of vertical and horizontal positioning is directly related to the resolution capabilities of the gravity method.

Many computations are involved in the reduction and interpretation of gravity data. The use of personal computers or programmable calculators is a practical necessity when dealing with many readings. Also, there are two unknowns that must be determined for the interpretation: 1) the density contrasts between the underlying material, and 2) the depths of the contacts between areas of density contrasts. Instrumentation

Gravity meters are extremely sensitive mechanical balances in which a mass is supported by a spring. Another spring counter-balances the mass to null the instrument. Small changes in gravity move the weight against the restoring force of the spring. Recent developments in gravity meter technology have greatly increased instrument versatility. Some new designs enable instruments to be automatically leveled, read, and to electronically store the data.

Most land gravity meters have a precision as great as 0.01 milligal (1 milligal = 0.001 cm/sec²). All readings of gravity meters are in arbitrary scale divisions, and calibration is necessary to express these scale divisions in milligal. The manufacturer usually does the calibrating of the gravity meter. Gravity meter springs are not perfectly elastic but are subject to a slow creep over long periods. Uncompensated temperature also effects the gravity meter. Spring creep, temperature compensation and earth tides cause variation of gravity readings with time. These temporal variations, known as drift must be compensated for prior to interpretation.

8.4.4 Survey Design, Procedure and Quality Assurance

Gravity survey design depends on specific site conditions and survey objectives. Gravity data can be collected in a grid configuration or along a traverse. In some instances, the grid data may not be regularly spaced due to inaccessibility. Irregularly spaced areola data may be useful to delineate or establish the existence of buried valleys where a precise determination of the depth is not required. Data should be collected beyond the area of interest to determine the regional gravity field.

It is preferable to collect gravity data along a traverse if a quantitative interpretation of bedrock topography is the objective. Smaller station intervals and greater topographic surveying accuracy can improve the resolution of the interpretation. For an error of +0.1 foot in elevation and +40 feet in latitude the error in gravity is approximately +0.01 milligal.

Measurements at a gravity base station near the survey area should be repeated at intervals of two hours or less for regional surveys and one hour or less for detailed microgravity surveys to correct for instrument drift and tidal effects. The base station should be established by repeated loops from the nearest know gravity base station. A listing of established base stations throughout New Jersey is available from the New Jersey Geological Survey.

A gravity meter, capable of being read to the nearest 0.001 milligal, should be used to minimize measurement error. Gravity station elevation and latitude should be surveyed to an accuracy of ±0.1 foot and ±40 feet, respectively. It is recommended that the gravity stations be surveyed for elevation and latitude control as soon as gravity measurements are taken so the data can be immediately reduced and modification can be made to the survey design, if necessary. Accuracy of gravity readings should be maintained by taking consecutive observations at each station until satisfactory duplication is obtained.

8.4.5 Data Reduction and Interpretation

Gravity observations have to be reduced to simple Bouguer gravity anomalies. Dobrin (1976) and Telford and others (1976) give the formulas used to perform these calculations. Reduction of gravity data involves the correction for tidal effects, instrumental drift, latitude, elevation and terrain.

The gravity readings at each station are converted to “observed gravity” by first correcting for tidal and instrumental drift. The theoretical gravity at sea level at each station is determined using the International Gravity Formula of 1930 (Dobrin, 1976) or the International Association of Geodesy Formula of 1967 (Telford and others, 1976). These formulas are used for latitude corrections. Latitude correction is applied where there is any appreciable north-south excursions of the stations.

The effect of the elevation of the station above sea level (or a reference datum) is determined by calculating the “free-air” and “Bouguer” corrections. The free-air correction compensates for the normal vertical gradient of gravity by applying a correction factor to the difference in elevation between the station and a reference datum. The free-air correction is added to the field reading when the station is above the datum and subtracted when below it. The Bouguer (pronounced ‘boogay’) or mass correction accounts for the gravity acceleration due to a mass of material between datum and station elevation. The Bouguer correction is subtracted from the gravity reading when the station is above the datum.

Terrain corrections are calculations that correct the gravity data to account for the deviation of topography from a horizontal surface. These corrections are required when the ground surface is very irregular in the vicinity of the gravity station - that is, hills rising above the gravity station and valleys lying below it. There are several graphical methods for calculating terrain corrections. The most commonly used are the Hammer (1939) template and tables. The terrain correction is added to the gravity reading. When the topography in the vicinity of the study area is gentle, terrain corrections are not required.

When all the corrections are made the resulting gravity value is called the “Simple Bouguer Gravity Anomaly.”

Gravity data can be analyzed using techniques that remove the regional gravity from the simple Bouguer gravity anomalies to obtain a residual gravity, which is more useful for gravity interpretation. There are various techniques to remove this regional gravity. Some techniques are graphical and others are analytical. Commonly used analytical techniques include surface fitting (polynomial or Fourier series), frequency filtering, and downward continuation.

Residualization (removal of the regional gravity) is one of the most important aspects in gravity interpretation and depends, to a large degree, on the experience of the interpreter. The residual gravity data is then used in the interpretation. For example, a trend of negative gravity anomalies may be due to a buried valley.

Modeling gravity data in profile form is useful in the calculation of the depth of various features and can be done by either forward or inverse algorithms. Software to model 2-dimensional gravity data is available from various sources, such as Ballantyne and others (1981). Talwani and others (1959) have developed the algorithm, which is most widely used.

The interpretation of gravity data is non-unique because there are many possible models that would result in the same gravity anomaly. Constraints, such as depths to rock obtained from well

information, rock densities, or other geophysical interpretations, are required during the modeling process to remove the ambiguity.

8.4.6 Presentation of Results

The final report should state the type of gravity meter, together with its accuracy and calibration requirements, used in the investigation. The accuracy of the topographic (elevation and location) surveying used should also be stated in the report. An explanation of the data reduction, modeling and interpretation programs or calculations used should also be presented.

The report should also include gravity profiles with the interpreted model, a Bouguer gravity anomaly map and a residual gravity map showing locations of various interpreted features. The profiles should show orientations and locations of gravity stations on a location map. A table of the gravity data should also be included. This table must contain station number, latitude, or north-south distance from base, longitude, elevation, observed gravity and simple Bouguer gravity anomaly of each station.

8.5 Electrical Resistivity

8.5.1 Fundamentals

The electrical resistivity method is used to map the subsurface electrical resistivity structure, which is interpreted by the geophysicist to determine geologic structure and/or physical properties of the geologic materials. The electrical resistivity of a geologic unit or target is measured in ohmmeters, and is a function of porosity, permeability, water saturation and the concentration of dissolved solids in pore fluids within the subsurface.

Electrical resistivity methods measure the bulk resistivity of the subsurface as do electromagnetic methods. The difference between the two methods is in the way that electrical currents are forced to flow in the earth. In the electrical resistivity method, current is injected into ground through surface electrodes, whereas in electromagnetic methods, currents are induced by the application of time-varying magnetic fields.

8.5.2 Advantages

A principal advantage of the electrical resistivity method is that quantitative modeling is possible using either computer software or published master curves. The resulting models can provide accurate estimates of depth, thickness and electrical resistivity of subsurface layers. The layered electrical resistivities can then be used to estimate the electrical resistivity of the saturating fluid, which is related to the total concentration of dissolved solids in the fluid.

8.5.3 Limitations

Limitations of using the electrical resistivity method in ground water pollution investigations are largely due to site characteristics, rather than in any inherent limitations of the method. Typically, sites are located in industrial areas that contain an abundance of broad-spectrum electrical noise. In conducting an electrical resistivity survey, the voltages are relayed to the receiver over long wires that are grounded at each end. These wires act as an antenna receiving the radiated electrical noise that in turn degrades the quality of the measured voltages.

Electrical resistivity surveys require a fairly large area, far removed from power lines and grounded metallic structures such as metal fences, pipelines and railroad tracks. This requirement precludes using this technique at many ground water pollution sites. However, the electrical

resistivity method can often be used successfully off-site to map the stratigraphy of the area surrounding the site. A general “rule of thumb” for electrical resistivity surveying is that grounded structures be at least half of the maximum electrode spacing away from the axis of the electrode array. Electrode spacing and geometry or arrays (Schlumberger, Wenner, and Dipole-dipole) are discussed in detail in the section below entitled, *Survey Design, Procedure, and Quality Assurance*.

Another consideration in the electrical resistivity method is that the fieldwork tends to be more labor intensive than some other geophysical techniques. A minimum of three crewmembers is required for the fieldwork.

8.5.4 Instrumentation

Electrical resistivity instrumentation systems basically consist of a transmitter and receiver. The transmitter supplies a low frequency (typically 0.125 to 1 cycles/second or “Hertz”) current waveform that is applied across the current electrodes. Either batteries or an external generator, depending on power requirements can supply power for the transmitter. In most cases, the power requirements for most commonly used electrode arrays, such as Schlumberger (pronounced “schlum-bur-zhay”) and Wenner arrays are minimal and power supplied by a battery pack is sufficient. Other electrode configurations, such as Dipole-dipole arrays, generally require more power, often necessitating the use of a power generator. The sophistication of receivers range from simple analog voltmeters to microcomputer-controlled systems that provide signal enhancement, stacking, and digital data storage capabilities. Most systems have digital storage of data. Some systems may require the field parameters to be input via PC (personal computer) prior to collection of the data. The trend in manufacturers of resistivity equipment is to have the entire system controlled from a PC or preprogrammed software built into the instrument.

8.5.5 Survey Design, Procedure and Quality Assurance

Survey design depends on the specific characteristics of the site and the objective of the survey. The three most common modes of electrical resistivity surveying are profiling, sounding, and profiling-sounding, each having its own specific purpose. If the purpose of the survey is to map the depths and thickness of stratigraphic units, then the electrical resistivity data should be collected in the sounding mode. Lateral electrical resistivity contrasts, such as lithologic contacts, can best be mapped in the profiling mode. In cases where the electrical resistivity is expected to vary both vertically and horizontally, such as in contaminant plume mapping, the preferred mode is profile sounding.

8.5.6 Sounding Mode

The two most common arrays for electrical resistivity surveying in the sounding mode are the Schlumberger and Wenner arrays. Electrode geometry for both arrays is shown in Figure 8.1. Increasing the separation of the outer current electrodes, thereby driving the currents deeper into the subsurface increases the depth of exploration.

8.5.7 Profiling Mode

The two most common arrays for electrical resistivity surveying in the profiling mode are the Wenner and dipole-dipole arrays. The electrode geometry for the Wenner array is the same as the sounding mode — the difference is that in profiling mode the entire array is moved laterally along the profile while maintaining the potential and current electrode separation distances.

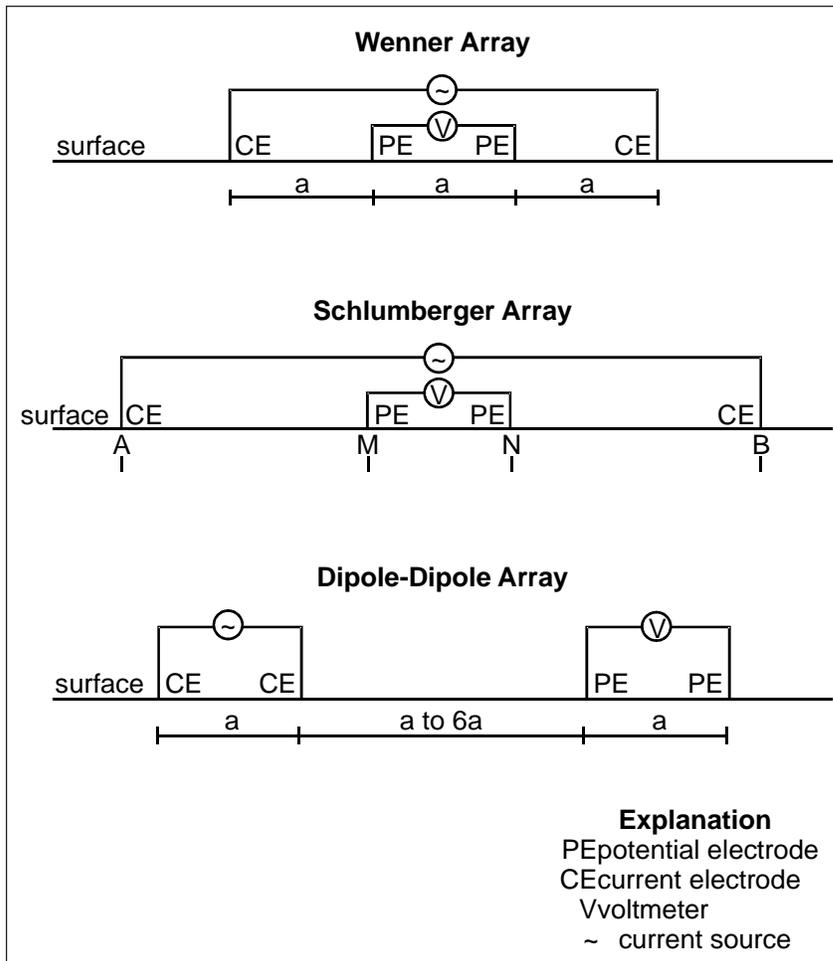


Figure 8.1 Common Arrays

The electrode geometry for the dipole-dipole array is shown in Figure 8.1. In the profiling mode, the distance between the potential and current dipoles (a dipole consists of a pair of like electrodes) is maintained while the array is moved along the profile.

8.5.8 Profiling-Sounding Mode

As in the profiling mode, the Wenner and dipole-dipole arrays are the most common arrays used in the profiling-sounding mode. As the name implies, this mode is a combination of the profiling and sounding modes.

In the Wenner array the typical field procedure is to collect the data in a succession of profiles, each having a different electrode separation. The resulting data therefore contains information about the lateral and vertical electrical resistivity variations.

In the dipole-dipole array, the typical field procedure is to transmit on a current dipole while measuring the voltages on up to six of the adjacent potential dipoles. When the data collection is completed for the particular transmitter dipole, the entire array is moved by a distance equal to one dipole separation and the process is repeated.

The most frequent source of inaccuracy in electrical resistivity surveying is the result of errors in the placement of electrodes when moving electrodes and/or expanding the electrode array. These distance measurement errors are easily detected on apparent electrical resistivity versus electrode separation curves and for this reason the apparent electrical resistivities should be plotted as the data is acquired in the field. A qualified field geophysicist will recognize these errors and direct the field crew to check the location of the electrodes.

The second most common source of error in electrical resistivity surveying is caused by the electrical noise generated by power lines. The most effective means of reducing power line noise is to minimize the contact electrical resistance at the potential electrodes. This can be easily accomplished by using non-polarizing potential electrodes along with wetting the soil under the electrode with water. Non-polarizing electrodes are recommended instead of metal potential electrodes, because the metal electrodes generate electrical noise due to oxidation reactions occurring at the metal-soil (pore water) interface.

8.5.9 Resistivity Data Reduction and Interpretation

Reducing electrical resistivity data is a simple process in which the apparent electrical resistivity is calculated by dividing the measured voltages by the applied current. The quotient is then multiplied by the geometric factor specific to the array used to collect the data. Once the apparent electrical resistivities have been calculated, the next step is to model the data in order geologic structure.

The method used to model the apparent electrical resistivity data is specific to each data acquisition mode. Electrical resistivity data acquired in the sounding mode, using either the Wenner or Schlumberger array, can be modeled using master curves or computer modeling algorithms. When using master curves, the interpreter attempts to match overlapping segments of the apparent electrical resistivity versus electrode separation plots with a succession of two-layer master curves. This modeling method provides coarse estimates of the model parameters, is time consuming, and requires skill on the part of the interpreter.

An alternative method of modeling sounding mode electrical resistivity data is to use readily available computer modeling software packages (Sandberg, 1990). There are a variety of different types of algorithms; some assume discrete electrical resistivity layers while others assume that electrical resistivity is a smooth function of depth. The discrete layer algorithms require interaction on the part of the interpreter, but allow for constraining model parameters to adequately reflect known geologic conditions. The continuous electrical resistivity algorithms are automatic, that is, they require no interaction on the part of the operator, and therefore geologic constraints cannot be incorporated into the models.

The modeling of profiling and profiling-sounding mode data is much more involved than in the case of sounding data. The profiling-sounding data reflects electrical resistivity variations in the lateral and vertical directions, resulting in a much more complicated computer simulation of the potential fields. The computer techniques capable of simulating these fields are finite difference, finite elements and integral equation algorithms. In the past, all of these techniques are extremely time consuming, and therefore expensive, and require a detailed understanding of the underlying physical principles on the part of the interpreter. PC based software is available to interpret these data, but caution should be exercised when using automatic interpretation routines: the inexperienced interpreter can make assumptions that will lead to a statistically accurate result, but not (necessarily) a correct geological interpretation. Generally, most profiling-sounding mode data is interpreted in a qualitative manner, with the accuracy of the interpretation being based solely on the experience of the geophysicist.

8.5.10 Presentation of Results

Listings of the electrode separations, current amplitudes, measured voltages and reduced apparent resistivities should be included in the report. Any specific information regarding the manner in which the data were reduced or modeled should be outlined in the report. As with data interpretation, presentation of the final results is specific to the mode of data collection.

8.5.10.1 Sounding Mode

The electrical resistivity data collected in the sounding mode are presented as a bilogarithmic plot of electrical resistivity versus the distance from the current electrodes to the center of the array. If the data were modeled, the apparent electrical resistivities, as calculated from the model, should be presented on the bilogarithmic plot with the observed apparent electrical resistivities. In addition, the model should be presented in a section plot.

8.5.10.2 Profiling Mode

Data collected in the profiling mode are presented in a plot of apparent electrical resistivity versus distance. Any modeling results, either using computer algorithms or by “rule-of-thumb” methods should be presented and include a legend indicating any parameter values.

8.5.10.3 Profiling-Sounding Mode

Data collected in the profiling-sounding mode are presented in pseudosection format in which the apparent electrical resistivity is plotted as a function of position and electrode separation. Any modeling results presented using either computer algorithms or qualitative methods should include a legend indicating parameter values.

8.6 Induced Polarization

8.6.1 Fundamentals

The induced polarization (IP) method is an electrical geophysical technique, which measures the slow decay of voltage in the subsurface following the cessation of an excitation current pulse. Basically, an electrical current is imparted into the subsurface, as in the electrical resistivity method explained elsewhere in this chapter. Water in the subsurface geologic material (within pores and fissures) allows for certain geologic material to show an effect called “induced polarization” when an electrical current is applied. During the application of the electrical current, electrochemical reactions within the subsurface material takes place and electrical energy is stored. After the electrical current is turned off the stored electrical energy is discharged which results in a current flow within the subsurface material. The IP instruments then measure the current flow. Thus, in a sense, the subsurface material acts as a large electrical capacitor.

The induced polarization method measures the bulk electrical characteristics of geologic units; these characteristics are related to the mineralogy, geochemistry and grain size of the subsurface materials through which electrical current passes.

Induced polarization measurements are taken together with electrical resistivity measurements using specialized IP instruments. Although the IP method historically has been used in mining exploration to detect disseminated sulfide deposits, it has also been used successfully in ground water studies to map clay and silt layers which serve as confining units separating unconsolidated sediment aquifers.

8.6.2 Advantages

Induced polarization data can be collected during an electrical resistivity survey, providing the proper equipment is used. The addition of IP data to a resistivity investigation improves the resolution of the analysis of resistivity data in three ways: 1) some of the ambiguities encountered in resolving thin stratigraphic layers while modeling electrical resistivity data can be reduced by analysis of IP data; 2) IP data can be used to distinguish geologic layers which do not respond well to an electrical resistivity survey; and 3) the measurement of another physical property (electrical chargeability) can be used to enhance a hydrogeologic interpretation, such as discriminating equally electrically conductive targets such as saline, electrolytic or metallic-ion contaminant plumes from clay layers.

8.6.3 Limitations

The induced polarization method is more susceptible to sources of cultural interference (metal fences, pipelines, power lines, electrical machinery and so on) than the electrical resistivity

method. Also, induced polarization equipment requires more power than resistivity-alone equipment – this translates into heavier and bulkier field instruments. The cost of an IP system can be much greater than a resistivity-alone system. This, plus an added amount of complexity in the interpretation of the IP data and the expertise needed to analyze and interpret this data may exceed the resources of some contractors and consultants.

Induced polarization fieldwork tends to be labor intensive and often requires two to three crew members. Like electrical resistivity surveys, induced polarization surveys require a fairly large area, far removed from power lines and grounded metallic structures such as metal fences, pipelines and railroad tracks.

8.6.4 Instrumentation

Induced polarization instruments are similar to electrical resistivity instruments. There are two different types of induced polarization systems. Probably the most common type of IP instrument is the “time-domain” system. This instrument transmits a constant electrical current pulse during which time the received voltage is sampled for an electrical resistivity measurement, acting like a conventional electrical resistivity system. The electrical current is then shut off abruptly by the system, and after a specified time delay (several milliseconds) the decaying voltage in the subsurface is sampled at the IP receiver, averaging over one or more time windows or “time gates.” The units of measurement are in millivolt-seconds per volt.

The second type of IP instrument is the “frequency-domain” system. In this type of system, transmitted current is sinusoidal at a specified frequency. Since the system is always on, only an electrical resistivity measurement can be collected at a particular frequency. To collect induced polarization data, two frequencies are used, and a percent change in apparent electrical resistivity from measurements collected at the two frequencies is calculated. This number is called the “percent frequency effect” or “PFE,” and the units are dimensionless in percent. Two frequencies commonly used are 0.3 and 3.0 Hertz, representing low and high frequency responses, respectively.

Other types of Induced polarization may be encountered, although not commonly in environmental applications. These include “spectral induced polarization,” “complex resistivity,” and “phase” systems. A detailed description of these systems is beyond the scope of this chapter and the reader is advised to consult the literature for an extensive discussion of these systems.

8.6.5 Survey Design, Procedure and Quality Assurance

Induced polarization survey design depends on the specific characteristics of the site and the objective of the survey. Like electrical resistivity investigations, the three most common modes of IP surveying are profiling, sounding, and profiling-sounding, each having its own specific purpose.

If the purpose of the survey is to map the depths and thickness of stratigraphic units, then the induced polarization data should be collected in the sounding mode concurrently with an electrical resistivity investigation. Lateral contrasts in electrical properties of the subsurface, such as lithologic contacts, can best be mapped in the profiling mode. In contaminant plume mapping, where subsurface electrical properties are expected to vary both vertically and horizontally, the preferred mode is profile sounding.

8.6.6 Sounding Mode

The two most common arrays for induced polarization/electrical resistivity surveying in the sounding mode are the Schlumberger (pronounced “schlum-bur-zhay”) and Wenner arrays. Electrode geometry for both arrays is shown in the “Electrical Resistivity” section of this chapter.

Increasing the separation of the outer current electrodes, thereby driving the currents deeper into the subsurface increases the depth of exploration.

8.6.7 Profiling Mode

The two most common arrays for induced polarization/electrical resistivity data collection in the profiling mode are the Wenner and dipole-dipole arrays. The electrode geometry for the Wenner array is the same as the sounding mode — the difference is that in profiling mode the entire array is moved laterally along the profile while maintaining the potential and current electrode separation distances.

The electrode geometry for the dipole-dipole array is shown in the “Electrical Resistivity” section of this chapter. In the profiling mode, the distance between the potential and current dipoles (a dipole consists of a pair of matching electrodes) is maintained while the array is moved along the profile.

8.6.8 Profiling-Sounding Mode

As in the profiling mode, the Wenner and dipole-dipole arrays are the most common arrays used in the profiling-sounding mode. As the name implies, this mode is a combination of the profiling and sounding modes.

In the Wenner array, the typical field procedure is to collect the data in a succession of profiles, each having a different electrode separation. The resulting data therefore contains information about the lateral and vertical electrical properties of the subsurface.

In the dipole-dipole array, the typical field procedure is to transmit on a current dipole while taking measurements. When the data collection is completed the entire array is moved one dipole separation and the process is repeated.

8.6.9 Data Reduction and Interpretation

Induced polarization data values obtained in the field indicate the bulk chargeability of the subsurface. Therefore, induced polarization data, represented either in millivolt-seconds/volt or PFE (percent frequency effect), require no data reduction.

When data are collected in the profiling or profiling-sounding modes, electrical resistivity and chargeability data from the Wenner and dipole-dipole arrays are most often merely plotted in profile form. The geophysicist plots the chargeability values on a pseudosection. The data of this pseudosection or “electric vertical section” are then contoured and qualitatively evaluated.

Similar to electrical resistivity data, complex computer modeling software can be used to interpret dipole-dipole data. However, due to the complications involved with such an interpretation, profile-sounding mode data are usually interpreted in a qualitative manner, with the accuracy or the interpretation being based solely on the skill and experience of the interpreting geophysicist.

Induced polarization and electrical resistivity data acquired concurrently in the sounding mode can be simultaneously modeled using layered-earth modeling software (Sandberg, 1990). Alternatively, the data can be compared to layered-earth master curves for induced polarization data for analysis.

8.6.10 Presentation of Results

Listings of electrode separation, current amplitude, and chargeability should be included in the report. Any specific information regarding the manner in which the data were reduced or modeled

should outlined in the report. As with data interpretation, presentations of the final results are specific to the mode of data collection.

A site map showing location(s) of the electrical soundings and/or profiles and physical features of the site (buildings, wells, and so on) should be included in the report. If the data are modeled an electrical section plot should be included, together with the modeling results, and a legend indicating the parameter values.

Data collected in the profiling-sounding mode should be presented in pseudosection format.

8.7 Electromagnetics

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8.7.1 Fundamentals

The electromagnetic method is a geophysical technique based on the physical principles of inducing and detecting electrical current flow within geologic strata.

Electromagnetics (EM) should not be confused with the electrical resistivity method. The difference between the two techniques is in the way that the electrical currents are forced to flow in the subsurface. In the electromagnetic method, currents are induced in the subsurface by the application of time-varying magnetic fields, whereas in the electrical resistivity method, current is injected into the ground through surface electrodes. The electromagnetic method measures the bulk conductivity (the inverse of resistivity) of subsurface material beneath the instrument's transmitter and receiver coils. Electromagnetic readings are commonly expressed in conductivity units of millimhos/meter (pronounced "milly-moes per meter") or milliseimens/meter (1 millimho = 1 milliseimen). A "mho" is the reciprocal of an ohm.

Electromagnetics can be used to locate pipes, utility lines, cables, buried steel drums, trenches, buried waste, and concentrated contaminant plumes. The method can also be used to map shallow geologic features such as lithologic changes, clay layers, and fault zones.

8.7.2 Advantages

Most electromagnetic equipment used in ground water pollution investigations is lightweight and easily portable. Measurements can be collected rapidly and with a minimum number of field personnel. The electromagnetic method is a technique commonly used on ground water pollution investigations.

Most electromagnetic instrumentation now commonly in used has the capability to electronically store data. This capability provides for a greater degree of accuracy than older analog-readout instruments and also allows for faster data collection.

8.7.3 Limitations

The main limitations of the electromagnetic method when used for hydrogeologic purposes (mapping contaminant plumes, clay layers, and geologic contacts) are cultural noise. Sources of cultural noise can include large metal objects, buried cables, pipes, buildings, and metal fences. However, some of these objects, which are considered sources of interference when an electromagnetic investigation is used for hydrogeologic mapping, can be successfully delineated in their own right. Therefore, electromagnetics can successfully be used to map buried steel drums, tanks, pipelines and so on, although the presence of these objects will effectively mask the more subtle response of most geologic features.

Lateral variability in the geology can also cause conductivity anomalies or lineations. These features can easily be misinterpreted as a contaminant plume.

8.7.4 Instrumentation

The most common type of electromagnetic system used in ground water pollution site investigations consists of coplanar transmitter and receiver coils with fixed separation. Typically, increasing the coil separation increases the depth of exploration. Most systems have only a few discrete allowable coil separations in order to internally process the data for the output to be in conductivity units (millimhos/meter). Some systems produce an output in units of secondary field as a percentage of the primary field.

Electromagnetic equipment commonly used in ground water pollution investigations operates in the frequency domain, where the current flowing in the transmitter coil is sinusoidal with time, running at a fixed frequency. Most electromagnetic equipment allows measurement of both the “in-phase” (or “real”) component and 90° “out-of-phase” (or “quadrature”) components of the induced magnetic field.

Another type of electromagnetic equipment used more for regional ground water studies, minerals exploration, and geologic mapping is called “transient” or “time-domain” electromagnetic (TEM, or TDEM) equipment. This equipment operates in the time-domain, where a transmitted current is kept on long enough to create a steady-state magnetic field in the earth, and is then shut off. Currents, which are thereby induced to flow in the ground, then dissipate with time. The secondary magnetic field associated with these dissipative currents is sampled at a remote receiver as a function of time after transmitter shut-off.

8.7.5 Survey Design, Procedure and Quality Assurance

A qualified geophysicist should oversee all aspects of the survey, including data collection, processing, and interpretation. Survey planning is very important in order to obtain accurate and useful information. Poor planning and survey design results in meaningless data.

Electromagnetic data can be acquired in two configurations: 1) rectangular grid pattern, or 2) along a traverse or profile. Grid data consists of readings taken at the nodes of a rectangular grid and traverse data is acquired along a line. Each configuration has its advantages and disadvantages, which are dependent upon variables such as the site conditions, size and orientation of the target, and so on. The survey configuration should be selected on a site-specific basis.

With both grid and profiled data, the station interval is important. If an electrically conductive contaminant plume is to be investigated, the station interval should ensure that several stations (preferably five or more) are within the anomalous zone. Also, the station interval near the suspected edge of the plume should be adjusted so that an accurate resolution of the conductivity gradient is made. Station intervals away from the anomalous area can be expanded if low variability is observed in the data. In general, station intervals are not required to be constant, and can be modified very easily during the survey by noting the instrument responses and adjusting the station interval accordingly.

Traverse length and grid sizes are two parameters very crucial to an effective investigation. It is necessary to extend data collection far enough beyond the conductive target to obtain background levels, and to understand background variability.

Grid or traverse coordinates must be surveyed from a known location, such as a property corner, existing well, building or other point, which can be referenced at a future date. Features such as buildings, roads, monitoring wells, property lines, and potential sources of cultural interference should be noted. General features of the surface topography should also be included, because the readings are often dependent upon water-table depth and overburden thickness.

Readings should be considered inaccurate (unless known to be otherwise) when the midpoint between the transmitter and receiver coils is within four coil separations from a metal fence, pipeline, power line, or other source of cultural noise. Evaluation of the field notes by the geophysicist during the interpretation allows for a qualitative compensation for the effects of these features.

When electromagnetic data are collected for the purpose of modeling the data for a geologic model of two or more layers (as opposed to locating shallow clay layers, plumes, buried drums or other metallic objects) readings should be collected at a single station for at least three different coil separations. Meaningful quantitative depth determinations cannot be obtained using a single frequency, coil separation, or orientation. When the objective of the survey is to locate a metallic conductor, in-phase readings should be collected. Out-of-phase readings are more applicable when mapping electrically conductive contaminant plumes, shallow clay layers, near-surface geologic contacts or similar targets.

8.7.6 Data Reduction and Interpretation

Instrument readings in millimhos/meter need no further data reduction because they are already in units corresponding to the bulk conductivity of the subsurface. Data can be interpreted using two layer master curves or computer algorithms. It should be noted that layer determinations require a different field procedure than profiling or areal mapping. A detailed description of these procedures can be found in the literature. Profile or traverse data can be qualitatively interpreted by comparison to published modeling results or computer modeling programs (Sandberg, 1988).

Depth of penetration is less in the vertical coplanar (horizontal dipole) configuration than in the horizontal coplanar (vertical dipole) configuration. The horizontal coplanar configuration is more commonly used and is recommended to compare results with other geophysical survey results. Depth of penetration is roughly considered to be one-half the coil separation, whereas in actuality it is a complex function of conductivity structure, coil separation and orientation, and transmitter frequency.

8.7.7 Presentation of Results

Grid data should be presented in profile and contour map form, showing the contour interval and the scale of the profile plots. Traverse data should be presented in profile form, and include the scale of the plots. Location of the traverses should be indicated on a site map. Areas of probable drum burial or contaminant plume position, indicating a high, low, or medium priority, should also be indicated on the contour map, together with physical and cultural features. It is recommended that a listing of the electromagnetic data be included in the report. The report should also contain information pertinent to the instrumentation, field operations, and data reduction and interpretation techniques used in the investigation.

8.8 Very-low Frequency (VLF) Electromagnetics

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8.8.1 Fundamentals

The very-low frequency (VLF) electromagnetic method detects electrical conductors by utilizing radio signals in the 15 to 30 kiloHertz (kHz) range that are used for military communications. The VLF method is useful for detecting long, straight electrical conductors, such as moderate to steeply dipping water-filled fractures or faults.

The VLF instrument compares the magnetic field of the primary (transmitted) signal to that of the secondary signal (induced current flow within the subsurface electrical conductor). In the absence

of subsurface conductors the transmitted signal is horizontal and linearly polarized. When a conductor is crossed, the magnetic field becomes elliptically polarized and the major axis of the ellipse tilts with respect to the horizontal axis (McNeill, 1988). The anomaly associated with a conductor exhibits a crossover. As with other frequency domain electromagnetic systems, both the in-phase (“real” or “tilt-angle”) and the out-of-phase (“imaginary,” “ellipticity,” or “quadrature”) components are measured.

A number of VLF transmitting stations operated by the military are located worldwide; the most commonly used in North America are Annapolis, Maryland (21.4 kHz), Cutler, Maine (24.0 kHz), and Seattle, Washington (24.8 kHz) stations. Commercially available VLF systems utilize one or more of these transmitting stations for survey applications.

8.8.2 Advantages

The VLF method is very effective for locating zones of high electrical conductivity, such as mineralized or water-filled fractures or faults within the bedrock. Structures such as these often act as conduits along which ground water and contaminants flow. The information from a VLF investigation can be used to optimally locate monitor and/or treatment wells in order to intercept these hydrologic conduits.

Another advantage of VLF is that data collection is fast, inexpensive and requires a field crew of only one or two people.

8.8.3 Limitations

The VLF method is affected by all electrical conductors, including those that are man-made (power lines, wire fences, pipes, and so on). The bearing or direction from the VLF transmitting station to the intended target must be located nearly parallel to strike (or long axis) of the conductor, or intended target for it to be detected. Unfortunately there are only a limited number of transmitting stations available with enough primary field strength to be usable, thus limiting the direction that traverses can be collected. Therefore, the geometry of the target, the survey traverses and the bearing to the VLF transmitting station(s) must be resolved in the survey plan.

VLF transmitting stations often shut down for scheduled and unscheduled maintenance. If this happens, another transmitting station may have to be used or data collection may have to be halted until the transmitting station resumes operation. Care must be taken to make sure that the antenna of the VLF receiver is correctly and consistently oriented (always oriented in the same direction for all stations of a traverse).

8.8.4 Instrumentation

VLF instruments have historically fallen into two types. Early instruments were hand-held, and measured the tilt-angle of the major axis of the magnetic field polarization ellipse. This angle is obtained by rotating the instrument until a null is obtained (indicated audibly through a speaker); then, the angle is read from an inclinometer mounted on the instrument case. Some instruments of this type also could provide reading indicating the magnitude of the maximum in-phase component.

More recent instruments are either belt or backpack mounted due to the increased weight of batteries needed for microprocessors which control these devices. These instruments measure both in-phase and quadrature components of the ratio of horizontal-to-vertical magnetic field. Some instruments have real-time interpretive capability for use while still collecting data.

In either case, the measured quantity is such that variations in the source field over time (from atmospheric fluctuations or actual signal-strength changes) are normalized out and the resulting information is repeatable hour-to-hour or day-to-day.

8.8.5 Survey Design, Procedure and Quality Assurance

VLF data are normally collected along traverses, and anomalies are correlated from traverse to traverse. When planning a VLF survey several considerations must be taken into account. First, is the target's strike direction. Traverses must be located perpendicular to strike so those anomalous zones can be compared to background levels. Every effort should be made to avoid putting traverses in areas that contain a number of cultural features that may mask anomalies associated with the intended target. Second, consideration must be given to which transmitting stations are available for use during the survey. The direction toward the transmitting station must be nearly perpendicular to the traverse (or in line with the strike of the target).

When designing a survey, several traverses should be placed parallel to one another and close enough (25 to 50 feet apart) so that anomalies can be correlated from traverse to traverse. It is crucial that traverses are long enough that the entire anomaly caused by the target is covered and the readings return to a background level. Data can be collected on a grid; however, the data must be collected along grid lines that are perpendicular to the target. Station spacing should be close enough together that the entire form of the anomaly can be observed (15 to 30 feet).

Each traverse must be accurately located on a map and related to a point or landmark that can be recovered later.

During data collection, care must be taken to properly orient the VLF receiver antenna and to consistently collect data facing the same direction. Failure to do so will result in anomalies that do not "cross-over" in the proper sense and could result in improper interpretation of these data. Careful field notes should be kept while collecting data, noting the location of any cultural features (including buried pipes, wire fences, power lines, fieldstone or concrete walls, and building foundations). Keeping careful and observant field notes will save time when interpreting the data.

If the transmitter stops transmitting during data collection, another transmitter may have to be used. If this happens, the entire traverse should be read again using the new transmitter station. In some cases, another transmitter that is located in the correct orientation may not be available. In this instance, data collection will have to cease until the transmitter station resumes operation. It is best if the same transmitter station can be used during the entire survey, because strength and orientation of different transmitters can lead to slightly different shaped anomalies, making the data more difficult to interpret.

To ensure data quality and to help in data interpretation, it is suggested that readings be taken along the traverse using more than one transmitting station. This does not add significantly to the amount of time it takes to collect data. Often it improves the accuracy of the interpretation.

8.8.6 Data Reduction and Interpretation

Most commonly used VLF interpretation methods are qualitative. Data collected in the field can be interpreted without further data reduction. By plotting the "real" and "imaginary" components versus distance along a traverse, an experienced geophysicist can often interpret where fractures or zones of high electrical conductivity are located.

Filtering techniques are often used to enhance data and make tilt-angle crossovers easier to identify. Two commonly used filtering methods include the Fraser filter (Fraser, 1969) and the Karous-Hjelt filter (Karous and Hjelt, 1985). The Fraser filter simply converts tilt-angle cross-

overs into peaks. The Karous-Hjelt filter calculates the equivalent source current at a given depth, commonly known as current density. This current density position can aid in the interpretation of the width and dip of a fracture with depth. Commercial programs are available to calculate and plot data using the Karous-Hjelt filter. Using such a program, current density can be plotted with respect to depth and gray-tone plots can be created to further aid in interpretation.

In order to determine the strike direction of a fracture it is necessary to have two traverses (preferably more) close enough to one another so that the same anomaly can be correlated from one traverse to the other. By stacking sets of profiles it is then possible to correlate fractures or conductive zones across the entire survey area. Once the strike direction of a fracture has been determined, the fracture can be projected along strike to determine if it intersects any areas of interest. Projecting fracture zones along strike can also aid in determining where to place monitor and/or treatment wells, or where contaminants can migrate in a fracture-flow system.

More quantitative methods of interpretation include curve matching. Vozoff and Madden (1971) developed a number of interpretive curves that can help in the interpretation of VLF data. Simple, numerical forward modeling can be accomplished done using formulas found in Telford and others (1976). It must be emphasized that when modeling, a number of assumptions are made some of, which may be incorrect in a given situation.

If enough parallel traverses are collected it is possible to contour the data to further aid in identifying zones of increased conductivity. If the data is to be contoured, filtered data should be used so that the zones of increased conductivity correspond to “highs” on the contour map.

8.8.7 Presentation of Results

The report should explain the methods and the reasoning behind the methods used for data collection. Explanations for what transmitting station was used, the traverse station spacing and field procedures should be discussed in the report. Any problems encountered during data collection (such as a transmitting station shutting down or excessive atmospheric interference) should be noted.

The most common way to present VLF data is to plot the “real” and “imaginary” component values on the y-axis and distance along a traverse on the x-axis of a plot. Plots for each traverse should appear in the appendix of the report. All of the plots should be drafted at the same vertical and horizontal scales for consistency and ease of comparison. The location of cultural features, as well as areas interpreted as fracture zones should also be indicated on annotated plots.

The locations of the traverses should be shown on a base map. It is also useful to identify anomalies interpreted as fracture zones on the map. The correlation of anomalies from traverse to traverse should also be indicated on the map, in order to delineate the continuation of interpreted fractures.

8.9 Seismic

8.9.1 Fundamentals

Surface seismic techniques used in ground water pollution site investigations are largely restricted to seismic refraction and seismic reflection methods. The equipment used for both methods is fundamentally the same and both methods measure the travel-time of acoustic waves propagating through the subsurface. In the refraction method, the travel-time of waves refracted along an acoustic interface is measured. In the reflection method, the travel-time of a wave which reflects off an interface, is measured. The advantages, limitations, and other details of each method are discussed separately below.

The interpretation of seismic data will yield subsurface velocity information, which is dependent upon the acoustic properties of the subsurface material. Their acoustic properties or velocities can categorize various geologic materials. Depth to geologic interfaces can be calculated using the velocities obtained from a seismic investigation. The geologic information gained from a seismic investigation can then be used in the hydrogeologic assessment of a ground water pollution site and the surrounding area. The interpretation of seismic data can indicate changes in lithology or stratigraphy, geologic structure, or water saturation (water table). Seismic methods are commonly used to determine the depth and structure of geologic and hydrogeologic units (for example, depth to bedrock or water table), estimate hydraulic conductivity, detect cavities or voids, determine structure stability, detect fractures and fault zones, and estimate rippability. The choice of method depends upon the information needed and the nature of the study area. A geophysicist who is experienced in both methods, is aware of the geologic information needed by the hydrogeologist, and is also aware of the environment of the study area must make this decision.

8.9.2 Instrumentation

Both refraction and reflection data are acquired using a seismograph. A seismograph records the arrival of reflected and refracted seismic waves with respect to time. These waves are detected at the surface by small receivers (geophones), which transform mechanical energy into electrical voltages. The voltages are relayed along cables to the seismograph, which records the voltage output versus time, much like an oscilloscope.

There are a variety of seismographs used in the industry. Engineering seismographs are the most common types of seismograph used in ground water pollution site investigations. Each seismograph has different capabilities to handle data that is dependent on the number of “channels” in the seismograph. Seismographs are available with one, six, twelve, twenty-four or forty-eight channels, or as many channels as desired (usually the number of channels is a multiple of six). Each channel records the response of a geophone or array of geophones. Other capabilities of a seismograph may include analog or digital recording, frequency filters, electronic data storage, and signal enhancement hardware.

On multichannel systems, geophone stations are located at established distances along the seismic cable; on single channel systems, the geophone is moved to the next station after each shot. Geophones are coupled to the ground, usually by a small spike attached to the bottom of the geophone. Care must be taken in the placement of geophones; each geophone gives the best response when the axis of the geophone element is positioned vertically with the attached spike driven firmly into the ground. Geophones are manufactured at different natural frequencies depending upon the desired result. High natural frequency geophones (usually greater than 30 hertz) are used when collecting shallow reflection data and lower natural frequency geophones are used in refraction surveys. More detail on this can be found in Dobrin (1976).

There are many types of seismic sources used to impart sound into the earth. The most common type of source in seismic investigations for ground water pollution studies is a sledgehammer and strike plate. Other sources include explosives, shot gun shells detonated in shallow augerholes, and various mechanical devices that shake the ground or drop large weights. The types of sources used are dependent on the signal versus noise ratio in the survey area. Noise can come from vehicular traffic, people or animals walking near the geophones, electrical current in the ground (electromagnetic interference which affects the geophone cables), low-flying aircraft, or any sound source. Generally, the noise can be overcome by using a larger source, which effectively increases the signal. Filtering on the seismograph can also reduce noise.

8.9.3 The Seismic Refraction Method

Seismic refraction is most commonly used at sites where bedrock is less than 500 feet below the ground surface. Seismic refraction is defined as the travel path of a sound wave through an upper medium and along an interface and then back to the surface, as shown in 8.2. A detailed discussion of the seismic refraction technique can be found in Dobrin (1976), Telford and others (1985), and Musgrave (1967).

8.9.3.1 Seismic Refraction Advantages

The seismic velocity of a geologic horizon can be determined from a seismic refraction survey, and a relatively precise estimate of the depth to different acoustic interfaces (which may be related to a geologic horizon) can be calculated.

Seismic refraction surveys can be useful to obtain

depth information at locations between boreholes or wells. Subsurface information can be obtained between boreholes at a fraction of the cost of drilling. Refraction data can be used to determine the depth to the water table or bedrock. Refraction surveys are useful in buried valley areas to map the depth to bedrock or thickness of overburden. Sites in the northern portion of New Jersey are generally well suited for the seismic refraction method.

The velocity information obtained from a refraction survey can be related to various physical properties of the bedrock. However, rock types have certain ranges of velocities and these velocities are not always unique to a particular rock type. For instance, some dolomites and granites have similar seismic velocities. However, seismic velocity data can allow a geophysicist to differentiate between certain units with divergent seismic velocities, such as shales and granites.

8.9.3.2 Seismic Refraction Limitations

The seismic refraction method is based on several assumptions. To successfully resolve the subsurface using the refraction method the conditions of the geologic environment must approximate these assumptions. These conditions include the following: 1) the seismic velocities of the geologic layers increase with depth; 2) the seismic velocity contrasts between layers is sufficient to resolve the interface; 3) the geometry of the geophones in relation to the refracting layers will permit the detection of thin geologic layers, and 4) the apparent dip of the units or layers is less than ten to fifteen degrees. If these conditions are not met, accurate depth information will not be obtained.

There are several disadvantages to collecting and interpreting seismic refraction data. Data collection can be labor intensive. Also, large line lengths are needed — as a general rule, the distance from the shot, or seismic source, to the geophone stations (or geophone “spread”) must be at least three times the desired depth of exploration.

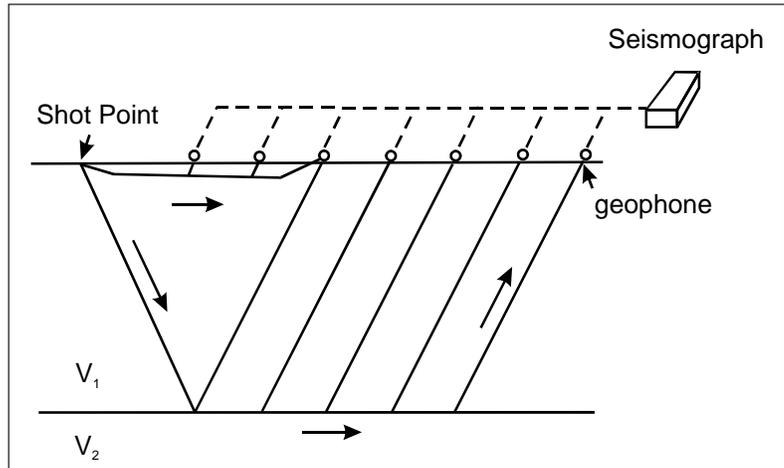


Figure 8.2 Seismic Refraction

8.9.3.3 Seismic Refraction Survey Design, Procedure and Quality Assurance

Survey design is site dependent and must be planned so that the geometry of the geophone spread will allow the target to be resolved. A primary limitation of the refraction method on many sites is that long refraction traverses are sometimes required. The spacing of the geophone stations within the spread can vary from several feet to tens of feet, depending on the depth of the geologic layer and required resolution. A closer spacing of geophones within the spread is chosen when a higher resolution of a shallow target is the objective. Shotpoints should extend along the entire traverse length and show a redundant sampling of the resolved interfaces. Care must be taken to maintain quality control on distance measurements. Small differences in horizontal displacements can cause a considerable change in the interpretation.

The geophone stations should lie along as straight a line as possible (for profile data). Deviations from a straight path will result in raypath projection inaccuracies. This will affect the accuracy of the survey. Also, deviations in elevations will cause errors in the calculations. Shotpoint and geophone elevations must be surveyed using a level or transit if variations in elevation occur along the traverse. These elevations are used in the static elevation corrections of the refraction data. Elevations to the nearest half-foot are adequate for most purposes.

A diligent field procedure will result in optimum results and will eliminate problems when processing and interpreting data. The geophysicist must be aware of any problems encountered during the survey, which may degrade the quality of the data. Modification of the original survey plan may become necessary if problems are encountered in the field. The field geophysicist should fill out an “observers log” listing pertinent information. An example of an observer’s log is shown in Figure 8.3.

8.9.3.4 Seismic Refraction Data Reduction and Interpretation

Static elevation corrections must be made when there are significant changes in topographic relief along the traverse. Failure to make elevation corrections will simply transfer those differences in elevation to the interpreted results or otherwise cause errors in the interpreted results. The geophone and shotpoint elevations obtained from the leveling or surveying are used to compensate for travel-time differences caused by the changes in shotpoint and geophone elevations. Corrections should also be made when the geophone stations deviate from a straight line.

Seismic refraction data can be interpreted graphically or with the aid of a computer. There are multitudes of interpretation schemes for seismic refraction data, depending upon the method and desired results. A detailed description of each interpretation algorithm is beyond the scope of this report but an overview of many of the methods can be found in Musgrave (1967) and other literature cited in the *References And Suggested Reading* section of this chapter.

8.9.3.5 Seismic Refraction Presentation of Results

The interpretation should be presented in profile form and in contour map form when a grid of data is collected. The contour map should include all information pertinent to the site, including locations of buildings, property lines, roads, and other cultural and physical features. Locations of the traverses should also be indicated on the site map. Traverse sections or profiles should include details showing fixed positions, labeled interpretations, surface landmarks intersected by the traverse, areas of poor data quality, and a vertical time/depth scale.

A listing of the seismic data, including the elevation data, time-picks (where applicable), and the respective layer velocities should be included in the report. A brief description of the survey

Tape Erased

Processed Raw Data

County-Line-S.P. # _____

Observer's Log

Tape # _____

Slide # _____

File # _____

Line # _____

Shotpoint # _____

Geophone _____ Hz

Source: Hammer
 Explosives (lb.)
 Dynasource
 Buffalo Gun

Refraction _____ / _____

Reflection _____

C D P
 Wide Angle
 Common Offset
 V S P

Well # _____

County _____

Project _____

Date _____ / _____ / _____

Quad Sheet _____

Latitude _____

Longitude _____

Field Personnel _____

Weather _____

Shotpoint Offset _____ ft.

Sweep Time _____ ms.

Delay Time _____ ms.

Filters HP _____ ms.
LP _____

Notch _____

Prog. Gain _____ ms.

	SP	1	2	3	4	5	6	7	8	9	10	11	12
elevation													
geophone													
gains													
# enhancements													
# EX													
polarity													

Trace Interval _____

Enter S.P. (*) location & distance to first geophone

○ --- ○ --- ○ --- ○ --- ○ --- ○ --- ○ --- ○ --- ○ --- ○ --- ○ --- ○

Remarks _____

Figure 8.3 Observer's Log

procedure, instrumentation, and data reduction and interpretation procedures should also be included in the report. If the original survey plan has been altered, the reasons for the alteration should also be explained in the text. The best report will contain not only the positive results of the investigation, but will also detail the limitations and negative results encountered during the investigation.

8.9.4 The Seismic Reflection Method

In the seismic reflection method, a sound wave travels down to a geologic interface and reflects back to the surface, as shown in Figure 8.4. Reflections occur at an interface where there is a change in the acoustic properties of the subsurface material.

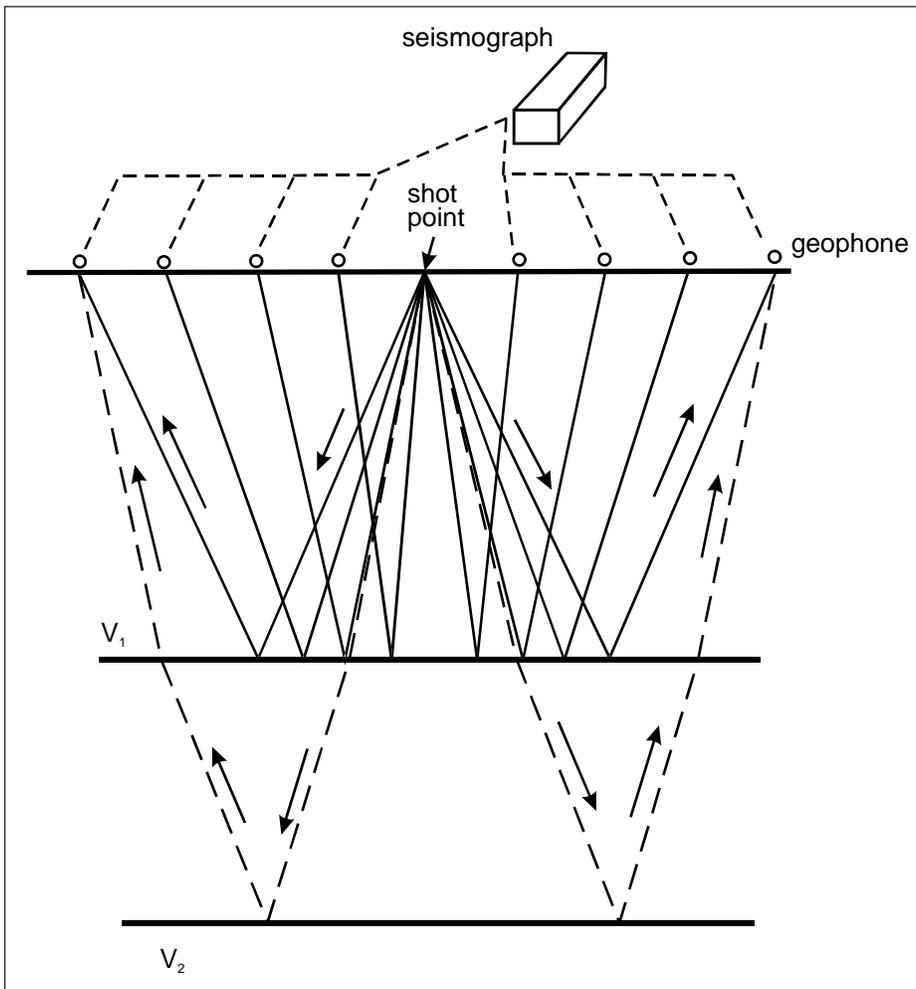


Figure 8.4 Seismic Reflection

8.9.4.1 Seismic Reflection Advantages

The seismic reflection method yields information that allows the interpreter to discern between fairly discrete layers. The reflection method has been used to map stratigraphy. Reflection data is usually presented in profile form, and depths to interfaces are represented as a function of time. Depth information can be obtained by converting time sections into depth from velocities obtained from seismic refraction data, sonic logs, or velocity logs. The reflection technique requires much less space than refraction surveys. The long offsets of the seismic source from the geophones, common in refraction surveys are

not required in the reflection method. In some geologic environments reflection data can yield acceptable depth estimates.

8.9.4.2 Seismic Reflection Limitations

The major disadvantage to using reflection data is that a precise depth determination cannot be made. Velocities obtained from most reflection data are at least 10% and can be 20% of the true velocities.

The interpretation of reflection data requires a qualitative approach. In addition to being more labor intensive, the acquisition of reflection data is more complex than refraction data.

The reflection method places higher requirements on the capabilities of the seismic equipment. Reflection data is commonly used in the petroleum exploration industry and requires a large amount of data processing time and lengthy data collection procedures. Although mainframe computers are often used in the reduction and analysis of large amounts of reflection data, recent advances have allowed for the use of personal computers on small reflection surveys for engineering purposes. In most cases, the data must be recorded digitally or converted to a digital format, to employ various numerical processing operations. The use of high resolution reflection seismic methods places a large burden on the resources of the geophysicist, in terms of computer capacity, data reduction and processing programs, resolution capabilities of the seismograph and geophones, and the ingenuity of the interpreter. These factors should be carefully considered before a reflection survey is recommended.

8.9.4.3 Seismic Reflection Survey Design, Procedure, And Quality Assurance

Because the seismic reflection method is extremely dependent upon the geology and physical conditions of the site, a thorough evaluation of the survey area, including a site visit and review of all available geologic data, is necessary.

There are many different seismic energy sources, geophone and shotpoint array configurations, and survey plans that may be used in a particular investigation. However, there is no “best” survey plan. Due to the many variables in site conditions and reflection survey parameters, each site must be evaluated separately. Only a geophysicist with substantial experience in high-resolution reflection seismology is able to prepare such a site-specific survey plan. Experience can be substantiated by the presentation of case histories where reflection has been used successfully.

Several generalities with respect to instrumentation and field procedure should be followed. The seismograph should be able to record data digitally, and signal enhancement and filtering capabilities are often necessary. The geophysicist should choose a seismic source that not only imparts a sufficient signal, but also generates a minimum airwave. The seismic sources used in reflection surveys are the same as those used in refraction work. A comparison of various high-resolution seismic reflection sources can be found in the literature (Miller and others, 1896).

Shotpoint and geophone locations should be surveyed for elevation control. Elevations should be surveyed to the nearest half-foot. As mentioned in the *Seismic Refraction* section, the geophone stations should lie along a straight line, with the geophones properly coupled to the ground.

A complete discussion of survey design and field procedures would be too lengthy to include in this report. A good discussion of these parameters can be found in Coffeen (1978).

The field geophysicist should be able to make changes to the initial survey plan if necessary. These changes should be discussed in detail with the State geophysicist prior to implementation.

8.9.4.4 Seismic Reflection Data Reduction and Interpretation

Seismic reflection must be corrected for static elevation and normal moveout. In some instances, dip moveout corrections can be applied. Dip moveout corrections are applied in areas where the dip of the reflecting layer is several degrees from horizontal. A complete discussion of the many methods of data reduction and interpretation is beyond the scope of this outline, but can be found in Dobrin (1976), Coffeen (1978), and Telford and others (1985).

8.9.4.5 Seismic Reflection Presentation of Results

The final report should present the results of the investigation as outlined above in the *Seismic Refraction Presentation of Results* section.

8.10 Borehole Geophysical Methods

8.10.1 Introduction

There are various borehole tools, probes, or sondes that can be used for logging wells. Most borehole methods are based on the same principles as surface geophysical methods. It is recommended that borehole geophysics be done on all wells drilled, and kept as a permanent record. The two most commonly used borehole methods in the water well industry are natural gamma ray and resistivity logs.

8.10.2 Advantages

Borehole methods supply an abundance of subsurface information. Information on the stratigraphy, hydrogeology and contamination of ground water at a site can often be derived from the borehole logs. In addition to the initial assessment of the subsurface conditions at a site, borehole information can sometimes be used to monitor the remediation of a site.

8.10.3 Limitations

Borehole logging can be expensive. One must realize that information from borehole logs only comes from a limited radius around the well (no more than 1 to 3 feet); if subsurface conditions vary between wells, discrepancies may have to be qualitatively evaluated. In addition, some geophysical logging tools must be used in uncased or ungrouted wells. Certain logging tools require different borehole conditions. The advantages, limitations, and requirements of each borehole method must be considered when planning the investigation. The site/case manager should therefore request the assistance of a geologist or geophysicist with experience in borehole methods throughout the investigation. Likewise, a responsible party or consultant proposing to perform borehole geophysics should include specific details of the proposed method(s) in the work plan submitted to the appropriate site/case manager in the Site Remediation Program.

8.10.4 Types of Borehole Tools

Geophysical logging devices can be categorized into five major types: 1) natural gamma ray and self-potential devices, 2) resistivity/induction devices, 3) porosity/density devices, 4) mechanical devices and 5) acoustic/optical/radar devices. Categories 1, 2, and 4 are more commonly seen in ground water studies because they are relatively inexpensive and easily handled. Porosity/density devices (category 3) can sometimes yield more information, but they are generally expensive and some require careful handling due to the radioactive sources required for their operation. Category 5 logging methods are relatively recent methods but have much potential in providing useful information in the groundwater industry. Each of the five categories will be discussed briefly below.

8.10.4.1 Gamma Ray and Self Potential (SP) Devices

A natural gamma ray (scintillation) detector contains a sodium iodide crystal that gives a flash of light when struck by a gamma ray. The results of a gamma ray log are in counts per second. Nearly all natural gamma rays in the earth come from potassium isotope 40 and decay products of uranium and thorium. Natural gamma rays are usually highest in shales and clays. A typical gamma ray log from the New Jersey Coastal Plain will often show peaks at the clay layers.

However, a small amount of clay or sand can sometimes yield a high response. This may be due to feldspar, glauconite or mica in the sand or sandstone, which will increase the count rate. In addition, the gamma ray log cannot easily distinguish between interbedded sequences of thin clays and sands and silty or clayey sand. Thus, a quantitative estimate of the amount of clay or sand in a layer cannot be obtained from a natural gamma ray log by itself. The interpretation of natural gamma ray logs is strictly qualitative and information from other logging tools (and soil and rock samples) should be considered along with the gamma ray results.

Gamma ray tools can be used in uncased, steel-cased, and PVC-cased holes. However, it should be noted that casing shields some of the gamma rays, thus, lowering the count rate compared to that in uncased holes. Likewise, water in the borehole can shield some of the gamma rays and both the water level and the casing (e.g., in an open-hole bedrock well) can be discerned with the gamma log.

Self-potential or SP tools measure a voltage difference between a fixed surface electrode and a probe in the borehole. The voltage difference is usually caused by electrochemical action between two electrolytes of different concentrations. Such a condition will occur when the borehole probe passes between porous sand and clay. The boundary between the two layers occurs at the inflection point on the log curve. SP data cannot be quantified and shows a relative response. SP tools cannot be used in either PVC or steel-cased holes. They also cannot be used above the water table, i.e., in air-filled boreholes.

8.10.4.2 Electrical Resistivity and Induction Devices

There are several different kinds of logging devices that will be discussed in this category: 1) resistance, 2) fluid conductivity, 3) normal, 4) lateral, 5) laterolog, and 6) induction tools. For the most part, normal and lateral resistivity logs are commonly used in ground water studies. Resistance logs may be seen in some older reports. Induction and laterologs have been used in the mining and oil industry, but these tools are generally too large (length and width) and too expensive to be applicable to ground water studies. However, electromagnetic induction tools have recently been developed for groundwater applications. Induction tools do not require a fluid-filled hole, as resistivity tools do.

Electrical resistance logs or single-point resistance logs measure the electrical resistance between an electrode in the borehole and one on the surface. Resistance logging has a small radius of investigation and essentially measures the electrical resistance at the in-hole electrode. The method is most useful in locating fractures. However, this method can give variable data on different logging runs due to oxidation and reduction on the in-hole electrode that changes the resistance across the surface of the electrode. The electrode configuration is the same as the SP device and data are normally acquired while running the SP device.

Fluid conductivity or resistivity devices measure the electrical resistivity of the borehole fluid. These tools are called conductivity logs to avoid confusion with resistivity logs. Even though they measure resistivity, resistivity is the inverse of conductivity (see 8.5 *Electrical Resistivity* or 8.7 *Electromagnetics*). The tool measures the voltage drop across two closely spaced electrodes. Conductivity logs are most useful when correlated to other electrical logs to obtain a true resistivity of a formation. Conductivity gradients may also be directly correlated to water-quality measurements or recharge areas. The fluid conductivity or fluid resistivity tools and the temperature tools are logged down hole to preserve the stratification in the fluid.

Normal resistivity devices are constructed as shown in Figure 8.6. The principle of operation and physics are similar to surface resistivity measurements. It must be understood that the

electrode spacings are built into tools or sondes, resulting in a fixed distance of investigation. There are two types of normal resistivity devices: long-normal (64 inches between the “A” and “M” electrodes), and short-normal (16 inches between the “A” and “N” electrodes). The short-normal sonde yields information about the borehole and the drilling mud invaded zone of the borehole, and the long-normal yields information further into the formation. This log is also run with the SP device.

Lateral resistivity devices are constructed as shown in Figure 8.5. The configuration of the electrodes is different from that of normal resistivity devices, but the potential is still measured between “M” and “B” electrodes. The lateral sonde has one additional electrode that acts as an electrical ground and assists in noise rejection. The lateral sonde allows for resistivity to be measured further into the formation. The distance of investigation beyond the side of the borehole is roughly equal to the A-O spacing as shown in Figure 8.7. Thin, high resistivity beds are difficult to detect and the true resistivity is difficult to determine from this log, but it can be estimated.

Laterologs (focused current devices) are similar to the normal device except the current is focused into the formation by two extra electrodes as seen in Figure 8.5. This tool is generally designed to work best in 8-inch boreholes and when the ratio between the true resistivity and resistivity of the mud is greater than 100 to one. The best feature of the tool is that it gives a

sharp response at layer boundaries and is often used for thin-bed resolution. Laterologs are not used extensively in ground water investigations.

Induction devices are discussed with electrical resistivity tools in this outline even though induction devices are electromagnetic tools. The principle of operation is similar to surface electromagnetic methods. The devices use high-frequency electromagnetic energy (see Figure 8.7), and measure the conductivity of the formation. For the principle of operation, see the section on surface geophysical methods dealing with electromagnetics. Induction tools can be run in either dry or fluid-filled holes, and they can also be used in PVC-cased holes. Until recently, induction tools were primarily used in

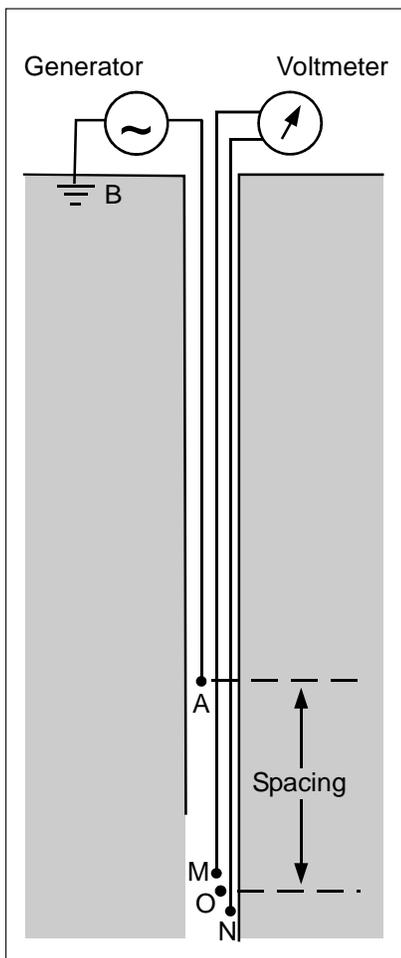


Figure 8.5 Lateral Resistivity Sonde

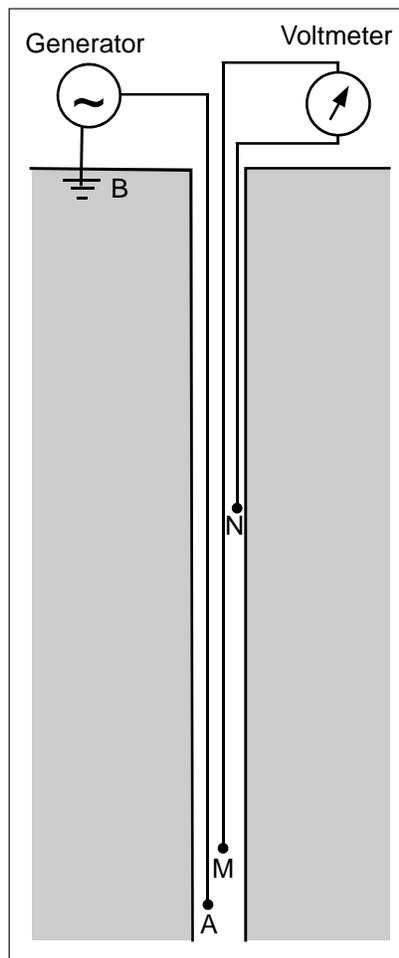


Figure 8.6 Normal Resistivity Sonde

the petroleum industry. A smaller tool is now available with a total length of 36 inches as opposed to six- to eight-foot-long tools used in the past.

8.10.4.3 Porosity/Density Devices

This category includes sonic, gamma-gamma (density), and neutron logs. These tools are not used as extensively in ground water studies as the methods previously outlined, but they can provide an abundance of subsurface information, when used with other logs, including determining the lithology and type of fluid in the formation (water versus hydrocarbons), as well as porosity.

Velocity or sonic logs measure the transit time of elastic waves for a short distance, usually one-foot. The unit of measurement is referred to as “Delta T” or DT [(DT) = microseconds per foot = velocity in 1×10^{-6} feet/second]. There is a relationship between DT and the density, lithology, and porosity of the geologic material. Usually, higher DT values indicate that the sound wave is traveling slower, and this implies a less dense formation. This could indicate an increase in formation porosity or change in lithology. In some instances, fractures and/or vuggy porosity can be determined. A basic sonic system involves one transmitter and two or three receivers, as shown in Figure 8.8. The transmitter emits elastic sound waves, and pulses at a constant amplitude and frequency. The transmitter pulses 15 times per second. As with surface seismic methods, rocks can be categorized by the velocities. Density is an important factor controlling velocity, and density is influenced by porosity. Sonic logs can be used in cased holes to locate areas of poor cement bond to the casing (cement bond logs).

Gamma-Gamma Ray logs or “density” logs are not commonly used in ground water studies. However, these logs may be seen on some investigations. The device is similar to the natural gamma ray tool because it also detects gamma rays, but the gamma-gamma ray tools use a radioactive source (Cesium 137) to generate gamma rays. Count rates are inversely proportional to bulk electron density, therefore, the higher the count rate, the lower the bulk density. The tool consists of one source and two detectors. If there is a mudcake on the side of the borehole, the short detector and the long detector will exhibit different counts. The gamma-gamma tool only measures on one side of the borehole and in one direction. If the density varies across the

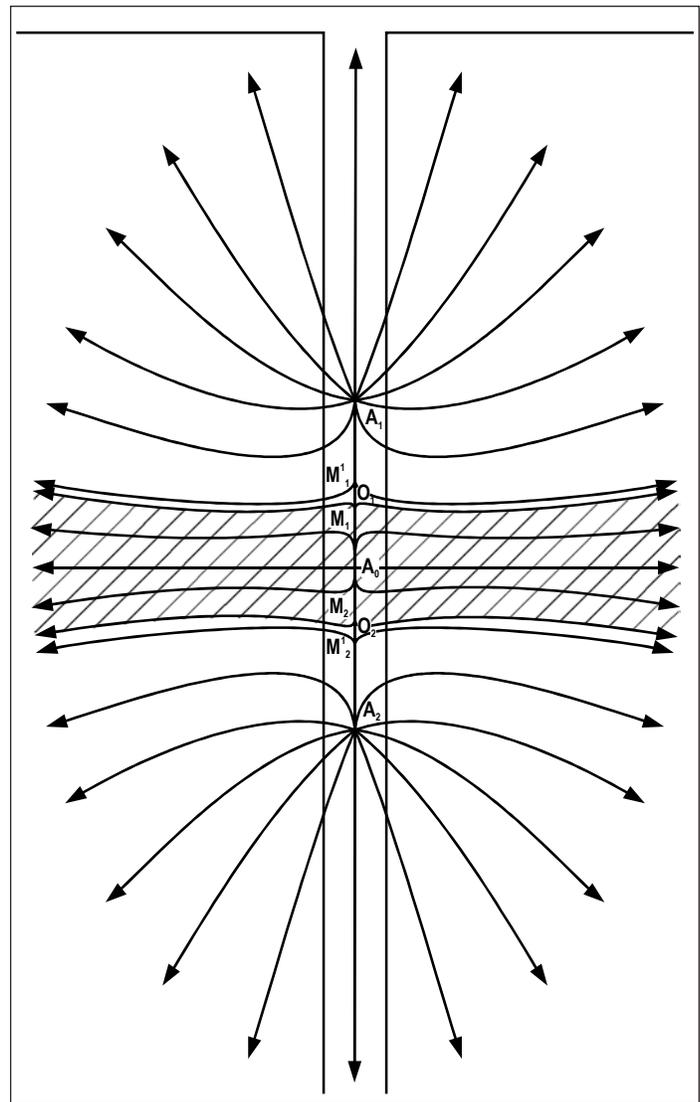


Figure 8.7 High Frequency Electromagnetic Energy

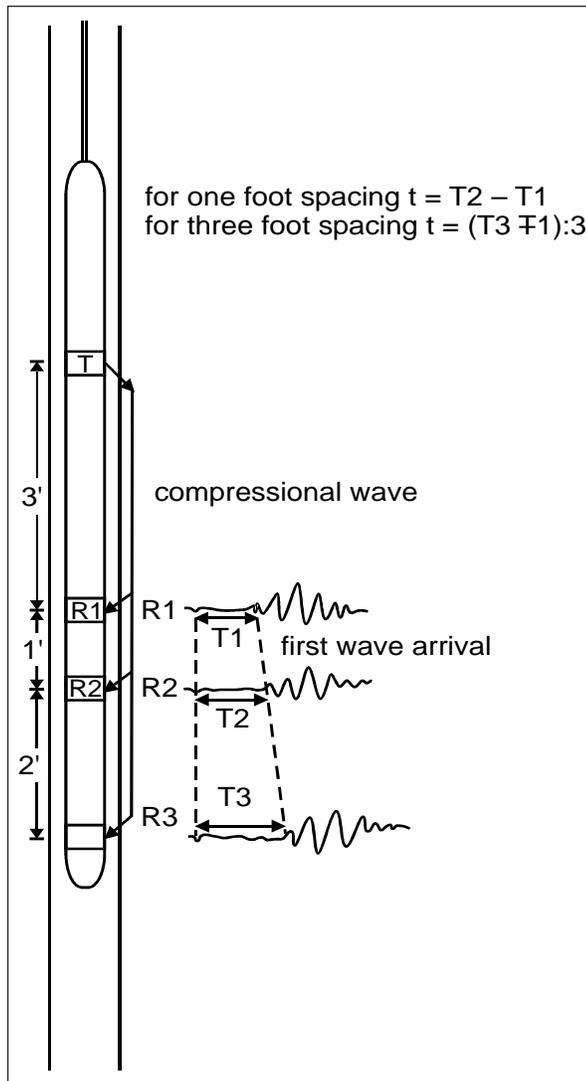


Figure 8.8 Basic Sonic System

borehole, a variation will result in the data from subsequent logging passes. These tools can be used in cased holes but are more effective in open holes. However, they can be used effectively to evaluate the integrity of cement and bentonite grouts in cased holes.

Neutron logs are essentially hydrogen-ion detectors. Because water is partially composed of hydrogen, neutron logs can be used to locate water-bearing zones or water-filled fractures. These tools also require a radioactive source to operate, and are not commonly used in ground water investigations. The radioactive source in the tool is a combination of americium and beryllium. A neutron device radiates neutrons into a formation. The neutrons collide with other particles and the more they collide, the slower they travel. The greatest loss of energy of the neutron will occur when it strikes a hydrogen ion, because their masses are almost identical. Once the neutron has lost some energy, it will reach a thermal energy level. At the thermal energy level, the neutron will gain as much energy as it loses. However, the neutron is easily captured in this state, and once captured (absorbed), the neutron gives off a high-energy gamma ray to maintain a steady state of energy. Neutron tools may detect fast neutrons, with energies at just about the thermal level, thermal neutrons, gamma rays, or a combination of all these. Hydrogen is the main absorber of neutrons. Therefore, a neutron device is essentially a hydrogen-ion detector. High concentrations of hydrogen occur in water and hydrocarbons. Therefore, the neutron log

has potential for identifying whether free and/or residual product is present in an aquifer. There are many types of neutron devices, and some can be used in cased holes, others only in open holes, depending upon the detector.

8.10.4.4 Mechanical Devices

This category includes caliper, dipmeter, flowmeter, and temperature logging devices.

A caliper tool is a simple device that measures the diameter of the borehole by using a spring-loaded arm that applies constant pressure to the side of the borehole as the tool is brought up the hole. This tool can indicate sections of the borehole where cave-ins and washouts occur. It is necessary to know the open-hole diameter when running other geophysical tools. In most cases, a geophysical tool will yield a different response when the borehole is widened.

A dipmeter is a magnetically oriented tool (oriented with respect to magnetic north) that consists of four or more caliper arms with micro-conductivity electrodes that are pressed against the borehole. The data are used to collect information on the orientation (e.g., strike and dip) of planar features (e.g., bedding planes, cross-bedding, fractures, faults, etc.) encountered in the

borehole. The method was developed and is primarily used in the petroleum industry. The dip meter log includes a presentation of dip angle and direction of the feature with respect to depth (e.g., tadpole plots). The data can also be plotted as rose diagrams of azimuth frequency.

A flowmeter measures the vertical movement of fluid in the borehole. A rotor or impeller measures fluid movement. The flowmeter can be used to detect hydraulic head differences between two aquifers, or can be used to determine if an artesian system exists. These devices typically have lower measurement limits of about 2 meters per minute. However, newer flow meters are now available with lower measurement limits of less than 0.03 m/min. These include heat-pulse, or thermal, flow meters and electromagnetic flow meters. These flow meters can be used under static water-level conditions and pumping conditions to develop hydraulic-conductivity profiles of aquifers.

Temperature logs are used to relate temperature differences in the borehole to fluid movement. This tool, along with the fluid conductivity or fluid resistivity tools, are designed to log the hole on the trip down the borehole rather than up the borehole. This tool should be run several days (preferably weeks) after the water in the hole has been disturbed by pumping or other logging devices. Disturbing the water will cause large changes in the temperature gradient. Temperature gradients can be correlated to water flowing into and out of wells. Temperature logging has been effectively used for mapping fractures.

8.10.4.5 Acoustic, Radar and Optical Devices

Acoustic devices include velocity/sonic devices (discussed above under porosity/density devices), cement-bond logs and acoustic televiewer devices. All acoustic devices must be used in fluid-filled boreholes as the fluid in the borehole allows propagation of the sound waves.

Cement-bond logs use sound to measure the acoustic travel time and reflected amplitude of sound waves in the borehole emitted by the cement-bond log tool. These are used to evaluate the integrity of the cement-to-casing and cement-to-formation bond. The method was developed in the petroleum industry.

The acoustic televiewer provides a magnetically oriented, 360-degree, photograph-like image of the acoustic reflectivity of the borehole wall. Televiewer logs, which indicate acoustic transit time and reflected amplitude (like cement-bond logs), can be obtained from both water- and mud-filled boreholes. Like dipmeter logs, they can be used to determine fracture and bedding orientation as shown in Figure 8.9 below and dip angle and direction data can be plotted with respect to depth (tadpole plots) and in azimuth frequency diagrams.

Borehole radar provides a method to detect fracture zones at distances as far as 30 meters or more from the borehole in electrically resistive rocks. Fracture zones with electrical properties that differ from the surrounding non-fractured rock are excellent radar reflectors. Radar measurements can be made in a single borehole (transmitter and receiver in same borehole) or by cross-hole tomography (transmitter and receiver in separate boreholes). Single-hole, directional radar can be used to identify the location and orientation of fracture zones. Cross-hole tomography including radar velocity and attenuation can be used to delineate fracture zones between boreholes. The movement of a saline tracer through fracture zones can also be monitored by borehole radar.

Optical methods include conventional video logs and optical televiewer logs. Video logs have been used to inspect sewer lines and, in recent years, have been used to inspect monitor wells and open-hole bedrock formations.

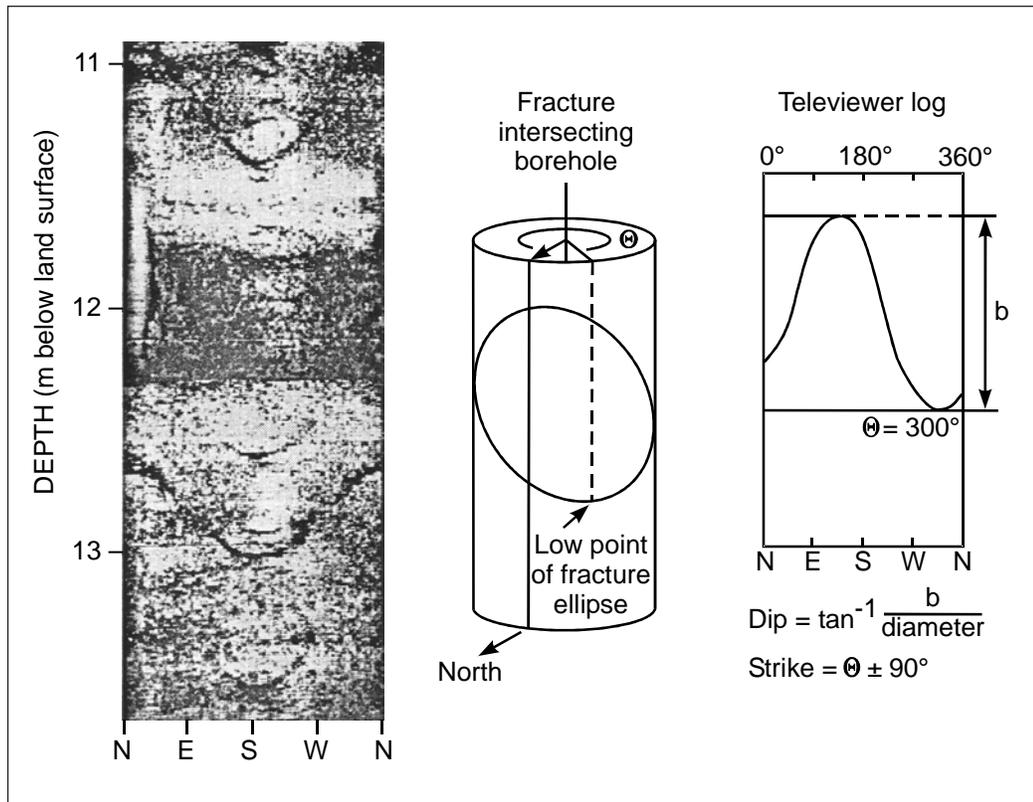


Figure 8.9 Magnetically oriented, acoustic-amplitude image of borehole wall generated from an acoustic televiewer. Fracture strike and dip are determined from depth scale and magnetic orientation. Source: Morin et. al., 1997.

Optical televiwers are similar to acoustic televiwers in that they provide a magnetically oriented, 360-degree image of the borehole wall. A video system is used to record the image on video tape. The information is also recorded digitally which allows evaluation of the strike and dip of planer features in the same way that

acoustic data are evaluated (see Figure 8.10). An advantage of the optical televiewer over the acoustic televiewer is the higher resolution of the recorded images. However, use of the optical televiewer is limited to situations where rather clear water is present in the borehole. High turbidity levels can reduce the resolution of the images. In these situations, use of the acoustic televiewer is necessary, as it can be used in both water- and mud-filled boreholes. In addition, some optical televiwers have limits on their effectiveness in large-diameter boreholes (e.g., greater than nine inches). An advantage of the use of the optical televiewer is that an oriented “virtual core” can be viewed (see Figure 8.10). This information can be used to supplement the collection of actual rock core, negate the need to collect oriented rock core, or may even be used in place of collecting rock core, reducing the cost of the bedrock investigation.

8.10.5 Quality Assurance

Certain logging tools require different borehole conditions. The requirements of the logger must be discussed with the driller during the planning of the drilling program. Topics, which must be discussed, include depth and width of the hole, casing material, and cementing or grouting of the hole.

Well-logging equipment is generally expensive and can be complicated to use. Consequently, only a few companies own or operate equipment. Except for temperature, fluid conductivity or resistivity, and video logging, well logging should be done coming up the borehole and not on the downward trip. There is the possibility that the tool may get caught on the sides of the borehole and slack the lines if logging is done going down the hole.

Electrical tools, such as SP, resistivity, and induction logging devices, are generally susceptible to the same types of interference as those methods used for surface geophysics. Buried cables, high-tension lines and cathodically protected tanks and pipelines cause electrical current to be shown on the logs. Usually, the current frequency is 60 cycles and at the same regular frequency which can be seen as an overprint on the curves. Generally, useful information can be extracted from the curves even though there is a 60-cycle overprint because the 60-cycle noise is of much higher frequency than the desired curve. The surface electrode should be kept as far away as possible (at least 100 feet) from the borehole to avoid electrode geometry effects.

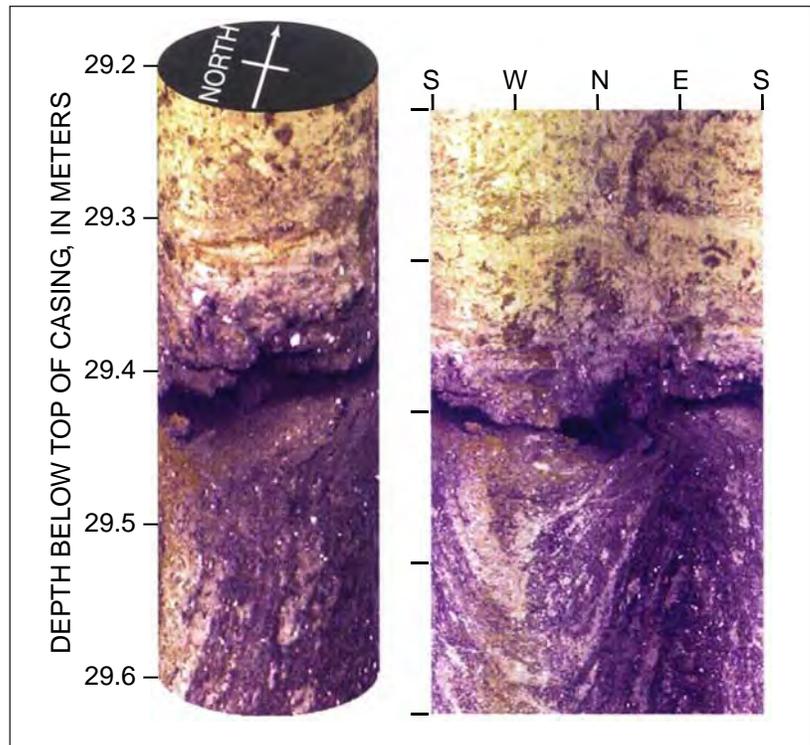


Figure 8.10 “Virtual core” wrapped (left) and unwrapped (right) images of a bedrock fracture at a depth of 29.4 meters collected with a digital television camera. The images show that the fracture is at the contact between pegmatite and gneiss. Source: USGS, 1998.

Sonic, neutron, and gamma-gamma ray logs are susceptible to “wash-outs” in the open hole (e.g., detectors may receive radiation directly from a nuclear source in a rough hole). These logs should be correlated to a caliper log to determine the hole diameter. An anomalous response seen on the density/porosity logs could be erroneous due to variations in the borehole diameter.

Generally, geophysical logging is recommended at all sites and for every well drilled. Geophysical logs are a consistent standard (assuming that the logging tools are calibrated regularly), as opposed to a driller’s (lithology) log, which can vary depending upon the person who describes the samples of the well.

8.10.6 Presentation of Results

A paper copy of the curves generated from each logging run should be displayed with all curves at the same vertical scale. Each paper log record should show the location of the well in latitude and longitude, and the date that the logging was performed. The site map should show the location of the wells that were logged. The type of probe and equipment settings used should be written on each paper log, along with a listing of other probes that were used on that well. ‘Interpretation should be annotated on the margins of the paper log record.

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<http://www.state.nj.us/dep/njgs>

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Chapter 9 Soil Gas Surveys

9.1 Introduction

Ground water contamination by volatile organic compounds (VOCs) is an extensive problem throughout New Jersey resulting from the spillage and improper disposal of chemicals from a wide variety of commercial and industrial processes. The most common techniques applied to the investigation and delineation of VOCs in ground water are typically performed by the use of soil borings and monitoring wells. Samples from these types of investigations provide the best method of detecting volatile organics in ground water both qualitatively and quantitatively. However, they also have some disadvantages. The combination of soil borings, well installation, and respective sampling and laboratory analysis can be very expensive and time consuming. The levels of contamination are not known until after the installation, sampling and the receipt of analytical data from the laboratory. Additionally, numerous installations and mobilizations are required to sufficiently delineate the contamination.

Soil gas sampling is a screening tool used to rapidly and cost effectively identify and delineate VOCs in the subsurface. It involves the collection of gas samples at shallow depths (3-25 feet) across a site. All volatile organic compounds that have become soil or ground water contaminants are present to varying degrees in the soil as a vapor due to their high vapor pressure and low aqueous solubility. The measurement of the vapors in the soil pore space can aid in assessing the presence, composition, source, and type of release and distribution of contaminants in the subsurface. The advantages of a soil gas survey are that a more thorough assessment of the site can be performed at a reduced cost with rapid analytical results. Soil gas sampling, when applied appropriately, is an acceptable screening procedure for aiding in the decision making process of locating monitor wells and soil sampling locations. Please refer to the *Technical Requirements for Site Remediation N.J.A.C. 7:26E-3.6(b.)*; or the *Vapor Intrusion Guidance document at <http://www.state.nj.us/dep/srp/guidance/vaporintrusion/vig.htm>*.

It should be noted that a soil gas survey is not intended to be a substitute for conventional methodology, but instead, as a screening tool to enable conventional methods to be used more effectively.

There are two basic types of soil gas surveys performed during site assessments. The first type is an active soil gas survey where a volume of soil gas is pumped out of the vadose zone and into a sample container or directly into an analyzer. The second type is the passive soil gas survey where a sorbent material is buried in the vadose zone so that contaminant vapors can be selectively absorbed over time using the ambient flow of vapors through the subsurface.

This chapter will give guidance to the theory, applications and some of the common methodologies employed for performing soil gas investigations.

9.2 Theory

Subsurface contamination by volatile contaminants produces a concentration gradient in soil gas that decreases in a direction away from the major source or body of contamination. For volatile organic contamination to be detected in the unsaturated (vadose) zone, it must move upward from the saturated zone, through the capillary fringe, (a transition zone between the ground water table and the vadose zone) and into the unsaturated zone area where the gas samples are obtained. The concentrations of volatile organics in soil gas are a function of their concentration in the ground water, aqueous solubility, soil and subsurface characteristics and vapor pressures.

Ideally, an upward vertically decreasing volatile organic concentration gradient is found in the soil gas. This is caused by the vertical migration of volatiles from contaminated ground water or soil to

the ground surface. A horizontal concentration gradient will also be present with decreasing concentrations of volatile organic vapors in the soil gas from the source of contamination. In some cases, the concentration gradient between the water table and ground surface in soil gas may be distorted by hydrologic and geologic variables such as perched water or impermeable layers. Movement of vapors will generally occur around geologic and hydrologic barriers unless they are of great lateral extent as compared to the area of the plume.

A summary of the applications of soil gas surveys is as follows:

- Assess the presence or absence of VOC contamination.
- Provide a 3-dimensional profile of contaminant distribution.
- Delineate the extent of VOC contamination in soil and ground water.
- Obtain a chemical characterization of the VOC contamination.
- Identify and differentiate between sources of VOC contaminants.
- Assess migration patterns of VOC contamination in ground water.
- Monitor byproducts from the chemical or biological breakdown of contaminants.
- Differentiate between one-time releases and ongoing releases of contaminants
- Assess the need for indoor air sampling (*Indoor Air Sampling Guide for Volatile Organic Contaminants, Jan 1999*).
- Collect data for the design of Soil Vapor Extraction (SVE) systems.
- Monitor remedial activities (SVE systems, bio-remediation).
- Monitor the subsurface for leaks from USTs or containment systems.
- Monitor the subsurface for the movement of landfill gases to structures or off-site properties and need for control of gas movement (40CFR 258.23, Solid Waste Regulations N.J.A.C. 7:26-2A.7(h)6).
- Optimize the location of soil borings and monitor wells (N.J.A.C. 7:26E-3.6(b)).

9.3 Soil Gas Generation and Movement

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Soil gas may be generated by biological, chemical and physical decomposition of spilled or dumped wastes. Waste characteristics such as type, source, quantities and the geologic and geographic location of entry into the subsurface can affect the rate of decomposition and gas production.

9.3.1 Biological Decomposition

Biological decomposition is important in most active and closed landfills containing organic wastes, which decompose due to anaerobic microbial degradation. Generally the amount of gas generated in a landfill is directly related to the amount of organic matter present. Waste type and in-situ characteristics and conditions can affect biological decomposition. Landfill gas production will vary spatially within a landfill unit as a result of pockets of higher microbial activity. Under anaerobic conditions, organic wastes are primarily converted by microbial action into carbon dioxide and methane. Also, trace amounts of hydrogen, ammonia, aromatic hydrocarbons, halogenated organics, and hydrogen sulfide may be present.

Biological activity is also an important factor in the detection of many VOC contaminants. It can have a negative effect on their detection. Oxidation can convert volatile organics into nonvolatile or water-soluble compounds that are not amenable to soil gas sampling and analysis. Hydrocar-

bons are easily oxidized under aerobic conditions in the upper unsaturated zone. Halocarbon compounds are generally more resistant to aerobic degradation but can undergo anaerobic degradation. The original contaminant can be biologically degraded into various byproducts of the original compound.

9.3.2 Chemical Decomposition

Gas production from chemical decomposition results from the mixing of incompatible materials. Reactive or ignitable wastes can cause explosions or heat producing reactions resulting in a rapid production of gases and increased temperatures. A strong oxidizing agent may react with organic wastes to produce ammonia and carbon dioxide in acidic conditions

Under natural conditions, soil gas production from chemical reactions is not expected to occur. These reactions are more likely to occur from liquids stored or spilled from underground tanks and pipelines.

9.3.3 Physical Decomposition

Volatile organic compounds can undergo a variety of equilibrium and transport processes in the subsurface. The most important physical process affecting the production of vapors is the solution/vapor equilibrium. Due to the high vapor pressures and low aqueous solubility, volatile organic compounds have an affinity to partition into the vapor phase. The physical law that quantitatively describes this process is Henry's Law. Volatile organic compounds with high Henry's law constants will favor to partition from the aqueous to the vapor phase.

9.3.4 Transport Mechanisms

Several physical mechanisms describe the movement of vapors through the subsurface. They are molecular effusion, molecular diffusion and convection.

9.3.4.1 Molecular Effusion – Molecular effusion occurs at the surface boundary of the soil and atmosphere. It is the process by which vapors are released from the soil surface to the atmosphere. Any VOCs, which are in the soil surface, are released to the atmosphere based upon the vapor pressure of the VOC. One of the physical effects on the release rate of VOCs from the surface is wind speed. Wind keeps the ambient concentration at or near zero, which creates a concentration gradient for material to migrate to the surface.

9.3.4.2 Molecular Diffusion – Molecular diffusion occurs when there is a concentration difference between two different locations. Diffusive flow is in the direction that the concentration decreases. The vapor density affects molecular diffusion, but the concentration will tend to overcome small differences in density. Specific compounds will exhibit different diffusion coefficients. In the soil atmosphere the diffusion coefficients are only relative indicators due to the tortuous path the vapors must travel in soil.

9.3.4.3 Convection – Convection flow occurs when a pressure or temperature gradient exists between two locations. Gas will flow from an area of higher pressure to an area of lower pressure. Where it occurs, convection flow of gas will overcome the influence of molecular effusion and molecular diffusion. This type of flow is usually associated with landfills. Biodegradation processes, chemical reactions within the landfill, compaction effects or methane generation in the lower regions of the landfill which will all drive vapors vertically and horizontally. Changes in barometric pressure will have an effect on convection flow. The rate of gas movement is generally orders of magnitude greater by convection than for diffusion.

9.4 Site Specific Characteristics

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The site conditions and the type of contaminant release must be evaluated prior to performing a soil gas survey. The type of contaminant spilled and its components, along with any breakdown products must be evaluated to determine the best compounds for detection in the vadose zone that will represent the contaminant source and plume. An assessment of site geologic conditions will help determine any potential contaminant sources and migration routes. Natural or anthropogenic structures at a site may produce areas of preferred pathways for soil gas migration or conversely, restrict and impede gas flow.

During the planning and preparation for conducting a soil gas survey, site specific parameter characteristics should be evaluated. This will aid in the recognition of the variability of the site-specific parameters so accurate interpretations of the results, can be made. The degree of preparation will have a direct bearing on the success or failure of an investigation. The following are some of the site conditions and contaminant properties that should be considered to determine if a soil gas survey will be successful and aid in the interpretation of the data.

9.4.1 Chemical and Physical Properties of the Contaminant

9.4.1.1 Concentration

The known or estimated concentration of the ground water contaminant will dictate the vertical concentration gradient of soil gas established in the vadose zone. The diffusion of vapors from areas of high concentrations to lower concentrations is the mechanism of great importance for gas transport in the unsaturated zone. Therefore, if the known or suspected concentrations of contaminants in ground water are low, the compound will be difficult to detect in the vadose zone. To counter this, samples can be obtained from multiple depths at several locations to establish a concentration gradient and aid in selecting the optimal sample depth for contaminant detection. This will determine if soil gas samples should be taken at greater depths in the unsaturated zone, closer to the ground water, the source of the contamination. A greater concentration of sampling locations can then be established or an alternate tracer compound can be selected.

In some cases, a compound may be a poor candidate for soil gas detection but, because of its high concentration in the subsurface, presence of free product or microbial breakdown products, it can easily be detected by soil gas sampling.

Monitoring impacts from landfill gas migration to surrounding properties and buildings is vital due to the history of fires and explosions caused from the migration of methane gas into structures. Landfill gas monitoring is also important due to the presence of toxic and carcinogenic compounds in the trace composition of landfill gas. Concentrations of these compounds will vary between landfills. A correlation does not exist between the major gas concentrations and the occurrence of trace compounds. Some typical compounds and concentrations found in landfill gas are included in Tables 9-1 and 9-2.

9.4.1.2 Partitioning

Partitioning represents a group of processes that control the movement of contaminants between physical

Compound	Concentration (%)
Methane	40-60
Carbon Dioxide	40-60
Nitrogen	2-5
Oxygen	0.1-1.0
Ammonia	0.1-1.0
Sulfides, Disulfides, Mercaptans	0-0.2
Hydrogen	0-0.2
Carbon Monoxide	0-0.2
Trace Compounds	0.01-0.6

phases. The phases include the liquid, vapor, and solid (ie.soil). The product phase must be included if free product is present in the subsurface. The relationship between the phases is represented in Figure 9.1.

Henry’s law constant (K_H) is expressed as a ratio of a vapor’s partial pressure to the concentration in the liquid. It is a coefficient that reflects the air-water partitioning of an organic compound. It is the process by which volatile contaminants move between the solute phase and the gas phase in dilute solutions. Henry’s law constants should not be used for determining the contaminant vapor pressures due to the unknowns related to the concentration of contaminants and additional partitioning process of the solution. Those compounds with Henry’s law constants greater than 0.05 k Pa M³/mole or, 1 microgram per liter soil gas/micrograms per liter water ratio would be good candidates for soil gas detection.

The soil-water partition coefficient (K_p) is the process by which VOCs move between the sorbed soil phase and the water phase. The soil-water partition coefficient is controlled by the available surface area of the soil for sorption of contaminants. Some of the important parameters for soil gas surveys are the sorbed contaminant concentration in the soil, soil makeup including the quantity, type and distribution of clay and organic material, vadose zone pore water content and soil porosity.

The sorption of product to soil and organic material is described by the contaminant’s soil-sorption coefficient (K_d). The sorption coefficient describes the affinity of a contaminant to sorb

Table 9.2 Trace Compounds Found in Municipal Solid Waste Landfills	
Compound	Average Concentration (ppbv)
Toluene	34,907
Dichloromethane	25,694
Ethyl Benzene	7,334
Acetone	6,838
Vinyl Acetate	5,663
Tetrachloroethylene	5,224
Vinyl Chloride	3,508
Methyl Ethyl K etone	3,092
Xylenes	2,651
1,1-Dichloroethane	2,801
Trichloroethylene	2,097
Benzene	2,057

to the soil or organic material. There is a strong relationship between the number of carbon atoms of a contaminant and the sorption coefficient. The larger the molecule (greater number of carbon atoms) the greater the tendency for the contaminant to sorb to the soil and organic material and become immobile in the subsurface.

Soil-air partitioning is the process by which VOCs move between the sorbed phase and the vapor phase. The pore water content along with the type and distribution of clay and

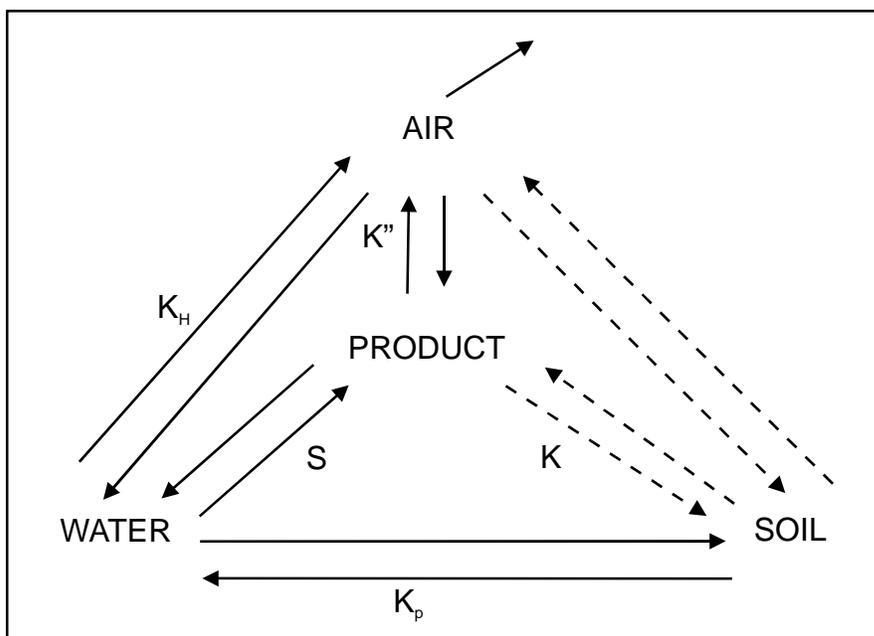


Figure 9.1 Phase Relationships for VOCs

organic material content largely controls this process. For compounds with a high affinity for sorption in the soil-air partitioning process, it is unlikely they will be available for soil gas sampling techniques.

The product-air partition coefficient (“K”) of a compound is a coefficient that relates the partitioning between the free product phase and the vapor phase. The major process for the movement of VOCs from the product phase to the vapor phase is volatilization. Depending upon the contaminant mixture and vapor pressures, a significant number of compounds can be present in the soil atmosphere by volatilization. The soil atmosphere will have a composition similar to the free product, except for the compounds with the lowest vapor pressures. The quantity of contaminant volatilized into the vapor phase is strongly dependent upon the temperature. The rate of volatilization is also controlled by the rate of transport of VOCs from the product/air interface. Volatilization is highest when there are pathways, like macropores, or driving forces such as concentration gradient, density gradient between the soil and vapor saturated atmospheres, temperature gradients, barometric pressure and wetting fronts.

The organic carbon distribution coefficient (K_{oc}) of a compound is a coefficient that relates the partitioning of the organic compound between the adsorbed phase and the soil solution relative to the organic carbon fraction. This coefficient reflects the affinity of an organic compound to adsorb out of solution onto organic soil material. The affinity for organic compounds to adsorb onto soil in the unsaturated zone is dependent upon the presence of organic material in the soil. Generally the organic carbon content in the vadose zone decreases with depth, so the greatest influence will be at or near the surface.

The solubility (S) of a compound is the saturated concentration of a compound in water at a given temperature and pressure. This is an important parameter in determining the fate and transport of a compound in groundwater. Compounds with high water solubility tend to desorb from soil and sediments (low K_{oc}) and move into the ground water. They will also have a short residence time in the unsaturated soils decreasing the amount of time for the product to volatilize and establish a vapor concentration gradient. Once in the ground water, highly soluble compounds are less likely to partition to the vapor phase. VOCs that are highly water soluble such as ketones and alcohols are not good candidates for soil gas since they do not readily move into the vapor phase.

9.4.1.3 Vapor Pressure

Vapor pressure is the pressure of a confined liquid such that the vapor collects above it. Groundwater contaminants with high vapor pressures will diffuse readily into the soil horizons and are therefore excellent targets for soil gas analysis. Those compounds with vapor pressures of 1mm Hg at 20°C or higher are the best target analytes for soil gas analysis.

9.4.1.4 Microbial Degradation

Biodegradation of contaminants refers to the conversion of a contaminant to mineralized end products (CO_2 , H_2O and salts) through the metabolism of living organisms. The resistance of a compound to biodegradation can be a limiting factor to the applicability of a soil gas at a site. If conditions permit, microbial degradation of contaminants can lead to significant degradation of organic compounds. The amount of degradation will depend upon the number of species available and the degree of difficulty in breaking down the compounds. Degradation can reduce the amount of contaminant, especially non-halogenated hydrocarbons, particularly C5 and higher. These compounds will degrade readily in an oxygenated soil if they are present at low concentrations. This limits the effectiveness of a soil gas survey in cases where the ground water is

deeper than 25 feet or shallower than 5 feet. When the ground water is deeper than 25 feet, the limitation is the ability, time and expense to drive a soil gas probe to an adequate depth for contaminant detection. In most geologic settings the soil gas probe must be driven within 5 feet of the ground water table to obtain a reliable soil gas signal. In some cases, biodegradation rates can exceed the rate at which vapors move into the vadose zone. In these cases, contaminants are not detectable for soil gas sampling techniques.

In areas of high concentrations of contaminant vapors, such as around leaking underground fuel tanks, the degradation of VOCs is inhibited. The concentration of VOCs in these areas is high enough to destroy the soil bacteria.

The stability of halogenated compounds is generally related to the number and type of halogens. Fluorocarbons tend to persist in the environment, even at low concentrations. Solvents having three or four chlorines will degrade to some extent in the environment, but will degrade slowly so there is little impact on their detectability in the soil gas. Dichloro- compounds (DCE, DCA)

are produced in the subsurface as the first breakdown products of primary chlorinated compounds. These products tend to degrade in the soil faster than the primary solvents. As a result, soil gas data for the dichloro compounds is less representative of their concentrations in the ground water than the primary chlorinated solvents. Vinyl chloride, a mono chlorinated compound and second stage degradation product, is the least stable chlorinated solvent in soil gas. This is why vinyl chloride is seldom detected in soil gas over a contaminated ground water. Therefore vinyl chloride is a unreliable indicator of ground water contamination. Several examples of biodegradation products of chlorinated compounds are included in Figure 9.2.

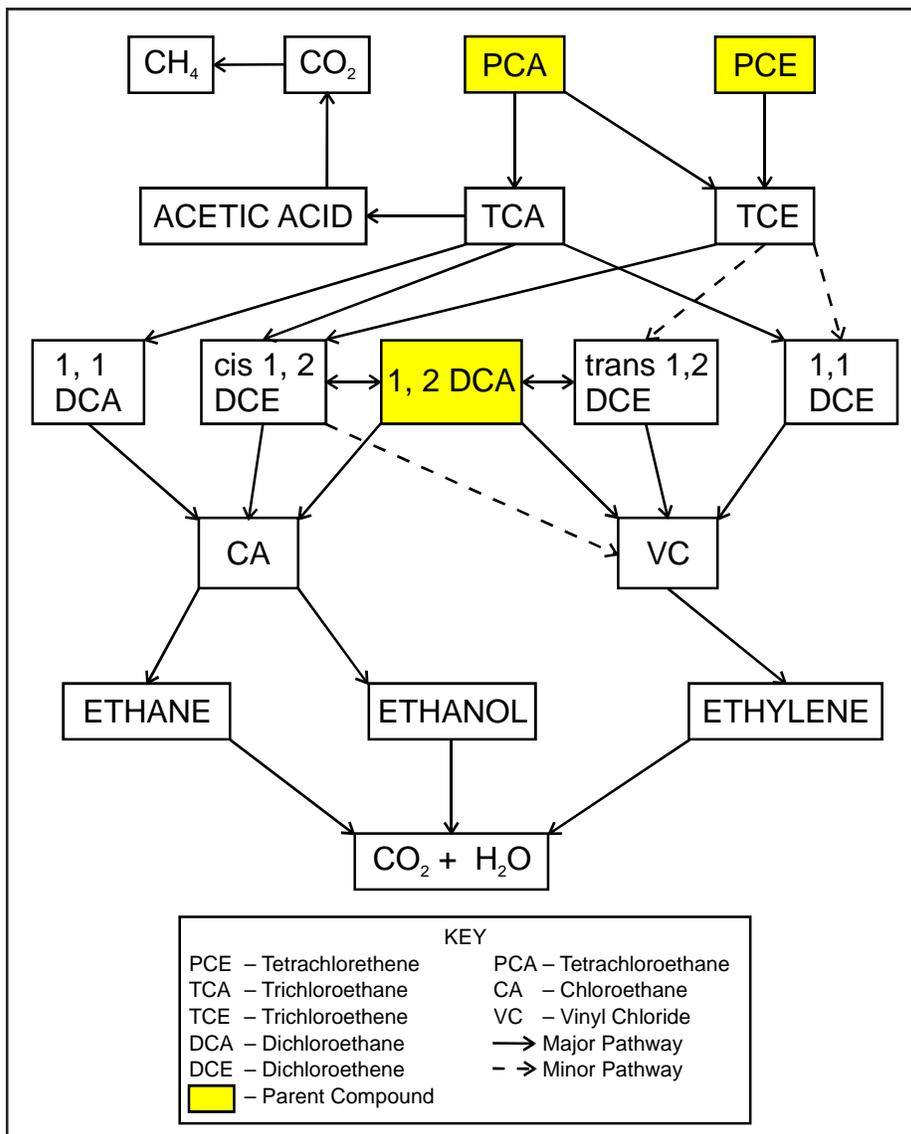


Figure 9.2 Transformations of Chlorinated Aliphatic Hydrocarbons

Sampling the gases produced by biodegradation of a contaminant will allow for the indirect detection of contamination. These gasses include methane, carbon dioxide, oxygen and hydrogen sulfide. These gasses can provide useful information about the contaminant source area and plume. Measurement of these gasses is most useful when active-soil gas sampling methods are being employed and the volatile contaminant is not directly detected or is a semi-volatile compound.

9.4.2 Geologic Factors

9.4.2.1 Soil Permeability

One of the most important factors in the movement of vapors through soil is the soil permeability. The soil permeability is the measure of the ease at which a gas or liquid can move through rock, soil or sediment. Soil permeability is related to the grain size and the amount of water in the soil. Soils with smaller grain sizes are less permeable. When soils contain clay size particles, soil gas movement is severely limited. Or if the soils become poorly sorted with increased fine-grained material content, the pore space is decreased, water content increases and the rate of vapor diffusion decreases. The most retarding layer will dictate the rate of diffusion of vapors in the vadose zone.

Heterogeneous soil conditions across a site under investigation can lead to poor delineation and misinterpretation of site contaminants due to the interference from the different soil conditions. Data from areas of horizontal low permeability zones within the vadose zone could be interpreted as being an area of low contamination, when the level of contamination could be the same or higher. Conversely, data from an area of high permeability in an otherwise low permeability area can be interpreted as an area of high contamination. High porosity areas such as sewer and utility trenches can serve as conduits for rapid vapor or gas migration, giving a false indication of high contamination areas. In situations where little or no soil data is available, several soil borings should be logged to aid in the interpretation of the generated soil gas data.

Soil gas sampling is most applicable to sites where the vadose zone is comprised of dry coarse-grained homogeneous sediments with a minimal amount of organic material. At sites where tight or wet silts and clays are present, or the contaminated aquifer lies beneath a clean aquifer, soil gas sampling cannot be used effectively to detect ground water contamination.

The presence of moisture in the soil decreases the rate of vapor migration. This occurs because as the volume of soil water increases, the soil airspace decreases thereby inhibiting vapor movement. Soil moisture decreases the amount of contaminant available for transport by allowing contaminants to partition into the pore water. Active-soil gas sampling methods are not effective in soil conditions where the water content is 80-90% saturated.

9.4.2.2 Thickness of the Unsaturated Zone

The thickness of the unsaturated zone will determine the distance vapors must migrate from the ground water to an area for sampling. The greater the thickness of the vadose zone, the greater the chance for soil texture changes, the greater distance the concentration gradient must be established and the deeper soil gas probes would be required to be placed for detection of the vapors. Conversely, if the thickness of the vadose zone is small there is a greater chance of dilution of the soil gas by ambient air and a severe alteration of the concentration gradient. A steep concentration gradient can cause misinterpretation of data by small variations in sample depths. The deeper samples will show a greater concentration of contaminants, which may erroneously be interpreted as a “hot spot” of contamination.

9.4.2.3 Barriers and Conductive Zones

Two geologic factors that can lead to misinterpretations of the data are barriers and conductive zones. Barriers to soil gas diffusion are obstructions, either man-made or natural, which will impede the movement of vapor. The obstacles can be structures, blacktop, cement, landfill caps, clay layers, perched water, frozen soil, irrigated or recently disturbed soils. The location and extent of the barrier will dictate the direction of movement of the soil vapor around the obstacle. Figures 9.3 A through E illustrate the effect of barriers on the soil gas concentration gradient.

Conductive zones are areas where soil gas vapors and gases will preferentially move since vapors will move along the path of least resistance to gas movement. Conductive zones can be natural, such as old stream beds, and gravel lenses and fractures, or man made, for example bedding around pipelines.

Soil Gas Concentration Gradients

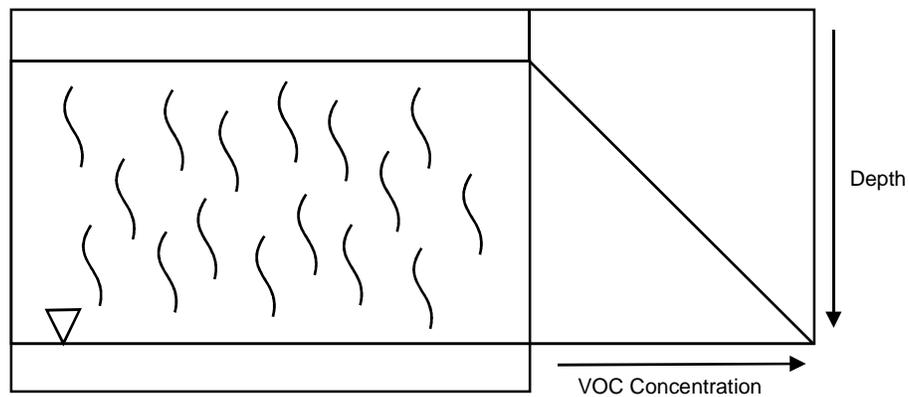


Figure 9.3A Homogenous Soils in the Vadose Zone (Marrin,D. and Kerfoot, H.B.)

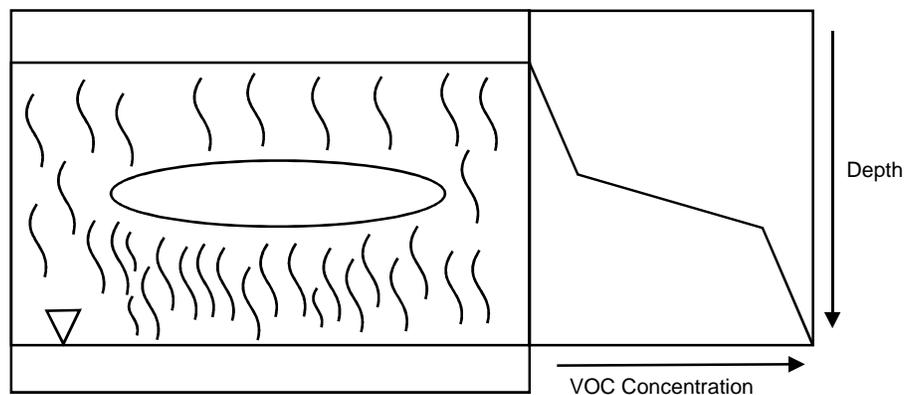


Figure 9.3B Impermeable Clay Subsurface Layer (Marrin,D. and Kerfoot, H.B.)

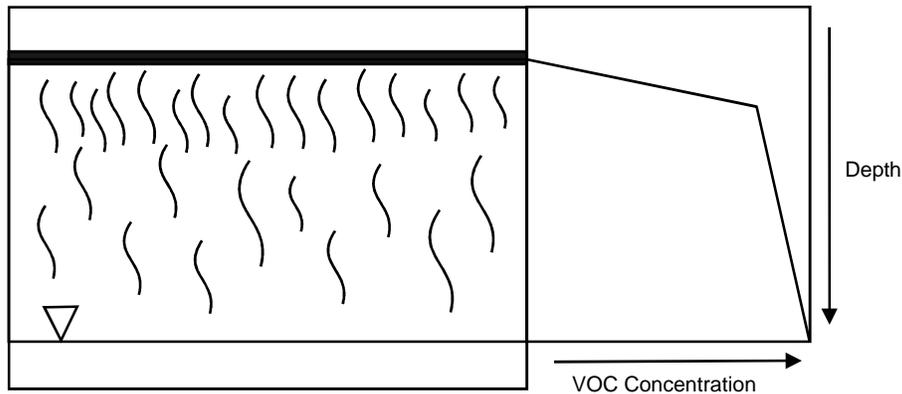


Figure 9.3C Impermeable Surface Layer (Marrin,D. and Kerfoot, H.B.)

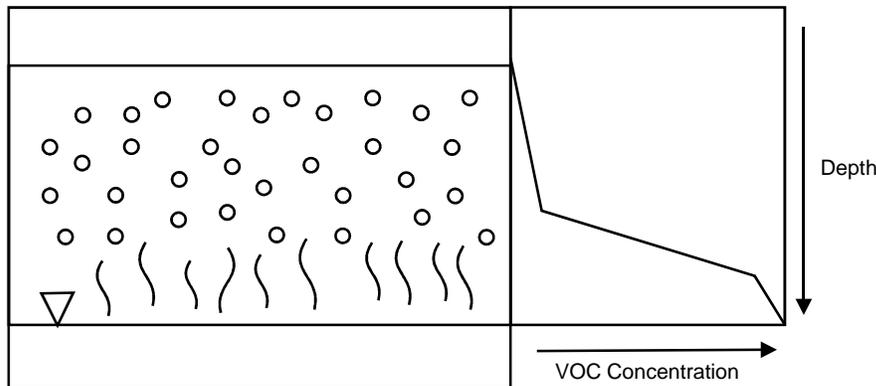


Figure 9.3D Zone of High Microbial Activity (Marrin,D. and Kerfoot, H.B.)

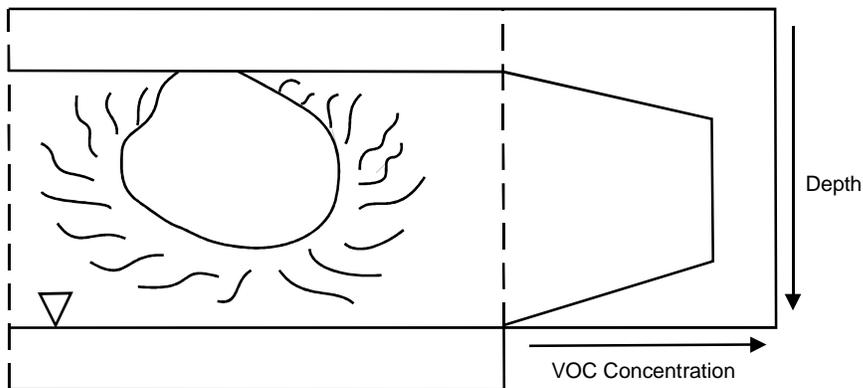


Figure 9.3E Source of VOCs in the Vadose Zone (Marrin,D. and Kerfoot, H.B.)

9.4.3 Hydrologic and Hydrogeologic Properties

9.4.3.1 Water Table Oscillations

Changes in the depth of the water table can have a large impact on the vertical transport of contaminants. The movement of ground water allows the contaminated water to “smear” across the sediments, increasing the surface area of contamination. A significant water level rise followed by a decline in the water table will have the greatest effect of introducing VOCs into the vadose zone than other types of water table fluctuations.

9.4.3.2 Background Water Quality

The background water quality can have a significant effect on a soil gas survey. If other contaminants are present, the greater the difficulty in delineating a particular contaminant in question. Background water quality can be affected by off-site sources, or other sources on the site. At some locations several plumes may exist that are partially or completely overlapping from different discharges. In such cases, greater instrument sensitivity is required to separate the contaminant of interest from the “contaminant soup.”

9.4.3.3 Rainfall, Barometric Pressure and Wind

All of these weather conditions will have varying degrees of influence on soil gas concentrations and movement. In general, rainfall has a short-term effect on soil gas measurements. Even in heavy rains, if the soils are normally unsaturated, the rain will not produce a saturated condition for more than an hour. However, soils consisting of large amounts of silts and clays and a shallow water table (6 feet or less) can be a problem for soil gas sampling and is not recommended. These soils will remain saturated for long periods of time.

Low Barometric pressure and increasing winds will increase the out-gassing of soil vapors in the soil pores at or near the surface (upper 1%) and will not have an effect on samples collected several feet below the surface. Barometric pressure changes can affect soil venting discharge rates and soil gas probes where an air conduit exists to the subsurface.

The key to limiting these effects is to acquire all the samples in the shortest period of time possible under the same meteorological conditions. This leads to reducing the effects of meteorological changes and therefore, a greater confidence in the correlation of results can be made.

9.5 Investigation Sampling Designs

The design of the investigation should be constructed to obtain all necessary and required information with a minimal expenditure of time and resources. The development of the design should be based on background information obtained regarding physical and chemical properties of the contaminant, properties of the vadose zone and hydrologic and hydrogeologic properties of the area. All this information should be used to design a sampling strategy specific to the characteristics of the site.

9.5.1 Grids

Grids consist of sampling points set on perpendicular lines at equal distances along the line from each other. Grid pattern sampling will vary in size and design depending upon the site characteristics and objectives of the soil gas survey. Grid sampling is an effective way to provide data over a large area for a low cost.

Small areas of potential source(s) or complex vadose zone geology will require grid spacing as small as 100 ft² to 400 ft². Smaller grids are applied best in UST investigations and determining contaminant plume boundaries. Wide grid spacing is best applied for site reconnaissance work. An example of a grid utilized in a soil gas survey design is shown in Figure 9.4.

9.5.2 Transect Lines

For transect lines sampling points are placed on a line between the impacted area and a suspected source area(s) of contamination. This network is most commonly used to quickly find a source area(s) of contamination. Further sampling methods are then used to pinpoint the exact source(s) of contamination. This can significantly decrease the number of sampling points. An example of using a transect line investigation technique is shown in Figure 9.5.

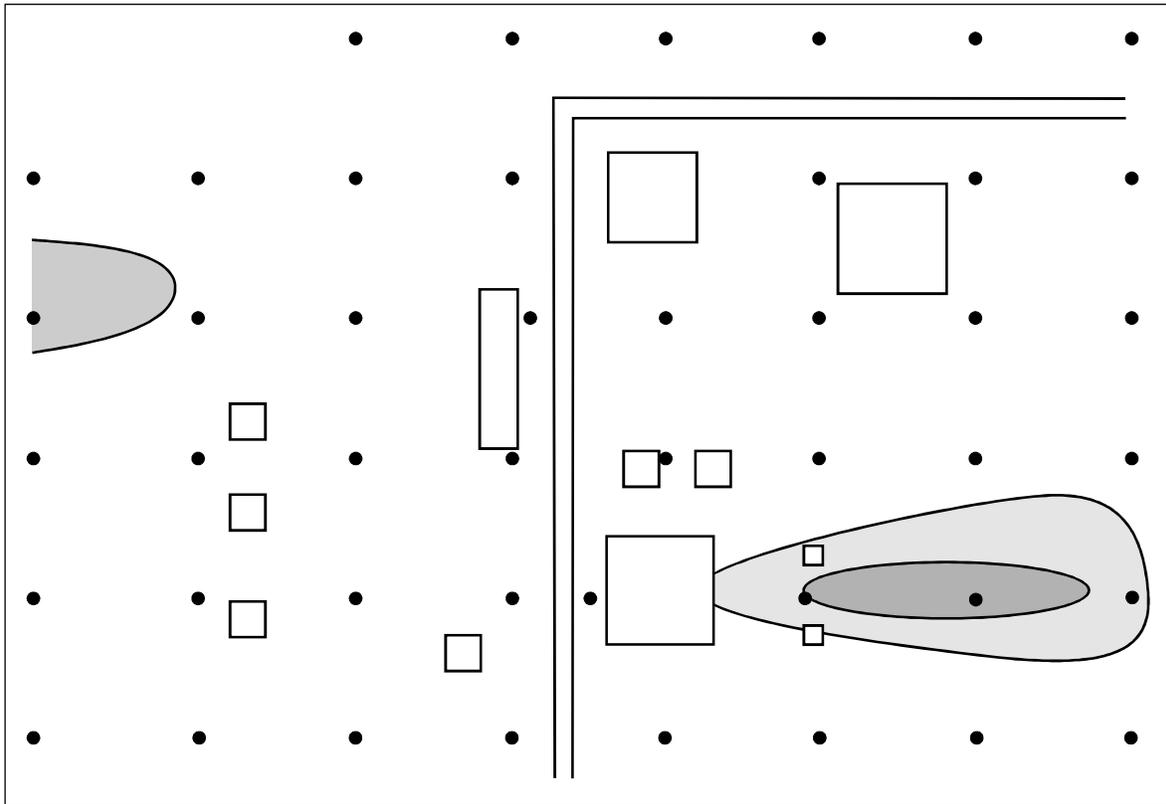


Figure 9.4 Site Monitoring Network Grid Sampling

9.5.3 Biased

In this approach, sample points are placed near a suspected source in an area of contamination to find “hot spots” for further delineation or remediation. This type of network can be used to find potential source areas or, once a source area is determined it can be used to determine the extent of contamination.

9.5.4 Random

Random sampling networks use a grid pattern with numbers designating nodes or areas. A random number generator is used to designate which areas are targeted for sampling.. This type of network is used in areas where no information is known or no contamination is suspected.

9.5.5 Combined

This type of sampling design is the most commonly used. It is a combination of the four sampling designs. As contamination is detected, the sampling pattern and locations will change to accomplish the goal of the sampling plan. When performing a soil gas survey, the sampling plan is most effective when it is fluid and subject to change. This allows for the evaluation of data as it is generated, then incorporating the collected data in the decision process to dictate the locations and depths of additional data point if required. Keep in mind that safety concerns and utility mark outs must take precedence in a fluid sampling design.

9.5.6 Vertical Profiling

Vertical profiling is the acquisition of multiple soil gas samples at various depths from the same location. Ideally, the VOC soil gas concentration gradient in the vadose zone will increase towards

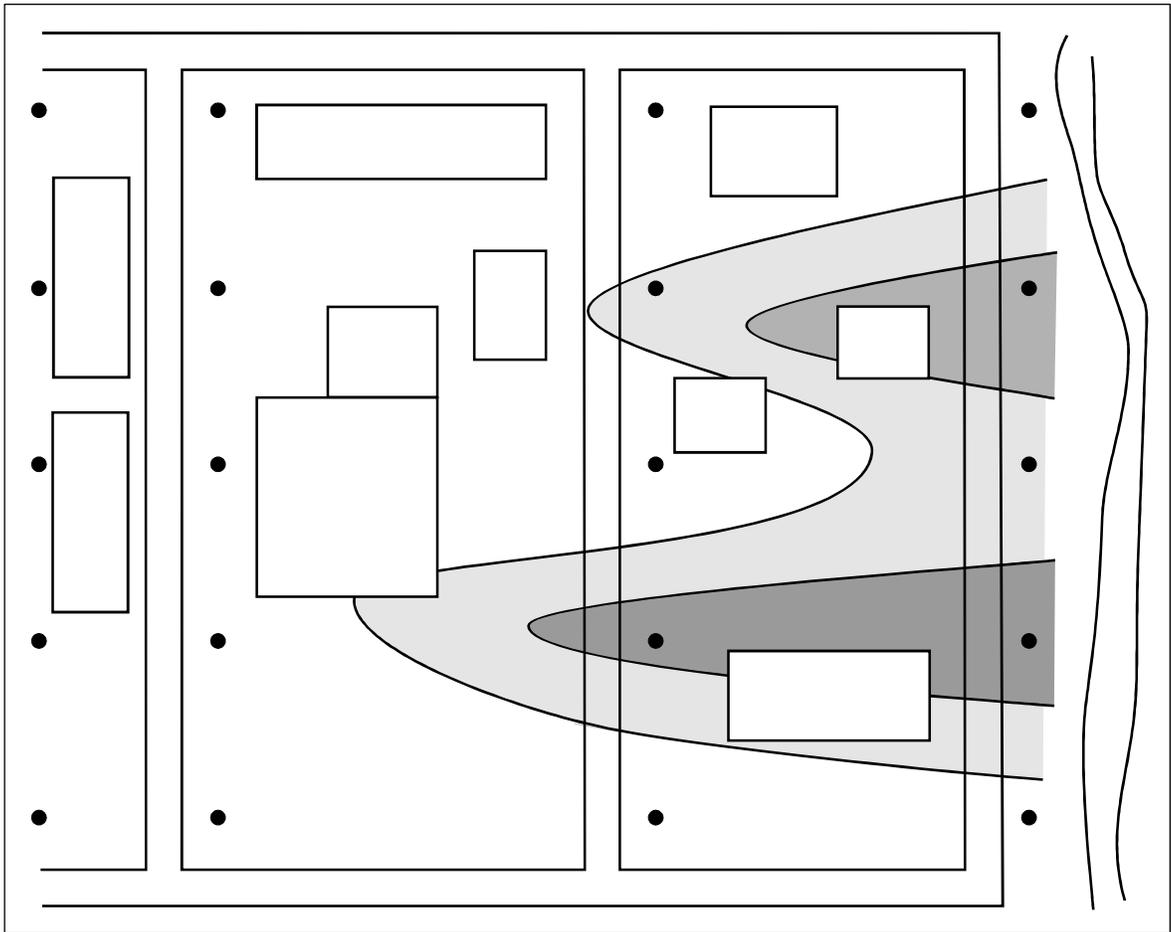


Figure 9.5 Site Monitoring Network Transect Lines

the source of contamination. Subsurface heterogeneity, soil porosity, biodegradation, moisture content and source VOC concentrations will affect the soil gas concentration gradient. Vertical profiling can determine the differences in the physical nature of the soil to aid in detecting contaminant sources and pathways.

Vertical profiling can aid in:

- Determining the concentration gradient of contaminants at the site.
- Evaluating optimum sampling depth.
- Determining the effects of biodegradation on the contaminants of interest.
- Providing a vertical concentration gradient across the vadose zone to aid in differentiating if a surface spill or ground water contamination is responsible for the concentration profile.
- Determining if vadose zone barriers are present.

When performing vertical profiles, sample depths should be corrected for changes in surface elevation changes so concentration contours represent a horizontal layer.

One of the difficulties with vertical profiling is the potential for cross contamination when the same sampling equipment is used for each subsequent sample. Also, the tools being withdrawn

and reinserted into the borehole may lead to venting of the soil gas from the open hole. Both of these conditions will lead to a reduction in the representativeness of the subsequent sample.

9.5.7 Sample Spacing

Sample spacing is the horizontal distance between sample locations across a site. Spacing of sample locations depends upon the objectives of the investigation, size of the site and size of the potential contaminant sources. Sample spacing may also be dependent upon the number of subsurface conditions that allow or impede the migration of vapors.

For small 1-2 acre UST sites, sample spacing can be 10-50 feet between samples. On large industrial sites or landfill perimeters, sample spacing can be as large as 400-500 feet. In general, sample spacing should be at a minimum of two to three times the depth to ground water. If two sample locations have two to three orders of magnitude difference in concentration, samples should be collected between the two points. Reducing the sample intervals below this distance across a site will not necessarily provide for better resolution of contamination. It will only indicate the variability in the soil horizon rather than changes in VOC concentrations. Soil gas sampling is not a high-resolution technique for contamination delineation and should not be used for this type of interpretation.

9.5.8 Sampling Frequency

The sampling frequency will depend upon the objective and the results of the soil gas survey. For initial site screening only one round of sampling may be required to find potential VOC sources with possibly a second round of sampling for further delineation or exploration. Soil gas monitoring programs using permanent probes at landfills and UST sites may use a quarterly or monthly program sampling frequency. A greater frequency can be used for monitoring remediation activities or monitoring the migration of explosive landfill gasses near buildings. In these cases, it may be best to employ the use of a continuous monitor.

9.6 Health And Safety

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9.6.1 Underground Utilities

Many accidents in subsurface investigations are due to encountering subsurface utilities. Prior to mobilizing for any soil gas investigation, health and safety concerns must be answered. Of greatest concern would be to locate any underground utilities. NJ One Call is a free service and can be contacted at 1-800-272-1000 (out of State call 908-232-1232). They will contact all utility companies that may have services in the area of investigation. Calls must not be made less than 3 full working days and not more than 10 working days prior to the planned work. If work is delayed past the 10 days, you are required to renew your ticket. “One Call” legislation mandates that all owners of underground infrastructures become New Jersey One Call members. The “One Call” will require the following information:

- County
- Municipality
- Street address
- Nearest cross street
- Type of work being performed
- Extent of work
- Name of caller and title
- Start date of work

The caller will receive a “ticket” number for the mark-out locations. If you must contact the “One Call” system regarding a mark-out, you must supply them with your ticket number.

The mark-out methods used by the utilities will include flags, stakes and color-coded paint. In many cases these are not permanent. It is requested the mark-outs be refreshed if work is completed past the 10 business days. Utilities are marked by the uniform color code recommended by the American Public Works Association. The mark-out color and associated utility are as follows:

- RED – electric
- YELLOW – gas, oil, petroleum products
- ORANGE – telephone, cable TV, communications
- BLUE – water
- GREEN – sewer
- PINK – temporary survey marking
- WHITE – proposed excavation

This is by no means an all encompassing list of utilities that may be present at a site targeted for a soil gas investigation. Historical and/or current commercial process may include unlisted buried utilities. Therefore such underground utilities should be thoroughly identified and located.

It is also important to contact the municipal utility authority in the town in which you will be performing work. There may be “road-opening” permits that must be obtained prior to the start of the investigation. Police departments and emergency services often wish to know if a roadway is going to be partially blocked or detoured, and may require that a traffic safety officer be present during any road work.

The utility companies are only obligated to mark-out the utility lines on public property. They are not required to mark out the utility lines on private property. The property owner or a private company must complete utility mark-outs on private property.

Above all, if it is suspected that a utility line is present, move the sample location. A few feet in a soil gas survey won’t have a great impact on the results in lieu of possible injury or death.

9.6.2 License Requirements

The license requirement for performing a soil gas survey is for the installation of the soil gas probes used for the collection of a soil gas sample as depicted in Table 9.3. The requirement is based on depth and diameter of the boring and the length of time a probe will remain in the hole.

This table is a brief overview of the license requirement for the construction of borings and monitor wells in New Jersey. Please consult N.J.A.C. 7:9D-*Well Construction; Maintenance and*

Requirement	Capability
None	1. Borings 10 feet or less in depth. 2. Borings 4 inches or less in diameter
New Jersey Licensed Soil Borer or New Jersey Licensed Monitoring Journeyman, Journeyman Class B or Master Well Driller	1. Borings greater than 10 feet in depth 2. Borings greater than 4 inches in diameter 3. Probes placed for 48 hours or less
New Jersey Licensed Monitoring Journeyman or Master Well Driller	1. Borings greater than 10 feet in depth 2. Borings greater than 4 inches in diameter 3. Probes placed for greater than 48 hours

Sealing of Abandoned Wells for further information. A copy is available through the Bureau of Water Allocation at 609-984-6831 or online at <http://www.state.nj.us/dep/watersupply/>.

9.7 Active Sample Collection Methodologies

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Active sample collection methods involve “pulling” a vapor sample through a temporary or permanent probe to a collection or analytical device. Samples are then transported to a laboratory for analysis or analyzed on-site so real time data can be obtained and used for directing the investigation. Active sample collection gives a “snap shot” of the soil gas conditions at a particular time and depth. This method allows for rapid soil-gas sample collection and analysis from target depths. Contamination from VOCs can be detected directly with contaminant specific analysis or VOCs and SVOCs can be detected indirectly by measuring the concentrations of oxygen, carbon dioxide, methane and hydrogen sulfide produced from the biodegradation processes on contaminants or waste.

9.7.1 Ground Probes

There are several different types of ground probes that can be used for collecting soil gas samples. One type, a passively placed ground probe is used by first making a hole with the use of a bucket auger or slide hammer. The initial size of the hole must be kept to a minimum in order to reduce excessive purge volumes. The probe is then placed into the hole and the annular space at the surface is sealed with an inert impermeable material, such as pottery clay. Different probe designs can be used with this method. One probe is designed with predrilled holes or a small diameter well casing ($\frac{1}{2}$ " or $\frac{1}{4}$ " PVC) on the leading end. Another probe design uses a $\frac{1}{4}$ " tubing, such as a brake line that has an open end (Figure 9.6). A wire is placed in the probe during installation to prevent

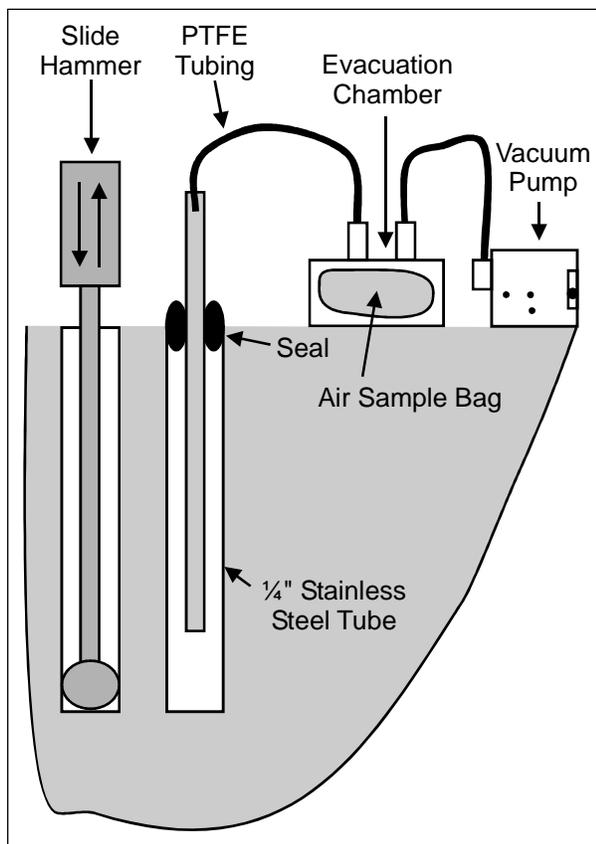


Figure 9.6 Passive Placed Probe

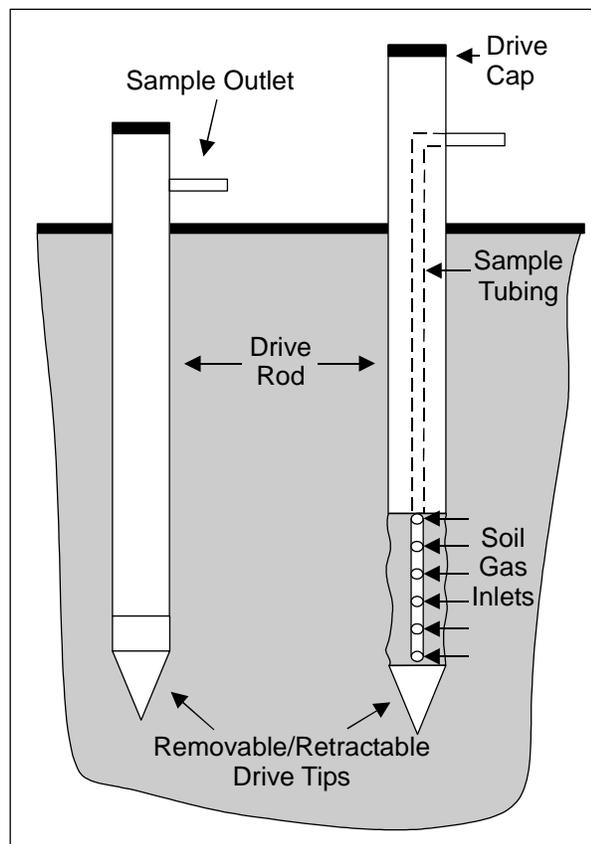


Figure 9.7 Drive Ground Probe

the probe from being clogged. It is recommended that the drill cuttings not be used to seal the surface annular space since they will not provide an effective seal. The annular surface seal must be made with an inert impermeable material such as clay. Once sealed, the probe is evacuated and a sample withdrawn for analysis.

Other types of ground probes are driven to the targeted depth by a slide, electric or hydraulic hammer. Drive ground probes consist of a tube, which has a removable or retractable drive tip (Figure 9.7).

Once at the targeted depth, the drive rods are pulled back to “open” the probe. One type of drive ground probe has a removable drive tip. When this type of probe is driven to the desired sampling depth, the drive rods are pulled back and the removable drive tip is opened, exposing the open end of the drive rod for sample collection; the tip is not recovered. The trailing end has a drive cap to protect it when the tube is driven into the ground. A sample port of the manifold for gas extraction can be located on the trailing end of the probe. Another type of drive ground probe that is available has a retractable tip. This probe is used for obtaining soil gas samples at discrete depths with fewer failures due to hole clogging. This probe consists of two parts, an outer tube and a small inner tube with sample parts connected to the drive point. The probe is driven to the desired depth and the probe is pulled up to “open” the probe for sampling.

The annular seal is maintained by the soil against the probe rods. Therefore the drive tip cannot be larger than the probe rods or there will be no annular seal provided when the probe is pulled back to open the probe (Figure 9.8). Probes or rods, which have an irregular shape, will not allow for a competent seal and can lead to sample dilution and erroneous results.

Modifications in the probes can be made to vary the length to attain greater depths or to decrease the inside volume of the probe or allow for disposable tubing to be used. A decreased probe volume will cut down on the volume needed to purge the system, thereby giving a more representative sample of the gas present at the sampling depth.

The success of the use of active sampling methods will depend upon the amount of clay, organic material, and moisture content. Driven probes also destroy the natural soil permeability around the probe due to the displacement and compaction of soil during placement. This can be a severe limitation in some soils. In very dry cemented soils, driven probes can form cracks that can cause “short

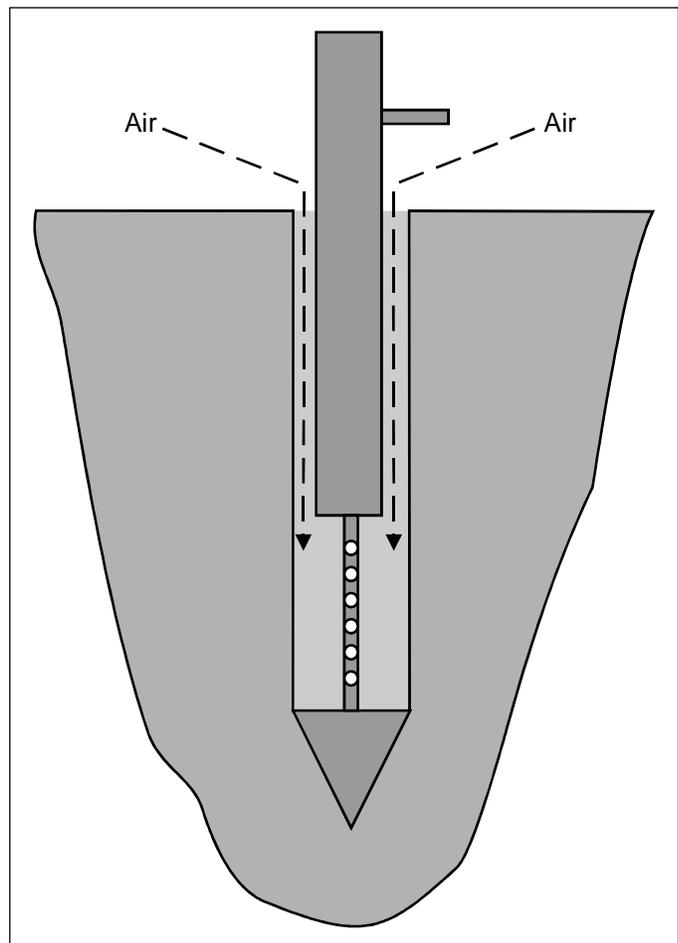


Figure 9.8 Ground Probes Ambient Air Short Circuiting

circuiting” with atmospheric air and can result in sample dilution. Use of a predrilled hole for probe insertion can also encourage contaminant venting and lower sample representativeness.

9.7.2 Permanent Soil Gas Probes

Permanent soil gas probes are constructed so soil gas samples can be obtained from the same location over time. They are used to obtain data on changes in soil gas concentrations over time. Single or multiple probes may be installed into a single borehole to obtain vertical profile data. Permanent probes are recommended for projects requiring more than one soil gas sampling event to monitor subsurface gas conditions for gas migration control or to monitor remediation activities. (UST's, landfills, SVE Systems). The use of permanent soil gas probes can aid in optimizing remediation activities and decrease the number of man-hours required to complete the remediation effort.

Location and depth of permanent soil gas probes will be based on the objective of the monitoring program. Their placement can be based on the results of previous soil gas surveys or in specific areas to obtain monitoring data.

The method of installation and construction of permanent soil gas probes vary. Probe holes can be advanced with hand or power augers, soil cores, hollow or solid stem augers and direct push

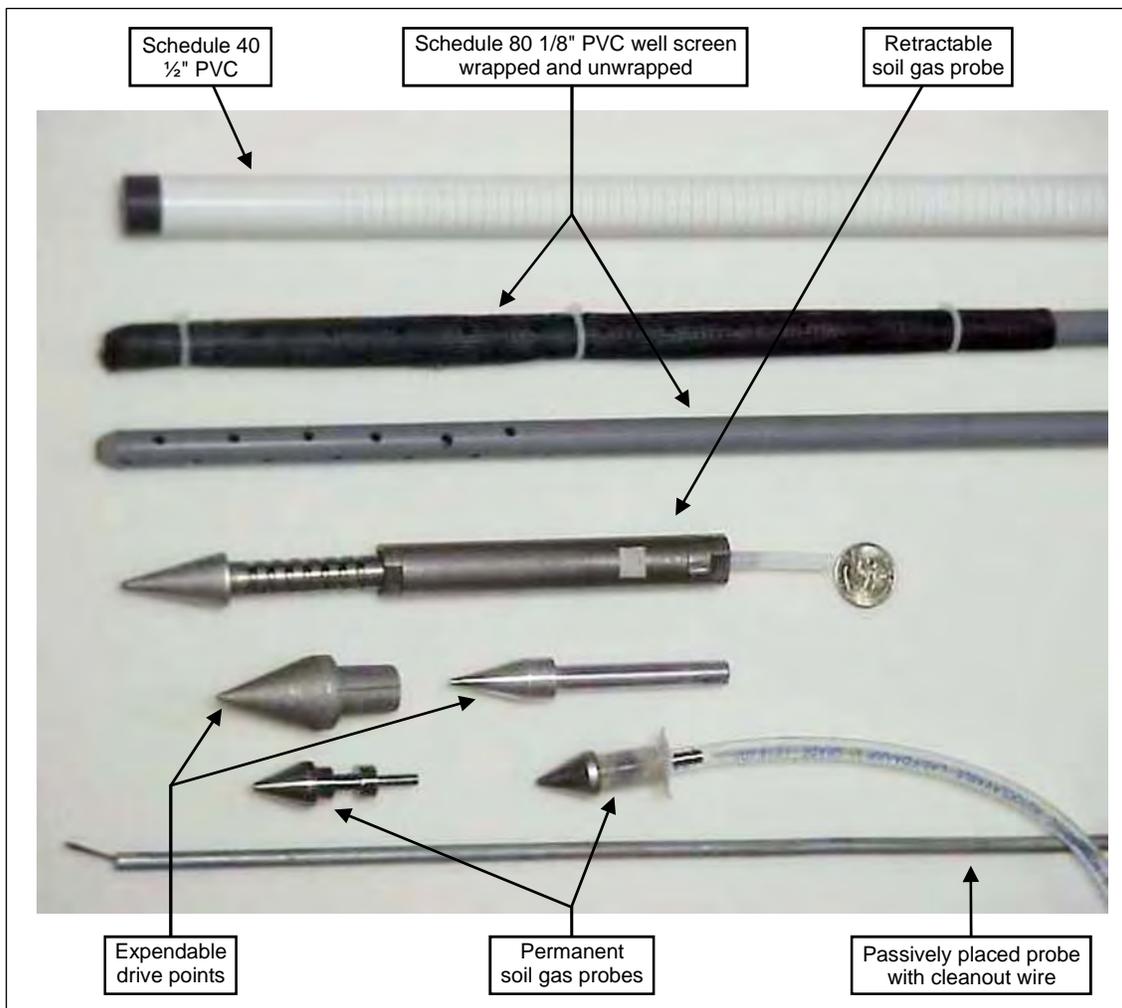


Figure 9.9 Soil Gas Sampling Probes, Photographed by C. Van Sciver

methods. The probes can be constructed of various size PVC pipe (¼ inch schedule 80) with predrilled small diameter holes, ½" schedule 40 PVC slotted well screen and riser with flush jointed threads (FJT) or commercially available soil gas well points manufactured by companies specializing in soil gas equipment (Figure 9.9).

The construction of a permanent soil gas probe is the same as a monitor well, only above the water table. The length of screens can vary, depending upon the objective of the monitoring but should not be longer than 5 feet. A Morie Number 1 or 2 sand is used for the gravel pack with a minimum two foot bentonite seal above the screen to eliminate infiltration of ambient or non-sample zone air. The probe can be completed with a surface protective casing, either flush mount or above grade. The probe casing should be covered with a cap to prevent venting of the soil gas or providing a home for insects. As an alternative, a small ball valve can be installed on the probe that will aid in obtaining pressure measurements (Figure 9.10 & 9.11).

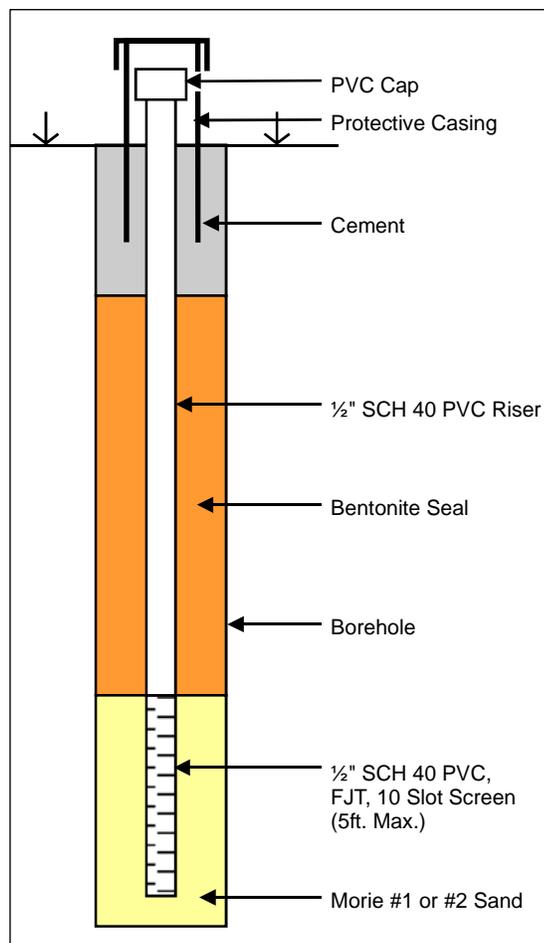


Figure 9.10 Soil Gas Well Schematic



Figure 9.11 Ball Valve for Soil Gas Well, Photographed by C. Van Sciver

If multiple depths are targeted for monitoring, the installation of the soil gas probes can be completed using various designs (Figure 9.12). Probes can be installed using several designs they are as follows:

- Cluster
- Nested

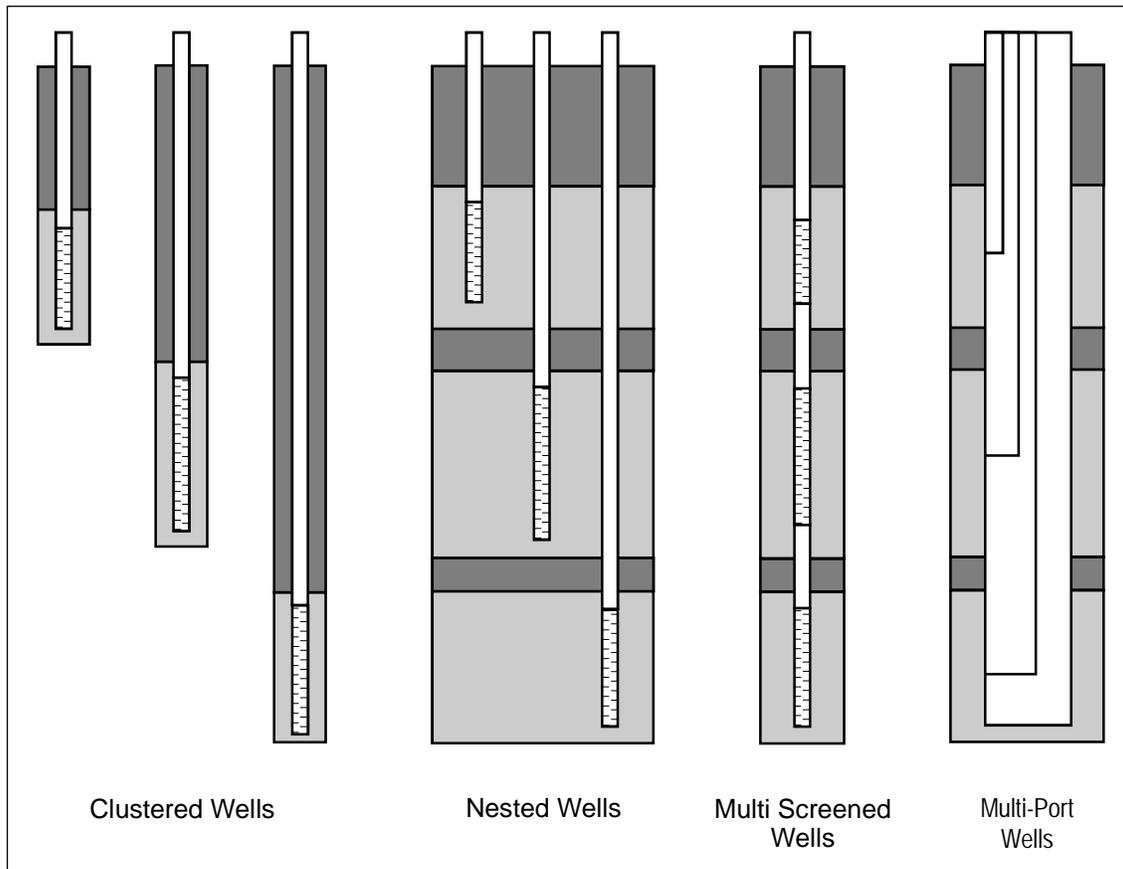


Figure 9.12 Comparison of Multi-Depth Soil Gas Well Designs

- Multi-Screen
- Multi-port

If probes are placed in a single borehole, a 2-foot bentonite seal must separate the zones.

If permanent probes are placed with direct push tools, the probe screen must be protected during advancement by the drive rods. This will prevent damage to the screen during advancement. Direct push rods are available which are designed for this purpose. The drawback to this technique is the potential for soil compaction during installation reducing the permeability in some soils and the inability to place a gravel pack or a bentonite seal other than at the surface. Therefore, the use of direct push (DP) probe installations may be limited to shallow probe applications.

9.7.3 Materials of Construction

During any soil gas sampling, the materials must not impact sample integrity. The material of construction for soil gas probes and sampling equipment will depend upon the objective of the sampling, contaminants of concern, concentration, analytical sensitivity and type of soil gas probe. The lower the expected concentration of contaminants and increased analytical sensitivity, the higher the quality of materials required for sampling (sample tubing, syringes, level of QA/QC) to prevent the alteration of the contaminant quality or quantity through sorption, desorption or cross contamination. If materials cannot be decontaminated between samples, they must be replaced between samples or replaced by a more suitable material. The quality of materials for sampling percent levels of landfill gasses will not have to be as high as the material used in delineating a dissolved VOC contaminant plume. Generally, the more inert the sample tubing, the more suitable

it would be for lower concentration soil gas sampling. Checks on the material applicability must be revealed in good QA/QC procedures.

9.7.4 Purge Rates and Volume

After a soil gas probe is installed, the air inside the probe must be purged to bring a soil gas sample to the surface for analysis. The purge rate and volume is a critical factor in soil gas sampling and will vary from site to site. Prior to initiating a soil gas-sampling event, tests should be conducted at several areas of the site to determine the optimum purge volume and rates. Optimum flow rate and purge volumes are achieved when vacuum pressure is at atmospheric and the contaminant concentration is stable. Use of the optimal purge rates and volumes should be made a “standard” sampling technique for the site investigation. Deviation of the procedures may give variable concentrations and make interpretation of the results difficult. The probe volume and evacuation time can be calculated using the following formula:

Purge Time Calculation for One Probe Volume

$$\frac{D^2 \times P_d \times 9.27}{P_r} = P_t$$

D = Diameter of probe, inches

P_d = Probe depth, feet

P_r = Pump rate, liters per minute

P_t = Purge time for one probe volume, seconds

Volumes for various probe diameters are included in Table 9.4.

Purging of the soil gas probe is best performed with a small air pump. The pump should have a flow meter and an in-line vacuum gage so changes in the flow rate and vacuum can be monitored (Figure 9.13). The use of an inline vacuum gauge and flow meter allows the operator to determine if soil vapors are being pulled into the probe and at an accurate volume and rate. This will ensure constant evacuation volumes for all probes during a sampling event thereby eliminating variability in sampling technique. Variations in the sampling technique can lead to variability in results. Use of this device also allows for estimates of soil-air permeability. Flow and vacuum readings should be recorded to help identify low permeability areas to aid in interpretation of the data.

If soil gas probes were constructed of larger diameter pipe (2 inches or greater) it has been shown that a “drop tube” or “feeder tube” can be used to reduce the time for purging a soil gas probe to obtain a representative sample. A drop tube is a small diameter (usually ¼ inch) installed in a soil gas probe from a bulkhead fitting on an airtight cap to the screened interval of the probe. As the probe is evacuated, soil gas is drawn directly into the screened interval for sampling. The stagnant air in the riser does not need to be removed and the airtight cap eliminates air intrusion that could dilute the sample. This greatly reduces the time required for purging larger diameter deep soil gas probes.

Monitoring vacuum pressure during and after purging allows for sampling from the probe with no vacuum pressure. This is important when sampling with a syringe for direct injection. For example, if a probe is sampled with a syringe while the system has 15 inches Hg vacuum, the concentration in the syringe will be half what it should be before removing it from the system. (Assuming normal atmospheric pressure is 30 inches Hg). When the syringe is removed from the

Tubing Size (inches ID)	Volume/ft. (liters)
3/16	0.005
1/4	0.010
1/2	0.039
3/4	0.087
1	0.15
2	0.62
4	2.46
6	5.54

ID = Inner Diameter



Figure 9.13A Purge pump with flow control and vacuum gauge, Photographed by C. Van Sciver



Figure 9.13B Purge pump with DRI inline, Photographed by C. Van Sciver

system it has 15 inches of Hg and will quickly go to atmospheric pressure by drawing in ambient air, diluting the sample by half of the original concentration. If the syringe is worn and has a weak seal between the plunger and the syringe barrel wall, then ambient air can be drawn into the syringe through this weakness, diluting the sample. After purging the soil gas probe, the vacuum pressure on the probe must always be allowed to return to atmospheric pressure before taking a syringe sample.

Many people employ the use of direct reading instruments (DRI) for the analysis of vapor samples in a soil gas survey. The DRI (PID, FID) is usually connected directly to the soil gas probe for analysis. This can be problematic since the DRI is sensitive to the mass of contaminant flowing to the detector. As the operational flow rate to a DRI is decreased, the response of the instrument decreases. Spatial variations in soil permeability across a site due to changes in soil lithology, texture and moisture will introduce variations in soil gas readings which are not concentration related. This will complicate the interpretation of soil gas survey results. Use of a purge system with flow and vacuum readings will determine if the DRI can be connected directly to the soil gas probe for sampling. If vacuum pressures are at atmospheric pressure and the flow rate is above the operational range of the instrument during purging, then the instrument can be connected directly to the soil gas probe. If flow rates and/or vacuum pressures during purging are outside the operational range of the instrument, a bag sample must be collected. This allows the instrument to analyze the sample at ambient conditions and obtain accurate readings.

9.7.5 Short Circuiting

During soil gas sampling it is important to have a good annular seal between the probe and soil. A poor annular seal will lead to “short circuiting” of vapors by ambient air as it moves down the annulus (Figure 9.8). This will lead to results that are non-representative and difficult to interpret. The type and need for an annular seal will depend upon the type of soil gas probe being employed. Some probes require a clay seal to be placed at the surface while others use the design of the probe, the drive point being smaller than the probe and rods. A poor annular seal can also be caused from multiple insertions into the same hole during vertical profiling.

9.7.6 Pressure Measurements

Pressure measurements in soil gas wells can be measured with a pressure/vacuum gauge that measures pressure in inches of water. The gauge can be installed permanently at the well head or a portable gauge can be used for measurements. The soil gas probe can be sealed with the sampling

cap or a ball valve. The ball valve can be permanently installed to minimize the time for pressure stabilization by not exposing the well to ambient pressure prior to measurement. Measurements must be made prior to obtaining a gas sample. After pressure and gas measurements are obtained, the cap to the gas probe must be replaced to reduce the effects of venting or barometric pressure variations on future gas sample compositions.

Pressure measurements from soil gas wells at various depths have shown a strong correlation with atmospheric pressure oscillations. These oscillations in barometric pressure occur twice daily due to solar and lunar gravitational forces (atmospheric tides), with high pressures at 10:00AM and 10:00PM and low pressures at 4:00 AM and 4:00PM. The deeper the interval the greater the lag time for the change in pressure. These data can be used to determine the depth and magnitude of pressure fluctuations that might induce “barometric pumping” in the vadose zone. When the curve for soil gas and barometric pressure cross, a reversal of the pressure gradient has occurred and the direction of gas flow changes from “soil to atmosphere” to “atmosphere to soil.” This will be seen as a negative pressure in the soil gas well compared to barometric pressure (Figure 9.14).



Figure 9.13C Purge pump with syringe adapter, Photographed by C. Van Sciver

For example, in landfills with vigorous microbial activity, gas pressures of 1-3 inches of water relative to atmospheric pressure are common with higher pressures recorded. Falling barometric pressures may cause an increase in landfill gas pressures and methane gas content as gas readily migrates from the landfill. Negative gas pressures are commonly observed and are a delayed result

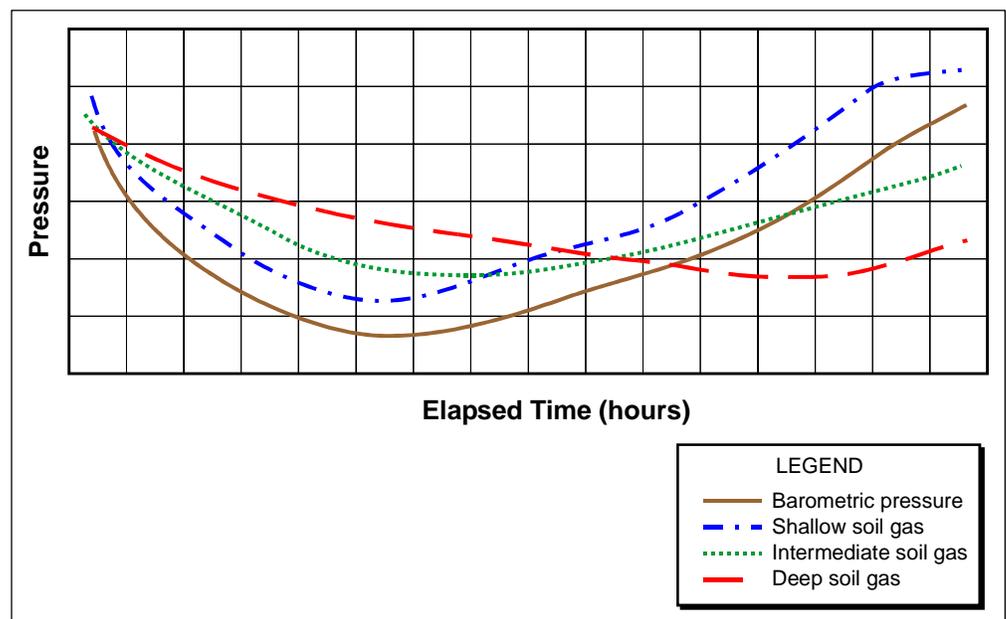


Figure 9.14 Soil Gas Pressure vs. Barometric Pressure

of the passing of a high-pressure system or atmospheric tides. High-pressure systems will introduce atmospheric oxygen into the surface soils in shallow portions of the landfill, which can alter methane concentrations and production from microbial activity. The relative gas pressure measurements at a particular area of a landfill along with the ability of site conditions to contain landfill gas, barometric pressure variations and the rate of gas production will control pressure induced landfill gas migration.

9.8 Passive Sample Collection Methodologies

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Passive sample collection includes two general sample collection techniques. These techniques include the passive collection of contaminants onto sorbent material placed in the vadose zone and a whole-air passive collection technique for collecting vapors emissions from the soil surface using an emission isolation flux chamber.

9.8.1 Sorbents

Passive sorbent sample collection utilizes diffusion and adsorption for soil gas collection onto a sorbent collection device over time. Depending upon the sorbents, they can be used to sample both VOCs and semi-volatiles (Figure 9.15).

The upward movement of contaminant vapors creates a concentration gradient in the vadose zone.

The passive sorbent collection method uses this to collect long-term non-disruptive samples of VOCs, SVOCs and biogenic gases. The principal of passive sorbent sample collection relies on the sorbent reducing the concentration of contaminants around the sampler over time. This creates a concentration gradient that decreases toward the sampler. This concentration gradient sustains the movement of vapors toward the sampler. Also since the sorbent can collect contaminants over a long period of time, this concentrates the mass of contaminants absorbed to the sampler, enhancing detection sensitivity. The quantity of VOCs collected by passive sorbent samplers is proportional to the concentration gradients of the contaminants near the passive sorbent sampler and the affinity of the contaminants to the sorbent material.

Passive sorbent samplers can be used in a variety of geologic and environmental conditions. The sorbents are placed in small diameter holes, made

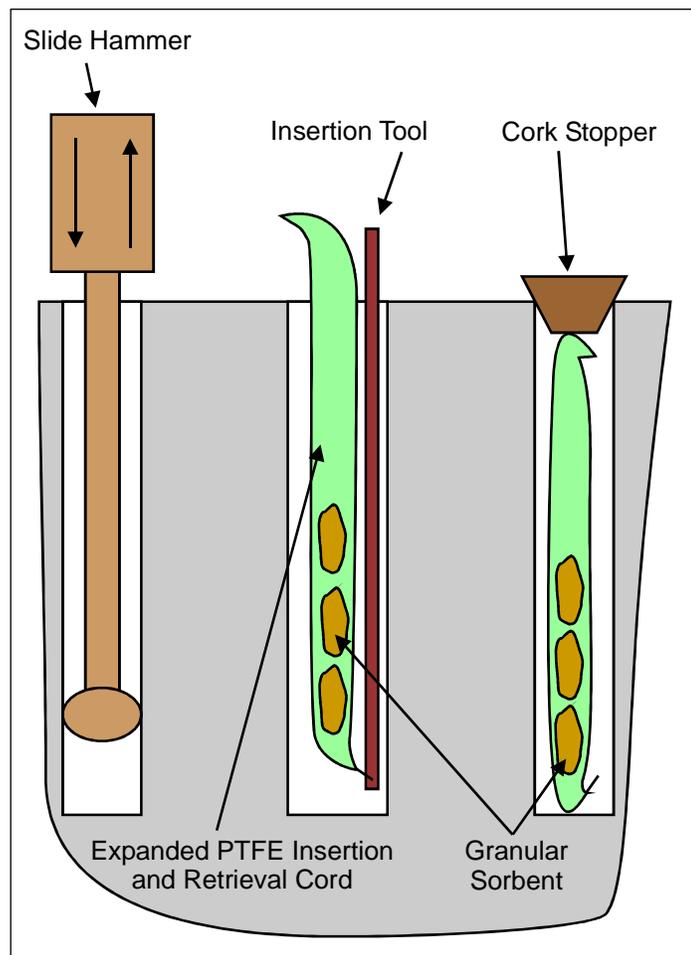


Figure 9.15 Passive sorbent sampler

with simple hand tools, that vary in depth, from a few inches to 5 foot deep. They are left in the ground for a few days or weeks depending upon the application and site conditions. The characteristics of the vadose zone and the chemical and physical properties of the contaminant will control migration of the contaminants. Passive sorbent samplers provide an integrated sample that compensates for any short-term fluxes in soil gas concentrations. This method is recommended when the ground water contaminants are not known and concentration is low.

9.8.1.1 Gore-Sorber® Passive Sampler

The Gore-Sorber® passive sampler is constructed of a hollow polytetrafluoroethylene (ePTFE) cord, used for insertion and retrieval of the sampler. The cord contains smaller ePTFE tubes that contain the granular adsorbent material. The granular sorbent material consists of various polymeric and carbonaceous adsorbents selected for their affinity to a wide variety of compounds. The adsorbents also minimize the uptake of water vapor. The sampler is stored and transported in a glass vial.

The cord is about four feet long and the sorbers are contained in a one-foot section of the cord. This allows for enough sorbers for two samples. This allows for duplicate analysis or as a backup. The membrane allows for the transport of vapors across its entire surface area while providing strength for the retrieval of the sampler. The contaminant vapors move unimpeded through the membrane to the adsorbent contained in the sorbers. This design prevents impact to the sorbers from soil particles and water vapor.

Gore-Sorber® Samplers are analyzed at the Gore Laboratory. They are analyzed by thermal desorption in accordance with EPA Method 8260/8270 using GC/MS. The Gore-Sorber® can detect VOCs, SVOCs, Explosives, PCBs, Chemical agents and breakdown products. The sample concentrations are reported in mass, by target compound and will be organized on a data table. The results can also be mapped based on mass concentration, with a supplied base map.

The Gore-Sorber® Samplers are installed into a small diameter hole, ½-inch or greater. The hole can be advanced with a slide hammer with tile probe, rotary hammer equipped with a 3-foot drill bit or direct push probe. Once the hole is opened, tie a length of cord to the loop on the sampler and a cork is tied to the surface end of the cord. The cork will seal the hole and the cord will allow for retrieval of the sampler. A stainless steel insertion rod, which is supplied by Gore, is placed in the pocket at the opposite end of the sampler and the sampler is inserted into the hole. The insertion rod is then removed and the cork tamped flush with the soil surface. The sample location should be marked to relocate the sampler for retrieval. Retrieval of the sampler requires pulling the sampler out of the hole the retrieval cord. The cord is separated from the sampler and the sampler is returned to its respective container.

9.8.1.2 BEACON BeSURE Soil Gas Sampler™

The BeSURE Soil Gas Sampler™ consists of two sets of hydrophobic adsorbent cartridges sealed in a 7ml screw top borosilicate glass vial that is pre-wrapped with a length of wire. The adsorbents used are chosen to concurrently target a broad range of compounds from the lighter VOCs (*e.g.*, Vinyl Chloride) to the heavy SVOCs (*e.g.*, PAHs), with the system calibrated to target over 100 compounds. Each cartridge contains the same, measured amount of adsorbents, which are hydrophobic and not required to be wrapped in a membrane.

To install a BeSURE Sampler™, the solid shipping cap is removed and replaced with a sampling cap that allows for the free transfer of compounds onto the adsorbent. A small diameter hole is then advanced to a typical depth of 1 to 3 feet and the Sampler is lowered into the upper portion of the hole, which is then sealed in the ground by collapsing the upper two inches of soil (or using

a plug when necessary). For locations covered by asphalt or concrete surfacing, an approximately 1" diameter hole is drilled through the surfacing to the underlying soils, and the upper portion of the hole is sleeved with a sanitized metal pipe provided in the Kit. After the Sampler is installed inside the metal pipe, the hole is patched with an aluminum foil plug and a thin concrete patch to protect the sampler from surface runoff and ambient air. Following the exposure period, the Samplers are retrieved and shipped under chain of custody to BEACON's laboratory for analysis. A minimum of one trip blank, which remains with the other samples during preparation, shipment, and storage, is included with the field samples. A two-person team can install approximately 50 to 100 samplers per day depending on the number of sample locations that are covered with asphalt or concrete.

Analysis of the samplers is completed by BEACON using gas chromatography/mass spectrometry (GC/MS) instrumentation, following modified EPA Method 8260B procedures. Analytical results are based on an initial five-point calibration and internal standards and surrogates are included with each sample analysis. The laboratory's reported quantitation level (RQL) for each of the targeted compounds is 25 nanograms; however, the actual detection limits are even lower, with MDLs at or below one nanogram for most compounds. Data are provided in tabular format as well as depicted on color isopleth maps showing the distribution of compounds identified.

9.8.1.3 Sample Depths

It is recommended that Passive Soil Gas Samplers be placed in holes created to a depth of 1 to 3 feet. This allows for the use of hand tools for the installation of the samplers. Samplers can be placed deeper, but deeper installations will require more time and sample retrieval from deeper depths is difficult. Shallow installations should be avoided due to affects from changing weather, off-gassing from porespace in the near surface and biologic degradation of contaminants in the near surface. Surface barriers such as paved areas will yield areas of artificially high concentrations or false positives as vapors collect and migrate along the barrier. These characteristics are discussed in further detail in Section 9.4, *Site Specific Characteristics*.

9.8.1.4 Sample Spacing

The size of the site, the objectives of the sampling and the amount of funds available will determine the sample spacing. The range of sample spacing for environmental investigations is 25-75 foot, with many surveys using 50-foot sample spacing. Smaller sample spacing should be used if the objective is to locate areas that are likely sources of contamination or small permeable zones of contamination migration. Larger sample spacing should be used in suspected non-contaminated areas or a broad screening of a large area. If contamination is discovered in these areas, then a soil gas survey with a higher density of sampling points can be conducted at a later time and the data combined on one set of maps.

9.8.1.5 Sample Exposure Time

Samplers should be exposed to the soil gas vapors for about 3-14 days depending on the type of sampler, soil characteristics, contaminant concentrations and the compounds of interest. This will allow the samplers to reach equilibrium with the soil gas environment to provide for a representative sample. Longer exposure time does not improve sensitivity except during prolonged rain events that can cause soil saturation and interrupt the vapor migration in the subsurface.

9.8.1.6 Multiple Surveys

In some site investigations, the results of the soil gas survey may warrant returning to the site and collecting additional samples. This may be due to requiring further delineation in contami-

nated areas, sampling beyond the initial site sampling area or confirming results that were not expected. In these cases it is desirable to tie in two or more soil gas surveys together. To accomplish this, several new samplers are placed in locations of prior samplers. If variables such as the exposure time, installation depth and analytical parameters are held constant from one soil gas survey to the next, the results can be comparable. It is best to place the co-located samplers in areas that will provide a range of mass levels reported in the original soil gas survey. This will provide duplicity in the data, and tie the soil gas surveys together.

9.8.1.7 Data Interpretation

The soil gas data will delineate the nature and extent of subsurface contamination. The soil gas data at one location can be compared relative to the soil gas data from other sample locations in the survey. The mass levels will show patterns of the spatial distribution indicating areas of greatest subsurface impact. These areas can then be targeted for further investigation.

9.8.2 The Emission Isolation Flux Chamber

The use of the emission isolation flux chamber is used for specific applications. The flux chamber is an enclosure device used to sample gaseous emissions from a defined surface area. These data can be used to develop emission rates for a given source for predictive modeling of population exposure assessments. This technique is applied to determine contaminant emissions from soils, landfills or water to determine the health risk to the public. The data can also be used to develop emission factors for remedial action designs.

The emission isolation flux chamber is a dome superimposed on a cylinder (Figure 9.16). This shape provides efficient mixing since no corners are present and thereby minimizing dead spaces. Clean dry sweep air is added to the chamber at a controlled volumetric flow rate. The gaseous emissions are swept through the exit port where the concentration is moni-

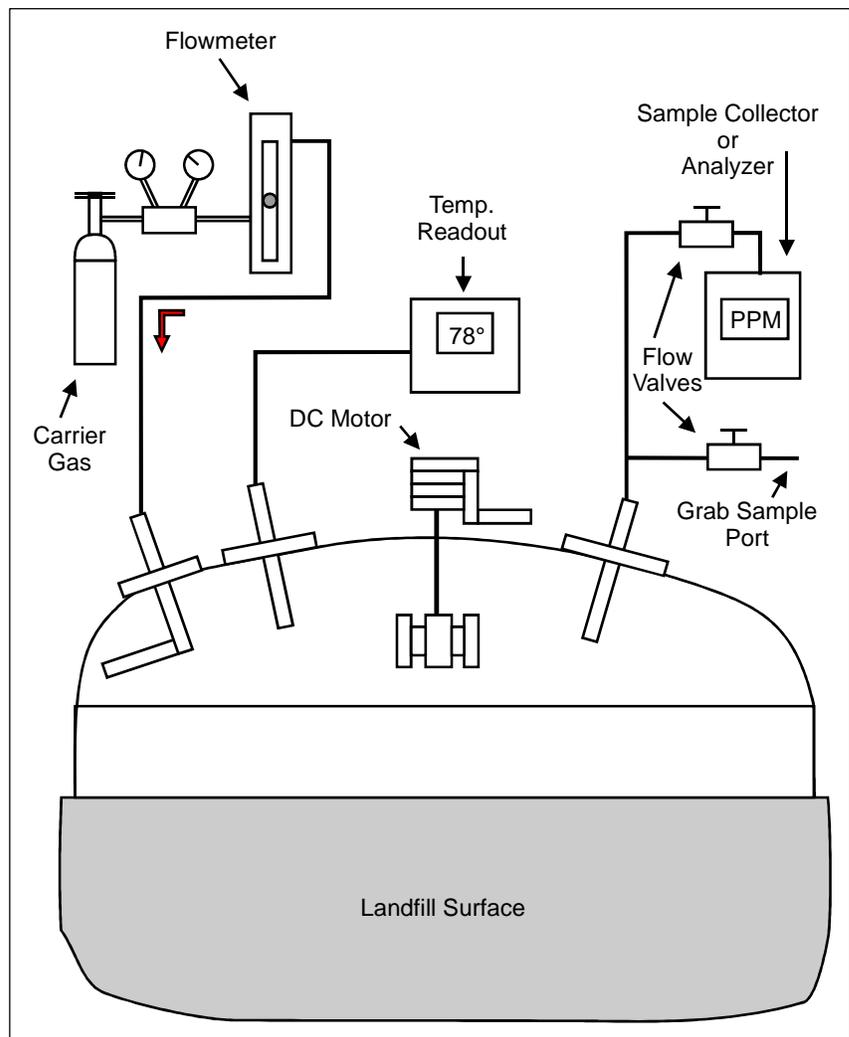


Figure 9.16 Surface flux chamber

tored by a real time or discrete analyzer. Real time measurements are typically performed with portable survey instruments to determine relative measurements of flux chamber steady state operation and hot zones. Discrete samples are taken when absolute measurements are required for steady state concentrations and emission rate levels. The emission rate is calculated based upon the surface area isolated, sweep airflow rate, and the gas concentration. An estimated average emission rate for the source area is calculated based upon statistical or biased sampling of a defined total area.

9.9 Soil Gas Sample Containers

[◀ Return to TOC](#)

The collection of the soil gas sample for analysis will vary depending upon probe design and analytical methodology. The most common types of collection methods (Figure 9.17) are as follows:

9.9.1 Gas Sample Bags – One of the more common soil gas sample container and collection techniques is using a gas sample bag (Tedlar[®], Teflon[®], metal-coated Tedlar[®], etc.) with an evacuation chamber. The use of an evacuation chamber allows an air sample to be collected without the sample passing through a pump. The evacuation chamber is an airtight container, which can hold a gas sample bag and has two fittings. One fitting is a through hull fitting for connection of the tubing from the soil gas probe directly to the gas sample bag and the other allows the removal of the air around the gas sample bag in the chamber. A gas sample bag is connected and placed in the evacuation chamber. The air surrounding the bag in the container is pumped out; creating a vacuum that causes the bag to fill. Vacuum chambers can be made from common materials or purchased commercially.

All gas sample bags must be checked for leaks and cross contamination between each sample. Sample bags can be purchased with septum ports and hose valves. These fittings can be a major source of leakage from the bags so they must be checked for tightness and integrity. Sorption of the contaminants to the bag is another area where loss of contaminants can occur and be a source of cross contamination. Depending on the contaminants, the holding times for samples in the gas sample bags will vary. In general, Tedlar[®] bags are the best choice for short holding times of samples (<3hr.). Aluminized bags are the best choice for longer holding times. Gas sample bags are cleaned between samples by purging with air or nitrogen until contaminants are non-detect.

9.9.2 Glass Bulbs – A second technique uses glass bulbs, which are glass cylinders with openings at each end, and having a septum port to withdraw sample aliquots with a syringe. The air sample is collected by connecting one end of the bulb to the probe and the other to a pump. The pump then draws the sample through the bulb. The sample of air does not go through the pump prior to collection. The advantage of glass bulbs is the material is inert and they are easy to use. The limitations of the glass bulbs are they are easily breakable and can loose contaminants to the Teflon[®] valves. Sample holding times for the glass bulbs is 24 hours.

9.9.3 Syringes – Syringes are used to withdraw a soil gas sample from a probe and inject it directly into an analytical instrument for on-site analysis. Syringes come in varying volumes, materials of construction and designs to meet the analytical criteria. They are easy to clean and replace. They have a short sample holding time (minutes) due to the potential for leakage and sorption of contaminants. As the seal of the plunger and barrel becomes worn, the syringe must be discarded due to the potential of sample dilution from leakage and short-circuiting around the plunger.

9.9.4 Stainless Steel Canisters – Stainless steel canisters are excellent for the collection and holding of soil gas samples. They can be used for sampling with a pump system or be per-evacuated so samples are collected by vacuum pressure. Laboratory calibrated valves may be attached to the canisters to allow for a time composite sample, as is required under certain lab methods. These

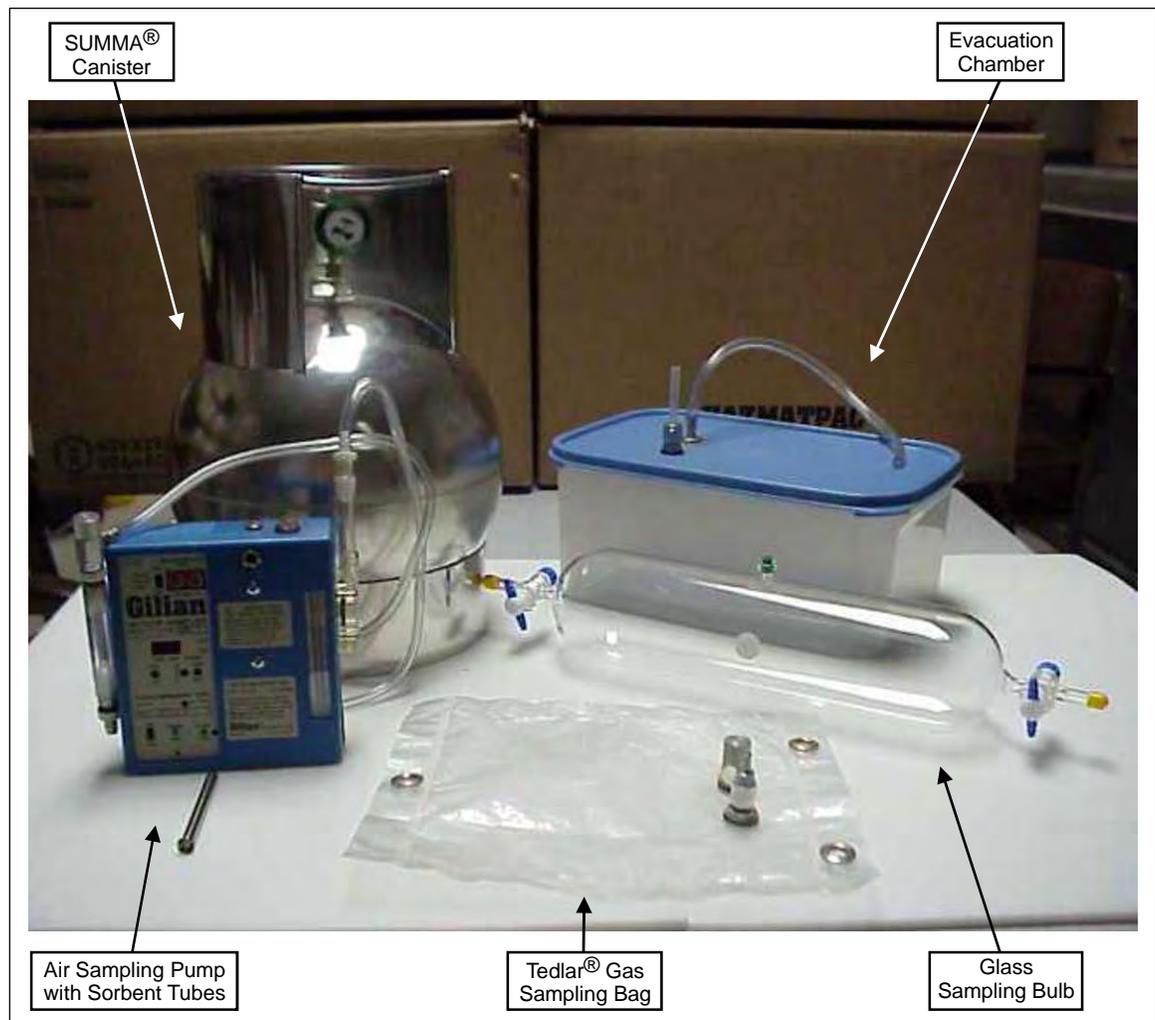


Figure 9.17 Air sampling equipment, Photographed by C. Van Sciver

samplers are commonly used for indoor air sampling. (*Indoor Air Sampling Guide for Volatile Organic Compounds – January 1999*) To use these devices the sample lines must be purged with sample air prior to opening for sampling to prevent sample dilution. They cannot be decontaminated in the field; a laboratory must clean them. Sample holding time is 14 days.

9.9.5 Sorbents – Soil gas samples can be collected on sorbents dependent upon the species of interest. Some of the sorbents used are charcoal, tenax, carbotrap, polyurethane foam (PUF) and carbon molecular sieve (CMS). A sorbent tube is connected to the soil gas probe and a sample is pumped through the tube while the sorbent strips the analytes from the air. Sample volumes must be measured accurately. The tube is then analyzed by thermal or solvent extraction and analyzed. Sorbent tubes allow for the concentration of low level contaminant concentrations, not detectable by other methods. Holding time for the samples depend upon the type of sorbent but are generally 14 days.

9.10 Analytical Methodologies

The method selected to analyze the soil gas samples must be consistent with the collection methodology to achieve the objectives of the investigation. Some basic criteria for selection of the proper analytical method includes:

- Sensitivity: Is ppb, ppm or percent concentration required? Is the relative concentration or the absolute concentration required?
- Selectivity: Will the analytical methodology identify specific compounds or will a total value satisfy the data objectives?
- Cost: Is the analytical methodology cost effective?

Based on these criteria, an analytical methodology can be chosen which will achieve the objectives of the soil gas investigation. Some of the methods used in soil gas sampling are as follows:

9.10.1 Detector Tubes

Detector tubes operate by drawing a known amount of gas through a tube with the use of a mechanical pump. If the indicator chemical is present in the sample, a stain will appear. The length of the stain will correspond to the concentration of the chemical in the sample. This analytical method is the most inexpensive, has good selectivity, and the sensitivity is usually high. Also, the user must be aware of the influence other gases and water moisture, which may be high in soil gas, will have on the method.

9.10.2 Direct Reading Instruments (DRI)

There are many types of DRIs available, which can provide dependable data if used within their limits. These units can be cost effective for obtaining analytical data, which has ppm sensitivity and limited selectivity. DRIs include organic vapor monitors (PID, FID), combustible gas monitors, (O_2 , CH_4 , H_2S) and landfill gas analyzers with infrared detectors (IR) for monitoring CH_4 and CO_2 .

These instruments have been used successfully in delineating VOC and SVOC contaminant plumes and monitoring landfill gas migration. These instruments can measure the subsurface contamination directly by measuring the VOC concentrations or indirectly by measuring the O_2 , CH_4 , H_2S and CO_2 concentrations, which are microbial byproducts from the breakdown of hydrocarbons and other organic material.

There are some problems with the use of these instruments for soil gas sampling. They include:

- Readings will be biased low if the sample flow rates are less than operational flow rates.
- Variations in readings from multi-component vapor samples, which will vary across a site.
- Soil gas concentrations above the linear range of the instrument.
- Relative humidity of the sample.
- Low levels of oxygen can cause a “flame out” in the FID.
- Elevated levels of methane and alkanes in a sample can “quench” the PID signal, resulting in a reading biased low.
- Sensitivity of the FID is increased with elevated levels of carbon dioxide and nitrogen.
- Combustible gas instruments with catalytic sensors do not function properly in anaerobic atmospheres. When methane concentrations greater than the LEL are expected, instruments equipped with thermal conductivity sensors should be used. These sensors are less sensitive below the LEL of methane.

To compensate for these potential problems, sampling techniques such as serial dilutions of samples or use of a dilutor for sampling must be used.

9.10.3 Portable Gas Chromatographs (G.C.)

Gas chromatography is a physical separation technique. The sample is carried through the column by the carrier gas, which separates the contaminants. As the gas stream emerges from the column, it passes into a detector providing a response. The responses are recorded as a function of time required for the sample to pass through the column. The sample response is compared to the response of a known standard to determine the contaminant identity and concentration. These instruments, though more expensive, can be very sensitive (sub ppb) and selective to the contaminant. This is due to the ability to select the type of detector (FID, PID, ECD) and column most amenable to the contaminants of concern.

9.10.4 GC/Mass Spectroscopy (GC/MS)

This method of analysis is a combination of gas chromatography and mass spectroscopy. The GC separates the contaminants and the mass spectrometer is used to obtain a mass spectrum of each compound. Positive identification of compounds is obtained by comparison of the compounds mass spectrum with a known spectral library. This method is very selective for target compounds. The drawback of the use of this analytical method is the cost.

9.11 Quality Assurance/Quality Control

QA/QC must be an integral part of any sampling activities. QA/QC procedures must be included in any sampling activities to ensure the samples are representative of the subsurface conditions. Without attention to detail the project becomes suspect and the data meaningless. QA/QC checks are required for any project will be dependent on the sampling and analytical methods selected. The following list of quality control considerations is applicable to most soil gas measurement programs:

- 9.11.1 Adhere to Sampling Procedures – Results from a soil gas survey are highly sensitive to procedure. All soil gas samples must be collected following established standard procedures for the site. Doing so provides consistency of data throughout the investigation. Examples include purge volumes, sample depths and techniques used. It is critical that sampling personnel collecting descriptive data should use standard procedures due to the subjective nature of tasks such as soil classifications (% sand, silt, clay, % moisture, etc.) Sampling should also be completed in the shortest period of time to prevent variation in the results from temporal effects (temperature, humidity, barometric pressure, etc.). Deviations from the standard procedures must be documented to assist in data interpretation.
- 9.11.2 Equipment Blanks – Equipment blanks are samples taken from clean sample containers and sampling equipment to determine if residual contaminants are present in the equipment prior to sampling. If contamination is present, the decontamination procedure or source of equipment must be modified to eliminate non-sample contamination. Frequency of equipment blanks will vary but should be run at least daily or prior to use of the equipment. This must include all probes, syringes and sample containers (bags, glass bulbs). Equipment blanks will prevent the occurrence of false positives of contaminants due to carryover in the sampling system.
- 9.11.3 Trip Blanks – Trip blanks are the samples taken from the sample container, which have been handled in the same manner as the sample containers, except there has been no sample placed into the sample container. The trip blank determines the integrity of the sample container for loss or addition of analytes due to sample handling and transport. The results of the trip blank will determine the need to alter sample handling and transport procedures. At least one trip blank should be included in each shipment of samples.

- 9.11.4 Background Measurements – Background measurements are samples collected upgradient for the known or suspected area of contamination. This allows for comparison of all measurements detected in the contamination zone and ensures that discrepancies, which arise, are the result of the sampling method.
- 9.11.5 Duplicates – Duplicate samples determine the variability associated with the sampling and analysis procedure. They should be performed at a minimum rate of one per every twenty samples. Duplicates should be taken from the same probe since different probe locations may yield order of magnitude variation in results.
- 9.11.6 Decontamination – Probes must be decontaminated to prevent cross contamination of samples. Probes and equipment should be steam washed or cleaned withalconox and water solution, given a tap water rinse, a distilled/deionized water rinse and then be allowed to air dry. The probes should then be purged with air. If the field blanks determine the probes are still contaminated after purging with air, they must be re-cleaned. The sampling equipment must be dry prior to sampling since the presence of water can lower or raise the contaminant values.
- 9.11.7 Leak Checks – Sample equipment and containers must be leak checked to prevent loss of sample, which may yield false negative results. When sampling with probes, the annular space between the probe rod and the borehole must be sealed at the ground surface with an inert material or with the drive rods to prevent “short circuiting” during purging and sampling. The sample tubing and connections must also be leak checked to ensure no ambient air is entering the system. This includes tubing fittings, connections, pumps and septa.
- 9.11.8 Equipment Calibration – Equipment must be calibrated as per the manufacturer’s requirements. Calibration standards should be run at a minimum of 1 per 10 samples. If area counts, retention times or concentrations differ by more than 10 - 20%, recalibration is required.
- 9.11.9 Limitations of the Analytical Methodology – Depending upon the analytical methodology selected, the limitations and influences that the soil gas matrix will have on the instrument must be understood. This is especially true for survey instruments, which are influenced by humidity, oxygen, or uneven flow rates. With a greater understanding of analytical methodology limitations, a better assessment and interpretation of the data is achieved.

9.12 Soil Gas Data Interpretation

[◀ Return to TOC](#)

Soil gas measurements are an approximation of the contaminant of interest in the subsurface. There is a considerable amount of interpretation that must be incorporated before the selection of a down gradient ground water monitor well location or approximating the boundaries of ground water or soil contamination.

Because of site and compound specific considerations, soil gas surveys should be planned with a thorough knowledge of the site. Site history and other factors as previously discussed may impact the results that are important to the survey. A preliminary site reconnaissance can be valuable when determining the shallowest depth, which will provide the most adequate sensitivity, appropriate sampling and analytical methods, purge volumes while optimizing other operational details.

When selecting the target contaminant(s), the persistence of that contaminant in the subsurface must be evaluated. VOCs can be altered or eliminated by biological or chemical transformation. Examples include microbial degradation of TCE by sequential dehalogenation to cis-1, 2-DCE, trans-1, 2-DCE and vinyl chloride or the reduction of organic hydrocarbons to methane and carbon dioxide by oxidation.

Interpretation of soil gas data begins in the field. When using on-site analysis of samples, data can be placed on a site map. As new data are generated, it can be used to direct or refine the sampling program. Recent advances in mapping technology allow for real-time laser survey mapping to produce concentration contour mapping. This type of mapping can be applied and incorporated into Geographical Information System (GIS) databases.

When using survey instruments for measuring total VOCs, the nature or individual components of the volatiles cannot be determined. Influences such as humidity, oxygen content and the presence of naturally occurring volatile organics will complicate the measurements. Although each naturally occurring compound may be present in small amounts, when combined, these compounds can have a significant influence on the total volatile organic level.

In the analysis of soil gas, the phase or “mode of occurrence” can be estimated by the differing properties of the components comprising the contaminant. For example, the relative concentrations of benzene to xylene can be an indicator if the sample was collected above an area of free product or a recent release. Since benzene has a higher solubility in water, it is readily stripped out of the liquid hydrocarbon as it is flushed with water. A high ratio will represent a more recent release or free product while a low ratio will represent an older release. The relative concentrations of these components can also be used to differentiate between different sources and spills of different composition (diesel, heating oil, gasoline).

In contrast to other major fuel components, xylenes have the lowest solubility in water and have a higher K_{oc} value. Xylenes do not migrate easily in a dissolved or liquid phase. Therefore, their occurrence in soil gas is more closely associated with the presence of the liquid hydrocarbons.

Combining the knowledge of the site, soil characteristics and contaminant aids in making an accurate interpretation of results. One of the most common reasons for false negatives is due to barriers including perched water, buried foundations, clay lenses and disturbed soils. Conversely, false positives are usually a result of site specific factors, the most common being the presence of unknown, near surface source areas that may be mistakenly identified as ground water contamination.

Another useful tool generated by soil gas surveys is the “fuel fingerprint.” This technique encompasses the comparison of soil gas chromatograms with those of pure product, which can then be used to identify volatile petroleum products in soil gas. Fuel fingerprinting however, is limited due to the enormous differences in volatilization, migration and degradation that affect individual fuel products. This method is most successfully used at sites where recent spills have occurred creating free product layers in shallow aquifers. Generally, to determine the occurrence of recent spills and ground water contamination, vertical soil gas concentration gradients can be used. The success of this method will depend upon the characteristics of the soil, contaminant and age of the spill.

When conducting soil gas surveys and mapping subsurface contamination from petroleum hydrocarbons, it is important to measure the concentration of biogenic gases that are generated from the bacteria that attack hydrocarbons. Under aerobic conditions carbon dioxide is generated and oxygen is depleted. Under anaerobic conditions carbon dioxide and methane are generated. These gases are often present in the largest concentrations. The longer the contamination is present in the subsurface the higher the concentrations of biogenic gases. The biogenic gases can be measured with infra red detectors with reasonable accuracy. Concentration of carbon dioxide in ambient air is 0.03%, biodegradation of soil organic material will yield concentrations of 3-5%. In the vicinity of hydrocarbon contamination, concentrations of carbon dioxide can be in the range of 5-30%. Concentrations of methane in the ambient air are in the range of 1-4 ppm by volume.

Methane concentrations in soil where there is no contamination will range from 0.5-3 ppm by volume. Biogenic methane generated under anaerobic conditions will be deeper in the subsurface than carbon dioxide, and is usually associated with the presence of free product. Biogenic methane and carbon dioxide data, when used in conjunction with specific organic vapor components (C1-C4 and C5+) are very useful in defining the extent of hydrocarbon contamination in the subsurface. The presence or absence of specific petroleum related hydrocarbons could aid in the interpretation of the data and confirm the relationship of the biogenic gases to their source. These biogenic gases can be used for mapping contaminant plumes even if the contamination is old and the lighter hydrocarbons are absent.

Gases that are monitored to indicate biological activity in a landfill are methane, oxygen and carbon dioxide. Carbon dioxide is monitored to assess the condition of the landfill. Carbon dioxide levels that exceeded the levels of methane may indicate the landfill is operating anaerobically. This condition is known as composting which can lead to landfill fires. Methane is measured as an indicator of the quality of the landfill gas in extraction systems. If the methane gas concentrations are below 50% by volume, this may indicate that ambient air is intruding into the landfill. Intrusion of ambient air into an extraction system can be confirmed by the measurement of the % oxygen. Oxygen concentrations should be in the range of 0-2% by volume in the landfill.

Differences in landfill gas composition will be reduced due to partial pressure gradients that allow gases in and outside the landfill gas unit to commingle. Although methane gas is lighter than air and carbon dioxide gas is heavier than air, these gases are concurrently produced at the microbial level and will not separate by their individual density. The gases will remain mixed and will migrate according to the concentration gradients between the landfill gas and the surrounding gasses.

The most common mistake associated with interpretation of soil gas data is to extend the interpretation beyond the scope of the survey design. For example, the relationship between volatile concentrations obtained in a soil gas survey rarely match the ground water contours. Differences in the ground water contaminant plume and the soil gas concentrations will vary as a result of varying soil conditions at a site. Quantitative relationships between soil gas data and ground water contamination are also difficult to interpret due to the varying soil conditions. Correlation coefficients between ground water contamination and soil gas results can have a difference in orders of magnitude. The lack of a statistical correlation between soil gas and ground water does not indicate that soil gas results are not indicative of ground water contamination, but that the variability of each set are different. A good example of the difference in variability is when duplicate ground water analyses results are not within two percent whereas adjacent VOA soil gas concentrations can vary by a factor of 4 to 5 times and still be indicative of the same subsurface contamination.

An important issue for interpretation of data is the unit of measurement of the results. Two types of units are used for reporting soil gas data. Volume per volume (ppmV, ppbV) or mass per volume ($\mu\text{g}/\text{l}$ or mg/m^3). At standard temperature and pressure the conversion factor is as follows:

$$\text{ppbV} = \frac{\mu\text{g}/\text{l} * \times 2.447 \times 10^4}{\text{MW}}$$

MW = Molecular weight of the gas

* = At standard temperature and pressure

Soil gas sampling and its analyses are designed as a screening tool to be used in conjunction with water quality data. It will always be necessary to confirm the predictions of contamination identified by a soil gas survey through the analysis of soil borings or monitoring wells. Soil gas surveys can be used as one tool in an array of investigative techniques for a phased approach to site characterization.

The successful use of soil gas surveying in determining subsurface contamination is dependent upon collection and analysis as well as planning and data interpretation. A soil gas survey should be conducted on the basis of successfully interpreting the data, not on the feasibility of collecting the data.

9.13 Data Reporting

The reporting of the data generated from soil gas sampling and analysis must include information required to interpret results for the particular application. (See the Soil Gas Probe Monitoring Record form on page 40.) Information that should be included in the final report is as follows:

- The purpose and objective of the soil gas survey.
- The criteria used for the selection of the soil gas sampling and analytical procedures including information on the physical and chemical properties of the targeted chemical compounds.
- The type of QA/QC procedures including samples, detection limits units of measure, decontamination procedures, reliability of results, data representativeness, etc.
- If known, characteristics of the contaminant source or spill.
- Potential impacts of the vadose zone on the sampling and analytical results (hydrologic conditions, soil types, paved areas, etc.) and interpretation.
- A site map including above and below ground structures, paved areas, and all underground utilities past and present (i.e., pipelines, etc.). GPS coordinates for incorporation into GIS databases.
- Weather conditions during sampling including rainfall, temperatures, passing weather fronts, barometric pressure, etc.
- Chart of sample location and contaminant concentrations.
- Results of QA/QC procedures.
- Results of analyses set on a site plan for horizontal and vertical data.
- Conclusions and recommendations including identifying potential source(s), the contaminants detected, activities that may have impacted the results need for additional data acquisition, etc.

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Chapter 10

Documentation

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Chapter 10 Documentation

10.1 Introduction

Proper documentation of all site activities is a crucial part of the field investigation process. Documentation must be maintained to trace the possession and handling of samples from the time of collection through analysis and disposition. Documentation, relative to sampling procedures, includes sample labels, sample seals, field logbooks, chain of custody records, sample analysis request forms, and laboratory sample logs. The details of all activities whether part of the site inspection or a sampling episode must be recorded in a field logbook. When samples are collected, documentation in the form of sample analysis request forms must be completed. Proper completion of these forms and the field logbook are necessary to support potential enforcement actions that may occur from the results of sample analysis.

Information on “Documentation” requirements relative to the Technical Requirements for Site Remediation (N.J.A.C. 7:26E-1.6) can be found on the Internet at <http://www.state.nj.us/dep/srp/regs/techrule/techrl01.pdf>. Information on “Documentation” requirements relative to the Site Remediation Program’s Electronic Data Interchange (SRP-EDI) can be found on the Internet at <http://www.state.nj.us/dep/srp/regs/srpedi>.

10.2 Field Log Books

Field logbooks must be bound and should have numbered, water resistant pages. All pertinent information regarding the site and sampling procedures must be documented. Notations should be made in logbook fashion, noting the time and date of all entries. Recorded information recorded should include, but not be limited to the following:

- Name and exact location of site of investigation
- Date and time of arrival and departure
- Affiliation of persons contacted
- Name of person keeping log
- Names of all persons on site
- Purpose of visit
- All available information on site (processes or products, waste generation, nature of spilled material)
- Composition and concentration of substance, if known; description of sampling plan
- Field instrument calibration information
- Location of sampling points (including justification)
- Geographically-referenced location of sample point and how determined, per requirements in Technical Requirements and SRP-EDI (see <http://www.state.nj.us/dep/srp/hazsite/>)
- Number of samples taken, volume of samples taken
- Preservation
- Method of sample collection and any factors that may affect its quality
- Date and time of sample collection and any factors that may affect its quality

- Name of collector
- All sample identification numbers
- Description of samples
- Weather conditions on the day of sampling and up to forty-eight hours previous and any field observations.

10.3 Documenting Sampling Points

[◀ Return to TOC](#)

Sampling points should be documented as to their exact location for purposes of future sampling. It is also necessary to document sample locations in an approved geographically referenced format per the Tech Regs and requirements in the SRP-EDI when submitting analytical results for those samples. Guidance regarding the geographically referenced locations can be obtained from <http://www.state.nj.us/dep/srp/hazsite/>.

The most common method to document sample locations for field notes is accomplished through the use of a monument, measuring tape and compass. A monument should be chosen at each site to act as a stationary reference point from which all sampling points can be measured using a compass and measuring tape.

If a building or other stationary structure exists, a corner may act as this reference point. If no such monument already exists, it will be necessary to create your own. A piece of wood, approximately 2 in. by 2 in. should be hammered into the ground to almost ground level, making it difficult to remove and thus assuring its permanence. The stake should then be marked with flagging tape or fluorescent paint.

When establishing a sampling point, follow this procedure:

- Standing at the monument, facing sampling point, use the compass hairlines to determine degree of direction.
- Line of sight should run from the monument, through both hairline needles on the compass, to the sampling point.
- When first establishing the sampling point, record the degree and direction reading from the compass in the field notebook, along with the distance measurement, from the monument to the exact sampling point.
- In the future, field-investigating teams should have no difficulty finding the exact locations from which previous samples were taken when they are provided with the monument and compass data.

10.4 Photo-Documentation

[◀ Return to TOC](#)

All sampling points should be documented on film. A film record of a sampling event allows positive identification of the sampling point. Photographs are the most accurate and convenient demonstration of the field personnel's observations. Photographs taken to document sampling points should include two or more reference points to facilitate relocating the point at a later date.

Keeping a record of photographs taken is crucial to their validity as a representation of an existing situation. Therefore, for each photograph taken several items should be noted in the field notebook:

- Date
- Time
- Photographed by (signature)
- Name of site

- General direction faced and description of the subject taken
- Sequential number of the photograph and the roll number

Photo-documentation is invaluable if the sampling and subsequential analytical data ends in litigation, enforcement, or cost recovery actions. Video coverage of a sampling episode can be equally or even more valuable than photographs because it can be used to prove that samples were taken properly as well as where they were taken. It can be used as a record of site conditions and can give those who have not been on-site an idea of the circumstances.

10.5 Sample Collection Paperwork

10.5.1 Sample Labels

Sample labels are an important part of proper documentation as their use not only reduces the possibility of confusing sample containers, but also provides the information necessary during handling to complete chain-of-custody forms. Sample containers should be pre-labeled before sample collection and the labels themselves protected from the sample matrix with a clear tape covering. Sample labels should include the well or sample number; parameter sampled; date; time sampled; sampler's initials; preservative; and site name or location.

10.5.2 Chain of Custody/Sample Analysis Request

When samples are collected for laboratory analysis, additional documentation procedures are required. The Chain of Custody (COC) form is intended as a legal record of possession of the sample. The COC should be initiated at the lab at sample container receipt, remains with the sample at all times and bears the name of the person assuming responsibility for the samples. This person is tasked with ensuring secure and appropriate handling of the bottles and samples. When the form is completed, it should indicate that there were no lapses in sample accountability.

In order to assure that the proper analysis is performed on the samples, the lab performing the analysis may require additional information and/or the regulatory agency involved. Information may include identification of samples by number, location and time collected and desired analysis. This information should act as a confirmation to lab contacts made prior to the sample event initiation.

In order to reduce the amount of paperwork necessary to adequately document sample collection, the NJDEP has combined the "Chain of Custody" form with the "Sample Analysis Request Form". The format of this document may vary, depending upon the source of the sample bottles.

There are two (2) versions of the combined form:

10.5.2.1 External Chain of Custody and Sample Analysis Request Form With Shipping Container

This document is intended to be initiated by the laboratory performing the analysis and to accompany the samples until they return to the laboratory for analysis (See External COC With Shipping Container Form on following page).

10.5.2.2 External Chain of Custody and Sample Analysis Request Form Without Shipping Container

This form can be used in cases where the sample collector (See External COC Without Shipping Container Form on following page) initiates chain of custody.

Both forms are currently utilized within the Site Remediation Program to ensure handling and legitimate transfer of samples.

Chapter 11

Sample Shipment

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Chapter 11

Sample Shipment

11.1 Introduction

Samples collected during a planned sampling episode or in response to a hazardous material incident often must be transported elsewhere for analysis. The NJDEP **requires** compliance with United States Department of Transportation (USDOT) regulations **and** the International Air Transport Association (IATA) regulations governing the shipment of hazardous materials. These regulations, CFR 49 Parts 171 through 180 for USDOT and the Dangerous Goods Regulations (DGR) for IATA, describe proper marking, labeling, placarding, packaging and shipment of hazardous materials, substances and wastes. IATA regulations cover strictly air transportation, both domestic and international. DOT regulations cover all modes of transportation for shipments originating within the United States and imported to the United States.

11.2 Definitions

The definitions of dangerous goods and hazardous materials as defined by IATA and DOT are respectively described below.

Dangerous Goods – “Articles or substances which are capable of posing a significant risk to health, safety or to property when transported by air and which are classified according to” the UN hazard classes.

Hazardous Material – “A substance or material which has been determined by the Secretary of Transportation to be capable of posing an unreasonable risk to health, safety, and property when transported in commerce, and which has been so designated. The term includes hazardous substances, hazardous wastes, marine pollutants, and elevated temperature materials...”

11.3 Training

According to the DGR, 1.5.0.2, “Training must be provided or verified upon the employment of a person in a position involving the transport of dangerous goods by air.” Additionally, 1.5.0.3 states, “Recurrent training must take place within 24 months of previous training to ensure knowledge is current, unless a competent authority has defined a shorter period.” CFR 49 Part 172, Subpart H – Training, has similar training requirements.

11.4 Shipper’s Responsibility

A shipper must comply fully with the IATA and DOT regulations when offering a dangerous good or hazardous material consignment for commerce.

11.5 Hazard Classes

All dangerous goods or hazardous materials are divided into nine Hazard Classes, some of which have divisions. Substances in a particular class share certain unique characteristics. The classes are listed in Table 11.1 of this chapter. It is the shipper’s responsibility to determine the proper hazard class of the dangerous goods. According to DGR 4.1.2.2, “When the hazard class of a substance is uncertain and it is being transported for further testing, a tentative hazard class, proper shipping name and UN number must be assigned on the basis of the shipper’s knowledge of the substance....” Generic and Hazard Class Proper Shipping Names are listed in Table 4.1A of the DGR. All specific

dangerous articles and substances are listed in the DGR in Section 4.2 – List of Dangerous Goods and in CFR 49 Part 172.101 – Hazardous Materials Table. In all cases the dangerous good must be checked to determine if it is forbidden item. A list of forbidden dangerous goods on aircraft is in Table 2.1.A of the DGR and in the List of Dangerous Goods or Hazardous Materials Table.

11.6 Packing

All packages must comply with the IATA Dangerous Goods Regulations and USDOT regulations, CFR 49 Part 173.

According to the DGR, 5.0.1.2, “When preparing each package of dangerous goods, the shipper must: (a) comply with the set of packing requirements appropriate to the type of packaging to be used; (b) use only the packaging permitted by... the List of Dangerous Goods;... (e) ensure that his responsibilities for packing are completely fulfilled when the package is presented to the operator for shipment..” Additionally, the overall quantity of the package is limited by the quantities specified in the List of Dangerous Goods and the Hazardous Materials Table.

11.7 Marking and Labeling

According to the DGR, 7.0.1, “The shipper is responsible for all necessary marking and labeling of each package of dangerous goods, and each overpack containing dangerous goods, in compliance with these Regulations.” Additionally, CFR 49 Part 173 – Subparts D, E and F must also be complied with.

11.8 Documentation

For all shipments of dangerous goods or hazardous materials, a Shipper’s Declaration for Dangerous Goods must be completed and accompany the dangerous goods package. A certified shipper must sign these forms.

11.9 Preservation of Samples Relative to Dangerous Goods Shipment

Nearly all aqueous and some non-aqueous analytical methods require the addition of a chemical preservative in order to extend the viable “life” of an environmental sample. Without the use of these preservatives, analytical data and subsequent end-used decisions would be questionable at best. The use of preservatives however has caused some confusion among the analytical and shipping community since acids and bases are regulated under the hazardous materials and dangerous goods shipping regulations. After research-design and execution by the USEPA and subsequent negotiation with the USDOT on this issue, it has been determined that the following maximum concentrations of acid or base are not considered corrosive materials by definition/testing under USDOT regulations to dermal, steel or aluminum. These concentrations are:

Nitric acid	0.4 weight percent
Sulfuric acid	0.4 weight percent
Hydrochloric acid	0.4 weight percent
Sodium hydroxide	0.2 weight percent

Based on the results of the USEPA research, environmental samples do not have to be declared as “hazardous materials” if they are preserved within the prescribed limits of the above acids or base and shipped via carriers obligated to follow USDOT regulations. The application of this determination to IATA regulations has not yet been formalized. To purchase a copy of the, *Determination of Corrosivity of Preserved Environmental Samples* go to <http://www.catalystinforesources.com>.

Non-aqueous samples preserved with methanol or sodium bisulfate must comply with all USDOT and IATA regulations. In addition, aqueous samples preserved with materials other than those listed above must comply with all USDOT and IATA regulations. Again, any sample of known waste or product that falls into a defined classification must be shipped according to regulatory requirements.

Table 11.1 Hazard Classes and Applicable Regulations		
Hazard Class	DGR References	CFR 49 References
Class 1 - Explosives*	3.1	173.50-173.63
Class 2 - Gases Div. 2.1 - Flammable Gas Div. 2.2 - Non-flammable gas; non-toxic gas Div. 2.3 - Toxic Gas	3.2	173.115-173.116
Class 3 - Flammable Liquids	3.3	173.120-173.121; 173.150
Class 4 - Flammable Solids Div. 4.1 - Flammable Solid Div. 4.2 - Substances liable to spontaneous combust Div. 4.3 - Substances which, in contact with water, emit flammable gases	3.4	173.124-173.125; 173.151
Class 5 - Oxidizing Substances and Organic Peroxide Div. 5.1 - Oxidizer Div. 5.2 - Organic peroxide	3.5	173.127-173.129; 173.152
Class 6 - Toxic and Infectious Substances Div. 6.1 - Toxic substances Div. 6.2 - Infectious Substances	3.6	173.132-173.134; 173.153
Class 7 - Radioactive material	3.7	173.401-173.476
Class 8 - Corrosives	3.8	173.136-173.137; 173.154
Class 9 - Miscellaneous Dangerous Goods	3.9	173.140-173.141; 173.155

* There are six divisions to Class 1:

1. Division 1.1 – Articles and substances having a mass explosion hazard.
2. Division 1.2 – Articles and substances having a projection hazard but not a mass explosion hazard.
3. Division 1.3 – Articles and substances having a fire hazard, a minor blast hazard and/or a minor projection hazard but not a mass explosion hazard.
4. Division 1.4 – Articles and substances presenting no significant hazard.
5. Division 1.5 – Very insensitive substances having a mass explosion hazard.
6. Division 1.6 – Extremely insensitive articles, which do not have a mass explosion hazard.

References

International Air Transport Association, Dangerous Goods Regulations, 42nd Edition, Montreal – Geneva, 2001

Office of the Federal Register, National Archives and Records Administration, 49CFR Parts 171-179, US Government Printing Office, Washington, D.C., 2000

Chapter 12

Radiological Assessment

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Chapter 12 Radiological Assessment

12.1 Introduction

The purpose of this chapter is to provide guidance on conducting and documenting environmental radiological surveys and sampling episodes and demonstrating compliance with N.J.A.C. 7:28-12 *Soil Remediation Standards for Radioactive Materials*. This chapter does not address building contamination.

The person responsible for remediating a radiologically contaminated site must obtain a copy of the latest version of the Multi-Agency Radiation Survey and Site Investigation Manual (MARSSIM) (available at <http://www.epa.gov/rpdweb00/marssim/>) for reference. Please note that some of the requirements in this chapter are different than the guidance presented in the MARSSIM. This chapter instructs the reader when to use the MARSSIM.

Figure 12.1 shows the relationship between MARSSIM terminology and the NJDEP Technical Requirements for Site Remediation (N.J.A.C. 7:26E).

Any questions regarding this chapter should be directed to the NJDEP, Bureau of Environmental Radiation (BER) at (609) 984-5400 or through the radiation protection program's web site at <http://www.state.nj.us/dep/rpp>. A complete list of references, a glossary (statistical terms are defined in the MARSSIM glossary), and list of acronyms can be found at the end of this chapter.

12.2 The Planning Stage (Data Life Cycle)

The process of planning, implementing, assessing and evaluating survey results is known as the Data Life Cycle. Survey designs should be developed and documented using the Data Quality Objectives (DQO) Process outlined in the MARSSIM (Appendix D, *The Planning Phase of the Data Life Cycle*, and Section 2.3.1, *Planning Effective Surveys – Planning Phase*). The expected output of planning surveys using the DQO process is a Quality Assurance Project Plan (QAPP) which should integrate all the technical and quality aspects of the Data Life Cycle. It should define in detail how specific quality assurance and quality control (QA/QC) activities will be implemented during the various surveys.

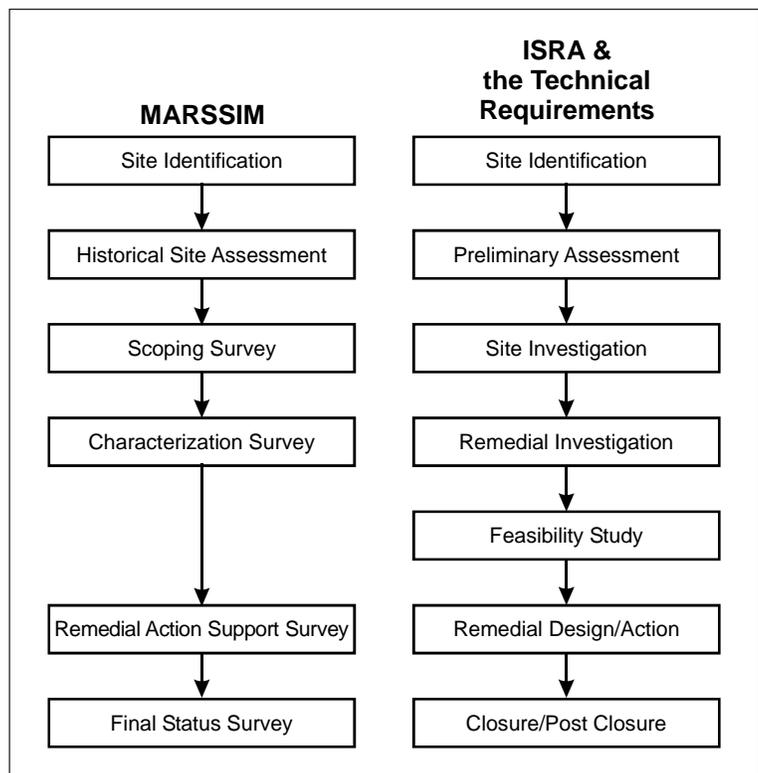


Figure 12.1 Comparison of MARSSIM and the Technical Requirements

Specific sampling, survey and laboratory requirements as they relate to QA/QC are found in N.J.A.C. 7:28-12.5, N.J.A.C. 7:26E-2, and Chapter 2 of this manual.

Comparison of the Radiation Survey & Site Investigation Process (MARSSIM) with ISRA & the Technical Requirements for Site Remediation. Note: The relationship between the MARSSIM process, the CERCLA process and RCRA process is discussed in Appendix F of the MARSSIM.

12.3 Site Identification/Historical Site Assessment

The purpose of the Historical Site Assessment (HSA) is to collect existing information on the site and its surroundings. A *site* is considered any installation, facility or discrete, physically separate parcel of land that is being considered for survey and investigation.

The objectives of the HSA are to identify potential or known sources of contamination, determine if the site, or any portion of it, poses a threat to human health and the environment, and differentiate between impacted and non-impacted areas. It should also provide input for scoping and characterization surveys, assess the likelihood of contaminant migration, if migration off site is possible, and identify additional potential radiation sites related to the site being investigated (such as neighboring properties). The three steps of the HSA are 1) identify the candidate site, 2) perform a preliminary investigation of the site, and 3) visit or inspect the site.

The checklist on page 3-5, *Table 3.1 Questions Useful for the Preliminary HSA Investigation*, of the MARSSIM should be used to collect existing information on the site. Further guidance on conducting a Historical Site Assessment is provided in Chapter 3 and Appendix A, *Example of MARSSIM Applied to a Final Status Survey*, of the MARSSIM, including documentation (Section 3.8, *Historical Site Assessment Report*, of the MARSSIM).

12.4 The Scoping Survey

The purpose of the scoping survey is to provide site-specific information based on limited measurements. The objectives of the survey may include performing a preliminary risk assessment and providing data to complete the site prioritization scoring process (CERCLA and RCRA sites only), supporting classification of all or part of the site as a Class 3 area¹ (area classification is discussed further in Section 12.4.3 of this chapter), evaluating the suitability of the survey plan for use in characterization, providing input into the design of the characterization survey obtaining an estimate of the variability in the residual radioactivity of the site, and identifying non-impacted areas that may be appropriate for reference areas. These surveys typically consist of judgement measurements based on the results of the Historical Site Assessment. Sufficient data should be collected to facilitate the area classification process. Figure 4.1, *Sequence of Preliminary Activities Leading to Survey Design*, in the MARSSIM illustrates the preliminary steps necessary for planning a scoping survey

12.4.1 Identify Contaminants

For sites with multiple radionuclide contaminants, one of the objectives of the scoping survey could be to establish the ratios between each nuclide. For some sites, a review of the operating history would be helpful in establishing a ratio, and a limited number of samples could be collected to verify the suspected ratio. For other sites, a ratio might be better established as part of the characterization survey. Parts of the site might have different ratios, or there may not be a consistent ratio. Determining a consistent ratio may be difficult. Before establishing the derived concentration guidance levels² (DCGLs) based on a ratio, consultation with the BER is recommended. If hazardous substances are commingled with the radionuclide contamination, the user is referred to Chapter 3 of this Manual for details on sampling.

To determine whether the radionuclides are correlated or not, MARSSIM states “a simple way to judge this would be to make a scatter plot of the concentrations against each other, and see if the points appear to have an underlying linear pattern.”³ The correlation coefficient should be calculated as well to see if it lies nearer to one than to zero. A curve fit and test of the significance of the results should also be performed.

12.4.2 Establish the Derived Concentration Guideline Levels (DCGLs)

The DCGLs (soil remediation standards) to be used in New Jersey for naturally occurring radioactive materials (NORM) are established in N.J.A.C. 7:28-12, *Soil Remediation Standards for Materials* for unrestricted, limited restricted, and restricted use. DCGLs for any radioactive material may be developed by the person responsible for remediating the site by following the methodologies in *Development of Generic Standards for Remediation of Radioactively Contaminated Soils in New Jersey, A Pathways Analysis Approach*. This document may be obtained by calling (609) 984-5400 or from the Radiation Protection Programs web site at <http://www.state.nj.us/dep/rpp>. If an alternative standard is proposed, the requirements in N.J.A.C. 7:28-12.12, “Petition for alternative remediation standards for radioactive contamination,” must be met. The DCGLs listed in N.J.A.C. 7:28-12.9, “Minimum remediation standards for radionuclide contamination of soil,” are for use when only one radionuclide is present in the radioactive contamination on the site. If more than one nuclide is present, the sum of the fraction calculation must be performed as outlined in N.J.A.C. 7:28-12.9(b). It may be necessary to determine the ratio between the nuclides in order to establish the nuclide-specific DCGLs. The Radioactive Soil Remediation Standards spreadsheet, or RaSoRS, will be essential in determining the DCGLs for NORM and is available from the Radiation Protection Programs web site or by calling (609) 984-5400.

Section 4.3.3, *Use of DCGLs for Sites With Multiple Radionuclides*, of the MARSSIM discusses multiple radionuclides and how to apply the sum of the fractions rule. For sites with multiple radionuclide contaminants, it may be possible to measure just one of the contaminants and still demonstrate compliance for all the contaminants present using surrogate measurements. A discussion of the use of surrogates is found in Section 4.3.2, *DCGLs and the Use of Surrogate Measurements*, of the MARSSIM.

The proper use of surrogate measurements takes into account the contribution to dose from multiple radionuclides by establishing a modified DCGL_{mod}, and in this case, the sum of the fraction calculation is not necessary. The surrogate method depends on establishing consistent ratios and this may be difficult for two or more radionuclides. Consultation with the BER is recommended when multiple radionuclides are involved.

12.4.3 Classify the Area by Contamination Potential

The NJDEP supports the MARSSIM classification methods as discussed in Section 4.4, *Classify Areas by Contamination Potential*, of the MARSSIM. The area classification process looks at areas as either *non-impacted* or *impacted*, and further classifies *impacted* areas into Class 1, 2 or 3 based on the potential for residual radioactive contamination, with Class 1 having the greatest likelihood of being affected. The significance of survey unit classification is that this process determines the final status survey design and the procedures used to develop this design.

The scoping survey and historical site assessment can be used to determine initial classifications, but classification may change throughout the site investigation process. In order to classify an area, a comparison with the DCGL is made. All impacted areas are initially classified as Class 1 so that if a survey unit is classified incorrectly the potential for making decision errors does not increase. MARSSIM defines Class 1 areas as areas that have, or had prior to remediation, a potential for

radioactive contamination or known contamination above the DCGL, while Class 2 and 3 areas are not expected to exceed the DCGL.

The site should be broken down into smaller survey units if appropriate and each survey unit should have only one classification. Sections 2.5.2, *Classification*, and 4.6, *Identify Survey Units*, in the MARSSIM has further information on identifying survey units. The suggested size of the survey units for each classification is given in this section. These are suggested maximum sizes and may be modified based on site-specific information. If an area greater than these suggested sizes is proposed, consultation with the BER is suggested before continuing with the site investigation process.

12.4.4 Determine Background

For radionuclides that are also present in background, Section 4.5, *Select Background Reference Areas*, of the MARSSIM provides information on selecting a background reference area. The scoping survey should be used to verify that the selected background reference area is non-impacted. Determination of the number of samples to collect in the background reference area is discussed under Section 12.5.2 of this manual, *The Final Status Survey*. If it is desirable to determine background before the final status survey NUREG 5849, Manual for Conducting Radiological Surveys in Support of License Termination, Section 2.3.1 should be used. This section discusses the number of samples needed and how to determine if they are representative.

12.4.5 Perform the Survey

Information on how to conduct surveys is discussed in Section 4.7, *Select Instruments and Survey Techniques*, of the MARSSIM. The flow diagram (Fig. 4.2, *Flow Diagram for Selection of Field Survey Instrumentation for Direct Measurements and Analysis of Samples*) for selection of field instruments for direct measurements and analysis of samples should be used before proceeding with the survey. Criteria for selecting sample collection and measurement methods are discussed in Section 4.7.3, *Criteria for Selection of Sample Collection and Direct Measurement Methods*, of the MARSSIM.

For additional information regarding soil sampling, please refer to Chapter 6, *Sample Collection*, Subsection 6.2 in this sampling manual. For scanning soil with a NaI detector, the MDC_{scan}^4 values given in Table 6.7, *NaI(Tl) Scintillation Detector Scan MDCs for Common Radiological Contaminants*, of the MARSSIM provide an acceptable estimate of MDC_{scan} . The instruments selected must be capable of detecting the nuclides of interest at the levels of interest.

Section 4.8, *Site Preparation*, in the MARSSIM discusses how to prepare the site for the survey and how to lay out the reference coordinate system. Appendix A of the MARSSIM also has some useful information on the grid system and examples of scanning patterns. It may be useful to lay out the grid at this point for use later in the site investigation process.

Chapter 6 of this manual outlines the methodology for sampling surface soil, subsurface soil, ground water, streams, sediments, etc. These procedures shall be used. Water samples shall be analyzed for gross alpha and gross beta and isotopic gamma activity. If the gross alpha exceeds 5 pCi/L, additional tests shall be performed to identify and quantify specific radionuclides such as radium isotopes. If gross beta exceeds 50 pCi/L, the contributing radionuclides shall be identified. See N.J.A.C. 7:28-12.5, *Sampling, surveying and laboratory requirements*, for information pertaining to laboratory requirements.

Quality Control, as it relates to survey activities, is discussed in Chapter 2 of this manual and Section 4.9, *Quality Control*, of the MARSSIM.

12.4.6 Document the Scoping Survey Results

Documentation should include identification of the survey areas, classifications of each (and justification), proposed use of surrogates and the established ratios of nuclides, if applicable, the site-specific DCGLs and supporting documentation for these items. Guidance on reporting requirements can also be found in N.J.A.C. 7:26E, Technical Requirements for Site Remediation.

12.5 The Characterization Survey

The characterization survey may be used to satisfy a number of specific objectives, including those outlined in N.J.A.C. 7:26E-4.1. It is important to identify *specific* characterization objectives before planning to collect and analyze samples or make measurements in the field. Some examples of specific questions that might be asked in order to formulate the objectives are:

- How deep is the contamination in the survey unit (area of concern)?
- What is the concentration of ^{226}Ra in the pile of soil near the fence line?

In order to answer these and other questions, measurements will have to be taken for comparison with the established DCGLs.

Examples of some other objectives include: 1) evaluation of remedial alternatives (e.g. unrestricted use, limited restricted use, or alternative standards), 2) collect additional data to be used: as input to the final status survey design, to reevaluate the initial classification of survey units, to select instrumentation based on the necessary MDCs, to establish the acceptable Type I and Type II errors, and to fulfill the requirements for a Remedial Investigation/Feasibility Study (CERCLA sites only), and 3) evaluation of remediation technologies. The characterization objectives themselves determine the kinds of measurements, and in turn, the analyses and sensitivities needed for comparison with the DCGLs.

12.5.1 Determination of Lateral and Vertical Extent of Contamination

As discussed in Section 12.4.5 above, the DEP soil sampling procedures shall be used for the characterization survey. Gamma logging of boreholes is performed to identify the presence of subsurface deposits of gamma-emitting radionuclides.

A sensitive gamma detector such as a NaI gamma scintillation probe is lowered into the hole and a count rate determined at 0.5-foot increments. The sensitivity and specificity of this technique may be improved by placing the detector inside a shielded collimator assembly. A geologic description of the subsurface shall also be made. Soil sampling at depth should also be performed, based on the results of the gamma logging. It may be necessary to take only one sample if the readings are consistent, or more if there is greater variability in the gamma readings along the core.

Soil samples shall be analyzed in a DEP-certified laboratory. A list of certified laboratories may be obtained by contacting the NJDEP Office of Quality Assurance. It may be possible to limit the cost of analysis by correlating the gamma readings to concentration values. This may be acceptable provided enough data is collected to demonstrate a correlation. A correlation coefficient shall be calculated to support the assumed correlation. A minimum of 30 samples, representing the range of values shall be used to establish the correlation.

The number of samples to be taken depends on the objectives of the survey. If the characterization data is intended to be used for the final status survey, then the number of samples must be determined as outlined in Section 12.7, *The Final Status Survey*. Otherwise, a sufficient number of samples shall be collected to determine the vertical and lateral extent and to identify areas that require remediation (by comparing to the DCGLs).

12.5.2 Determine Background

For radionuclides that are also present in background, Section 4.5, *Select Background Reference Areas*, of the MARSSIM provides information on selecting a background reference area. The characterization survey can be used to further define the background reference area by determining radionuclide concentrations in environmental media.

12.5.3 Classify the Area by Contamination Potential

Review the initial area classifications made during the Scoping Survey and determine if any of them have changed.

12.5.4 Document the Characterization Survey Results

Documentation of the characterization survey should provide a complete record of the radiological status of the site. All sampling and analysis data (including QA/QC data) should be included, along with justifications for changes made to area classifications (if any). There should be enough information in this report to support approaches or alternatives to site cleanup.

12.6 The Remedial Action Support Survey

The remedial action support survey is conducted in order to support remediation activities by monitoring the effectiveness of the decontamination efforts. This survey should be limited to activities such as direct measurements and scanning surveys. One of the goals of the remedial action support survey is to help determine when a site is ready for a final status survey.

Measurement methods should be chosen which are capable of detecting the radiation of interest at concentrations between 10% and 50% of the DCGL_w.

Section 5.4, *Remedial Action Support Surveys*, of the MARSSIM provides specific guidance on this type of survey.

12.7 The Final Status Survey

The final status survey is performed in order to demonstrate that the residual radioactivity in each survey unit meets the predetermined criteria for release, whether it be for unrestricted, limited restricted, restricted, or alternate use. For the final status survey, the fundamental components being examined are the survey units.

Compliance is demonstrated through the use of statistical tests (either the Wilcoxon Rank Sum (WRS) test when the contaminant is present in the background, or the Sign Test, if the contaminant is not present in the background. The statistical tests evaluate the average concentration in each survey unit with the elevated measurement comparison for evaluating small areas of elevated activity. Section 8.2.3, *Select the Tests*, in the MARSSIM discusses the choice of statistical tests). It is the primary goal of the final status survey to demonstrate that all radiological parameters satisfy the established guideline values and conditions. Data obtained at other points in the survey and site investigation process can provide useful information.

It may be possible, that the DCGLs selected for a given site are close to background. This may be the case where multiple nuclides are present, the background is variable, and the site is to be released for unrestricted use. In this case, following the MARSSIM methods may be difficult. In these situations, it is recommended that the guidance in NUREG 1505, *A Non-Parametric Statistical Methodology for the Design and Analysis of Final Status Decommissioning Surveys*, be used, specifically, Scenario

B. In Scenario B, instead of having to prove that the survey unit meets the release criterion, the owner has to prove that the survey unit does not meet the release criterion.

12.7.1 Revisit the Area Classifications

It is important at this stage in the process to be certain that all areas are classified correctly, as this information will be used to determine compliance. The criteria used for designating areas as Class 1, 2, or 3 shall be described in the final status survey and compliance with the classification criteria shall be demonstrated in the final status survey. More information on survey investigations and reclassifications can be found in Section 5.5.3, *Developing an Integrated Survey Strategy*, of the MARSSIM.

12.7.2 Determine the Relative Shift

To be certain that the conclusions drawn from the samples are correct, a minimum number of samples are needed to obtain statistical confidence. In order to determine the number of samples, you must first determine the relative shift (Δ/σ_s). The relative shift is the ratio involving the concentration to be measured relative to the variability in that concentration, and can be thought of as an expression of the resolution of the measurements.

$$\Delta/\sigma_s = (\text{DCGL}_w - \text{LBGR}) / \sigma_s$$

where:

DCGL_w = derived concentration guideline

LBGR = concentration at the lower bound of the gray region; the Type II (β) error is set at the LBGR. The LBGR is always below the DCGL_w

σ_s = an estimate of the standard deviation of the concentration of residual radioactivity in the survey unit

The value for σ_s is determined either from existing measurements or by limited sampling. It could also be estimated if remediation will be performed. If, during the survey process, a background reference area is used and the σ_r in the reference area is greater than the σ_s in the survey unit, the larger value should be used to design the survey.

The DEP concurs with the MARSSIM recommendation to initially set the LBGR at 0.5 DCGL_w. Alternatively, the LBGR could be set at the expected concentration in the survey unit following remediation, or at the time of the final status survey. Since small values of Δ/σ_s result in large numbers of samples, it may be desirable to make the Δ/σ_s greater than 1. There are two ways to increase Δ/σ_s . The first is to increase the width of the gray region by making LBGR small. Only Type II decision errors occur in the gray region. The disadvantage of making the gray region larger is that the probability of incorrectly failing to release a survey unit will increase. The second way to increase Δ/σ_s is to make σ smaller. One way to make σ smaller is to have survey units that are relatively homogeneous for measured radioactivity. That is why selecting the boundaries of the survey unit is an important consideration. Another way to make σ small is by using more precise measurement methods. The more precise methods might be more expensive, but this may be compensated for by the decrease in the number of required measurements.

Generally, the design goal should be to achieve Δ/σ_s values between one and three. Overly optimistic estimates for σ should be avoided. The consequence of taking fewer samples than are needed, given the actual measurement variations, will be unnecessary remediations (increased Type II decision errors).

Section 5.5.2.2, *Contaminant Present in Background-Determining Numbers of Data Points for Statistical Tests*, and Appendix D, *The Planning Phase of the Data Life Cycle*, in the MARSSIM provide greater detail.

12.7.3 Determination of Acceptable Type I and Type II Decision Errors

A decision error is the probability of making an error in the decision on a survey unit by passing a survey unit that should fail (alpha or Type I) or by failing a survey unit that should pass (beta or Type II). The acceptable Type I (alpha) decision error rate is 0.05 or less. Any Type II (beta) decision error rate is acceptable to the NJDEP. However, the higher the Type II rate, the greater the probability that the site will not pass the statistical test, even though the site should pass.

Section 5.5.2.1, *Application of Decommissioning Criteria*, and Appendix D.6, *Specify Limits on Decision Errors*, of the MARSSIM provide greater detail on this process.

12.7.4 Determine the Number of Samples Needed

The minimum number of samples needed, N, can be determined from the equation for N found in Equation 5.1 in the MARSSIM. N is the total number of data points for each survey unit/reference area combination. For contaminants that are also present in background, the N data points are divided between the survey unit and the reference area. So N/2 measurements are performed in each survey unit, and N/2 measurements are performed in each reference area. Fewer samples will increase the probability of an acceptable survey unit failing to demonstrate compliance. Alternately, once the values for Δ/σ and the error types (α and β) have been established, the values for N/2 or N can be found in Tables 5.3, *Values of N/2 for Given Values of the Relative Shift, Δ/σ , when the Contaminant is Present in Background*, and 5.5, *Values of N for Given Values of the Relative Shift, Δ/σ , α , and β when the Contaminant is Not Present in Background*, of the MARSSIM.

Section 5.5.2.2, *Contaminant Present in Background-Determining Numbers of Data Points for Statistical Tests*, in the MARSSIM outlines the process. If the radionuclides of interest are not present in the background, or they are a small percentage of the $DCGL_w$, then a determination will need to be made for the number of samples needed to perform a Sign Test, instead of the WRS Test. This information can be found in the same sections of the MARSSIM.

As an example, suppose you had the following scenario:

Background: A site has 14 survey units and one (1) reference area. ^{238}U is the radionuclide of concern, and measurements will be of nuclide concentration.

$$\begin{aligned} DCGL_w \text{ } ^{238}\text{U} &= 10 \text{ pCi/g} \\ \sigma_s &= 3.2 \text{ pCi/g} \\ \text{Bkg. in reference area} &= 1.2 \text{ pCi/g} \\ \sigma_r &= 0.6 \text{ pCi/g} \\ \text{LBGR is selected to be} &= 5 \text{ pCi/g} \\ \Delta/\sigma \text{ is then} &= (10-5)/3.2 = 1.56 \end{aligned}$$

If α is 0.05 and β is 0.10, looking at Table 5.3, *Values of N/2 for Given Values of the Relative Shift, Δ/σ , when the Contaminant is Present in Background*, in the MARSSIM gives a value of N/2 of 13 (meaning 13 samples from the reference area and 13 from the survey unit).

12.7.5 Additional Samples for Elevated Measurement Comparison in Class 1 Areas

Class 1 survey units may have small areas where concentrations exceed the $DCGL_w$ which the statistical tests described above may not successfully detect. Therefore, class 1 areas must be

tested to demonstrate that they meet the dose criteria for release. This test is known as the elevated measurement comparison.

The number of survey data points needed for the statistical test is determined as discussed in Section 12.7.4 above. These data points are then positioned throughout the survey unit by first randomly selecting a start point and establishing a systematic pattern. The systematic sampling grid must be triangular for Class 1 areas. The number of calculated survey locations, $N/2$ (for when the contaminant is present in background; N if the Sign test is used), is used to determine the grid spacing, L , of the systematic sampling pattern (see Section 5.5.2.5 *Determining Survey Locations* in the MARSSIM). The grid area that is bounded by these survey locations is given by $A_{\text{GRID}} = 0.866 \times L^2$ for a triangular grid. For a rectangular grid, $A_{\text{GRID}} = L^2$. This is the size of the area that could be missed through the established sampling pattern. In order to avoid missing an elevated area of this size, a DCGL_{EMC} must be determined using the equation below:

$$\text{DCGL}_{\text{EMC}} = (\text{Area Factor}) \times (\text{DCGL}_w)$$

Area factors were calculated using RESRAD⁵ (version 6.2.1) and are presented in Table 12.1. These area factors were determined by running RESRAD for each nuclide and varying the lot size and the length parallel to the aquifer. The area factors were then computed by taking the ratio of the dose per unit concentration generated by RESRAD for the default values (10,000 m²) to that generated for the other areas listed. For sites with multiple radionuclides, the most conservative area factor (the smallest) can be used.

Next, the minimum detectable concentration (MDC) of the scan procedure, needed to detect an area of elevated activity at the limit determined by the area factor, must meet the following condition:

$$\text{Scan MDC}_{\text{required}} = \text{DCGL}_{\text{EMC}}$$

The actual MDCs of scanning techniques are then determined for the available instrumentation (see Section 6.7 *Detection Sensitivity* of the MARSSIM). If the actual scan MDC of the selected instrument is less than the required scan MDC, no additional sampling points are necessary for assessment of small areas of elevated activity. In other words, the scanning technique exhibits adequate sensitivity to detect the small areas of elevated activity that are missed by sampling. If the actual scan MDC is greater than the required scan MDC, then it is necessary to calculate the area factor that corresponds to the actual scan MDC using the following equation:

$$\text{Area Factor} = \frac{\text{scan MDC}(\text{actual})}{\text{DCGL}_w}$$

Next, find the grid area corresponding to that Area Factor from Table 12.1. Then calculate the number of sample points needed to produce that grid area as follows:

$$n_{\text{EA}} = \frac{(\text{Survey Unit Area})}{(\text{Grid Area})}$$

The calculated number of survey locations, n_{EA} , is used to determine a revised spacing, L , of the systematic pattern (refer to Section 5.5.2.5 *Determining Survey Locations* of the MARSSIM). Specifically, the spacing, L , of the pattern (when driven by areas of elevated activity) is given by:

$$L = \sqrt{\frac{A}{0.866n_{\text{EA}}}}$$

for a triangular grid or:

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$$L = \sqrt{\frac{A_{SU}}{n_{EA}}}$$

for a rectangular grid.

where A_{SU} is the area of the survey unit. Grid spacing shall be rounded down to the nearest distance that can be conveniently measured in the field. If n_{EA} is calculated to be smaller than N (the number of data points calculated in Section 12.7.4 of this chapter), then N should be used to determine L .

Continuing with the example above, suppose you had the following:

$$\begin{aligned} \text{Survey Unit area} &= 380\text{m}^2 \\ \text{DCGL}_W &= 10 \text{ pCi/g of } ^{238}\text{U} \\ \text{Number of samples} &= 13 \end{aligned}$$

To determine the area that might be missed, first calculate L , the length of the grid:

$$L = \sqrt{\frac{380\text{m}^2}{(0.866)(13)}}$$

$$L = 5.8\text{m}$$

Then determine the area of the grid:

$$\begin{aligned} A &= .866 \times L^2 \\ A &= 29 \text{ m}^2 \end{aligned}$$

Look in Table 12.1. The area factor that corresponds to a 29m^2 for ^{238}U is 6.2. Now determine the DCGL_{EMC} :

$$\begin{aligned} \text{DCGL}_{EMC} &= (\text{Area Factor})(\text{DCGL}_W) \\ \text{DCGL}_{EMC} &= 6.2 \times 10 \text{ pCi/g} = 62 \text{ pCi/g} \\ \text{Actual MDC}_{\text{scan}} &= 80 \text{ pCi/g} \end{aligned}$$

Since the Actual MDC is greater than the DCGL_{EMC} , the grid spaces must be made smaller by increasing the number of samples.

To determine the new number of samples needed (n_{EA}), the area factor corresponding to the MDC must be determined:

$$\begin{aligned} \text{Area Factor} &= \text{MDC}_{\text{scan}} / \text{DCGL}_W \\ \text{Area Factor} &= 80/10 = 8 \end{aligned}$$

Next, go to Table 12.1 and find the size of the new grid block area. In this case, for ^{238}U , an area factor of 8 corresponds to an area of about 20 m^2 .

Now, calculate the number of sample points needed to produce that grid area:

$$n_{EA} = 380\text{m}^2 / 20\text{m}^2 = 19$$

So the length of the grid spacing is:

$$L = \sqrt{\frac{380\text{m}^2}{0.866(19)}}$$

$$L = 4.8 \text{ m}$$

For multiple radionuclides, an MDC and an Area Factor of the mix may be needed. Chapters 9 and 12 of *Decommissioning Health Physics: A Handbook for MARSSIM Users*, (Abelquist, 2001) provides examples of how to determine these values.

Figure 5.3 (*Flow Diagram for Identifying Data Needs for Assessment of Potential Areas of Elevated Activity in Class 1 Survey Units*) in the MARSSIM provides a concise overview of the procedure used to identify data needs for the assessment of small areas of elevated activity.

If the following condition is met, then the elevated measurement comparison is acceptable:

$$(\delta / \text{DCGL}_W) + \{(\text{avg. conc. in elevated area} - \delta) / (\text{area factor for elevated area} \times \text{DCGL}_W)\} < 1$$

where δ = the average residual radioactivity concentration for all sample points in the survey unit.

If there is more than one elevated area, a separate term should be included for each one.

As an example, suppose you had the following data:

$$\begin{aligned} \text{DCGL}_W^{226\text{Ra}} &= 3 \text{ pCi/g} \\ \text{DCGL}_{\text{EMC}} &= 79.5 \text{ pCi/g (for a 1m}^2 \text{ area)} \end{aligned}$$

There is one elevated area with an average concentration of 60 pCi/g.

The area factor for the elevated area is 26.5.

The results (pCi/g) of the other sampling points are:

$$\begin{aligned} &1.0, 2.0, 1.5, 0.5, 2.2, 2.9, 1.0, 0.3, 2.0, \text{ and } 1.0. \\ &\delta = 6.76 \text{ pCi/g above background} \end{aligned}$$

Since

$$6.76/3 + (60-6.76)/(26.5 \times 3) \text{ is not } < 1, \text{ therefore, the elevated area must be remediated.}$$

The elevated measurement comparison method is described further in Section 8.5.1, *Elevated Measurement Comparison*, and Section 5.5.2.4, *Determining Data Points for Small Areas of Elevated Activity*, of the MARSSIM.

Table 12.1 Outdoor Area Dose Factors									
Nuclide	Grid Area								
	1 m²	3 m²	10 m²	30 m²	100 m²	300 m²	1000 m²	3000 m²	10,000 m²
Ra-226, Po-210	26.5	11.9	5.6	3.9	2.8	2	1	1	1
Th-232, Th-228, Ra-228	15	6.9	3.3	2.4	1.8	1.5	1.1	1	1
U-238, Th-230, U-234	48.8	22.1	10.1	6.2	3.4	2.1	1.1	1	1

12.7.6 Determining Sample Locations

A reference coordinate system must first be established for the impacted areas. A single reference coordinate system may be used for a site, or different systems may be used for each survey unit or groups of survey units. Section 4.8.5, *Reference Coordinate System*, of the MARSSIM describes how to establish such a system.

Class 1 sampling locations are established in a triangular pattern. A rectangular or triangular pattern may be used for Class 2 areas. Measurements and samples in Class 3 survey units and reference areas should be taken at random locations. More information on establishing survey locations can be found in Section 5.5.2.5, *Determining Survey Locations*, of the MARSSIM.

12.7.7 Investigation Levels and Scanning Coverage Fractions

Investigation levels are radionuclide-specific levels of radioactivity used to indicate when additional investigations may be necessary. Investigation levels also serve as a quality control check to determine when a measurement process begins to get out of control. For example, a measurement that exceeds the investigation level may indicate that the survey unit has been improperly classified or it may indicate a failing instrument.

The investigation levels in Table 12.2 should be implemented. When an investigation level is exceeded, the first step is to confirm that the initial measurement/sample actually exceeds the particular investigation level. This may involve taking further measurements to determine that the area and level of the elevated residual radioactivity are such that the resulting dose meets the release criterion. Depending on the results of the investigation actions, the survey unit may require reclassification, remediation, and/or resurvey. If after further investigation it is determined that the area does exceed the investigation level, then it should be remediated. Further information on investigation levels is found in Section 5.5.2.6 *Determining Investigation Levels* of the MARSSIM.

Scanning is performed to locate small areas of elevated concentrations of residual radioactivity. Table 5.9 *Recommended Survey Coverage for Structures and Land Areas*, in the MARSSIM illustrates the acceptable scanning coverage based on Area Classification.

Table 12.2 Final Status Survey Investigation Levels		
Survey Unit Classification	Flag Direct Measurement of Sample Result When:	Flag Scanning Measurement Result When:
Class 1	> $DCGL_w$ and a statistical parameter-based value	> $DCGL_{EMC}$
Class 2	> $DCGL_w$	> $DCGL_w$ or MDC_{SCAN}
Class 3	> fraction of $DCGL_w$	> $DCGL_w$ or MDC_{SCAN}

12.7.8 Special Survey Considerations Subsurface Residual Radioactivity

The MARSSIM final status survey method was designed specifically for residual radioactivity in the top 15 cm of soil. If previous surveys have shown that there is significant subsurface residual radioactivity, this must be taken into account. (consult with BER staff to determine if significant quantities of subsurface contamination exist). The characterization survey should determine the depth of the residual radioactivity. If RaSoRS was used to develop the $DCGL_w$, it was based on the assumption that this activity may be excavated in the future and that mixing of the residual radioactivity will occur in the process (note that since N.J.A.C. 7:28-12 bases the $DCGLs$ on the vertical extent of contamination, subsurface residual radioactivity is permitted to be left in place).

When the appropriate $DCGLs$ are established, the final status survey is performed by taking core samples to the depth of the residual radioactivity. The number of cores to be taken is the number N required for the WRS or sign test, as appropriate. Since the final status survey is performed before any cover is placed over the area, the elevated measurement comparison test should be performed to detect any areas of elevated activity (on the surface). The grid spacing shall be adjusted if necessary.

The Department is awaiting the MARSSIM guidance on subsurface contamination. Until that time, subsurface contamination will be treated on a case by case basis.

Triangular grids are required for Class 1 areas due to their better efficiency in location areas of elevated concentration.

12.7.9 Determining Compliance

The measurement data should first be reviewed to determine if the areas were properly classified. Refer to Section 8.2.2, *Conduct a Preliminary Data Review*, of the MARSSIM for an acceptable method. If it is shown during the final status survey that an area was misclassified with a less restrictive classification, the area should receive the correct classification and the final status survey for that area should be repeated.

If there are several areas that appear to be misclassified, it may be necessary to repeat the characterization, reclassify the areas, and re-survey them for the new classification.

The next step is to determine if the measurement results show that the survey unit(s) meets the release criteria. Chapter 8, *Interpretation of Survey Results*, of the MARSSIM provides an in-depth discussion of the interpretation of survey results, particularly for the final status survey.

Table 8.2, *Summary of Statistical Tests*, in the MARSSIM summarizes acceptable ways to interpret the sample measurements. Note that a description of the WRS test is found in Section 8.4, *Contaminant Present in Background*, of the MARSSIM, the Sign Test is found in Section 8.3, *Contaminant Not Present in Background*, and the elevated measurement comparison is described in Section 8.5 *Evaluating the Results: The Decision*.

If a survey unit fails, the measurement results should be evaluated to determine why. A survey unit fails when the null hypothesis is not rejected. When the null hypothesis is not rejected, it may be because it is in fact true, or it may be because the test did not have sufficient power to detect that it is not true. A retrospective power curve can be generated to determine if the test had sufficient power. If the retrospective power analysis shows that the test did not have sufficient power, then more samples may be all that is necessary rather than remediation. Of course, some failures may be because the residual radioactivity does not meet the remediation standards and further remediation will have to be performed.

Passing the statistical test is not the only criteria for determining compliance with the remediation standards. The following example illustrates this point. A Class 1 Survey unit passes the statistical tests and contains some areas that were flagged for investigation during scanning. Further investigation, sampling and analysis indicates one area is truly elevated. This area has a concentration that exceeds the $DCGL_{EMC}$. This area is then remediated. Remediation control sampling shows that the residual radioactivity was removed, and no other areas were contaminated with removed material. In this case one may simply document the original final status survey the fact that remediation was performed, the results of the remedial action support survey, and the additional remediation data. In some cases, additional final status survey data may not be needed to demonstrate compliance with the release criterion.

Sections 8.2.2, *Conduct a Preliminary Data Review*, 8.5.3, *If the Survey Unit Fails*, and Appendix D, *The Planning Phase of the Data Life Cycle*, of the MARSSIM provide acceptable methods for reviewing measurement results.

12.7.10 Mixing After Demonstrating Compliance with the Pre-mixing DCGLs

N.J.A.C. 7:28-12.9(b) allows soils at the DCGLs listed in Tables 4A through 5B to remain at the specified thickness (vertical extent) together with the specified thickness of uncontaminated surface soil (USS). After it is demonstrated that the site meets the DCGLs in these tables, there is a requirement to mix the residual layer with the uncontaminated surface soil so that a uniform concentration is achieved throughout the soil column. This is done to avoid the requirement for a deed restriction to maintain the cover. A uniform concentration is determined by using the same number of sample points as determined above. At each sample point, a borehole shall be advanced to the depth of the disturbed soil. Surface soil samples shall be taken and analyzed at a certified laboratory. Gamma scanning may be used to verify that the concentration at depth does not vary by more than 30%.

12.7.11 Documenting the Final Status Survey

Documentation for the final status survey should be complete, and provide a clear record of the radiological status of the survey unit(s) relative to the established DCGLs. Sufficient data and information should be provided so that an independent evaluation of the survey results can be performed.

While much of the information in the final status survey will be available in other reports generated during the site survey and investigation process, where practical, this report should be a stand-alone document. Further guidance on documentation may be found in Appendix N, *Data Validation Using Data Descriptors*, of the MARSSIM.

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Acronyms

CERCLA	Comprehensive Environmental Response, Compensation, and Liability Act
DCGL	derived concentration guideline level
DQO	data quality objectives
DEP	Department of Environmental Protection
EMC	elevated measurement comparison
EPA	Environmental Protection Agency
HSA	Historical Site Assessment
LBGR	lower bound of the gray region
MARSSIM	Multi-Agency Radiation Survey and Site Investigation Manual
MDC	minimum detectable concentration
NORM	naturally occurring radioactive material
NRC	Nuclear Regulatory Commission
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RCRA	Resource Conservation and Recovery Act
RI/FS	Remedial Investigation/Feasibility Study

Glossary

Area of concern – any existing or former location where radioactive materials are or were known or suspected to have been discharged, generated, manufactured, refined, transported, stored, handled, treated, disposed, or where radioactive materials have or may have migrated.

Contaminated site – all portions of environmental media at a site and any location where contamination is emanating, or has emanated, therefrom, that contain radioactive materials at a concentration which fails to satisfy any applicable remediation standard.

Derived concentration guideline level (DCGL) – a derived, radionuclide-specific activity concentration within a survey unit corresponding to the release criterion (regulatory limit expressed in dose or risk). The DCGL is derived from the activity/dose relationship through various exposure pathway scenarios and is established in N.J.A.A. 7:28-12.

Data quality objectives (DQO) – qualitative and quantitative statements derived from the DQO process that clarify study technical and quality objectives, define the appropriate type of data, and specify tolerable levels of potential decision errors that will be used as the basis for establishing the quality and quantity of data needed to support decisions.

Data Quality Objectives Process – a systematic strategic planning tool based on the scientific method that identifies and defines the type, quality, and quantity of data needed to satisfy a specified use.

Final status survey – a survey or analysis, performed after remediation, which provides data that demonstrates that all radiological parameters satisfy the remediation standards.

Impacted area – any area with a possibility of containing residual radioactivity in excess of natural background levels.

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Natural background radionuclide concentration – the average value of a particular radionuclide concentration in soils measured in areas in the vicinity of the site, in an area that has not been influenced by localized human activities, including the site's prior or current operations.

Piezometer – a small-diameter well generally used for water-level measurement.

Quality assurance – the total integrated program for assuring the reliability of monitoring and measurement data which includes a system for integrating the quality planning, quality assessment and quality improvement efforts to meet data end-user requirements.

Quality assurance project plan (QAPP) – a document which presents in specific terms, the policies, organization, objectives, functional activities and specific quality assurance/quality control activities designed to achieve the data quality goals or objectives of a specific project or operation.

Quality control – the routine application of procedures for attaining prescribed standards of performance in the monitoring and measurement process.

Remediation standards – the combination of numeric standards that establish a level or concentration, and narrative standards, to which radioactive contaminants must be treated, removed, or otherwise cleaned for soil, ground water or surface water, as provided by the Department pursuant to N.J.S.A. 58:10B-12, in order to meet the health risk or environmental standards.

Soil remediation standards – these are the specific DCGLs determined for a particular site through the use and implementation of N.J.A.C. 7:28-12, *Soil Remediation Standards for Radioactive Materials*.

Vertical extent – the average depth, measured in feet, of the post-remediation radioactive contamination over an affected area not to exceed the limits specified in the Multi-Agency Radiation Survey and Site Investigation Manual (NUREG 1575, EPA 402-R-97-016) and any subsequent revisions thereto.

Endnotes

¹An impacted area with little or no potential for delivering a dose above the release criterion, and little or no potential for small areas of elevated activity.

²Derived from the activity / dose relationship through various exposure pathway scenarios; established in N.J.A.C. 7:28-12.

³Section I.11, *Multiple Radionuclides*, in the MARSSIM.

⁴Minimum detectable concentration – the *a priori* activity level that a specific instrument and technique can be expected to detect 95% of the time. The MDC_{scan} is simply the minimum detectable concentration of the scanning survey.

⁵The RaSoRS spreadsheet cannot be used when the size of the elevated area is smaller than the size of the house (1000 ft²). However, since the area factors used in RaSoRS were obtained directly from RESRAD, the numbers in Table F.1 are acceptable for determining a $DCGL_{EMC}$.

Chapter 13

Personnel Protection

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Chapter 13

Personnel Protection

13.1 Introduction

For adequate protection and prevention of contaminant exposure to workers at hazardous waste sites in all phases of investigation, personal protective equipment must be utilized and personnel contamination reduction practices must be implemented (see Chapter 14). The procedures must be appropriate to protect against the potential or known hazards at a site. All personal protective clothing and equipment utilized at hazardous waste sites must comply with 29 CFR 1910.120 of the OSHA Standard for Hazardous Waste Site Operations and with 29 CFR 1910.134 and 139 which are the OSHA requirements for the use of Respiratory Protection

The information in this chapter on Personal Protective Clothing and Equipment (PPE) is excerpted from the, *Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities*, developed by NIOSH, OSHA, USCG and EPA in October 1985. Included here are key factors in the selection and use of PPE and discussion of heat stress and other physiological factors for consideration when planning site activities. Chapter 4 of this manual, *Site Entry Activities*, addresses other factors for consideration prior to site entry.

In addition to general guidance provided here on levels of protection, a more subjective determination must be made of the PPE required for initial safety should situations exist where the type of materials/contaminants have not been identified, the potential for contact with contamination is unknown and/or the hazards are not clearly identifiable. Level B protection is the minimum level recommended for initial entries until the hazards have been further identified and defined through monitoring, sampling and other reliable methods of analysis, and PPE corresponding with these findings can be utilized. The appropriate level of protection shall be determined prior to the initial entry into an area suspected of containing hazardous materials, or contamination, base on the best available information. Subsequent information may suggest changes in the original level selected.

13.2 Selection of Respiratory Equipment

13.2.1 Self-Contained Breathing Apparatus (SCBA)

A self-contained breathing apparatus (SCBA) usually consists of a face-piece connected by a hose and a regulator to an air source (compressed air, compressed oxygen, or an oxygen generating chemical) carried by the wearer. Only positive-pressure SCBAs are recommended for entry into atmospheres that are immediately dangerous to life and health (IDLH). SCBAs offer protection against most types and levels of airborne contaminants. However, the duration of the air supply is an important planning factor in SCBA use. This is limited by the amount of air carried and the rate of consumption by the user, which can be highly variable. Also, SCBAs are bulky and heavy, thus they increase the likelihood of heat stress and may impair movement in confined spaces. Generally, only workers handling hazardous materials or operating in highly contaminated areas (exclusion zones) require SCBAs.

13.2.2 Supplied-Air Respirators (SARs)

Supplied-air respirators (also known as airline respirators) supply air, never just oxygen, to a face-piece via a supply line from a stationary source. SARs are available in positive-pressure and negative-pressure modes. Pressure-demand SARs with escape provisions provide the highest level of protection (among SARs) and are the only SARs recommended for use at hazardous waste sites.

SARs are not recommended for entry into IDHL atmospheres (MSHA/NIOSH 30 CFR Part II) unless the apparatus is equipped with an escape SCBA.

The air source for supplied-air respirators may be compressed air cylinders, or a compressor that purifies and delivers ambient air to the face-piece.

13.2.3 Combination SCBA/SAR

A relatively new type of respiratory protection is available that uses a regulator to combine the features of an SCBA with a SAR. The user can operate the respiratory in the SCBA or SAR mode, through either the manual or automatic switching of air sources. This type of respirator allows entry into and exit from an area using the self contained air supply, as well as extended work periods within a contaminated area while connected to the airline. It is particularly appropriate for sites where workers must travel an extended distance to a work area within a hot zone and remain within that area for relatively long work periods (e.g., drum sampling). In such situations, workers would enter the site using the SCBA mode, connect to the airline during the work period, and shift back to the SCBA mode to leave the site.

13.2.4 Air-Purifying Respirators

Air-purifying respirators consist of a face-piece and an air-purifying device, which is either a removable component of the face-piece or an air-purifying apparatus worn on a body harness attached to the face-piece by a corrugated breathing hose. Air-purifying respirators selectively remove specific airborne contaminants (particulates, gases, vapors, and fumes) from ambient air by filtration, absorption adsorption, or chemical reactions. They are approved for use in atmospheres containing specific chemicals up to designated concentrations, and not for IDLH atmospheres. Air-purifying respirators have limited use at hazardous waste sites and can be used only when the ambient atmosphere contains sufficient oxygen (19.5 percent) (30 CFR Part 11.90(a)). Conditions that may exclude the use of air-purifying respirators include:

- Oxygen deficiency.
- IDHL concentrations of specific substances.
- Entry into an unventilated or confined area where exposure conditions have not been characterized.
- Presence or potential presence of unidentified contaminants.
- Contaminant concentrations are unknown or exceed designated maximum use concentration(s).
- Identified gases or vapors have inadequate warning properties and the sorbent service life is not known and the unit has no end-of-service-life (ESLI) indicator.
- High relative humidity (may reduce the protection offered by the sorbent).

There are three types of air-purifying devices: 1) particulate filters; 2) cartridges and canisters, which contain sorbents for specific gases and vapors and; 3) combination devices. Their efficiencies vary considerably even for closely related materials.

MSHA and NIOSH have granted approvals for manufacturers' specific assemblies of air-purifying respirators for a limited number of specific chemicals. Respirators should be used only for those substances for which they have been approved. Most chemical sorbent canisters are imprinted with an expiration date. They may be used up to that date as long as they were not opened previously. Once opened, they begin to adsorb humidity and air contaminants whether or not they are in use. Their efficiency and service life decreases and therefore they should be used immediately.

Cartridges should be discarded after use but should not be used for longer than one shift or when breakthrough occurs, whichever comes first.

Where a canister or cartridge is being used against gases or vapors, the appropriate device shall be used only if the chemical(s) has “adequate warning properties” (30 CFR Part 11.150). NIOSH considers a substance to have adequate warning properties when its odor, taste, or irritant effects are detectable and persistent at concentrations below the recommended exposure limit (REL). A substance is considered to have poor warning properties when its odor, or irritation threshold, is above the applicable exposure limit. Warning properties are essential to safe use of air-purifying respirators since they allow detection of contaminant breakthrough, should it occur. While warning properties are not foolproof, because they rely on human senses which vary widely among individuals and in the same individual under varying conditions (e.g., olfactory fatigue), they do provide some indication of possible sorbent exhaustion, poor face-piece fit, or other malfunctions. OSHA permits the use of air-purifying respirators for protection against specific chemicals with poor warning properties provided that (1) the service life of the sorbent is known and a safety factor has been applied or (2) the respirator has an approved end-of-service-life indicator.

13.3 Selection of Protective Clothing and Accessories

In this manual, personal protective clothing is considered to be any article offering skin and/or body protection. It includes:

- Fully encapsulating suits.
- Non-encapsulating suits.
- Aprons, leggings, and sleeve protectors.
- Gloves.
- Boots, or protective footwear
- Firefighters’ protective clothing.
- Proximity, or approach, garments.
- Blast and fragmentation suits.
- Cooling garments.
- Radiation-protective suits.

Each type of protective clothing has a specific purpose; many, but not all, are designed to protect against chemical exposure. Accessories that might be used in conjunction with a PPE ensemble include:

- Knife
- Flashlight or lantern
- Personal locator beacon
- Inactivity/non-movement alarm
- Personal dosimeters
- Two-way radio
- Safety belts and lines

13.3.1 Selection of Chemical-Protective Clothing (CPC)

Chemical-protective clothing (CPC) is available in a variety of materials that offer a range of protection against different chemicals. The most appropriate clothing material will depend on the chemicals present and the task to be accomplished. Ideally, the chosen material resists permeation, degradation, and penetration. Permeation is the process by which a chemical dissolves in and/or moves through a protective clothing material on a molecular level. Degradation is the loss of or

change in the fabric's chemical resistance or physical properties due to exposure to chemicals, use, or ambient conditions (e.g., sunlight). Penetration is the movement of chemicals through zippers, stitched seams or imperfections (e.g., pinholes) in a protective clothing material.

Selection of chemical-protective clothing is a complex task and should be performed by personnel with training and experience. Under all conditions, clothing is selected by evaluating the performance characteristics of the clothing against the requirements and limitations of the site- and task-specific conditions. In all cases, the employer is responsible for ensuring that the personal protective clothing at the work site is adequate and of safe design and construction for the work to be performed (see OSHA standard 29 CFR Part 1910.132-1910.137).

13.3.2 Other Considerations

In addition to permeation, degradation and penetration, several other factors must be considered during clothing selection. These affect not only chemical resistance, but also the worker's ability to perform the required task. The following checklist summarizes these considerations.

- Durability: strength for task at hand.
- Flexibility: should not interfere with worker's ability to perform task.
- Temperature effects: maintain protective integrity under hot and cold extremes.
- Ease of decontamination: can it be decontaminated or should disposable clothing be used?
- Compatibility with other equipment: should not preclude the use of another piece of protective equipment.
- Duration of use: will it break through or will degradation occur during use?

13.3.3 Special Conditions

Fire, explosion, heat, and radiation are considered special conditions that require special-protective equipment. Unique problems are associated with radiation and it is beyond the scope of this manual to discuss them properly. A qualified health physicist should be consulted if a radiation hazard exists. When using special-protective equipment, it is important to also provide protection against chemicals, since the specialized equipment may provide little or no protection against chemicals that may also be present.

13.4 Selection of Ensembles/Level of Protection

Table 13.1 lists ensemble components based on the widely used EPA Levels of Protection: Levels A, B, C, and D. These lists should be considered a starting point for ensemble creation however, each ensemble must be tailored to the specific situation in order to provide the most appropriate level of protection.

The type of equipment used and the overall level of protection should be reevaluated periodically as the amount of information about the site increases, and as workers are required to perform different tasks. Personnel should be able to upgrade or downgrade their level of protection with concurrence of the Site Safety Officer and approval of the Field Team Leader.

13.5 PPE Use

PPE can offer a high degree of protection only if it is used properly. The following aspects of PPE use must be considered and depending on the hazards and complexity of hazardous site work anticipated must be implemented as part of a PPE and Respiratory Protection Program as per OSHA requirements.

Table 13.1 Sample Protective Ensembles – Level of Protection – A			
Equipment	Protection Provided	Should be Used When:	Limiting Criteria
<p>RECOMMENDED:</p> <ul style="list-style-type: none"> • Pressure demand, full face-piece SCBA or pressure demand supplied-air respirator with escape-SCBA • Fully-encapsulating chemical-resistant suit • Inner chemical resistant gloves • Chemical-resistant safety boots • Outer chemical resistant gloves • Chemical-resistant shoes • Two-way radio communications 	<p>The highest available level of respiratory, skin, and eye protection</p>	<ul style="list-style-type: none"> • The chemical substance is identified and requires highest Level of protection for skin, eyes and the respiratory system based on either: <ul style="list-style-type: none"> – measured (or potential for) high concentration of atmospheric vapors gases, or particulates or – site operations and work functions involving a high potential for splash immersion, or exposure to unexpected vapors, gases or particles of materials that are harmful to skin or can be absorbed through the intact skin • Substances with a high degree of hazard to the skin are known or suspected and contact with the skin is possible • Operations must be conducted in confined, poorly ventilated areas until the absence of conditions requiring Level A protection are determined 	<p>Fully encapsulating suit material must be compatible with the substances involved</p>
<p>OPTIONAL:</p> <ul style="list-style-type: none"> • Cooling unit • Coveralls • Long cotton underwear • Hard hat • Disposable gloves and boot covers 			

- Training
- In-use monitoring
- Work mission duration
- Doffing
- Personal use factors
- Inspection
- Fit testing
- Storage
- Donning
- Maintenance
- Medial surveillance

13.5.1 Training

Training in PPE use is recommended and, for respirators, required by federal regulation in the OSHA standards in 29 CFR Part 1910 Subparts I and Z. This training:

- Allows the user to become familiar with equipment in a non-hazardous situation.
- Instills confidence of the user in his/he equipment.
- Makes the user aware of the limitations and capabilities of the equipment.
- Increases the efficiency of operations performed by workers wearing PPE.
- May increase the protective efficiency of PPE use.

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Table 13.1 Sample Protective Ensembles – Level of Protection – B			
Equipment	Protection Provided	Should be Used When:	Limiting Criteria
<p>RECOMMENDED:</p> <ul style="list-style-type: none"> • Pressure-demand, full face-piece SCBA or pressure-demand supplied air respirator with escape SCBA • Chemical-resistant clothing (overall and long sleeved jacket; hooded one or two piece chemical splash suit; disposable chemical-resistant one-piece suit) • Inner and outer chemical-resistant gloves • Chemical-resistant safety boots/shoes • Hard hat • Two-way radio communication 	<p>The same level of respiratory protection but less skin protection than Level A.</p> <p>It is <i>the</i> minimum level recommended for initial site entries until the hazards have been further identified</p>	<ul style="list-style-type: none"> • The type and atmospheric concentration of substances have been identified and require a high level of respiratory protection, but less skin protection. This involves atmospheres: <ul style="list-style-type: none"> – with IDHL concentrations of specific substances that do not represent a severe skin hazard; or – that do not meet the criteria for the use of air purifying respirators. • A atmosphere contains less than 19.5% oxygen • Presence of Incompletely identified vapors or gases is indicated by direct-reading organic vapor detection instrument, but vapors and gases are not expected of containing high levels of chemicals harmful to skin or capable of being absorbed through the intact skin 	<ul style="list-style-type: none"> • Use only when the vapor or gases present are not suspected of containing high concentrations of chemical that are harmful to skin or capable of being absorbed through the intact skin • Use only when it is highly unlikely that the work being done will generate either concentrations of vapors, gas or particulates or splashes of material that will affect exposed skin
<p>OPTIONAL:</p> <ul style="list-style-type: none"> • Coveralls • Disposable boot of containing covers • Face shield • Long cotton underwear 			

Table 13.1 Sample Protective Ensembles – Level of Protection – C			
Equipment	Protection Provided	Should be Used When:	Limiting Criteria
<p>RECOMMENDED:</p> <ul style="list-style-type: none"> • Full face-piece, air purifying canister-equipped respirator • Chemical-resistant clothing (overall and long sleeved jacket; hooded one or two piece chemical splash suit; disposable chemical-resistant one-piece suit) • Inner and outer chemical-resistant gloves • Chemical-resistant safety boots/shoes • Hard hat • Two-way radio communications 	<p>The same level of skin protection as Level B, but a lower level of respiratory protection</p>	<ul style="list-style-type: none"> • The atmospheric contaminants, liquid splashes, or other direct contact will not adversely affect any exposed skin • The types of air contaminants have been identified, concentrations measured, and a canister is available that can remove the contaminant • All criteria for the use of air purifying respirators are met 	<ul style="list-style-type: none"> • Atmospheric concentration of chemicals must not exceed IDHL levels • The atmosphere must contain at least 19.5% oxygen
<p>OPTIONAL:</p> <ul style="list-style-type: none"> • Coveralls • Disposable boot covers • Face shield • Escape mask • Long cotton underwear 			

Table 13.1 Sample Protective Ensembles – Level of Protection – D			
Equipment	Protection Provided	Should be Used When:	Limiting Criteria
RECOMMENDED: <ul style="list-style-type: none"> • Coveralls • Safety boots/shoes • Safety glasses or chemical splash goggles 	No respiratory protection	<ul style="list-style-type: none"> • The atmosphere contains no known hazard • Work functions preclude splashes, immersion, or the potential for unexpected inhalation or contact with hazardous levels of any chemicals 	<ul style="list-style-type: none"> • This level should not be worn in the Exclusion Zone • The atmosphere must contain at least 19.5% oxygen
OPTIONAL: <ul style="list-style-type: none"> • Gloves • Escape mask • Face shield 			

- Reduces the expense of PPE maintenance.

Training should be completed prior to actual PPE use in a hazardous environment and should be repeated at least annually.

The discomfort and inconvenience of wearing PPE can create a resistance to the conscientious use of PPE. One essential aspect of training is to make the user aware of the need for PPE and to instill motivation for the proper use and maintenance of PPE.

13.5.2 Work Mission Duration

Before the workers actually begin work in their PPE ensembles, the anticipated duration of the work mission should be established. Several factors limit mission length.

- Air supply consumption rate
- Suit/ensemble permeation and penetration
- Ambient temperature extremes
- Physical condition of the user (extremely variable from user to user, and even day to day for individual user)

13.5.3 Personal Use Factors

As described below, certain personal features of workers may jeopardize safety during equipment use. Prohibitive or precautionary measures should be taken as necessary.

Facial hair and long hair interfere with respirator fit and wearer vision, and should be prohibited.

Eyeglasses with conventional temple pieces (ear piece bars) will interfere with the respirator-to-face seal of a full face-piece. A spectacle kit should be installed in the facemasks of workers requiring vision correction.

When a worker must wear corrective lenses as part of the face piece, the lenses shall be fitted by qualified individuals to provide good vision, comfort, and a gas-tight seal (29 CFR Part 1910.134(e)(5)).

Gum and tobacco chewing should be prohibited during respirator use since they may cause ingestion of contaminants and may compromise the respirator fit.

13.5.4 Donning an Ensemble

A routine should be established and practiced periodically for donning a fully encapsulating suit/SCBA ensemble. Assistance should be provided for donning and doffing. These operations are difficult to perform alone, and solo efforts might increase the possibility of suit damage.

13.5.5 Respirator Fit Testing

The “fit” or integrity of the face-piece to face seal of a respirator affects its performance. A secure fit is important with positive pressure equipment, and is essential to the safe functioning of negative-pressure equipment, such as most air-purifying respirators. Most face pieces fit only a certain percentage of the population; thus each face-piece must be tested on the potential wearer in order to ensure a tight seal. Facial features such as scars, hollow temples, very prominent cheekbones, deep skin creases, dentures or missing teeth, and the chewing of gum and tobacco may interfere with the respirator to face seal. A respirator shall not be worn when such conditions prevent a good seal. The workers’ diligence in observing these factors shall be evaluated by periodic checks.

For respirator fit testing protocols, refer to 29 CFR 1910.134, Appendix A *Part I. OSHA – Accepted Fit Test Protocols*. For specific quantitative testing protocols, literature supplied by manufacturers of quantitative fit test equipment should be consulted. Note that certain OSHA standards require quantitative fit testing under specific circumstances (e.g., 29 CFR Parts 1910.1018 (h) for arsenic, 1910.1025 (f) for lead (3)(ii), and 1910.1045 (h) for acrylonitrile.

13.5.6 Doffing an Ensemble

Exact procedures for removing fully encapsulating suit/SCBA ensembles must be established and followed in order to prevent contaminant migration from the work area and transfer of contaminants to the wearer’s body, the doffing assistant, and others. (See Chapter 14)

13.5.7 Inspection

An effective PPE inspection program features five different inspections:

- Inspection and operational testing of equipment received from the factory or distributor.
- Inspection of equipment as it is distributed to workers.
- Inspection after use or training and prior to maintenance.
- Periodic inspection of stored equipment.
- Periodic inspection when a question arises concerning the appropriateness of the selected equipment, or when problems with similar equipment arise.

13.5.8 Storage

Clothing and respirators must be stored properly to prevent damage, contamination or malfunction due to exposure to dust, moisture, sunlight, damaging chemicals, extreme temperatures, and impact. Procedures must be specified for both pre-issuance warehousing and, more importantly, post-issuance (in-use) storage. Many equipment failures can be directly attributed to improper storage.

SCBAs, supplied air respirators, and air purifying respirators should be dismantled washed and disinfected after each use.

13.6 Heat Stress and Other Physiological Factors

Wearing PPE puts a hazardous waste worker at considerable risk of developing heat stress. This can result in health effects ranging from transient heat fatigue to serious illness or death. A number of interacting factors, including environmental conditions, clothing, workload, and the individual characteristics of the worker may lead to heat stress. Because heat stress is probably one of the most common (and potentially serious) illnesses at hazardous waste sites, regular monitoring and other preventative precautions are vital.

Individuals vary in their susceptibility to heat stress. Factors that may predispose someone to heat stress include lack of physical fitness, lack of acclimatization, age, dehydration, obesity, alcohol/ drug use, infection, sunburn, diarrhea and chronic disease.

The amount and type of PPE worn directly influence reduced work tolerance and the increased risk of excessive heat stress. PPE adds weight and bulk, severely reduces the body's access to normal heat exchange mechanisms (evaporation, convection, and radiation), and increases energy expenditure. Therefore, when selecting PPE, each item's benefit should be carefully evaluated in relation to its potential for increasing the risk of heat stress. Once PPE is selected, the safe duration of work/rest periods should be determined based on the anticipated work rate, ambient temperatures and other environmental factors, protective ensembles used, and individual worker characteristics and fitness.

13.6.1 Monitoring

Because the incidence of heat stress depends on a variety of factors, all workers, even those not wearing protective equipment, should be monitored.

To monitor the worker, measure:

- Heart rate. Count the radial pulse during a 30-second period as early as possible in the rest period. If the heart rate exceeds 110 beats per minute at the beginning of the rest period, shorten the next work cycle by one-third and keep the rest period the same. If the heart rate still exceeds 110 beats per minute at the next rest period, shorten the following work cycle by one-third.
- Oral temperature. Use a clinical thermometer (3 minutes under the tongue) or similar device to measure the oral temperature at the end of the work period (before drinking). If oral temperature exceeds 99.6°F (37.6°C), shorten the next work cycle by one-third without changing the rest period. If oral temperature still exceeds 99.6°F (37.6°C) at the beginning of the next rest period, shorten the following work cycle by one-third. Do not permit a worker to wear a semi-permeable or impermeable garment when his/her oral temperature exceeds 100.6°F (38.1°C).
- Body water loss, if possible. Measure weight on a scale accurate to 0.25 lb. at the beginning and end of each workday to see if enough fluids are being taken to prevent dehydration. Weights should be taken while the employee wears similar clothing or, ideally, is nude. The body water loss should not exceed 1.5- percent total body weight loss in a workday.

13.6.2 Prevention

Proper training and preventive measures will help avert serious illness and loss of work productivity. Preventing heat stress is particularly important because once someone suffers from heat stroke or heat exhaustion, that person may be predisposed to additional heat injuries. To avoid heat stress, management should take the following steps:

- Adjust work schedules
- Provide shelter or shade during rest periods

- Maintain worker's body fluids at normal levels
- Encourage physical fitness
- Provide cooling devices
- Train workers to recognize heat stress (see Table 13.2)

Table 13.2 Signs and Symptoms of Heat Stress

- Heat rash may result from continuous exposure to heat or humid air.
- Heat cramps are caused by heavy sweating with inadequate electrolyte replacement. Signs and symptoms include:
 - muscle spasms
 - pain in the hands, feet, and abdomen
- Heat exhaustion occurs from increased stress on various body organs including inadequate blood circulation due to cardiovascular insufficiency or dehydration. Signs and symptoms include:
 - pale, cool, moist skin
 - heavy sweating
 - dizziness
 - nausea
 - fainting
- Heat stroke is the most serious form of heat stress. Temperature regulation fails and the body temperature rises to critical levels. Immediate action must be taken to cool the body before serious injury and death occur. Competent medical help must be obtained. Signs and symptoms are:
 - red, hot, usually dry skin
 - lack of or reduced perspiration
 - nausea
 - dizziness and confusion
 - strong, rapid pulse
 - coma

References

National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA),

U.S. Coast Guard (USCG), and Environmental Protection Agency (EPA), Occupational Safety and Health Guidance

Manual for Hazardous Waste Site Activities, DHHS (NIOSH) Publication No. 85-115, October, 1985.

13.6.3 Other Factors

PPE decreases worker performance as compared to an unequipped individual. The magnitude of this effect varies considerably, depending on both the individual and the PPE ensemble used. This

section discusses the demonstrated physiological responses to PPE and the individual human characteristics that play a factor in these responses. The physiological factors, which may affect worker ability to function using PPE, include physical condition, level of acclimatization, age, gender, and weight.

13.6.3.1 Physical Condition

Physical fitness is a major factor influencing a person's ability to perform work under heat stress. The more fit someone is, the more work they can safely perform. At a given level of work, a fit person, relative to an unfit person, will have: less physiological strain, lower heart rate, lower body temperature (less retained body heat), more efficient sweating mechanism, slightly lower oxygen consumption, and slightly lower carbon dioxide production.

13.6.3.2 Level of Acclimatization

The degree to which a worker's body has physiologically adjusted or acclimatized to working under hot conditions affects his or her ability to do work. Acclimated individuals generally have lower heart rates and body temperatures than unacclimated individuals, and sweat sooner and more profusely. This enables them to maintain lower skin and body temperatures at a given level of environmental heat and work loads than unacclimated workers. Sweat composition also becomes more dilute with acclimatization, which reduces salt loss.

13.6.3.3 Age

Generally, maximum work capacity declines with increasing age, but this is not always the case. Active, well-conditioned seniors often have performance capabilities equal to or greater than young sedentary individuals. Age should not be the sole criterion for judging whether or not an individual should be subjected to moderate heat stress. Fitness level is a more important factor.

13.6.3.4 Weight

The ability of a body to dissipate heat depends on the ratio of its surface area to its mass (surface area/weight). Heat loss (dissipation) is a function of surface area and heat production is dependent on mass. Therefore, heat balance is described by the ratio of the two.

Since overweight individuals (those with a low ratio) produce more heat per unit of surface area than thin individuals (those with a high ratio), overweight individuals should be given special consideration in heat stress situations. However, when wearing impermeable clothing, the weight of an individual is not a critical factor in determining the ability to dissipate excess heat.

References

- National Institute for Occupational Safety and Health (NIOSH), Occupational Safety and Health Administration (OSHA), U.S. Coast Guard (USCG), and Environmental Protection Agency (EPA), Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities*, DHHS (NIOSH) Publication No. 85-115, October, 1985.
- National Institute for Occupational Safety and Health (NIOSH), Working in Hot Environments*, DHHS (NIOSH) Publication No. 86-112, April 1986 (reprinted 1992).

Chapter 14

Personnel Contamination Reduction

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References

Chapter 14

Personnel Contamination Reduction

14.1 Introduction

Before a worker may enter any area of a site where potential exposure to hazardous substances exists, a decontamination procedure needs to be developed, communicated to employees and implemented. This chapter will outline measures for workers to take when leaving contaminated areas at hazardous waste sites. The intent is to preclude the chance of spreading contamination from personal protective equipment (PPE) utilized into clean areas, to avoid contaminant exposure to workers when doffing PPE, and to address the ultimate fate of PPE after use and removal (disposal or decontamination and re-use). All decontamination procedures utilized at hazardous waste sites must comply with 29 CFR 1910.120 of the OSHA Standard for Hazardous Waste Site Operations.

Contamination reduction procedures may vary among hazardous waste sites, depending upon the associated hazards. For example, after sampling a well contaminated with volatile organics, avoiding hand and skin contact is the primary control measure while doffing the PPE. Or if heavy metal contamination of soil is the hazard, then the careful removal of PPE without exposing personnel to particles and avoiding a respiratory hazard from airborne release are the main control measures.

Prior to entry the site history should be reviewed in order to anticipate the main contaminants of concern. These contaminants, plus the potential for unanticipated contaminants, will form the basis of the site Health and Safety Plan. This information should be considered when planning decontamination procedures for workers that will exit contaminated areas at the site.

The planning for, and the setting up of the decontamination area must occur prior to any entry into any exclusion zone or, contaminated areas of a hazardous waste site.

14.2 Steps In Doffing Disposable PPE

The procedures/methods depicted in the figures 14.1 through 14.5 show the order recommended for contaminant reduction personnel and for doffing personal protective equipment. These figures are taken from the, *NIOSH/OSHA/USCG/EPA Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities*. Since the contamination hazards at hazardous waste sites vary greatly, the methods of decontamination may be adjusted by omitting, adding, or changing the stations identified to reflect the contamination hazards at a site. Once the order and method of decontamination and doffing equipment is established, it is important that the method be followed by workers and monitored for its effectiveness to insure the prevention of contaminant spread and exposure to personnel.

As outlined in Chapter 4, *Site Entry Activities*, the hazardous waste site should have a designated contamination reduction zone. At this location, decontamination/backup personnel wearing the appropriate PPE, based on the chemical characteristics of the contaminants at the site. In general, the level of protection worn by decontamination personnel will be one level lower than that worn by exclusion zone entry personnel. For example, if entry personnel are wearing Level B PPE, then the decontamination personnel should employ level C as a minimum for their PPE.

Figure 14.1 Maximum Decontamination Layout, Level A Protection

Figure 14.2 Minimum Decontamination Layout, Level B Protection

Figure 14.3 Maximum Decontamination Layout, Level C Protection

Figure 14.4 Minimum Decontamination Layout, Levels A&B Protection

Figure 14.5 Minimum Decontamination Layout, Level C Protection

14.3 Doffing Reusable PPE

When reusable personal protective equipment is worn, it must either be decontaminated on site or carefully packed and transported for later decontamination. Full decontamination of reusable suits is usually accomplished in two steps. The first step is performed on line in the contamination reduction zone, using a cleaning solution that has previously been determined acceptable based on limited background knowledge of the site's suspected chemical, or biological hazards (see figures 14.1 through 14.5). After cleaning, the protective clothing is turned inside out, if possible, and sealed in plastic bags for return shipment.

If necessary, the second decontamination step is taken after the site's environmental samples have been analyzed and a more suitable decontamination solution for the clothing has been determined. Personnel wearing disposable safety clothing then perform this second cleaning. Depending on the types of contaminants present and their concentrations, waste decontamination solutions may need to be treated as a hazardous waste and disposed of accordingly.

14.4 Low Level Contamination

In many, if not most cases, site work may be conducted at sites where the contamination hazards have been determined not to warrant the use of respiratory protection. However, just because work at these sites is carried out in Level D PPE, it does not necessarily mean there is no contamination threat. Decontamination of personnel at sites with low levels of contamination, or having no exclusion zone activities, is often overlooked. At Level D activity sites, decontamination should be provided for the following: washing of boots, or the removal and disposal of boot covers (booties); removal and disposal of disposable coveralls; removal and disposal of outer and inner gloves; and the washing of hands, arms and face prior to leaving the site, or taking any breaks for eating or, smoking.

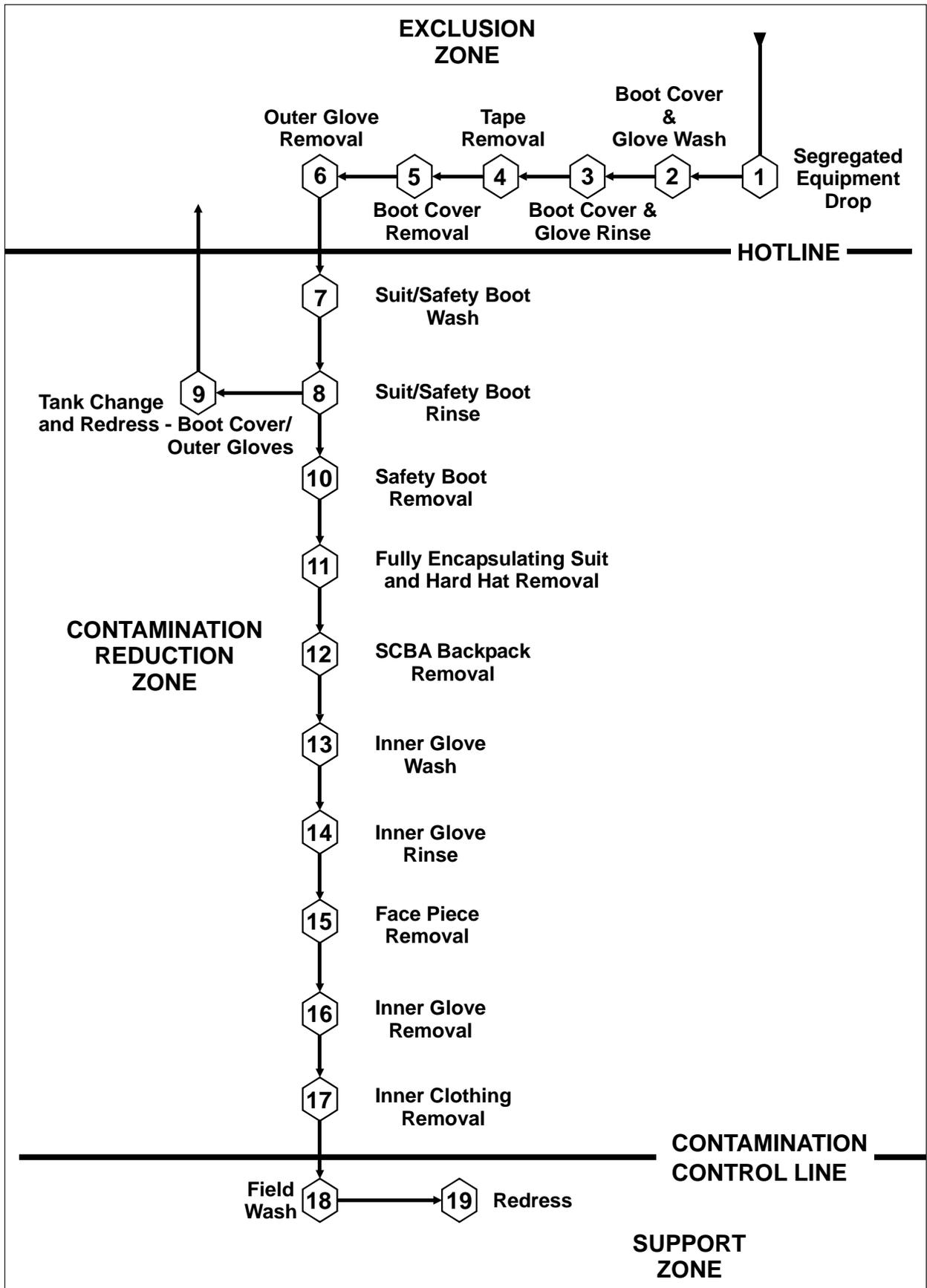


Figure 14.1 Maximum Decontamination Layout Level A Protection

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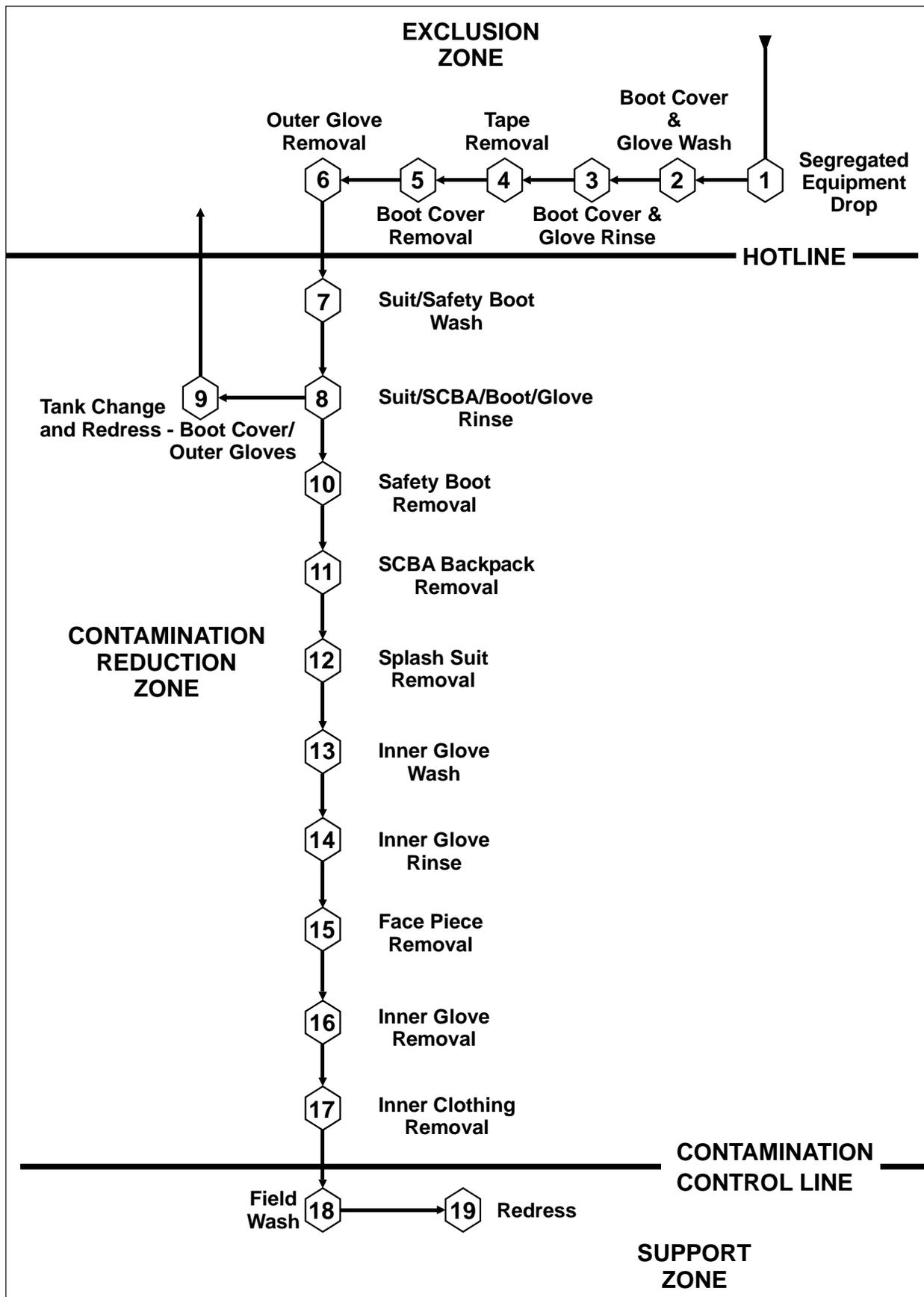


Figure 14.2 Maximum Decontamination Layout Level B Protection

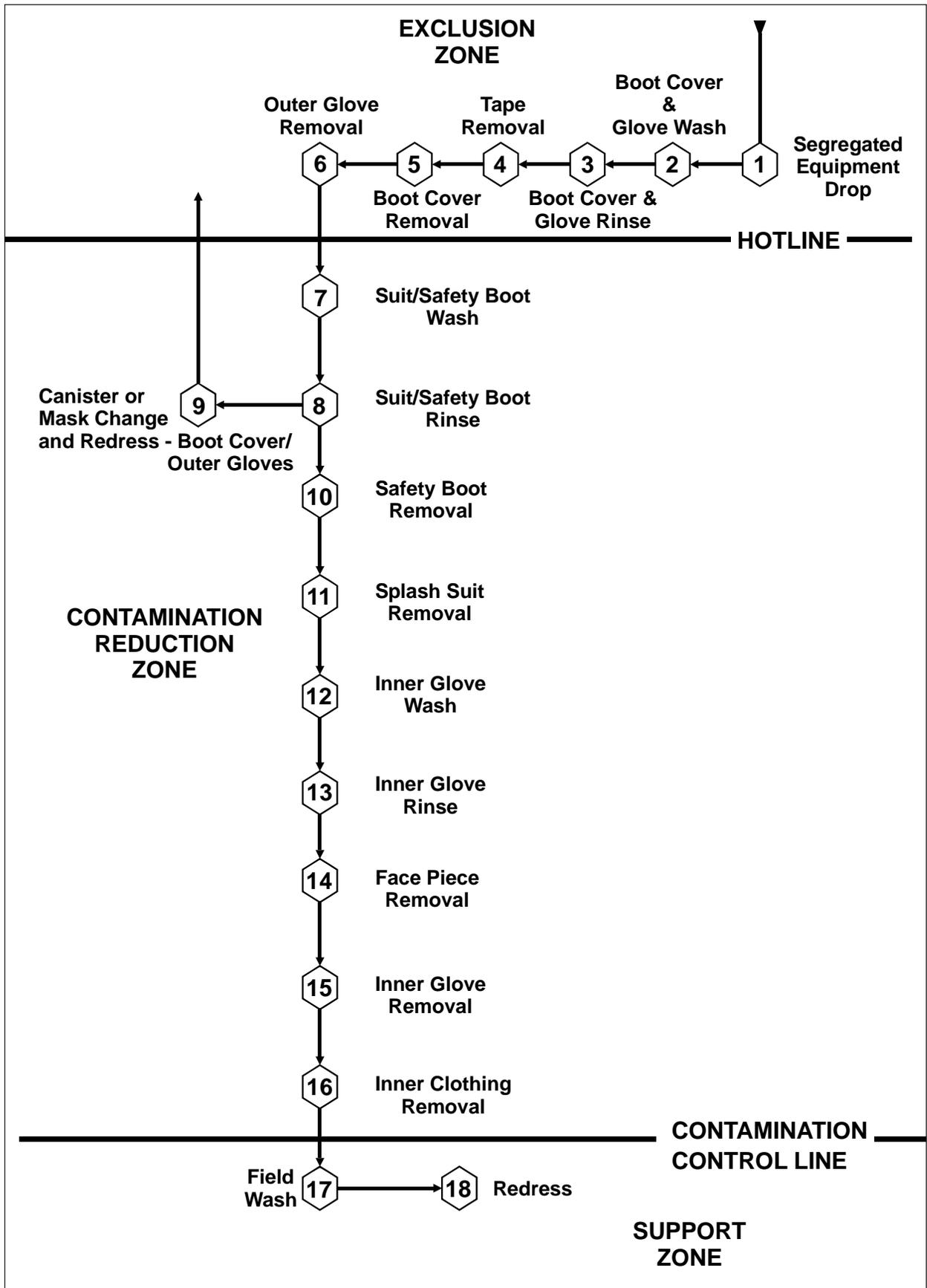


Figure 14.3 Maximum Decontamination Layout Level C Protection

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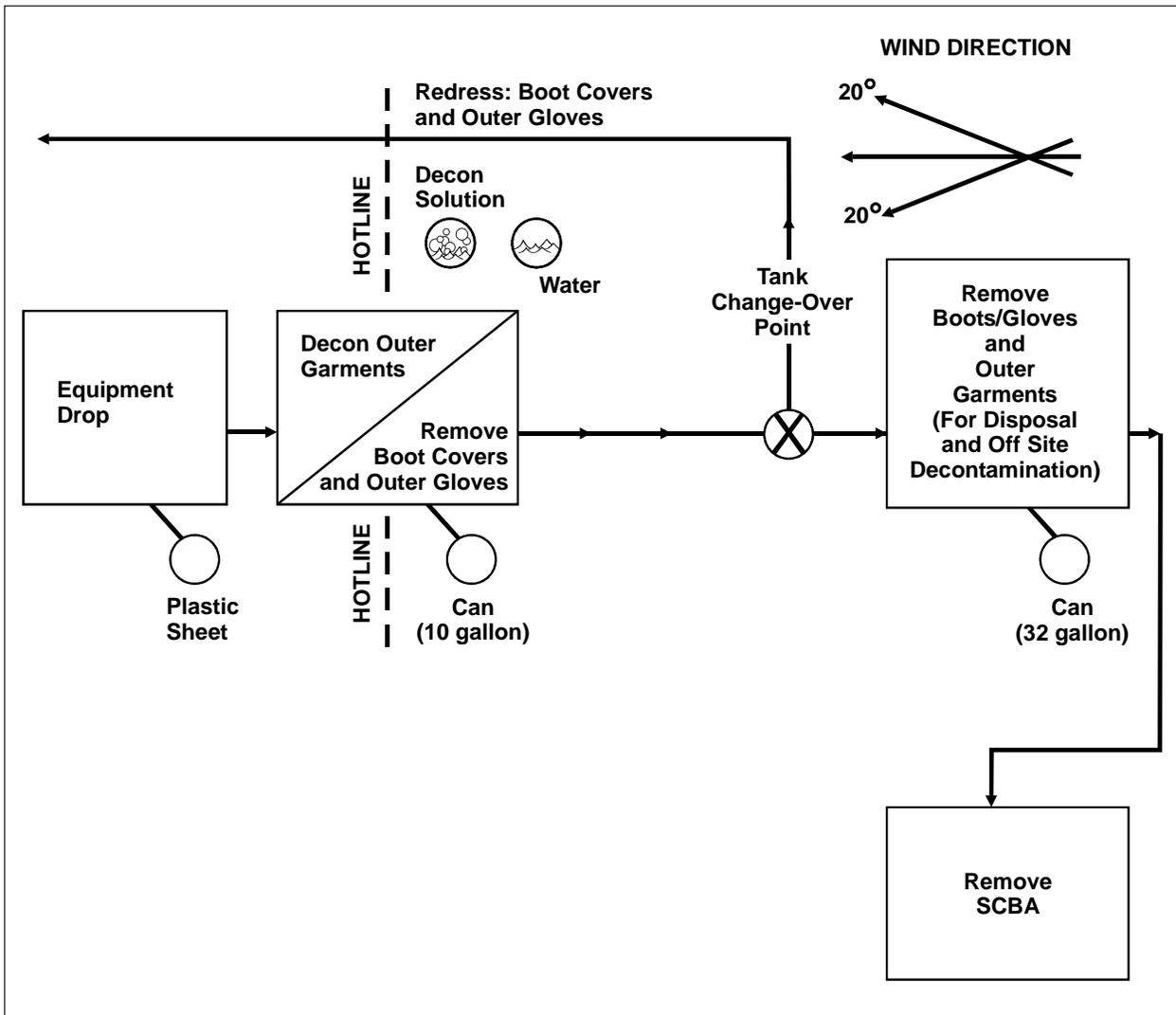


Figure 14.4 Minimum Decontamination Layout Levels A & B Protection

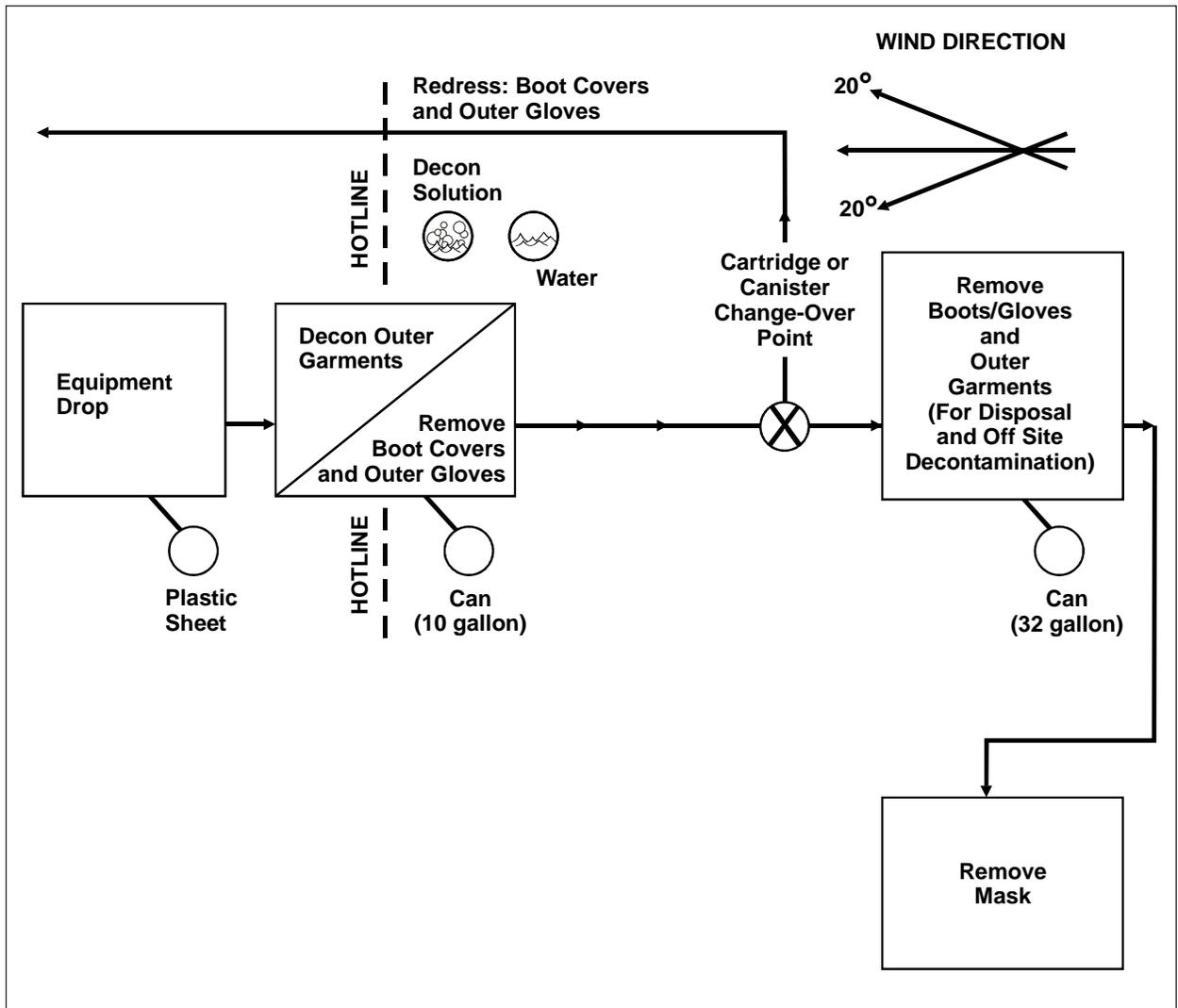


Figure 14.5 Minimum Decontamination Layout Level C Protection

References

NIOSH, OSHA, USCG, EPA, Occupational Safety and Health Guidance Manual for Hazardous Waste Site Activities, DHHS (NIOSH) Publication No. 85-115, October, 1985.

Glossary of Technical Terms

Administrative Consent Order (ACO) – An enforcement document that compels a responsible party to initiate cleanup efforts.

Background Samples – Samples that are collected and used to compare site conditions to the surrounding environment. Background samples are collected and handled in the same manner as all other samples.

Biased Sample – Samples which are collected at locations based on historical information; behavior of contaminants or; knowledge about the physical system's matrix (the physical system's effect on fate of transport).

Blind Samples – A quality assurance sample in which the laboratory performing the analysis is unaware of the sample's true location this sample is collected a duplicate.

Calibration – Process of adjusting an instrument's read out so that it corresponds to actual concentrations. It involves checking the instrument with a known concentration of a surrogate to insure that the instrument provides a proper response.

Caliper – A mechanical device that is used to measure the diameter of a borehole.

Cleanup Standard – The combination of numeric and narrative standards established pursuant to this chapter for a contaminant or group of contaminants.

Colorimetric Tube – Device used to estimate the concentration of a specific gas in air. A known volume of contaminant is pulled through the tube and reacts with the indicator chemical producing a colored stain whose length is proportional to the contaminant's concentration.

Combustible Gas Indicator (CGI) – Instrument used to determine the potential for combustion or explosion in an unknown atmosphere.

Composite Sample – A non-discrete sample composed of more than one specific aliquot collected at various sampling points or times.

Contamination Reduction Zone – Transition zone between contaminated area (exclusion zone) and clean area. The zone is where all personnel decontamination of hazardous waste is conducted.

Department – The New Jersey Department of Environmental Protection.

Dielectric Constant – The relationship between two charges, that is their distance of separation in relation to the force of attraction.

Diffusion Sampler – Type of sampling device which functions by the passive movement of contaminant molecules through a concentration gradient created within a stagnant layer of air between the contaminated atmosphere and the indicator material.

Distilled Water – Prepared by thermal distillation using a still of all-borosilicate glass, fused quartz, tin or titanium with the distillate meeting the following characteristics of Type I (Type II) water:

- Resistivity (megohm-cm @ 25°C) greater than 10 (greater than 1)
- Conductivity (umho/cm @ 25°C) less than 0.1 (equal to 1)
- Total oxidizable organic carbon (mg/L) less than 0.05 (less than 0.2)
- Total solids (mg/L) less than or equal to 0.1 (equal to 1)
- SiO₂ (mg/L) less than 0.05 (less than 0.1)

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Deionized Water – Prepared by passing feedwater through a mixed-bed ion exchanger, consisting of strong anion and strong cation resins mixed together. The resultant water shall have the same characteristics as those for distilled water noted above.

Electrical Resistivity – Geophysical sensing technique used to determine the structure and physical properties of subsurface geologic materials which can be used to detect anomalies which may indicate the presence of hazardous materials (e.g. drums, containers).

Electromagnetics – Geophysical method which induces and detects electrical current flow within geologic strata.

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

Exclusion Zone – Designated zone of a hazardous waste site where contamination is known to or may occur and can only be entered with appropriate personnel protection.

Field Blank – A QA/QC sample used to indicate potential contamination from ambient air and sampling instruments.

Flame Ionization Detector (FID) – An air monitoring instrument that utilizes the principle of hydrogen flame ionization for detection and measurement of organic vapors.

Flowmeter – Measures the vertical movement of fluid in a borehole.

Gas Chromatography – Analytical technique for separating compounds of a sample and qualitatively and quantitatively identifying them.

Geostatistics – Statistical methodology that incorporates contaminant relationships between sample locations to derive conclusions about concentrations at locations lying between those points.

Grab Sample – A discrete aliquot that is representative of one specific sample site location at a specific point in time.

Ground Water – The portion of the water beneath the land surface that is within the zone of saturation (below the seasonally high water table) where all pore spaces of the geologic formation are filled with water.

Handling Time – All trip blanks, field blanks, and environmental sample containers must be received in the field within one day of preparation in the lab. They may be held on site for a maximum of two calendar days. They must then be shipped back to the lab at the end of the second calendar day. All samples and blanks must be maintained at 4°C while on site and during shipment.

Henry's Law Constant – Expressed as a ratio between the partial pressure of the vapor and the concentration in the liquid.

Holding Time – The analytical time clock for all samples and blanks measured between the time of sample collection and analytical extraction. Typically determined by matrix and specific analytical method requirements.

Homogenization – Process whereby a sample is mixed in a stainless steel bowl or in-situ until a consistent physical appearance is achieved. This is performed for all parameters except volatiles.

Koc – A coefficient that relates the partitioning of the organic compound between the adsorbed phase and the soil solution relative to the organic carbon fraction.

Kriging – A geostatistical technique, which interpolates concentration values for locations between sampling points.

Laboratory Decontaminated – The decontamination of sampling equipment and bottles in a controlled setting.

Lower Explosive Limit (LEL) – Minimum concentration of a combustible gas measured as a percentage of the total constituents present in the atmosphere that will combust when ignited.

Magnetometer – Instrument which is used to measure magnetic field strength in units of gamma.

Matrix Spike – A laboratory Q/A sample comprised of the same matrix of the samples being analyzed. The sample is injected with a known concentration of a specific analyte.

Method Blank – A laboratory Q/A blank comprised of demonstrated analyte free water that is analyzed simultaneously with the environmental sample.

Method Detection Limit – The minimum concentration of a contaminant that can be measured and reported with a 99% confidence that the analyte concentration is greater than zero and is determined from analysis of a sample in a given matrix containing the analyte.

Passive Dosimeter – Device which utilizes the processes of diffusion and permeation to move a contaminant through a collection medium.

Performance Evaluation Sample (PE) – Pre-measured, pre-determined samples of known concentration that are submitted by the NJDEP as a QA/QC check on laboratory performance.

Photo Ionization Detector (PID) – An air monitoring instrument that utilizes the principle of photoionization for the detection and measurement of organic and inorganic vapors.

Pollutant – Any substance defined as such pursuant to the Water Pollution Control Act, N.J.S.A 58:10A-1 et seq.

ppb – Parts per billion, micrograms per liter (ug/L), or micrograms per kilogram (ug/Kg).

ppm – Parts per million, milligrams per liter (mg/L), or milligrams per kilogram (mg/Kg).

Piezometer – A cased boring used to determine the level of ground water.

Retention Time – Period of time from the injection of the sample into the gas chromatography system until the point of maximum detector response for each substance.

Sample Network – Statistical method used to describe the frequency and location of samples to be collected.

Semivariogram – Tool that shows the relationships between observations at sampling points based on the distance from each sample to the other samples.

Soil – The unconsolidated mineral and organic matter on the surface of the earth that has been subjected to and influenced by geologic and other environmental factors.

Soil Gas – Subsurface gas that may be generated by biological, chemical and physical decomposition of spilled, stored or illegally disposed waste.

Soil Texture – A measure of the percentages of various particles size groups in a volume of soil, typically sand, silt and clay.

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Sorbent Samples – Consist of air samples, which are collected utilizing special adsorbents such as activated carbon and silica gel.

Subsurface Soil – The soil more than two feet below grade and extending downward to the top of the seasonally high water table.

Support Zone – Uncontaminated area where administrative functions needed to keep site operations running smoothly are conducted.

Surface Soil – The top two feet of soil below grade.

Trip Blank – A QA/QC sample whose purpose is to place a mechanism of control on sample bottle preparation, blank water quality and sample handling.

Upper Explosive Limit (UEL) – Maximum concentration of a gas in percent that will combust in the atmosphere.

Vapor Pressure – The pressure of a confined liquid such that the vapor collects above it.

Volatilization – Process whereby certain compounds evaporate rapidly and easily into air at ordinary temperatures.

Volumetric Water Content – The ratio of the volume of water in a porous volume to the total volume.

Waste Samples – Samples that are comprised of process waste or other man made materials.

Water Solubility – The extent to which a compound dissolves in water.

Water Table – The seasonally high level in the saturated zone at which the hydraulic pressure is equal to atmospheric pressure.

Well Purging – Process in which the standing water in a well column is evacuated.

Weir – A device built to back up water.

Acronyms

ACO – Administrative Consent Order

AOC – Area of Concern

ARARS – Applicable or Relevant and Appropriate Requirements

ASTM – American Society for Testing and Materials

BA – Biological Assessment

BEERA – Bureau of Environmental Evaluation and Risk Assessment.

BEMSA – Bureau of Environmental Measurements and Site Assessment

BGWDC – Bureau of Ground Water Discharge Control

BHWE – Bureau of Hazardous Waste Engineering

BN/AE + 20 – Base Neutrals/Acid Extractables + 20

BOD – Biological Oxygen Demand

BTEX – Benzene, Toluene, Ethyl Benzene, Xylenes (also BTX)

CC – Calibration Compound

CERCLA – Comprehensive Environmental Response, Compensation, Liability Act

CFR – Code of Federal Regulations
CGA – Combustible Gas Analyzer
CI – Curie (Radiation Unit)
CIR – Color Infrared
CLP – Contract Laboratory Program
CM – 1. Case Manager
2. Corrective Measures
COC – Chain of Custody
COD – Chemical Oxygen Demand
COLWASA – Composite Liquid Waste Sampler
CPC – Chemical Protective Clothing
CRDL – Contract Required Detection Limit
CWA – Clean Water Act
DL – Detection Limit
DNAPL – Dense Non-Aqueous Phase Liquid
DOW – Depth of Well
DO – Dissolved Oxygen
DQO – Data Quality Objectives
DRI – Direct Reading Instruments
DRMR – Division of Remediation Management and Response
DRS – Division of Remediation Support
DSWHW – Division of Solid Waste and Hazardous Waste
DTW – Depth to Water
ECD – Electron Capture Detector
ECRA – Environmental Cleanup Responsibility Act
EIS – Environmental Impact Statement
EM – Electromagnetic (usually refers to geophysics)
EMS – Environmental Measurements Section
EPA – Environmental Protection Agency
EP – Extraction Procedure
ESLI – End of Service Life
FID – Flame Ionization Detector
FPXRF – Field Portable X-Ray Fluorescence (s)
FS – Feasibility Study
FSP-QAPP – Field Sampling Plan – Quality Assurance Project Plan
FSPM – Field Sampling Procedures Manual
GAC – Granular Activated Carbon
GC/MS – Gas Chromatograph/Mass Spectrometer
GFAA – Graphite Furnace Atomic Absorption Spectroscopy
GIS – Geographic Information System
GPC – Gel Permeation Chromatography
GPR – Ground Penetrating Radar

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HASP – Health and Safety Plan
HI – Hazard Index (for noncarcinogens)
HOA – Halogenated Organic Compounds
HPLC – High Pressure Liquid Chromatography
HSL – Hazardous Substance List
HSO – Health & Safety Officer
HSWA – Hazardous and Solid Waste Amendments (to SARA)
HRS – Hazard Ranking System
HWS – Hazardous Waste Sites
ICP – Inductively Coupled Plasma Atomic Emission Spec.
ID – Infrared Detector
IDL – Instrument Detection Limit
IDLH – Immediate Dangers to Life and Health
IFB – Invitation for Bids
IRIS – Integrated Risk Information System
IRM – Interim or Initial Remedial Measure
LC50 – Median Lethal Concentration in a Bioassay
LD50 – Dose Causing 50% Mortality in Bioassay
LDR – Land Disposal Restrictions
LEL – Lower Explosive Limit
MCL – Maximum Contaminant Level (for drinking water)
MDL – Method Detection Limit
MOA – Memorandum of Agreement
MOU – Memorandum of Understanding
MSDS – Material Safety Data Sheet
MSHA – Mine Safety and Health Administration
MSP – Medical Surveillance Plan
MTBE – Methyl Tertiary Butyl Ether
NAPL – Non-Aqueous Phase Liquid
NBS – National Bureau of Standards
NIOSH – National Institute of Occupational Safety
NJAC – New Jersey Administrative Code
NJDEP – New Jersey Department of Environmental Protection
NJPDES – New Jersey Pollutant Discharge Elimination System
NPDES – National Pollutant Discharge Elimination System
NPL – National Priorities List
O & M – Operation and Maintenance
ORD – Office of Research and Development (EPA – Cinn, Ohio).
To order EPA Publications call (513) 569-7562
ORME – Other Regulated Materials
OSC – On-Scene Coordinator
OSHA – Occupations Safety and Health Administrative

OSWER – Office of Solid Waste and Emergency Response
OVA – Organic Vapor Analyzer
PA/SI – Preliminary Assessment/Site Inspection
PAH – Polycyclic (Polynuclear) Aromatic Hydrocarbon
PCBs – Polychlorinated Biphenyls
PCI – Picocurie (equiv. 10-12 Curie Radiation)
PE – Performance Evaluation sample
PEL – Permissible Exposure Limit
PF – Protection Factor
PHC – Petroleum Hydrocarbons (see TPH)
PID – Photoionization Detector
PP + 40 – Priority Pollutant List + 40 Tentatively Ident. Compounds
PPB – Parts Per Billion
PPE – Personal Protective Clothing and Equipment
PPL – Priority Pollutant List (see PP + 40)
PPM – Parts Per Million
PSI – Pounds Per Square Inch
PTFE – Polytetrafluoroethylene (e.g. Teflon)
PVC – Polyvinyl Chloride
QA/QC – Quality Assurance/Quality Control
QAPP – Quality Assurance Project Plan (also QAPjP)
QAPMP – Quality Assurance Management Plan
RCRA – Resource Conservation Recovery Act
RD – Remedial Design
REL – Recommended Exposure Limit
RFA – RCRA Facility Assessment
RFI – RCRA Facility Investigation
RFP – Request for Proposals
RI/FS – Remedial Investigation/Feasibility Study
ROD – Record of Decision
RP – Responsible Party
RSD – Relative Standard Deviation
RTK – Right to Know
SAP – Sampling and Analysis Plan
SAS – Special Analytical Services
SAR – Supplied Air Respirator
SARA – Superfund Amendments and Reauthorization Act
SCBA – Self Contained Breathing Apparatus
SCS – Soil Conservation Service
SDWA – Safe Drinking Water Act
SOP – Standard Operating Procedure
SOW – Scope of Work or Statement of Work

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SP – Self Potential Devices

STEL – Short Term Exposure Limit

SVE – Soil Vacuum (Vapor) Extractions

SVOC – Semivolatile Organic Compounds (same as BN/AE)

SWDA – Solid Waste Disposal Act

SWMU – Solid Waste Management Unit (RCRA)

TAL – Target Analyte List (Inorganics)

TBA – Tertiary (Tert) Butyl Alcohol

TBC – To be Considered (Refers to ARARs)

TC – 1. Technical Coordinator
2. Toxicity Characteristic

TCDD – Tetrachlorodibenzo-p-dioxin, usually 2,3,7,8-TCDD

TCDF – Tetrachlorodibenzo furan

TCE – Trichloroethylene, syn. – Trichloroethene

TCL – Target Compound List (TCL + 30)

TCLP – Toxicity Characteristic Leaching Procedure

TEGD – Technical Enforcement Guidance Document (EPA, 1986)

TIC – 1. Tentatively Identified Compound from Mass Spec. Library Search, Syn. – Non-Target Compounds
2. Total Ion Chromatogram

TIP – Total Ionization Present

TLV – Threshold Limit Value

TOC – Total Organic Carbon

TOSCA – Toxic Substance Control Act

TOX – Total Organic Halogen Analysis

TPH – Total Petroleum Hydrocarbons (see PHC)

TWA – Time Weighted Average

UEL – Upper Explosive Limit

UGST – Underground Storage Tank (also UST)

USACE – U.S. Army Corps of Engineers (also COE)

USATHAMA – U.S. Army Toxic and Hazardous Materials Agency

USEPA – United States Environmental Protection Agency

USGS – Underground Storage Tank (also UST)

VO – Volatile Organics (VOC, VOA, VO + 10)

VOA + 10 – Volatile Organics + 10

VOC – Volatile Organic Compounds

VOST – Volatile Organic Sampling Train (Air Sampling)

VSP – Vertical Seismic Profiling

WP – Work Plan

XRF – X-Ray Fluorescence, Syn. (**FPXRF**) – Field Portable XRF