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National Field Manual for the Collection of Water-Quality Data

Chapter A2

SELECTION OF EQUIPMENT FOR WATER SAMPLING

Revised by Franceska D. Wilde, Mark W. Sandstrom, and Stanley C. Skrobialowski

Techniques of Water-Resources Investigations Book 9, Chapter A2

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Preface

The Water Mission Area of the U.S. Geological Survey (USGS) provides the information and understanding needed for wise management of the Nation's water resources. Inherent in this mission is the responsibility to collect data that accurately describe the physical, chemical, and biological attributes of water systems. These data are used for environmental and resource assessments by the USGS, other government agencies and scientific organizations, and the general public. Reliable and objective data are essential to the credibility and impartiality of the water-resources appraisals carried out by the USGS.

The development and use of a national field manual is necessary to achieve consistent application of the scientific methods and procedures used, to maintain USGS technical expertise and data integrity, and to publish USGS water-quality field methods for ready reference and review by others. USGS field personnel use this manual to ensure that data collected are of the quality required to fulfill our mission.

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Chapter A2. Selection of Equipment for Water Sampling

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Abstract

The *National Field Manual for the Collection of Water-Quality Data* (National Field Manual) describes protocols and provides guidelines for U.S. Geological Survey (USGS) personnel who collect data used to assess the quality of the Nation's surface-water and groundwater resources. This chapter addresses the selection of the equipment commonly used by USGS personnel to collect and process water-quality samples.

Each chapter of the *National Field Manual* is published separately and revised periodically. Newly published and revised chapters can be accessed at *http://pubs.water.usgs.gov/twri9A* or from the USGS Water-Quality Information Pages (*http://water.usgs.gov/owq/index.html*) under the heading "Methods: Data Collection, Analysis, & Interpretation".

Introduction

As part of its mission, the U.S. Geological Survey (USGS) collects data needed to assess the quality of our Nation's water resources. The *National Field Manual for the Collection of Water-Quality Data (National Field Manual*) describes protocols (requirements and recommendations) and provides guidelines for USGS personnel who collect those data on surface-water and groundwater resources. Chapter A2 provides information about equipment used to collect and process water samples to determine physical and chemical properties and composition. Requirements, recommendations, and guidelines are described that pertain to the selection and use of field equipment by USGS personnel. **Formal training and field apprenticeship are needed in order to correctly implement the requirements and recommendations described in this chapter.**

The *National Field Manual* is Section A of Book 9 of the USGS publication series "Techniques of Water-Resources Investigations" and consists of individually published chapters. Chapters are referred to in the text by the abbreviation "NFM" followed by the chapter number (or chapter and section number). For example, NFM 4 refers to chapter A4 titled "Collection of Water Samples". NFM 4.1 refers to chapter A4, section 1, titled "Surface-water sampling". NFM 4.1.2 refers to chapter A4, section 1, subsection 2, titled "Selection of surface-water sampling sites". This report is chapter A2, "Selection of Equipment for Water Sampling," and therefore is referred to as NFM 2. When referencing a chapter section within the same chapter, however, "NFM" is omitted and the section is identified; for example, as section 2.1 (Sample collection), or 2.1.1 (Surface-water equipment), or 2.1.1.A (Isokinetic depth-integrating samplers).

Purpose and Scope

The *National Field Manual* is targeted specifically toward field personnel in order to (1) establish and communicate scientifically sound methods and procedures, (2) provide methods that minimize data bias and, when properly applied, result in data that are reproducible within acceptable limits of variability, (3) encourage consistent use of field methods for the purpose of producing nationally comparable data, and (4) provide citable documentation for USGS water-quality data-collection protocols.

The purpose of chapter A2 of the *National Field Manual* is to provide information regarding the requirements, recommendations, and guidelines routinely used for equipment selection in USGS studies involving the collection and processing of water-quality samples. (The terms "required" and "recommended," as used in this manual, are explained below under "Requirements and Recommendations.") The information provided covers topics fundamental to the collection and processing of surface-water and groundwater samples that are representative of the ambient environment. This chapter does not attempt to encompass the entire spectrum of data-collection objectives, site characteristics, environmental conditions, and technological advances related to water-quality studies.[1]

Requirements and Recommendations

As used in this *National Field Manual*, the terms **required** and **recommended** have USGS-specific meanings.

► **Required** (require, required, or requirements) and "must" pertain to USGS protocols and indicate that USGS policy has been established on the basis of research and (or) consensus of the technical staff and has been reviewed by water-quality specialists and selected Water Science Centers[2] or other professional personnel, as appropriate.

- — Technical memorandums and other documents that define the policy pertinent to such requirements are referenced in this manual.
- — Personnel are instructed to use required equipment or procedures as described herein.
- — Departure from or modifications to the stipulated requirements that might be necessary to accomplish specific data-quality requirements or study objectives must be based on referenced research and good field judgment and must be quality assured and documented in permanent and readily accessible records.

► **Recommended** (recommend, recommended, recommendation, and "rule of thumb") indicates that USGS policy recognizes one or several alternatives to a given procedure or equipment selection are acceptable on the basis of research and (or) consensus, with respect to established good-science practices, including the professional judgment of field scientists. References to technical memorandums and selected publications pertinent to such recommendations are cited in this chapter to the extent that such documents are available.

- — Specific data-quality requirements, study objectives, or other constraints affect the choice of recommended equipment or procedures.
- — Selection from among the recommended alternatives should be based on referenced research and good field judgment, and reasons for the selection must be documented.

[1] *National Field Manual* chapters 7 and 8 describe equipment used to collect and process samples for analysis of biological indicators and suspended solids, respectively.

[2] Water Science Center" refers to an organizational unit of the USGS in any of the States or Territories of the United States.

— Departure from or modifications to recommended procedures must be quality assured and documented in permanent and readily accessible records.

Field Manual Review and Revision

Each chapter of the *National Field Manual* is reviewed and revised periodically to correct errors, incorporate technical advances, and address additional topics or emerging areas of relevance to water-quality studies. *National Field Manual* chapters are issued in electronic format only. The version number for a given chapter is shown in the footer on each page. A major update or revision will be designated as a new version by the number that precedes the decimal point, and updates that are limited in scope or importance with respect to the chapter as a whole are designated by an increase in the version number after the decimal point. Minor nontechnical changes, such as URL or editorial updates, are designated by a second number that follows the decimal point (for example, version 3.01).

Comments, questions, and suggestions related to the NFM should be sent to *nfm-owq@usgs.gov*. Newly revised and reissued chapters or chapter sections replace the former versions, which are archived and linked to the home page for that chapter. The home page also contains a link to the NFM "Comments and Errata" page (*http://water.usgs.gov/owq/FieldManual/mastererrata.html*) that chronicles changes to each chapter.

Chapter A2. Selection of Equipment for Water Sampling

This chapter assists field personnel conducting water-quality investigations to select the sample-collection and sample-processing equipment[3] appropriate for study objectives, data-quality requirements,[4] and site conditions. The selection of equipment for collecting or processing water-quality samples depends on the physical constraints and safe operation of the equipment and on its suitability with respect to achievement of study objectives.

Criteria for selecting equipment for water sampling depend on (1) the mechanical constraints of the equipment to perform adequately under given environmental conditions, (2) the adequacy of equipment operation to obtain water-quality samples that represent the environmental conditions of the sample source, and (3) the adequacy of the equipment materials and construction to maintain sample integrity and not to be a source of leaching and sorption of target analytes.

- ► **Always operate equipment safely.**
- ► Be thoroughly familiar with requirements for equipment operation and maintenance.
- ► Be aware of the limitations as well as applications of the equipment with respect to your field site.
- ► Maintain and test equipment on a regular schedule.

2.0 Chemical Compatibility with the Water Sample

The materials used to construct equipment and the materials that contact equipment can alter sample chemistry (table 2–1). Equipment designed for water-quality sampling commonly is constructed of a combination of materials, the most inert being used for components that will contact the sample. Nonsample-wetted components and manual contact with sampling equipment can be a source of sample contamination. Field personnel must wear gloves and use other techniques to minimize potential contamination, implement quality-assurance procedures, and quantify potential effects by analyzing quality-control samples collected using laboratory-certified deionized and blank water.

When selecting equipment to be used, consider keeping several sets of precleaned equipment available. Using a clean set of equipment for each sampling site can lessen the chance of cross contamination between sites and eliminate the need for time-consuming equipment cleaning in the field. An extra set of precleaned equipment could also serve as a backup should equipment break or become contaminated.

Check that the equipment to be used will not affect the sample chemistry.

[3] NFM 6 describes equipment used for field measurements of physical or chemical properties of water (temperature, dissolved oxygen, specific electrical conductance (conductivity), pH, reduction-oxidation potential, alkalinity, and turbidity). NFM 7 describes equipment used for determinations of biological indicators. NFM 8 describes equipment used for bottom-material sampling. NFM 9 describes equipment related to safety in field activities.

[4] The term “data-quality requirements” (as used in this field manual) refers to that subset of data-quality objectives specifically pertaining to the analytical detection level for concentrations of target analytes and the variability (or error brackets) allowable to fulfill the scientific objectives of the study.

Table 2–1. General guidelines for selecting water-sampling equipment to avoid sample contamination from materials used in equipment construction.

[‡, generally appropriate for use shown; Cr, chromium; Ni, nickel; Fe, iron; Mn, manganese; Mo, molybdenum; $^{3}H/^{3}He$, tritium/helium-3; CFC, chlorofluorocarbon; SF_6, sulfur hexafluoride]

Construction materials[1]		Inorganic and organic analyte(s) targeted for analysis	
Material	**Description**	**Inorganic**	**Organic**
Plastics[2]			
Fluorocarbon polymers[3]	Chemically inert for most analytes	‡, but 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
Silicone	Very porous. Relatively inert for most inorganic analytes	‡, but potential source of silica	Do not use
Nylon	Relatively inert for inorganic analytes	‡	Do not use.
Metals[3]			
Stainless steel, 316-grade (SS 316)	SS 316—metal with the greatest corrosion resistance. Comes in various grades	‡, but potential source of Cr, Ni, Fe, and possibly Mn and Mo if corroded[4]	‡, but do not use if corrosion is evident[5]
	Used for submersible pump casing[4]	**Do not use for surface-water sampling:** equipment must have a plastic coating (this does not apply to submersible pumps)	
Other metals: brass, iron, copper, aluminum, and galvanized and carbon steels	Refrigeration-grade copper or aluminum tubing is used routinely for collection of $^{3}H/^{3}He$, CFC, and SF_6 samples	Do not use (except as noted for isotopes)	‡, routinely used for CFCs. Do not use if corroded
Glass			
Glass, borosilicate (laboratory grade)	Relatively inert. Potential sorption of analytes	‡, but glass is potential source of boron and silica	‡
Ceramic			

[1]This table does not address the suitability of well-casing materials for given sampling and quality-assurance objectives. Such information is provided in Lapham and others (1997).

[2]Plastics used in connection with inorganic trace-element sampling must be uncolored or white (Horowitz and others, 1994).

[3]Fluorocarbon polymers include materials such as Teflon®, Kynar®, and Tefzel® that are relatively inert for sampling inorganic or organic analytes.

[4]Most submersible sampling pumps have stainless steel components. One usually can minimize effects on samples collected for analysis of inorganic constituents by, to the extent possible, using fluorocarbon polymers in the construction of sample-wetted components (for example, for a bladder, stator, impeller).

[5]Corroded/weathered surfaces are active sorption sites for organic compounds and can leach trace elements.

2.0.1 Equipment Materials

Materials used in the construction of water-sampling equipment can include glass, plastics, ceramics, and metals. Chemical reactivity varies widely within the same group of materials, depending on the chemical composition, the physical configuration, and the manufacturing process. Thus, regarding reactivity with water and most other chemical substances, fluorocarbon polymers are less reactive than plastics such as polyethylene, and 316-type stainless steel (SS 316) is less reactive than brass, iron, or galvanized steel (table 2–1). For plastics and metals in general:

- ► The softer or more flexible forms of any plastic or metal are more reactive than the rigid forms.
- ► The more polished the surface, the less reactive the material tends to be.

2.0.2 Disposable Gloves

Wearing disposable, powderless gloves is required when handling equipment used to collect and process water-quality samples. Gloves protect field personnel from contact with pathogens and chemical contaminants and preservatives. Wearing gloves also helps to avoid sample contamination that could result from improper sample handling. Neither gloved nor ungloved hands should come in contact with the sample or with an equipment surface that the sample could contact. Refer to NFM 4.0.2 for a detailed description of the Clean Hands/Dirty Hands requirements for using gloves.

Although common glove types include those made of vinyl, latex, and nitrile, nitrile is in standard use for USGS sampling work because of its resistance to most of the chemicals to which it typically will be exposed for an exposure time that is usually less than 15 minutes. Field personnel are cautioned that skin contact with materials such as latex or nitrile may cause severe allergic reactions in some individuals, and any changes to skin texture or color should be monitored.

- ► Wear powderless nitrile gloves when handling equipment and chemical solutions. Do not allow the water that enters the sample bottle to contact gloved (or bare) hands.
- ► When working in a sampling chamber, **wearing elbow-length gloves** is recommended if sampling for pharmaceutical or personal-care analytes—this will minimize exposure of the sample to chemicals (such as DEET (n,n-Diethyl-meta-toluamide)) that have been applied to skin.
- ► Check the manufacturer’s chemical resistance chart for any compound, such as acid, base, or organic solvent, to which the glove might be exposed.

Physical properties to consider when selecting disposable gloves are glove length, slip protection, puncture resistance, heat and flame resistance, cold protection, and comfort. These factors can vary among manufacturers. **Visually inspect gloves for defects.**

- ► During field work, routinely check for tears, punctures, and other flaws that can prevent the glove from being an effective shield.
- ► After putting the gloves on, rinse them with deionized water (DIW) while gently rubbing hands together to remove any surface residue before handling sampling equipment.

2.0.3 Blank Water and Chemical Reagents

USGS personnel are required to use the blank water that is quality assured by the USGS National Water Quality Laboratory (NWQL) and available to USGS field studies from the National Field Supply Service (NFSS) through the USGS One Stop Shopping service (*http://1stop.usgs.gov*). The NWQL provides a laboratory-certified analysis that documents the chemical composition and concentration of each lot of NFSS-supplied blank water that field personnel use to condition or rinse sampling equipment, as well as to collect quality-control samples.[5] Several grades of blank water are available from One Stop Shopping; selecting the appropriate grade depends on the sample analysis to be performed.

- **VPBW** (volatile/pesticide-grade blank water). Blank water that is suitable for collecting blank samples to be analyzed for volatile organic compounds (VOCs), pesticides, and organic carbon; purged with nitrogen gas.
  - — The shelf life of an unopened bottle of VPBW for analysis of VOCs is no more than 2 weeks after VPBW has been purged of VOCs by the NWQL (purge date is listed on the bottle label). For organic compounds other than VOCs, the expiration date varies for each lot certified by the NWQL and is available to USGS personnel at *http://wwwnwql.cr.usgs.gov/qas.shtml?obw*.
  - — Do not use VPBW to collect blank samples for analysis of inorganic constituents.
- **PBW** (pesticide-grade blank water). Blank water that is suitable for collecting blank samples to be analyzed for pesticides or organic carbon.
  - — The expiration date varies for each lot certified by the NWQL and is available to USGS personnel at *http://wwwnwql.cr.usgs.gov/qas.shtml?obw*.
  - — Do not use PBW for collecting blank samples for analysis of inorganic constituents.
- **IBW** (inorganic-grade blank water): Blank water that is suitable only for collecting blank samples that are to be analyzed for inorganic trace elements, major ions, or nutrients.
  - — IBW also can be used for blank samples for dissolved organic carbon (DOC), depending on project objectives and quality-assurance plans. DOC is listed on the IBW Certificates of Analysis provided by the NWQL.
  - — The expiration date varies for each lot certified by the NWQL and is available to USGS personnel at *http://wwwnwql.cr.usgs.gov/qas.shtml?ibw*.
  - — Do not use IBW to collect blank samples for analysis of organic compounds.

[5] USGS personnel can access the certificates of analysis for the type and lot of blank water they are using at *http://wwwnwql.cr.usgs.gov/qas.shtml?nfssqa_certificates*.

Deionized water (DIW) produced by a USGS Water Science Center (WSC), although quality assured periodically for concentrations of organic analytes (organic-grade water or OGW) and (or) inorganic analytes (DIW and ASTM International[6] Type 1 water from other sources), **are not acceptable substitutes for VPBW, PBW, and IBW for the collection of blank samples**.

► OGW and DIW that have been quality controlled through laboratory analyses may be used as equipment-cleaning solutions, as appropriate, for the equipment to be used and as instructed in NFM 3.

► Unopened bottles of NWQL-certified inorganic and organic blank water must be stored in a location with no exposure to vehicle exhaust, cleaning fluids, or other solvents (Office of Water Quality Technical Memorandum 2009.04; technical memorandums cited in this report are listed in the section "Selected References and Technical Memoradums"). No open bottles of blank water are to be stored for later use to collect blank samples. These requirements pertain also to WSC-produced water used for sampling activities; that is, the water should be produced and stored apart from exposure to potential sources of contamination.

Chemical preservatives, standards, buffers, and other reagents and substances used in the process of water-quality field and laboratory activities are not to be used beyond the expiration date listed. Discard expired chemical substances in a manner that conforms with Federal and local regulations and good environmental stewardship.

[6] ASTM International formerly was known as American Society for Testing and Materials.

2.1 Sample Collection

Guidelines for selecting sample-collection equipment and related supplies differ, depending on the chemical nature of the target analyte and on whether samples are collected for surface water or groundwater. Routine use should be made of checklists, field forms (see NFM 6.0.1 and 6.0.2), and logbooks. Examples of checklists for sample-collection equipment and supplies are provided in section 2.4.

A bound logbook must be maintained that is dedicated to keeping calibration and maintenance records for each field-measurement, field-analysis, and multiparameter instrument. A field book in which the equipment and methods used for project activities and field-site observations are recorded also is strongly recommended. Logbooks and other records documenting field activities may be requisitioned if the project data are a likely candidate for litigation. Documentation of equipment use and extra quality-control analyses are required if study objectives or site conditions result in a departure from published USGS required and recommended procedures.

- ► Logbooks must be bound so that pages are not readily removable (no looseleaf notebooks); pages should be preprinted with consecutive numbers.
- ► Entries in logbooks or on field forms must be dated and written with ballpoint pen or a permanent, non-smudge marker **(not with pencil or liquid ink)**.
- ► Incorrect entries or mistakes must not be erased: draw a single line through the mistake and initial and date it.

All equipment should be maintained and tested on a regular schedule (NFM 6). For example, the calibration of thermistor and liquid-in-glass thermometers should be checked at least annually (NFM 6.1). Equipment checks, calibrations, maintenance, and repairs must be entered in the logbook.

2.1.1 Surface-Water Equipment

Study objectives, flow conditions, and structures (such as a bridge, cableway, or boat) from which sample-collection equipment (a sampler) is deployed must be considered when determining which equipment to use. **Isokinetic depth-integrating samplers** and **nonisokinetic samplers** are the primary types of surface-water samplers in common use for USGS surface-water studies. USGS personnel obtain the surface-water sampling equipment described below either from commercial sources or from the USGS Hydrologic Instrumentation Facility (HIF; *http://water.usgs.gov/hif/*).

The equipment to be selected depends on whether or not the stream can be waded. To determine whether stream depth and velocity are too great to safely wade the stream (NFM 9), field personnel are advised to use professional judgment, but **at a minimum**, should not wade in flowing water if the measured depth (in feet) of the stream, multiplied by its velocity (measured in feet per second), equals 10 or greater. Application of this rule varies among individuals according to their weight and stature and depends on streambed conditions.

RULE OF THUMB: DO NOT wade in flowing water when the product of depth (in feet) and velocity (in feet per second) equals 10 or greater.

2.1.1.A Isokinetic Depth-Integrating Samplers

An isokinetic depth-integrating sampler is designed to accumulate a representative water sample continuously and isokinetically (that is, streamwater 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 (ASTM International, 1999; see NFM 4, Appendix A4–A). Isokinetic depth-integrating samplers are categorized into two groups, based on the method of suspension: handheld samplers and cable-and-reel samplers.

Types and pertinent characteristics of isokinetic depth-integrating samplers recommended for sampling in flowing water are summarized in table 2–2, illustrated on figure 2–1, and described below. For detailed descriptions of isokinetic depth-integrating samplers, refer to Szalona (1982), Ward and Harr (1990), Horowitz and others (1994), Edwards and Glysson (1999), Davis and the Federal Interagency Sedimentation Project (2005), and publications and information provided by the Federal Interagency Sedimentation Project (*http://water.usgs.gov/fisp/*).

- **Operational limits for isokinetic rigid-bottle samplers:**
  - The maximum allowable transit rate (R_t) relative to mean velocity (V_m) for a given rigid-bottle sampler varies with nozzle size and sample-bottle size (equipment properties were designed using English units; refer to Conversion Factors section for conversion to metric units) (table 2–2).
  - **Do not exceed the listed R_t/V_m ratio for the given nozzle and bottle size.** A lower R_t/V_m is better for ensuring that a representative velocity-weighted sample is collected, but care must be taken to not overfill the sampler bottle.
  - **Do not exceed the maximum depth of deployment for a rigid-bottle sampler** (table 2–2).
- **Operational limits for isokinetic bag samplers:**
  - The maximum allowable transit rate to collect an isokinetic sample for all depth-integrating bag samplers is the product of 0.4 and the maximum mean stream velocity.
  - The bag-sampler intake efficiency is tested before each set of samples is collected during a site visit. Nonisokinetic samples may be collected with a bag sampler if the efficiency test and the extenuating circumstances are documented.

For collection of an isokinetic sample, the minimum mean stream mean velocity must be greater than 1.5 ft/s for a rigid-bottle depth-integrating sampler, and varies for a depth-integrating bag sampler.

Table 2–2. Isokinetic depth-integrating water-quality samplers and sampler characteristics.

[Rt, transit rate in feet per second (ft/s); V_m, mean stream velocity in the vertical being sampled, in ft/s; DH, depth-integrating handheld sampler; PN, polypropylene cap and plastic (Delrin®) nozzle; PFA, perfluoroalkoxy bottle or bag; C&N, cap and nozzle; PC, plastic coated; PT, polypropylene or PFA bottle; PDC, plastic dip coated; D, depth-integrating sampler; P, plastic nozzle; TFE, tetrafluoroethylene nozzle]

Sampler designation	Sampler construction material	Sampler dimensions[1]			Unsampled zone[2] (inches)	Suspension method	Minimum calibrated velocity, (feet per second)	Maximum calibrated velocity, (feet per second)	Maximum depth, (depth at sea level, in feet)	Sampler container size (liters)	Nozzle intake size[3] (inches)	Maximum transit rate ratio,[4] R_t/V_m
		Length (inch)	Width (inch)	Weight (pound)								
US DH-81	PN or PFA-C&N	[1]6.5	3.2	[1]0.5	[2]4	Handheld (PC)	[5]2.0 [5]1.5 [5]2.0	6.2 7.6 7.0	15 15 13.3	1 (PT)	3/16 1/4 [1]5/16	0.2 0.3 0.4
US DH-95	Bronze (PDC) with PN or PFA-C&N	22	66	29	4.8	Handheld or reel and cable	[5]2.0 1.7 2.1	6.2 7.4 7.0	15 15 13.3	1 (PT)	3/16 1/4 5/16	0.18 0.32 0.4
US DH-2	Bronze (PDC) with P or TFE nozzle	19	6	30	4	Handheld or reel and cable	[5]2.0 2.0 2.0	6.0 6.0 6.0	35 20 13	1 (P or PFA)	3/16 1/4 5/16	0.4 0.4 0.4
US D-95	Bronze (PDC) with PN or PFA-C&N	26	6.7	64	4.8	Reel and cable	[5]1.7 [5]1.7 [5]2.0	6.2 6.7 6.7	15 15 13.3	1 (PT)	3/16 1/4 [1]5/16	0.18 0.32 0.4
US D-96	Bronze (PDC) with P or TFE nozzle	35	8	132	4	Reel and cable	[5]2.0 [5]2.0 [5]2.0	12.5 12.5 12.5	110 60 39	3 (P or PFA)	3/16 1/4 5/16	0.4 0.4 0.4
US D-99	Bronze (PDC) with P or TFE nozzles	47	10	285	9.5	Reel and cable	[5]3.0 [5]3.0 [5]3.0	15 15 15	220 120 78	6 (P or PFA)	3/16 1/4 5/16	0.4 0.4 0.4

[1]Length, width, and weight will depend on specific bottle dimensions. Weight indicated is for cap and nozzle only. Handle is plastic coated with clear heat-shrinking tubing.

[2]Distance from nozzle to the channel bottom will depend on specific bottle dimensions.

[3]Nozzle sizes are those recommended for the application shown.

[4]Refer to NFM 4, appendix A, for maximum transit-rate ranges, and to Office of Surface Water Technical Memorandum 94.05, *http://water.usgs.gov/admin/memo/SW/sw94.05.html*.

[5]Pertains to water temperature greater than 27 degrees Celsius. For water temperatures less than 27 degrees Celsius refer to Office of Surface Water Technical Memorandum 2013.03 and Office of Water Quality Technical Memorandum 2013.02, “Guidelines for FISP bag sampler intake efficiency tests and operational velocities policy,” and released jointly, *http://water.usgs.gov/admin/memo/QW/qw2013.02.pdf*.

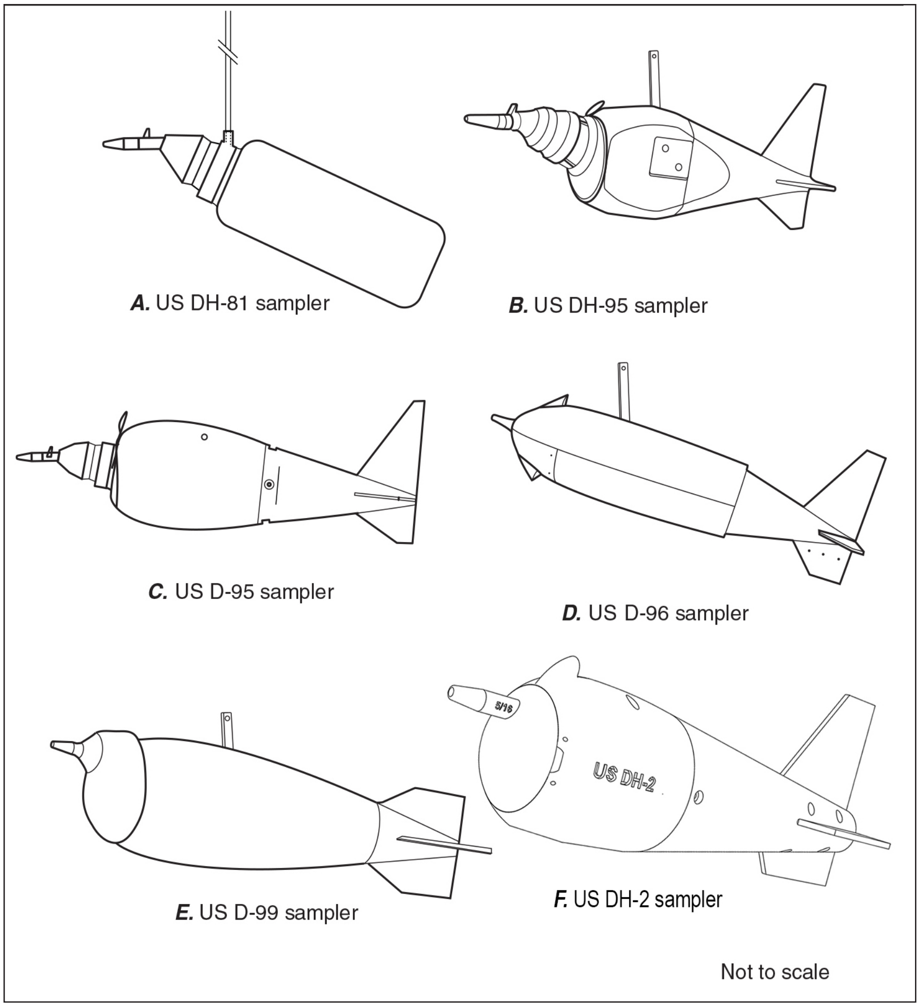


Figure 2–1. Isokinetic depth-integrating samplers: (*A*) US DH-81, (*B*) US DH-95, (*C*) US D-95, (*D*) US D-96, (*E*) US D-99, and (*F*) US DH-2. Illustrations *A–E* courtesy of Federal Interagency Sedimentation Project, Waterways Experiment Station, Vicksburg, Miss; illustration *F* courtesy of Carnet Technology, *carnettechnology.com*.

The cap-and-nozzle assembly is available in fluoropolymer and polypropylene materials. The same cap and nozzle can be used for the US DH-81, US DH-95, and US D-95 samplers. Owing to advances and improvements in sampler technology, and to keep abreast with data needs, sampling devices are periodically reevaluated to ensure they are appropriate for USGS data-collection activities. The US DH-81, US DH-2,7 US DH-95, US D-95, US D-96,[7] or US D-99 samplers are approved for collecting samples in flowing waters for all analyses except for samples to be analyzed for inorganic gases and VOCs (fig. 2–1). Technical Note 1 below lists samplers whose use has been discontinued by USGS water-quality personnel for the routine collection of surface-water samples.

► Water samples for which trace elements will be determined must contact only noncontaminating materials—typically a fluorocarbon polymer or polypropylene material.

[7] The US DH-2A incorporates some improvements to the DH-2, but components are interchangeable and it looks and functions identically. The US D-96A-1 is an aluminum version of the US D-96.

► Water samples for which organic compounds will be determined must contact only noncontaminating materials—typically a metal (such as stainless steel), a fluoropolymer or fluorocarbon polymer (such as Teflon®[8]), or a ceramic (such as hard-fused microcrystalline alumina).

TECHNICAL NOTE 1. Discontinued sampling devices

- The US D-77, US D-77 Bag, and Frame Bag (FB) samplers have been phased out for all USGS water-quality and sediment studies (Office of Water Quality Technical Memorandum 2002.09; see, "Selected References and Technical Memorandums").
- The US DH-48, US DH-59, US DH-76, US D-74, US P-61, US P-63, and US P-72 no longer are used for the collection of trace-element samples, but may be acceptable when sampling only for major ions, nutrients, and suspended sediments, depending on the data-quality requirements of the project. Collect additional quality-control samples if it is necessary to use any of these samplers (Horowitz and others, 1994).

Handheld samplers

Handheld samplers (table 2–3) are used to collect water samples where flowing water can be waded or where a bridge is accessible and low enough from which to suspend the sampler. The rigid-bottle sampler components (cap, nozzle, and bottle) are interchangeable. Both inorganic and organic samples can be collected with the DH series samplers (DH 81, DH 95, DH 2 (or DH 2A) provided the construction material of the sampler components (table 2–1) does not affect ambient concentrations of target analytes. Isokinetic depth-integrated samples for bacteria analysis also can be collected with these samplers because the cap, nozzle, and bottle can be autoclaved. All handheld samplers should be tested and maintained as described in table 2–3. The checklist also applies to cable-and-reel samplers.

► **When using the US DH-81 (fig. 2–1*A*) and US DH-95 (fig. 2–1*B*)**, use the 1-L bottle and adhere to the depth limit for the sampler deployment to avoid collecting a nonisokinetic sample. The depth limit depends on the nozzle diameter.

— To collect an isokinetic sample when using a 3/16-in. nozzle, flow velocity must be between 2.0 and 6.2 ft/s (~0.61 to 1.89 m/s).

— To collect an isokinetic sample when using a 1/4-in. nozzle, flow velocity must exceed 1.5 ft/s (~0.46 m/s) but be no greater than 7.6 ft/s (~2.32 m/s).

— To collect an isokinetic sample when using a 5/16-in. nozzle, flow velocity should be between 2.0 and 7.0 ft/s (~0.61 to 2.13 m/s), and depth of deployment should not exceed 13.3 ft (~4 m).

► **When using the US DH-2 (or DH-2*A*) bag sampler (fig. 2–1*F*) for isokinetic sampling:**

— Use a 3/16-, 1/4-, or 5/16-in. nozzle and mount. (Do not use the DH-2 sampler 1/8-in. nozzle.)

— The minimum flow velocity is 3.7 ft/s for the 3/16-in. nozzle when the water temperature is less than 27 °C and for the 1/4- and 5/16-in. nozzles when the water temperature is less than 10 °C. Make sure that flow velocity is no greater than 6 ft/s (~1.83 m/s). The minimum flow velocity is 2 ft/s for the 3/16-, 1/4-, and 5/16-in. nozzles when the water temperature is greater than 27 °C.

— Use in water with a maximum depth between 13 and 35 ft (~3.96 to 10.67 m), depending on nozzle diameter, for an isokinetic, depth-integrated sample.

— Water temperature must be equal to or greater than 4 °C.

[8] Teflon is a registered trademark of the DuPont Corporation.

Table 2–3. Pre-field checklist for handheld and cable-and-reel samplers.

Sampler Checklist	Comment
Mechanical operation	Test the working condition of the sampler. If tailfin is damaged or broken, sampler will not swim correctly.
Nozzles	Replace nozzles that have burrs or are damaged. Use only nozzles purchased from the Federal Interagency Sedimentation Project (*http://water.usgs.gov/fisp/*).
Plastic coating	If plastic coating is damaged or any metal parts are exposed, recoat or touch up with a plastic dip product.
Cleanliness of sampler	Before field work, clean appropriate parts of the sampler according to procedures described in NFM 3 and store parts in plastic for transport to the field site.
Laboratory results from analysis of the sampler and equipment blank(s)	Make sure the sampler has been quality assured with an annual equipment blank and certified for water-quality use (see NFM 1 and NFM 4).
Have separate sets of sampler components and backup equipment available	If at all feasible, for a given field trip when collecting multiple water samples, prepare and use separate sets of sampler bottles, caps, and nozzles for each sampling site. Have backup equipment available onsite.
Have field-cleaning supplies and blank water available	If separate sets of sampler components are not available, then clean equipment between sampling sites (see NFM 3) and be prepared to process the number of field blanks needed to document that equipment was adequately cleaned.

Cable-and-reel samplers

Cable-and-reel samplers are used to collect water samples where flowing water should not be waded. These include the US D-95 bottle sampler and the US D-96 and US D-99 bag samplers. (Refer to table 2–2 for sampler characteristics and sampling limitations.) Like the handheld US DH-81, US DH-2, and US DH-95, these cable-and-reel samplers can be used to collect inorganic and organic samples; however, appropriate sampler components (cap, nozzle, and bottle or bag) must be selected so as not to bias concentrations of target analytes. Isokinetic, depth-integrated samples collected for the analysis of bacteria also can be collected with these samplers because the cap, nozzle, bottle, and bags can be autoclaved.

The US D-96 bag sampler uses a perfluoroalkoxy (PFA) or polyethylene bag that is placed in a sliding tray that supports the bag and holds the nozzle holder with nozzle in place. The bag is attached to the nozzle holder with a hook-and-loop (for example, Velcro®) strap. The US D-99 bag sampler uses a 6-L PFA or polyethylene bag that is placed in a chamber behind the nozzle, through an access door.

Metal parts of the US D-95 bottle sampler and the US DH-2 bag, US D-96 bag, and US D-99 bag samplers must be coated with plastic (for example, Plasti Dip®) and recoated periodically to prevent possible sample contamination from metallic surfaces. **All cable-and-reel samplers should be tested and receive any necessary maintenance before use, as described in table 2–3**.

► **When using the US D-95 bottle sampler (fig. 2–1*C*):**

- — Use a 3/16-, 1/4-, or 5/16-in. nozzle. US DH-81 and US DH-95 nozzles can be used.
- — Make sure that flow velocity exceeds 1.7 ft/s (~0.52 m/s), but is no greater than 6.7 ft/s (~2.04 m/s), depending on the nozzle diameter used.
- — Use in water less than 13.3 to 15 ft (~4 to 4.6 m) deep (at sea level)—depending on the nozzle used and the altitude at the site—for an isokinetic, depth-integrated sample.

- **When using the US D-96 bag sampler (fig. 2–1*D*):**
  - Use only the 3/16-, 1/4-, or 5/16-in. nozzles designed specifically for this sampler.. The nozzles needed are unique to the D-96 sampler and mounts.
  - The minimum flow velocity is 3.7 ft/s for the 3/16-in. nozzle when the water temperature is less than 27 °C and for the 1/4- and 5/16-in. nozzles when the water temperature is less than 10 °C. Make sure that flow velocity is no greater than 12.5 ft/s (~3.8 m/s)
  - Use in water with a maximum depth of 39 to 110 ft (~11.9 to 33.5 m), depending on the nozzle diameter for an isokinetic, depth-integrated sample.
  - Water temperature must be equal to or greater than 4 °C. The sampler has been tested at temperatures equal to or greater than 4 °C and found to function properly, provided the flow velocities are greater than the minimums noted above.
- **When using the US D-99 bag sampler (fig. 2–1*E*) for isokinetic sampling:**
  - Use a 3/16-, 1/4-, or 5/16-in. nozzle and mount. (Do not use a 1/8-in. nozzle that is designed for the D-99 sampler.)
  - The minimum flow velocity is 4.0 ft/s for the 3/16-in. nozzle when the water temperature is greater than 4 °C. The minimum flow velocity for the 1/4- and 5/16-in. nozzles is 3 ft/s when the water temperature is greater than 27 °C, and 3.7 ft/s when the water temperature is less than 10 °C. Be sure that flow velocity is no greater than 12.5 ft/s (~3.8 m/s).
  - Use in water with a maximum depth of 78 to 220 ft (~23.8 to 67 m), depending on nozzle diameter, for an isokinetic, depth-integrated sample.
  - Water temperature must be equal to or greater than 4 °C.

2.1.1.B Nonisokinetic Samplers

Nonisokinetic samplers are sampling devices in which the sample enters the device at a velocity that differs from ambient stream velocity. All of the isokinetic samplers described in 2.1.1.A can be used to collect depth-integrated, although nonisokinetic, samples, when used beyond the minimum and maximum ranges of velocity and depth (table 2–2). When collecting a nonisokinetic sample, the sampler intake should not enter the unsampled zone. As with all samplers, the materials that contact the sample must not bias concentrations of target analytes by sorbing or leaching target analytes.

Open-mouth samplers

Open-mouth samplers used for the collection of water samples include the handheld bottle, the weighted-bottle sampler, the biochemical oxygen demand (BOD) sampler, and the VOC sampler (fig. 2–2).

- **The handheld bottle sampler** is the simplest type of open-mouth sampler. A bottle is dipped to collect a sample (fig. 2–2*A*) where depth and velocity are less than the minimum required for depth-integrating samplers.
- **The weighted-bottle sampler** is available in stainless steel (US WBH-96) (fig. 2–2*B*) or polyvinyl chloride. The weighted-bottle sampler can be used to collect samples where flow velocities do not meet the minimum requirement for isokinetic depth-integrating samplers and where the water body is

too deep to wade. An open bottle is inserted into a weighted holder that is attached to a handline for lowering. Sampling depth is restricted by the capacity of the bottle and the rate of filling.

► **The BOD sampler** and the VOC sampler (fig. 2–2 *C–D*, respectively), are open-mouth samplers designed to collect non-aerated samples.

— The BOD sampler accommodates 300-mL glass BOD bottles specifically designed to collect non-aerated samples for dissolved-oxygen determination (American Public Health Association and others, 1992, p. 4–99).

— The VOC sampler is specifically designed to collect non-aerated samples in 40-mL glass septum vials for determination of VOCs.

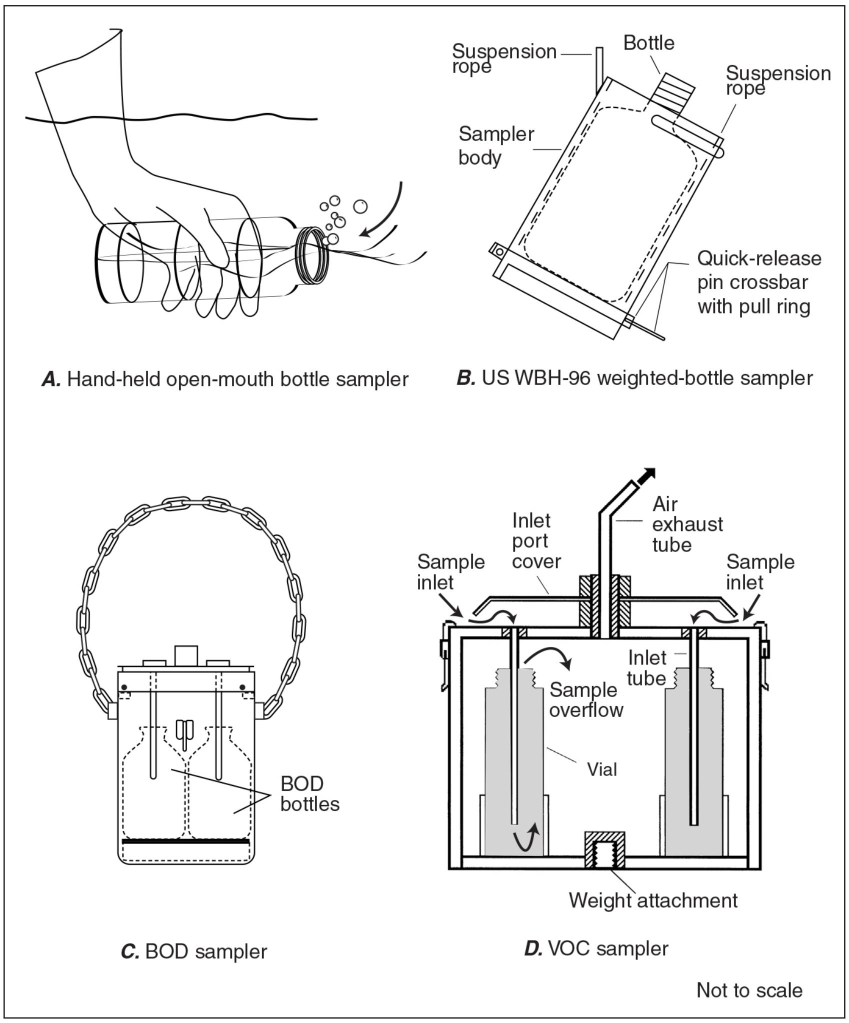


Figure 2–2. Nonisokinetic open-mouth samplers: (*A*) handheld open-mouth bottle sampler, (*B*) US WBH-96 weighted-bottle sampler, (*C*) biochemical oxygen demand (BOD) sampler, and (*D*) volatile organic compound (VOC) sampler. *A*, from U.S. Environmental Protection Agency, 1982b; B, courtesy of Federal Interagency Sedimentation Project, Waterways Experiment Station, Vicksburg, Miss.; *C*, published with permission of Wildlife Supply Company; *D*, from Shelton (1997).

Thief samplers

Thief samplers are used to collect instantaneous discrete samples. Thief samplers have been used primarily to collect samples from lakes, reservoirs, and some areas of estuaries. Smaller versions, designed to collect groundwater samples, also have been used in still and flowing surface water. The most commonly used thief samplers are the Kemmerer sampler, Van Dorn sampler, and double check-valve bailer with bottom-emptying device (fig. 2–3). These samplers are available in various sizes and mechanical configurations, and in various types of construction material (such as stainless steel, glass, polyvinyl chloride, fluorocarbon polymer). Disposable fluorocarbon polymer bailers also are available. For descriptions of additional thief samplers, see U.S. Environmental Protection Agency (1982b), Ward and Harr (1990), and American Public Health Association and others (1992), or consult the manufacturer of the environmental sampling equipment.

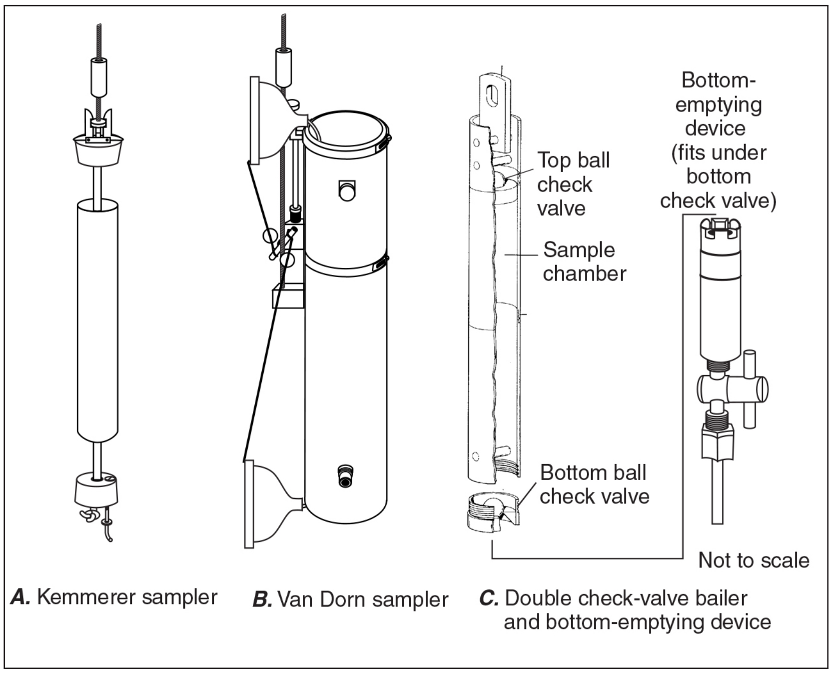


Figure 2–3. Nonisokinetic thief samplers: (*A*) Kemmerer sampler, (*B*) Van Dorn sampler, and (*C*) double check-valve bailer with bottom-emptying device. *A* and *B*, from the American Public Health Association and others (1992); used with permission. *C*, published with permission of Timco Manufacturing Inc.

Single-stage samplers

Single-stage samplers such as the US U-59 (fig. 2–4*A*) are designed to obtain suspended-sediment samples from streams at remote sites or at streams where rapid changes in stage make it impractical to use a conventional isokinetic, depth-integrating sampler. Single-stage samplers can be mounted above each other to collect samples from various elevations or times as streamflow increases and the hydrograph rises (fig. 2–4*B*) (Edwards and Glysson, 1999).

► **The US U-59** is a sample container mounted to collect a water sample as stage rises above the sampler intake.

— The vertical-intake sampler is used to sample streams carrying sediments finer than 0.062 millimeter (mm). When compared to a horizontal-type intake, the vertical intake is less likely to become clogged or fouled by floating solid materials.

— The horizontal-intake sampler is used to sample streams carrying sediment coarser than 0.062 mm.

► **The US U-73**, which can be used to sample water during either rising or falling stage, is constructed to provide some protection from trash or other solids that could clog or foul the intake.

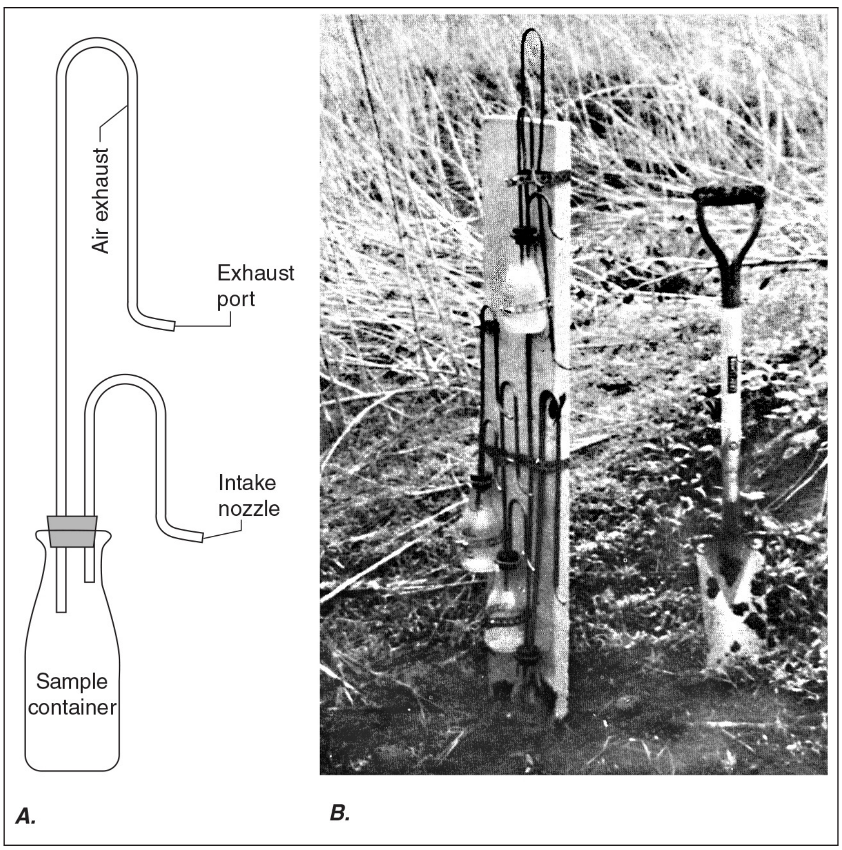


Figure 2–4. US U-59 sampler: (*A*) single stage and (*B*) a bank of U-59 samplers installed on a plank post. *A*, from Edwards and Glysson (1999); *B*, photograph by J.C. Mundorff, U.S. Geological Survey.

Automatic samplers and pumps

Automatic pumping samplers (autosamplers) with fixed-depth intake(s)[9] can be used to collect samples at remote sites; from ephemeral, small streams; or from urban storm drains where stage rises quickly (American Public Health Association and others, 1992; Edwards and Glysson, 1999). These samplers can be programmed to collect samples under a combination or variety of conditions such as precipitation, stage, or discharge. Samples from automatic samplers or pumps are considered point-integrated samples.[10]

Pumps used for water sampling are grouped into two general categories: suction-lift pumps and submersible pumps. Pumps can be used to collect water samples from lakes, reservoirs, and estuaries (Radtke and others, 1984; Radtke, 1985; Ward and Harr, 1990). Suction-lift and submersible pumps are described in section 2.1.2, “Groundwater Equipment.”

2.1.1.C Support Equipment

Clean Hands/Dirty Hands techniques, described in NFM 4, are required when sampling for trace elements (Horowitz and others, 1994) and are recommended as a general practice in sample collection, particularly when using heavy-duty support equipment.

Much of the equipment used to measure streamflow also can be used as support equipment when collecting water samples in water bodies that cannot be waded. Examples of commonly used support equipment are listed in section 2.4 near the end of this chapter.

Use of a vertical transit rate pacer, such as the US VTP-99 or the variable speed reel-drive system, can help to ensure an accurate flow-weighted sample after the appropriate transit rate has been determined (Office of Water Quality Technical Memorandum 2013.02; Edwards and Glysson, 1999, p. 53–60). Once programmed, the pacer produces an audible signal for pacing the raising and lowering of either handheld or mechanically hoisted samplers. The pacer is small enough to be carried in a shirt pocket, and the tone is audible for several feet in a quiet environment. The US VTP-99 can be used with a miniature phone-type monaural headphone jack; neither the jack nor the headphones are supplied. Tables for using the pacer when sampling with either a handheld sampler or a type “A,” “B,” or “E” reel can be found in the publication “Using the US VTP-99 vertical transit rate pacer.”[11]

The variable speed reel-drive system consists of a variable speed electric motor that is mounted to a crane or boom. A pair of V-belts drives a B–56 or E–53 reel at a constant user-selected speed in both the up and down directions. The system includes an operator control that displays the selected speed, actual speed, direction, cable length deployed, and battery voltage.

Exercise great care to avoid sample contamination when handling support equipment for samplers used to collect trace-element samples.

[9] Automatic pumping samplers are available through commercial manufacturers, such as Hach Company Sigma samplers (www.Hach.com),Teledyne Isco, Inc. (http://www.isco.com), and Manning Environmental,Inc. (*http://www.manningenvironmental.com*).

[10] Periodically scan the National Field Manual Comments and Errata page (*http://water.usgs.gov/owq/FieldManual/mastererrata.html*) for chapters NFM 2 and NFM 44 for updates on automatic samplers (autosamplers) guidance.

[11] The publication is available at *http://water.usgs.gov/fisp/docs/Instructions_US_VTP-99_990722.pdf*.

2.1.2 Groundwater Equipment

The type of sampler or sampling system selected for collecting groundwater samples depends on the type and location of a well, the depth to water from land surface, physical characteristics of the well, groundwater chemistry, and the analytes targeted for study. Selecting the appropriate equipment for collecting groundwater samples is important in order to obtain data that will meet study objectives and data-quality requirements. Groundwater sampling equipment is available from a variety of commercial sources. Support equipment (for example, tubing, valves, manifolds) is available commercially or, for USGS personnel, through the USGS Hydrologic Instrumentation Facility (HIF).

Groundwater most commonly is collected using either pumps designed specifically for water sampling from monitoring wells, pumps installed in supply wells, or a bailer or other point or thief-type sampler.[12] General considerations for selecting groundwater equipment are listed in table 2–4.

- ► Monitoring wells: Samplers can be portable, dedicated, or permanently installed in the well.
  - — Portable equipment is commonly used at multiple well sites and cleaned after each use.
  - — Portable samplers and sample tubing commonly are dedicated to a site with large contaminant concentrations.
  - — Some types of portable equipment can be installed in a well for the duration of the monitoring program. Remove the sampler from the well periodically for cleaning.
- ► Supply wells (for domestic, municipal, industrial or commercial, or agricultural use): Equipment selection is limited, as supply wells normally are equipped with permanent, large-capacity pumps.
  - — Choice of equipment usually depends on well configuration and type of pump installation (permanent or temporary).
  - — Modifications to the well and ancillary equipment attached at the wellhead are necessary in some cases (see section 2.1.2.A.)

Sampling equipment must not be a source of contamination or otherwise affect analyte concentration (table 2–1). Of specific importance for groundwater sampling is a potential change in groundwater chemistry due to atmospheric exposure.

- ► Select equipment that minimizes sample aeration.
- ► Select equipment that will not leach nor sorb significant concentrations of the target analytes, with respect to data-quality requirements.
  - — Submersible pumps that tested successfully[13] for inorganic constituents[14] included the Grundfos Redi-Flo2®, Fultz SP-300, Bennett, and several types of bladder pumps with Teflon® bladders.

[12] Sampling equipment not described in this report includes multilevel collection systems (LeBlanc and others, 1991; Smith and others, 1991; Gibs and others, 1993); samplers designed to collect groundwater under natural-gradient flow conditions (Margaritz and others, 1989; Vroblesky, 2001a); and pump-and-packer systems.

[13] Unpublished results of testing by the USGS in 1994 confirmed that commonly used sampling equipment with fluorocarbon polymer interior parts does not, in general, affect sample concentrations of inorganic constituents or organic compounds (U.S. Geological Survey Office of Water Quality, written commun., 1994) after being precleaned according to NFM 3 protocols and fitted with new, cleaned tubing. Water-quality sampling equipment developed or modified since the 1994 testing have not been similarly evaluated. USGS projects are directed to collect presampling equipment blanks to quality assure the appropriateness of the equipment to be used to produce samples of the quality required by the project.

[14] Trace-element concentrations in blank samples processed through these samplers were within the margin of analytical variability at a method reporting level of 1 microgram per liter.

Double-check-valve fluorocarbon polymer bailers also were found to be capable of producing uncontaminated samples for inorganic analyses.

— Samplers tested that achieved a greater than 95-percent recovery of VOCs included Grundfos Redi-Flo2®, Fultz SP-300, bladder pumps, and the Bennett pump.

— Double-check-valve fluorocarbon polymer bailers scored a less than 95-percent recovery of known analyte concentrations, particularly for VOCs (U.S. Geological Survey, 1992a,b).

Choice of equipment is constrained by many factors, including equipment construction and equipment specifications. For example, it is necessary to consider power requirements, lift capability, and discharge capacity of submersible pumps. Ideal equipment for sample collection might not exist, and compromise is often necessary. **Field personnel must understand the application, advantages, disadvantages, and limitations of the available equipment, with respect to study objectives and site characteristics, and must document how any compromises made might affect the data and data-quality objectives.**

Table 2–4. General requirements and considerations for selecting groundwater sampling equipment (thief samplers and pumps).

Requirements	Considerations
Construction materials	• Is the sampler constructed from materials that (initially or over time) could leach targeted analytes? If left in the well, is the sampler constructed of materials that will degrade appreciably within the lifetime of the study? • Can the sampler be cleaned? Can it withstand the level of decontamination needed and subsequently produce clean equipment blanks?
Operation, capabilities, and limitations	• Could operation of the sampler compromise sample integrity with respect to study objectives or data quality? For example, does the sampler heat or aerate the sample, or subject the sample to negative pressure, leading to volatilization of purgeable organic compounds, oxidation of target analytes, or changes in partial pressure of carbon dioxide or other gases? • Is the sampler capable of evacuating standing water (that is, can it be used for purging in addition to sample collection)? • Is the sampler capable of providing flow or sample volumes sufficient for sample collection and in a manner that minimizes suspension of sediments or colloids that could bias chemical measurements? • Is the sampler mechanically capable of withdrawing formation water from the desired depth?
Power requirements	• What are the power requirements of the sampler or the manner in which it will be deployed? Will it require electrical power (alternating or direct current), gasoline or other fuel-powered generators, or compressed gas such as air or nitrogen? • Will the capacity of the power source be sufficient to allow the sampler to run continuously throughout purging and sample collection? • Could the power source contaminate samples? (For example, gasoline-powered generators or compressors are a potential source of volatile organic compounds.) • Could the fuel be changed to a noncontaminating type (for example, convert a gasoline-powered generator to propane fuel)?
Transport	Is the sampler easily transported to remote sites and rugged enough for field use?
Sampler repair	Can the sampler be repaired in the field?
Availability and cost	• Are the available samplers suitable for study use? Are funds available to purchase, operate, and maintain the sampler? • Are funds available to purchase a spare pump head (or other equipment)? This would allow for sampling to continue while, for example, one pump head is being repaired.

2.1.2.A Pumps

Pumps transport water from depth to land surface either by suction lift or positive pressure.[15] The pumping mechanism for most suction-lift pumps (peristaltic, jet, and some nonsubmersible centrifugal pumps) is at land surface. Positive-pressure pumps (helical rotor, gear, bladder, piston, inertial submersible, and centrifugal) are grouped together as submersible pumps because they are placed below the static water level.

Supply-well pumps

Centrifugal and jet (venturi) pumps (fig. 2–5) that have the pumping mechanism above land surface, as well as high-capacity submersible pumps and turbine pumps, are common in domestic, municipal, and other supply wells.

- ► **Note that large- and small-capacity pumps used in supply wells can affect analyte concentrations** (see NFM 1 and Lapham and others, 1997).
  - — Erroneous data produced as a result of using these pumps are most likely for dissolved gases, VOCs, and reduction-oxidation (redox) chemical species.
  - — Oil in the water column is common for oil-lubricated pumps.
  - — Chemical treatment systems, pressure tanks, and holding tanks can compromise sample integrity.
- ► Install a hookup system for transfer of sample from the wellhead to the chamber or the area where samples will be processed (NFM 4 and 5). Clean such equipment to remove oils and other manufacturing and shipping residues (NFM 3) before use.
  - — Ensure that the point of sample discharge from the hookup system on supply wells is ahead of chemical treatments or holding tanks. Obtain permission to modify the discharge point by installing a spigot or other plumbing appropriate to preserve the quality of the sample, if possible. Otherwise, do not use the well. The spigot or other plumbing also must be cleaned before use.
  - — Install an anti-backsiphon device in line with the hookup system.
  - — Install an optional needle valve with flow-regulating capabilities in line with the hookup system (fig. 2–6*A*).

[15] For more detailed information on pumps, refer to manufacturers' instructions and specifications and to U.S. Environmental Protection Agency (1982b), Morrison (1983), Driscoll (1986), Imbrigiotta and others (1988), Ward and Harr (1990), American Public Health Association and others (1992), Gibs and others (1993), Sandstrom (1995), Koterba and others (1995), and Edwards and Glysson (1999).

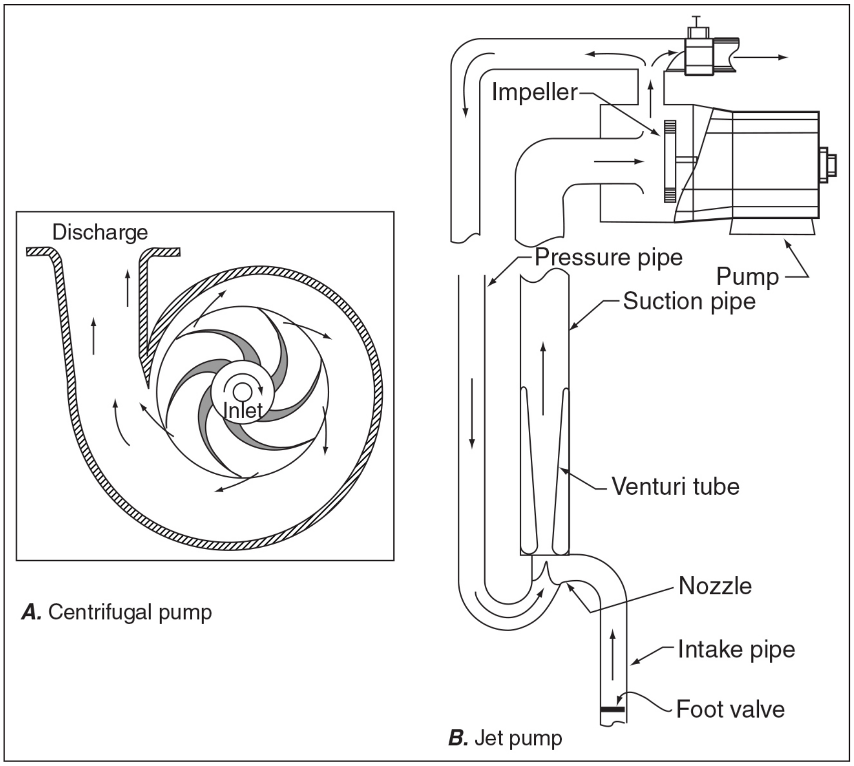
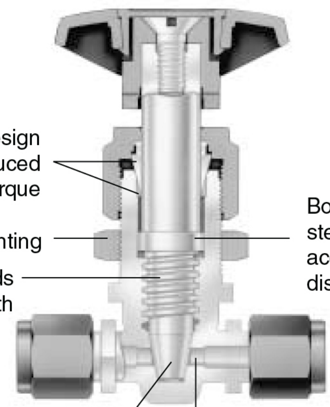


Figure 2–5. Above-land-surface pumps typically used to obtain water from supply wells are the (*A*) centrifugal pump and (*B*) jet pump. From Driscoll (1986); published with permission of US Filter/Johnson Screens.

A. Swagelok® PFA Needle Valve number PFA-4RPS8 (fits 1/2-inch tubing)



B. Materials of Construction

Component	Material Grade/ASTM Specification
1 Handle insert	PFA 440-HP/ D3307
2 Screw	
3 Handle	
4 Packing nut	
5 Upper packing	
6 *Lower packing*	
7 *Stem stop*	
8 Panel nut	
9 *Stem*	
10 *Body, ferrules*	
11 Nut	
Lubricant	PTFE based

Wetted components listed in *italics*.

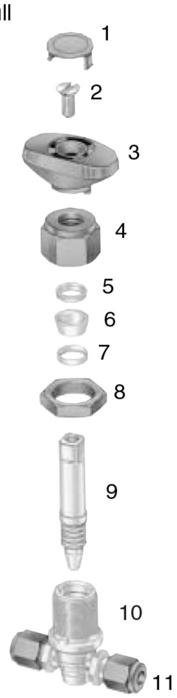


Figure 2–6. Swagelok® perfluoroalkoxy needle valve showing (*A*) front view and (*B*) exploded view.

Monitoring-well pumps

Suction-lift and positive-displacement pumps are commonly used to collect water samples from monitor (monitoring) wells. Field personnel should consider the criteria and guidelines listed in tables 2–4 and 2–5 when selecting a pump for sampling from monitoring wells.

- ► Suction-lift pumps create a vacuum in the intake line that draws the sample up to land surface (fig. 2–7*A*).
  - — The vacuum can result in the loss of dissolved gases and VOCs.
  - — Intake tubing could diffuse atmospheric gases sufficiently to affect some target analytes unless thick-walled low-diffusion tubing is used.
  - — Use of a peristaltic pump (1- to 2-L/min pumping rate) is limited to wells in which depth to water is less than about 25 ft (~9 m). The operation lift may be as small as 20 ft.
  - — Peristaltic pumps have the advantages of few moving parts, easily replaceable tubing and heads, and portability.
  - — Provided that data quality is not compromised, properly operated peristaltic pumps can be used to obtain samples from shallow wells, especially those that produce small volumes of water.
- ► Submersible pumps (positive pressure or other types of positive-displacement pumps) designed specifically for the collection of water samples from monitoring wells are preferred, generally, because they do not create a vacuum (fig. 2–7*B*–*F*).
  - — Install an anti-backsiphon device in-line (on top of the pump before the tubing connection) to prevent backflow from contaminating the groundwater.
  - — Select suitable materials for sample line, sample-line connectors (see “Pump Tubing,” section 2.2.4), and sample-line reels (see “Support Equipment,” section 2.1.2.C, and “Checklists for Equipment and Supplies,” section 2.4) for use with submersible pumps.
- ► The suitability and application of commonly used submersible pumps depends on pump and well characteristics and on practical constraints (tables 2–4 and 2–5). Determine that:
  - — The rate of pumping is suitable for a given lift (table 2–5).
  - — The maximum lift of the pump at the water surface is greater than the lift to land surface.
  - — The power source and pump characteristics are sufficient to allow the pump to run continuously throughout purging and sample collection.
  - — The height of the water column must be at least 5 ft above the top of the submersible pump (to avoid setting the pump intake too close to the bottom of the well).
  - — The pumping rate will not cause excessive drawdown, which could result in the intersection of the water level with the well screen or open interval or causing the well to go dry.

Portability and repairability are important logistical considerations when selecting a pump.

- Portability. The pumps shown in figure 2–7 are made for transport to and from the field, but fuel or electrical power requirements make some more awkward to transport and to operate at remote sites than others (not shown is the inertial-lift pump, which has no fuel or electrical power requirement when operated manually).
- Repairability:
  - Ruptured bladders for bladder pumps can be replaced easily in the field.
  - Fluorocarbon polymer impellers used in gear pumps are easily abraded and can be ruined by particulate-laden water. Such impellers can be replaced in the field, but usually with some difficulty.
  - Submersible centrifugal pumps and piston pumps generally are not easily repaired in the field. Such pumps, however, include features such as variable-speed capability that make them favored for many applications.
  - When selecting a pump for sampling, consider purchasing an additional pump head (the submerged motor component), because most repairs involve the pump head. The pump heads for some pump types or models (such as the Fultz pump) are constructed for quick connect and disconnect to ease pump head replacement under field conditions.

Table 2–5. Examples of pump capability as a function of well and pump characteristics in a 2-inch-diameter well.

[Table modified from Koterba and others (1995), p. 18–19; ft, foot; m, meter; gal, gallon; L, liter; TDH, total dynamic head; gal/min, gallon per minute; L/min, liter per minute; ~, approximately; ---, not available]

Well Characteristics			Pump Characteristics			
			Fultz SP-400: Lift capacity is exceeded at ~150 ft (~45.7 m)		Grundfos RediFlo2®: Lift capacity is exceeded at ~260 ft (~76.2 m)	
Water-column height, in ft (m)	Lift or TDH,[1] in ft (m)	Three-well-volume purge protocol,[2] in gal (L)	Pumping rate at lift or TDH shown, in gal/min (L/min)	Maximum volume after 2 hours of pumping,[3] in gal (L)	Pumping rate at lift or TDH shown, in gal/min (L/min)	Maximum volume after 2 hours of pumping, in gal (L)
20 (~6.1)	25 (~7.6)	10 (37.85)	1.0 (3.785)	120 (~454)	7.0 (~26.5)	840 (~3,179)
40 (~12.2)	160 (~48.7)	20 (75.7)	---	---	~4.8 (~18.2)	538 (~2,036)

[1]In these examples the lift is equivalent to TDH and is estimated as the depth to water in the well (see Koterba and others, 1995, for more information).

[2]Standard procedure is to purge a minimum of three well volumes while monitoring field measurements (NFM 4, NFM 6): purge volume = $V=0.0408HD^2$, where H is water-column height (in feet) and D is the well diameter (in inches).

[3]Maximum pumped volume is calculated from the pumping rate for a given pump system (from manufacturer's specifications) at the lift (or TDH) multiplied by an assumed total purging time of 2 hours (Koterba and others, 1995).

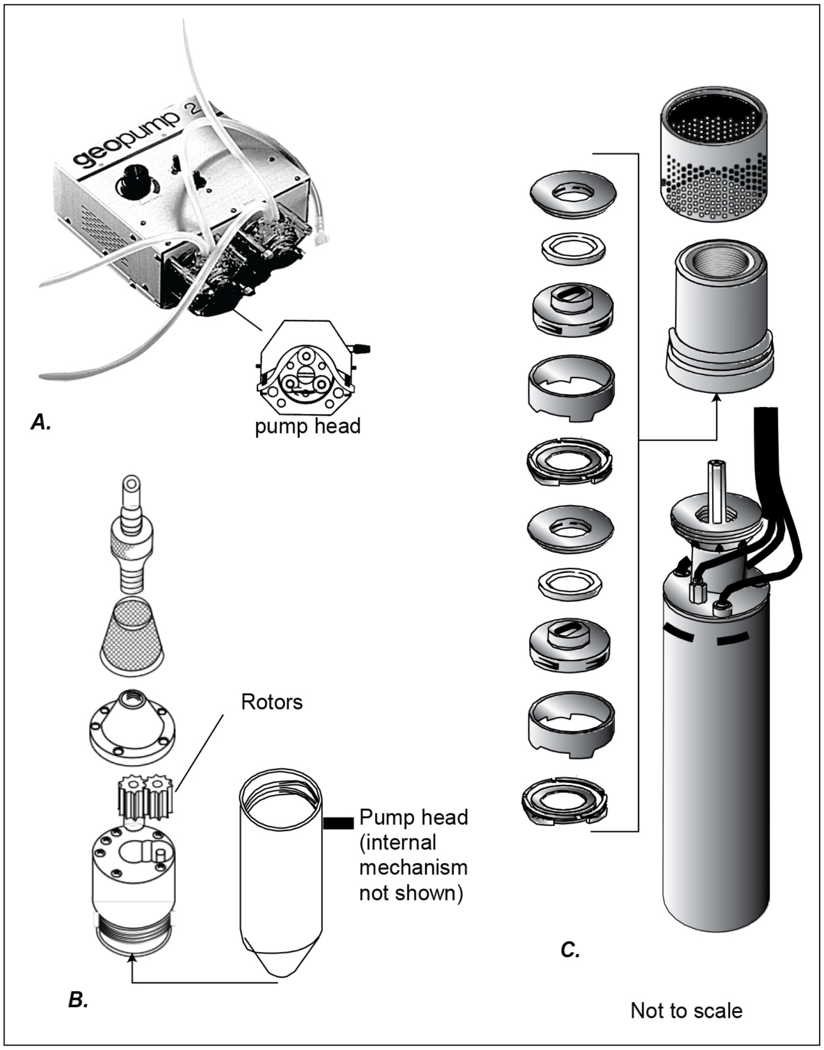


Figure 2–7a. Pumps typically used for withdrawal of water samples from monitoring wells: (*A*) peristaltic suction-lift pump and (*B*–*F*) examples of submersible positive-displacement pumps. *A*, peristaltic pump showing detail of pump head. *B*, electrical gear or rotor pump. *C*, electrical centrifugal impeller pump showing detail of impeller assembly. Illustrations published with permission: *A*, GeoTech Environmental Equipment, Inc., with pump head from Cole Parmer Instrument Company; *B*, Fultz Pumps, Inc.; *C*, Grundfos Pumps Corporation.

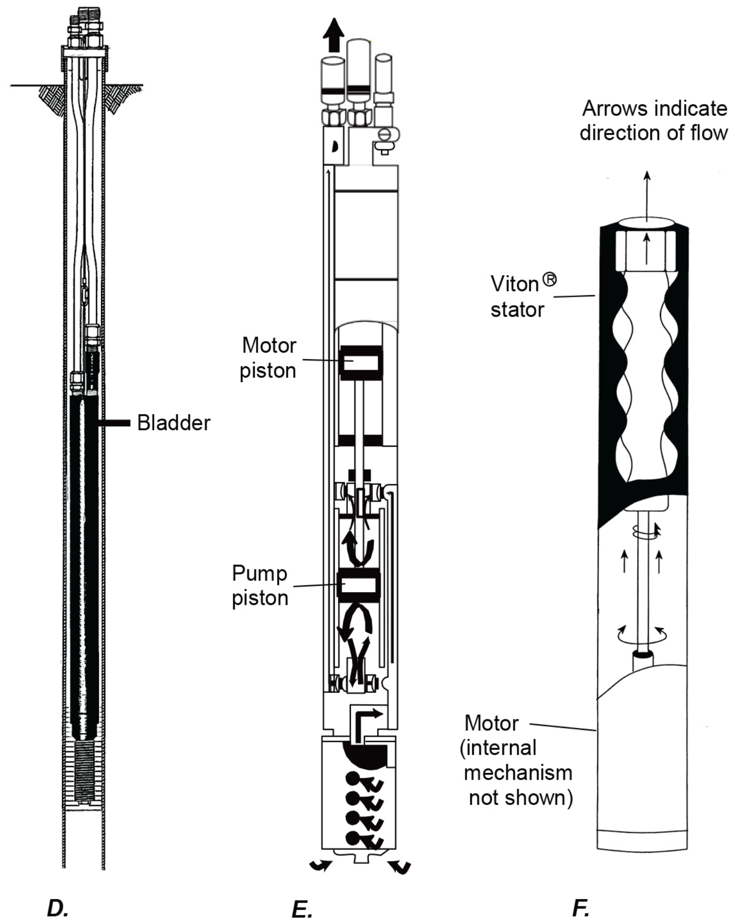


Figure 2–7b. Pumps typically used for withdrawal of water samples from monitoring wells: (*A*) peristaltic suction-lift pump and (*B–F*) examples of submersible positive-displacement pumps. (*D*) bladder pump, (*E*) reciprocating piston pump, and (*F*) progressive cavity pump. Illustrations published with permission: *D* and *F*, Geotech Environmental Equipment, Inc.; *E*, Bennett Sample Pumps, Inc.

Well-development pumps

Wells need to be developed after construction to remove sediment and other debris at the bottom of the well and to improve hydraulic connection to the aquifer. Wells might need to be redeveloped after long periods of inactivity before water-quality samples are collected. Sounding of the well (confirming the well depth) may indicate that the well should be redeveloped in preparation for collecting a representative sample.

► In general, the submersible pump that is used to purge and sample the well is not recommended for well development or redevelopment. Using the sampling pump to redevelop a well can ruin or shorten its functional life and (or) damage the smooth internal surfaces of the pump, which in turn can result in leaching of target analytes to the sample, thus causing an analytical bias (Lapham and others, 1997).

- Inertial pumps can be fitted with a surge block to provide an effective and easily operated method for well development or redevelopment (*http://www.waterra.com/pages/Applications/well_develop2011.html*; *http://www.solinst.com/Text/textprod/404text.html*).
  - Adding a surge block to an inertial pump creates a strong bidirectional churning effect that helps to remove sediment that collected at the bottom of the well.
  - Inertial pumps work well in silty/sandy environments; they can be successfully operated in wells with depths to 100 ft (~30.6 m) when using a hand pump, depths to 200 ft (~61 m) when using a pump powered by an electric motor, and depths to 250 ft (~76 m) when using a pump powered by a gasoline motor (Lapham and others, 1995; Waterra Pumps Limited, 2011; Solinst Canada Ltd., 2012.
- Another inexpensive option to consider in well development is to use inexpensive disposable plastic (clear or white) tubing with a suction-lift pump. This method, however, is limited to shallow wells with water table depths less than 25 ft (~7.6 m) from the land surface (Lapham and others, 1995).
  - To aid in removing sediments from the bottom of the well, add a surge block and one-way valve to the bottom of the tubing as described above. The tubing can be physically raised and lowered, producing a purging effect.
  - To prevent cross contamination of wells, it is recommended that new tubing and a new surge block and valve be used and quality-assured for each well that is developed or redeveloped.
- Wells can also be developed using the air/gas-lift method. This method is not recommended for shallow wells, but may be the only method available for very deep wells, especially for wells that approach 2,000 ft (~610 m) in depth (Lapham and others, 1995).
  - In this method, compressed air is forced down the well and replaces the water and debris in the casing. The displaced water and debris in the well casing is then forced up and out of the well.
  - **Air introduced into the aquifer can change the aquifer's geochemistry, either temporarily or permanently.** Ensure that air is not forced from the well screen into the surrounding aquifer system by determining the volume of water to be displaced, slowly removing and monitoring the volume being displaced, and halting the process when the required volume of water has been removed. This should be followed by pumping at least one well volume upon recovery of the water level in the well while monitoring the concentration of dissolved oxygen.

2.1.2.B Bailers, Thief Samplers, and Passive Diffusion Bag Samplers

Bailers and other thief samplers disturb the water column, especially when raised and lowered repeatedly; for this reason, use of these devices is not recommended. The disturbance can stir up or mobilize particulate matter, including colloidal or mineral precipitates that are artifacts of well construction and are not part of the ambient groundwater flow. This, in turn, can result in the analysis of substantially greater than ambient concentrations of trace elements and hydrophobic organic compound(s). Passive diffusion bag (PDB) samplers do not disturb the water column.

Bailers and thief samplers

Although bailers are not, in general, recommended for groundwater sampling because of the potential aeration of the sample, bailers can have some necessary and useful applications and may be the only sampling option, especially when sampling at great depth. Use of a bailer may be preferred, for example, for sampling sites at which contaminant concentrations are extremely large, because bailers are easier to clean or are disposable and less expensive to replace than pumps. **The following recommendations apply in situations where bailers are a reasonable choice for collecting samples at wells.**

- ► Select bailers with double check valves (fig. 2–3*C*) to ensure that a point sample has been collected and to help prevent sample aeration. The material of choice normally is fluorocarbon polymer (Teflon®) because it can be used when sampling for both inorganic and organic analytes and it can be readily cleaned.
- ► Consider using disposable fluorocarbon polymer bailers at sites where concentrations of contaminants are large. Discard disposable equipment after one use.
- ► Use a bottom-emptying device through which the rate of sample flow can be controlled. Place the bailer into a holding stand while emptying sample from the bailer through the bottom-emptying tube.
- ► Use either a fluorocarbon polymer-coated or colorless (white) polypropylene line for lowering the sample; keep the line on a reel. Polypropylene is easy to clean, inexpensive, and can be discarded after one use.

Specialized sealed downhole samplers, grouped loosely under the thief-sampler category (fig. 2–3), are designed to capture and preserve in situ groundwater conditions by precluding sample aeration and pressure changes from sample degassing (escape of VOCs) or outgassing (escape of inorganic gases). Such sampling equipment includes syringe samplers (Gillham, 1982), true thief samplers (Ficken, 1988), samplers using hermetic isolation methods (Gibs and others, 1993; Torstensson and Petsonk, 1988), and a combined well-bore flow and depth-dependent water sampler (Izbicki and others, 1999).

Passive diffusion bag samplers

Water-filled passive diffusion bag samplers (PDBs) are suitable for obtaining samples to be analyzed for selected VOCs.[16] A typical PDB sampler consists of a low-density polyethylene (LDPE) lay-flat tube closed at both ends and containing deionized water. The sampler is positioned at the target horizon of the well by attachment to a weighted line or fixed pipe. Sampler construction and application are described in Vroblesky (2001a,b).

2.1.2.C Support Equipment

The support equipment used during groundwater sampling depends on the type and size of the pump or sampler used, field conditions, and depth to water or to sampling interval in the well. A reel should be used for efficient and clean deployment of the sample line. Commonly used support equipment is listed in section 2.4. A detailed description of the various types of support equipment is beyond the scope of this manual.

[16] PDBs are not suitable when collecting samples to be analyzed for inorganic ions, methyl-*tert*-butyl, acetone, or phthalates, and PDBs have limited applicability for other non-VOCs.

2.2 Sample Processing

Water samples must be processed as quickly as possible after collection. The equipment most commonly used for sample processing includes sample splitters, disposable capsule and disk filters, filtration assemblies, solid-phase extraction systems, and chambers in which samples are processed and treated with chemical preservatives. Having several sets of cleaned processing equipment on hand is recommended. The equipment and supplies commonly used to process surface-water and groundwater samples are listed in section 2.4.

The collection of surface water generally results in a single composite sample. A groundwater sample generally is not collected as a composite; instead, the sample is pumped directly, one after the other, into separate bottles for designated analyses (NFM 4.2). There are exceptions. For example, groundwater samples withdrawn using a bailer or thief sampler can be collected as a composite, provided that sample integrity for the analytes of interest can be maintained.

2.2.1 Sample Splitters

A composite sample often is subdivided (split) into subsamples for analysis. Each whole-water subsample should contain suspended and dissolved concentrations of target analytes that are virtually equal to those in every other subsample. Use of the fluorocarbon polymer churn splitter, the polypropylene/polyethylene (poly) churn splitter, and the fluorocarbon polymer cone splitter are discussed in sections 2.2.1.A and 2.2.1.B, respectively. Testing and comparative data between the splitters are described in Capel and Larson (1996), Horowitz and others (2001), and Office of Water Quality Technical Memorandum 97.06. Advantages and limitations of these sample splitters are shown in table 2–6.

Table 2–6. Advantages and limitations of sample splitters.

[L, liter; mg/L, milligram per liter; µm, micrometer; mL, milliliter; >, greater than; ≤, less than or equal to]

Splitter	Advantages	Limitations
Fluorocarbon polymer (fluoropolymer) churn splitter	• Can be used to process samples for inorganic and nonvolatile organic analyses. • Simple to operate. • Easy to clean. • No modification of the splitter design is necessary.	• Although it can be used to split samples with mean particle sizes ≤ 250 µm[1] and suspended-sediment concentrations ≤ 1,000 mg/L, splitting accuracy becomes less efficient for mean particle sizes >250 µm and suspended-sediment concentrations >1,000 mg/L. • Sample volumes less than 4 L or greater than 13 L cannot be split for whole-water subsamples from this 14-L churn. • Samples for bacteria determinations are not to be taken from a churn splitter because the splitter cannot be autoclaved.
Polypropylene/polyethylene (poly) churn splitter	• Used only to process samples for inorganic analyses. • Simple to operate. • Easy to clean.	• Poly churn splitters must not be used to composite samples for determination of organic compounds. • Although it can be used to split samples with mean particle sizes ≤ 250 µm and suspended-sediment concentrations ≤ 1,000 mg/L, splitting accuracy becomes less efficient for mean particle sizes >250 µm and suspended-sediment concentrations >1,000 mg/L. • When using the 14-L churn, sample volumes that total less than 4 L or greater than 13 L cannot be split for whole-water subsamples. • Requires a modified spigot and construction of a funnel assembly. • Samples for bacteria determinations are not to be taken from a churn splitter because the splitter cannot be autoclaved.
Fluorocarbon polymer (fluoropolymer) cone splitter	• Used to process samples with suspended-sediment concentrations from 0 to 10,000 mg/L. • Samples containing sediment particles ranging in size from very fine clay and silt (1 to 10 µm) to mean sand-size particles (250 µm) can be split. • Samples as small as 250 mL can be split into 10 equal subsamples. • Samples greater than 13 L can be processed. • Can be used to process samples for both inorganic and nonvolatile organic analyses.	• Accuracy of the volume equivalents must be verified before using a new or modified cone splitter. • Splitter is awkward to operate and clean in the field. • Sample is vulnerable to contamination from atmospheric sources or from improper operation. • Splitting accuracy for mean sediment particles >250 µm or sediment concentrations >10,000 mg/L must be quantified by the user. • Samples for bacteria determinations are not to be processed through the cone splitter because the splitter cannot be adequately sterilized. • The cone splitter must be level for proper operation.

[1]Refer to Office of Water Quality Technical Memorandum 97.06 (*http://water.usgs.gov/admin/memo/QW/qw97.06.html*).

2.2.1.A Churn Splitter

Churn splitters are available in either fluorocarbon polymer (fluoropolymer or Teflon®) (fig. 2–8A) or polypropylene/polyethylene (poly) (fig. 2–8B) plastic. Both churn types are available in 14-L and 8-L sizes. A 4-L churn is available but it has not been evaluated for splitting efficiency and is not recommend for use. Splitter advantages and limitations are described in table 2–6. The 8- or 14-L poly churn splitter is recommended to composite and split surface-water samples for inorganic analyses. The 8- or 14-L fluoropolymer churn splitter is recommended to composite and split samples for either inorganic or nonvolatile organic analyses.

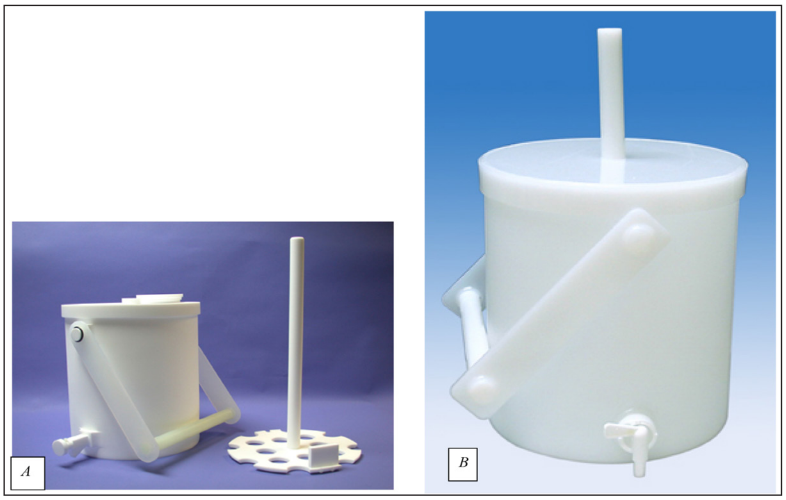


Figure 2–8. Churn-type sample splitters: (*A*) Fluorocarbon polymer (Teflon) churn splitter and (*B*) Polyethylene churn splitter. Photographs courtesy of the U.S. Geological Survey Hydrologic Instrumentation Facility.

- **Trace-element samples.** Use either the poly or fluoropolymer churn splitter. **Do not split samples for trace-element analyses from a metal compositing container.**
- **Organic compound samples.** Use only the fluoropolymer churn to collect or extract samples for analysis of organic compounds. Stainless-steel and glass containers and the plastic churn also can be used to composite samples for analysis of dissolved organic compounds. **Do not collect or extract samples for trace-element analyses from a metal container.**
- **Churn covering.** Place the churn splitter inside two pliable, clear plastic bags (double bagged) to **keep the entire churn-splitter assembly clean during sampling and to prevent potential contamination**. These bags should be large enough to completely enclose the churn splitter, including funnel and churn handle, with enough excess material so that the bag openings can be gathered, folded over, and kept closed.
- **Churn carrier.** The carrier is a white plastic container, with lid, large enough to hold the double-bagged churn splitter assembly.
  - — The lid of the carrier serves both as a seal for the carrier and as a windbreak when the collected subsample is poured into the churn funnel.
  - — The purpose of the carrier is to minimize contamination during transport. In exposed areas, such as bridges and roadways, the carrier can protect against atmospheric sources of contamination, particularly fumes and particulate material from motor vehicles.

- **Sample-volume requirements.** For a valid whole-water sample analysis, a limited volume of water should be withdrawn from the churn. The water level inside the churn should be no more than 2 in. (5.08 cm) from the top of the churn and no less than 2 in. (5.08 cm) above the spigot (Quality of Water Branch Technical Memorandum 78.03). The remaining volume of sample/sediment mixture in either churn (about 4 L in the 14-L churn and 3 L in the 8-L churn) can be used for filtered samples.

Modifications to the spigot and lid of the poly churn splitter are described below.

- **Spigot.** The original spigot on the poly churn splitter contains a metal spring that introduces a potential source of metal contamination and must be replaced if the churn is used to process samples for trace-element analysis (Horowitz and others, 1994). The churn splitter spigot can be replaced or refurbished with noncontaminating components by the manufacturer (USGS personnel can refer to the Office of Water Quality internal communication "Water-Quality Information Note 2005.07" at *http://water.usg.gov/usgs/owq/WaQI/index.html*.
- **Funnel assembly for plastic churn lid.** To meet requirements for trace-element sampling, a funnel assembly is inserted into a 1-in.- (2.54 cm) diameter hole drilled through the lid of the churn splitter (fig. 2–8).
  - — The funnel is used when pouring whole-water samples into the churn splitter so that the churn lid can be left on, thus minimizing exposure of the composite sample to atmospheric contamination.
  - — To make the funnel assembly, cut the top section (at the shoulder line) from a 1-L polypropylene sample bottle and insert it into the hole drilled in the churn lid. Cut the bottom two-thirds from a 1-L Nalgene® or other larger diameter sampler bottle and use this as a funnel cap.

2.2.1.B Cone Splitter

The cone splitter is a pour-through device constructed entirely of fluorocarbon polymer with 10 ports that can accommodate 10 fluorocarbon sample-discharge tubes (fig. 2–9). The cone splitter can be used to process samples for analysis of inorganic as well as nonvolatile organic analytes. The primary function of the cone splitter is to divide the sample simultaneously into as many as 10 equal-volume samples. **The cone splitter may be used to process samples with mean particle sizes of ≤250 micrometers (µm) and suspended-sediment concentrations of ≤10,000 milligrams per liter (mg/L)** (table 2–6).

Some cone splitters have a 2-mm mesh screen in the reservoir funnel to retain large debris, such as leaves and twigs, which could clog or interfere with the splitting process. Below the funnel is a short standpipe that directs sample water in a steady stream into a splitting chamber that contains a notched, cone-shaped splitting head with 10 equally spaced exit ports around its base. **There should be no ridges, benches, or surfaces inside the splitting chamber that could retain material or interfere with the splitting process.** The cone splitter is supported either by tripod legs or with an adjustable clamp and stand.

The cone splitter is built to very close tolerances in order to achieve accurate and reliable operation. **Bias to data can result from splitter imperfections or improper operation; therefore, calibration and proper use is necessary when processing samples.**

- **Cone-splitter covering.** Once leveled, place one pliable, clear plastic bag over the entire splitter, including tubes, to keep the entire cone-splitter assembly clean during sample splitting and to prevent potential contamination. The bag should be large enough to enclose the top of the splitter and the top of the receiving containers at the end of each tube.

► **Sample-volume requirements.** Because the cone splitter is a pour-through device, the volume that can be split is unlimited. The minimum volume that can be split is 250 mL. Larger volumes are split more effectively (Capel and Larson, 1995 and 1996).

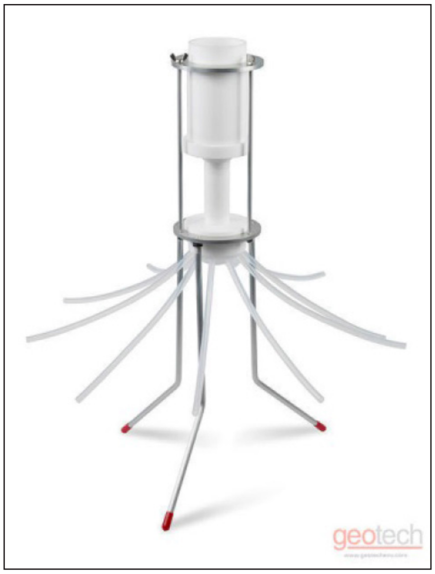


Figure 2–9. Dekaport® fluorocarbon cone splitter with 10 fluorocarbon discharge tubes. Illustration courtesy of Geotech Environmental Equipment, Inc.

Before using a new or modified cone splitter, test the splitter to be used as follows *(from Quality of Water Branch Technical Memorandum 80.17):*

1. Inspect the cone splitter housing and outlet ports. They should be smooth and symmetrical without any visible burrs or chips. **The cone splitter must be clean.**
2. Connect the 10 fluorocarbon discharge tubes to the outlet ports. The tubes must be the same length and as short as possible. Label the outlets from 1 to 10.
   - All tubes must be solidly seated in the cone-splitter base. The ends should be flush with the bottom of the inside of the port.
   - Tubes need only extend into the receiving containers sufficiently to prevent spillage.
   - Tubes must not extend in so far that the ends become submerged during the split.
3. Place the cone splitter on a stable platform or bench. **The splitter must be level for proper operation.** Use a bull's-eye level to check leveling and recheck during use; the level may change as personnel move inside the field vehicle.
4. Wet the cone splitter by pouring several liters of deionized water through it.
   - Lightly tap the system to dislodge adhering water drops, and discard the water.
   - Place an empty sample bottle under each outlet tube.

5. Accurately measure 3 L of deionized water into a 1-gal. narrow-mouth plastic bottle. Check that the splitter is level and adjust if necessary.
6. Rapidly invert the 1-gal. bottle over the reservoir, letting deionized water flow out as fast as possible. For proper operation, the standpipe must be discharging at its full flowing capacity.
7. After all deionized water has passed through the splitter, tap the assembly several times to dislodge adhering water drops. Check for spills and leaks. If any are observed, stop the test, correct the problem, and repeat steps 1–7.
8. Measure the volumes of the 10 subsamples carefully, within an accuracy of ±1.0 mL. Record the volumes for each outlet on a form similar to table 2–7.
9. Repeat the test a minimum of three times. Use the same initial volume for each test.

Calculate and document the results of the cone-splitter accuracy test as follows:

1. Referring to the example in table 2–7, calculate the mean volume of each subsample ($\overline{x}$) and standard deviation (S_x):

$$\overline{x} = \frac{\sum x_i}{n} \qquad (1)$$

and

$$S_s = \sqrt{\frac{\sum (x_i - \overline{x})^{-2}}{n-1}}\ , \qquad (2)$$

where

x_i is the measured volume for each subsample, and
n is the number of subsamples (outlet ports).

2. Calculate the standard deviation in percent (E_x):

$$E_x = \frac{S_x}{\overline{x}} \text{ x } 100. \qquad (3)$$

3. Calculate the error for each subsample (E_i):

$$E_i = \frac{x_i - \overline{x}}{\overline{x}} \text{ x } 100. \qquad (4)$$

4. Compute the mean standard error ($\overline{E_{\bar{x}}}$) for the three tests and document the maximum and minimum errors (E_i) for all tests in field notes.
5. If data-quality requirements warrant, note the error patterns for individual outlets to determine which outlets produce consistent bias and label them with their mean percent bias error. Depending on the objectives of the sampling effort and professional judgment of the project water-quality specialist, this pattern of error may not be of concern.

TECHNICAL NOTE 2. A cone splitter is considered acceptable for sample processing if the mean standard error ($\overline{E_{\bar{x}}}$) for the three tests is 3 percent or less, and no individual error (E_i) exceeds ±5 percent.

Table 2–7. Example of six cone-splitter accuracy tests using deionized water.

[Modified from Quality of Water Branch Technical Memorandum 80.17; na, not available]

Test number initial sample weight (grams)	1 2,499.4		2 2,499.5		3 2,499.5		4 2,499.5		5 2,499.5		6 2,499.4		Averages	
Outlet number	Outlet volume (x_i)	Percent (E_i)	Outlet volume (x_i)	Percent (E_i)	Outlet volume (x_i)	Percent (E_i)	Outlet volume (x_i)	Percent (E_i)	Outlet volume (x_i)	Percent (E_i)	Outlet volume (x_i)	Percent (E_i)	Outlet volume (x_i)	Percent (E_i)
1	248.4	-0.5	249.5	-0.1	247.4	-0.9	248.1	-0.7	247.8	-0.8	249.2	-0.2	248.4	-0.5
2	246.8	-1.2	246.8	-1.2	245.6	-1.6	248.4	-0.6	246.3	-1.4	246.7	-1.2	246.8	-1.2
3	249.4	-0.1	251.0	0.5	250.6	0.4	251.1	0.5	249.8	0	248.7	-0.4	250.1	0.1
4	250.7	0.4	252.6	1.1	252.5	1.1	251.3	0.6	251.8	0.8	250.5	0.3	251.6	0.7
5	248.1	-0.6	248.3	-0.6	249.8	0	249.3	-0.2	250.2	0.2	248.1	-0.6	249.0	-0.3
6	252.2	1.0	250.3	0.3	252.7	1.2	252.0	0.9	252.7	1.2	250.6	0.4	251.8	0.8
7	245.7	-1.6	246.2	-1.4	246.0	-1.5	246.3	-1.4	246.6	-1.3	245.9	-1.5	246.1	-1.5
8	252.7	1.2	254.2	1.8	252.9	1.3	253.3	1.4	253.1	1.3	254.6	2.0	253.5	1.5
9	248.7	-0.4	247.3	-1.0	247.5	-0.9	247.1	-1.1	248.3	-0.6	249.5	-0.1	248.0	-0.7
10	253.9	1.7	252.1	0.9	251.8	0.8	250.6	0.3	251.7	0.8	253.0	1.3	252.0	1.0
Final sample weight	2,496.6		2,498.3		2,496.8		2,497.5		2,498.2		2,496.8		2,497.4	
Sample loss	2.8		1.2		2.7		2.0		1.3		2.6		na	
Mean weight ($\overline{x}$)	249.7		249.8		249.7		249.8		249.8		249.7		249.8	
Standard deviation (S_x)	2.7		2.7		2.8		2.3		2.5		2.7		na	
Error percent (E_x)	1.1		1.1		1.1		0.9		1.0		1.1		na	

2.2.2 Sample-Processing Chambers

Working within a sample-processing chamber reduces the possibility of random atmospheric contamination during sample bottling, filtering, and chemical preservation. **Use of sample-processing chambers is a routine requirement when filtered samples will be analyzed for trace elements** (Horowitz and others, 1994); is recommended strongly when sampling for trace organic compounds; and also when sampling for most other analytes, such as major and minor inorganic ions and total or dissolved organic compounds. Field personnel should consult NFM 4 and NFM 5 in addition to their project quality-assurance plan and project data-quality objectives for project-specific guidance related to the use of sample-processing chambers and the collection of blank samples inside and outside of the chambers.

Use of separate chambers for sample collection, sample processing, and sample preservation generally is the most efficient approach. Space permitting, multiple preservation chambers can be dedicated to a specific chemical treatment. Alternatively, use of a single preservation chamber requires replacement of the bag covering with each change in chemical treatment. If insufficient space is available in which to set up a processing and preservation chamber, the processing-chamber frame also can function as a preservation-chamber frame by changing the clear plastic bag (chamber cover) after sample collection is completed and before preserving samples with a chemical treatment. The PVC chamber frames should be kept clean of dirt and exposure to chemical substances. Chamber covers must be replaced with each change in the sample collection and (or) type of filtration and chemical treatment.

- ► The **sample-collection chamber** is where sample water is pumped, either directly into sample bottles or through the filter unit, and then into sample bottles.
  - — The processing chamber either sits over a fixed or portable sink or contains a basin to which a waste-disposal funnel or hose has been attached, allowing excess water to drain readily to waste.
  - — The tubing through which sample is delivered to the chamber may be supported by the frame (or clipped to the outside) and inserted through a hole in the top of the chamber, allowing it to be connected to a filtration device inside the chamber.
- ► The **sample-preservation chamber** is the same as or similar to the sample-collection chamber but without an inlet for sample tubing or an outlet for drainage. The bottled sample is passed from the processing chamber to the preservation chamber, in which a chemical treatment is added to the sample in accordance with the specific sequence and instructions given in NFM 5.
  - — Also placed in the preservation chamber are preservative-containing vials required for the type of sample and a suitable waste container for storage of spent preservative ampoules (see NFM 5).
  - — Chemical reagents used to preserve samples are not to be used beyond their expiration date; they should be discarded in a manner that conforms with local and Federal regulations and good environmental stewardship.

Processing chambers can be portable and easily transferable between field sites and field vehicles or can be installed as permanent fixtures; for example, in a water-quality field vehicle or laboratory. These chambers are designed for use during sample collection and sample processing or preservation to prevent potential airborne contaminant sources from having contact with the sample (fig. 2–10 *A* and *B*). Glove boxes (fig. 2–10*C*) are a type of chamber designed to isolate the sample from contact with atmospheric oxygen when adding chemical preservatives or while performing a titration on the sample by filling the chamber with a clean inert gas, such as nitrogen or argon. Glove boxes typically are used for research projects and not for routine sampling. The most common type of sample-processing chamber used for routine USGS water-quality field work is portable and self-constructed (see fig. 2–10 *A* and *B* and refer to the appendix. While there is no standard design for constructing the chamber, the materials used for the frame and cover should be dedicated to analyte-specific processing so as to prevent sample contamination, as follows:

- Use tubing that is either nonmetallic or completely covered by or embedded in nonmetallic material (for example, PVC) to prevent contamination of samples to be analyzed for concentrations of trace elements.
  - This chamber is inexpensive and the frame is easily constructed with ≤1/2-in.-diameter white polyvinyl chloride (PVC) pipe or tubes (see fig. 2–10*A* and the appendix).
  - The frame supports a clear plastic covering (large, clear plastic bags are available from One Stop Shopping) (fig. 2–10*B*). The transparent bag forms a protective tent within which to work while collecting, processing, or preserving samples. The plastic covering (chamber bag) should be secured to the frame using white or clear plastic clips or clamps.
- The PVC tubing and clear plastic bag covers have been bench tested, and it was determined that a chamber constructed with these materials is appropriate for use for samples to be analyzed for trace organic compounds. The analysis of blank samples resulted in no detection of volatile organic substances.[17]

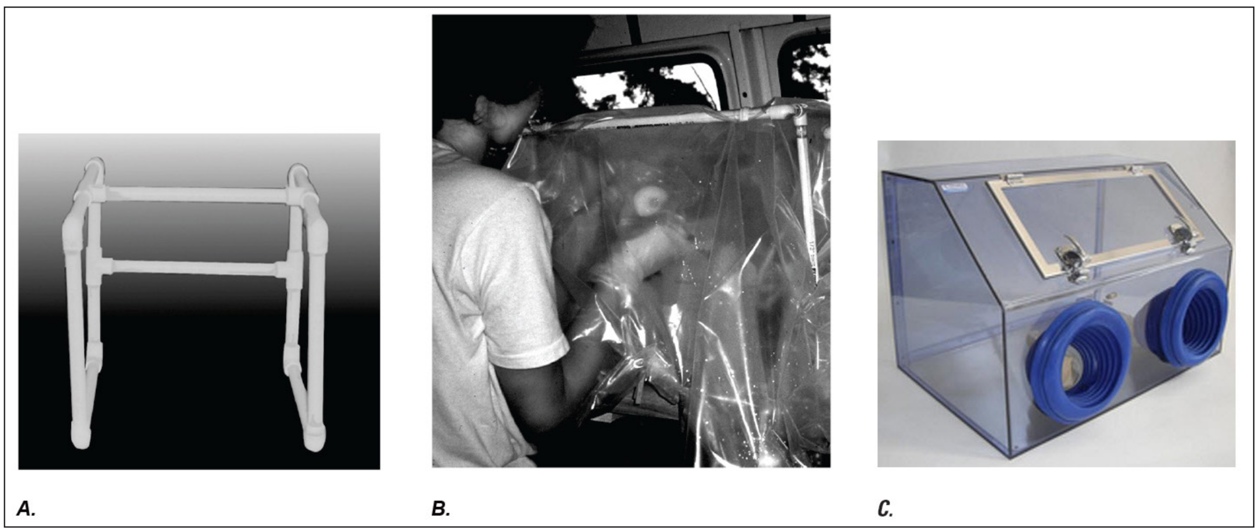


Figure 2–10. Photographs showing (*A*) a polyvinyl chloride frame of a processing or preservation chamber, (*B*) a covered chamber frame with a sample being processed inside the chamber, and (*C*) a simple glove box by Cleatech®, LLC. *A*, Photograph by B.A. Bernard, U.S. Geological Survey. *B*, photograph by Jacob Gibs, U.S. Geological Survey. *C*, Cleatech® 2200 Series PVC Mini-Glovebox ; photograph courtesy of Cleatech, LLC (*http://www.laboratory-supply.net/contact_us.php*, accessed December 30, 2013).

[17] Internal communication from the USGS National Water Quality Laboratory to the USGS Office of Water Quality, 2006. Depending on data-quality objectives, projects may further substantiate data quality by preparing an ambient blank for volatile organic compound (VOC) analysis that is collected and (or) preserved in the chamber(s).

2.2.3 Filtration Systems

Filtration systems separate particulate substances (solid phase and biological materials) from the solute or aqueous phase of a water sample. Water samples are filtered for analysis of inorganic constituents, organic compounds, and biological materials to help determine the environmental fate and quantify the transport of these target analytes. Additional information relevant to the selection of filtration systems can be found in NFM 5. Depending on sample type and analysis to be performed:

- For surface-water applications, the most common filtration systems consist of a variable-speed peristaltic pump or a metering pump that forces the whole-water sample through tubing into either (1) a plate-filtration assembly or (2) a disposable capsule or disk filter.
- For groundwater applications, the sample ordinarily is pumped directly from the well into a disposable capsule (or disc) filter or other filtration assembly. If the sample is collected by bailer, some bailers can be directly connected to a filtration device and hand-pump system, or the sample is decanted to a churn or other vessel and transferred to the filtration device by means of a peristaltic pump.
- For small-volume samples to be analyzed for pesticide and selected other organic analytes (for example, samples to be analyzed by direct-aqueous injection liquid chromatography tandem mass spectrometry (DAI LC-MS/MS), a syringe is used to push the sample through a small disposable filter in situations where an in-line pump (for example, when sampling groundwater) or another means is not available to push the sample through the designated filter.

TECHNICAL NOTE 3. Separation of solid from aqueous phases can be achieved by methods other than filtration, and data requirements may dictate the need for an alternative method such as centrifugation, ultracentrifugation, dialysis or lipid-membrane separation, or reverse-flow osmosis and tangential-flow filtration.

The filter membrane material to be used depends on the class of target analyte(s) (table 2–8):

- **Inorganic Samples.** The filter membrane through which water samples are passed for analysis of inorganic constituents typically is composed of polyethersulfone, cellulose nitrate, or a polycarbonate polymer. The disposable capsule filter that is in routine use by the USGS water-quality program is an acrylic copolymer material (Versapor®). The direction of the water flow through the filter is critical in order to prevent the filter from separating from the support medium and thereby allowing particulates to bypass the filter and enter the sample container.
- **Trace-Organic Samples.** Samples to be analyzed for trace organic compounds are filtered through a glass fiber (microfiber) (GF/F) membrane. The filter membrane material described above for inorganic samples should not be used for organic samples unless instructions specifically state that the material is acceptable (for example, see the information for dissolved organic carbon (DOC) samples described below).
- **Dissolved Organic Carbon Samples.** Samples for DOC analysis may be filtered either through GF/F disks using the Savillex DOC-25 mm unit (described below), GF/F disks using an inline 47-mm fluorocarbon assembly, or the disposable capsule (polyethersulfone) filter. The choice of filtration unit depends on the analytical, technical, and data-quality objectives of the project.

- **Total Particulate Carbon (TPC) and Total Particulate Nitrogen (TPN) Samples.** Samples to be analyzed for TPC and (or) TPN must be filtered through a GF/F disk using the 25-mm fluorocarbon pressure filtration assembly by Savillex (the U.S. Geological Survey DOC-25 filter-holder assembly).[18]

The filter-membrane pore size is determined by the type of samples to be analyzed. A filtered sample is defined operationally by the nominal pore size of the filter membrane. The filter pore size selected depends on study objectives, data requirements, and industry standards. The standard pore sizes of filters used by the USGS are:

- 0.45 µm for inorganic constituents (including major ions, radiochemicals, and trace elements), some bacteria (NFM 7), and possibly DOC, depending on project requirements.
- 0.7 µm for pesticides, DOC, and most other organic compounds (0.7 µm is the smallest nominal pore size available for GF/F) membranes.
- 0.65 µm for some bacteria (see NFM 7.1).

TECHNICAL NOTE 4. A filter pore size of 0.2 µm or less is used for trace-element samples that will be analyzed for some geochemical applications and interpretive studies, as well as for nutrient samples for which the exclusion of bacteria at the 0.2-µm threshold is desirable.

- **Construction materials and membrane material in filtering systems must not be a source of sample contamination with respect to the substances for which the sample will be analyzed.**
- **Only use equipment that is specified for the analyte schedule or for the analytical method of interest.**

2.2.3.A Inorganic Constituents

The standard device for filtering samples for analysis of inorganic constituents is the disposable capsule filter, which has replaced routine use of the plate-filter assembly for most applications (table 2–8). **Construction materials in filtering systems must not be a source of sample contamination with respect to the substances for which the sample will be analyzed.**

Disposable capsule and disk filters

The routine procedure for filtering a sample for analysis of inorganic constituents requires using a disposable capsule filter,[19] such as the Pall GWV® high-capacity 700 cm^2 sampling capsule with acrylic copolymer (Versapor®) filter membrane material (fig. 2–11)[20] or the Pall AquaPrep 19.6 disk filter with polyester-reinforced polysulfone (Thermopor®) filter membrane material.

[18] This 25-mm pressure filter-holder assembly is produced for the USGS by Savillex Corporation (*http://www.savillex.com/ProductDetail.aspx?ProductName=Filter-holder-assembly-US-Environmental-Protection-Agency*).

[19] This disposable capsule filter also can be used for processing samples for analysis of dissolved organic carbon, conditional according to project-dependent criteria (refer to section 2.2.3.B and NFM 5.2.2.C).

[20] The Pall Corporation groundwater capsule filter (AquaPrep 600) with a polyethersulfone membrane and a 600-cm2 filtration area (accessed November 19, 2013, at *http://www.pall.com/main/laboratory/product.page?id=20009*) was used originally in the USGS operational water-quality program.

- ► The high-capacity capsule is recommended when filtering sediment-laden waters (usually surface water) or at sites at which a large volume of sample will be collected.
- ► The 19.6 disk filter is used at surface-water and groundwater sites at which water is typically clear of sediment or other particulate matter and for which the required volume of sample is small.

These filtration devices are quality assured for the USGS use by the NWQL and are supplied by One Stop Shopping; however, quality-assurance tests have confirmed that, within a day of use, the capsule filter must be rinsed with a minimum of 2 L of IBW or quality-controlled DIW, and the AquaPrep disk filter must be rinsed with a minimum of 50 mL of IBW or quality-controlled DIW (NFM 3, amended version 2.0 or update; NFM 5.2.1, version 3.0, table 5–5).[21] USGS project personnel can access NWQL quality-assurance results (certificates of analysis) for each lot of capsule and disk filters (*http://wwwnwql.cr.usgs.gov/qas.shtml?filters_home*).

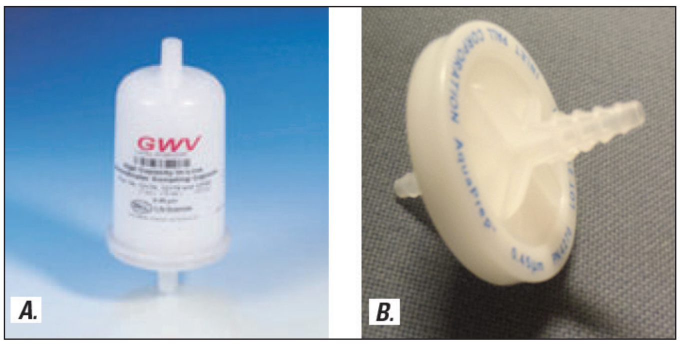


Figure 2–11. Disposable filtration devices: (*A*) GWV® high-capacity capsule filter, 0.45-µm pore size, 700-cm² pleated Versapor® filter membrane; and (*B*) Small-capacity AquaPrep® disk filter, 0.45 µm, 19.6 cm² Versapor/Thermopor® filter membrane. *A*, image courtesy of Pall Corporation; *B*, photograph by S.C. Skrobialowski, U.S. Geological Survey.

Do not reuse the disposable filtration devices. Discard after one use, in an environmentally appropriate manner.

Table 2–8. Analyte requirements and recommendations for filtering surface-water and groundwater samples using the disposable capsule and disk filters.

[The table, modified from Horowitz and others (1994), includes only those constituents evaluated in the experiments described in the reference and in Office of Water Quality Technical Memorandum 2000.08, *http://water.usgs.gov/admin/memo/QW/qw00.08.html*]

Analytes for which the disposable capsule or disk filter is required[1]			Analytes for which the disposable capsule or disk filter is recommended[2]
Aluminum	Cobalt	Molybdenum	Anions (chloride, sulfate)
Antimony	Copper	Nickel	Calcium
Barium	Iron	Silver	Dissolved organic carbon
Beryllium	Lead	Thallium	Magnesium
Boron	Lithium	Uranium	Nutrients (nitrogen, phosphorus)
Cadmium	Manganese	Zinc	Radiochemicals (excluding radon gas)
Chromium			Silica
			Sodium
			Strontium

[1]Requirements for surface-water and groundwater sample filtration are described in NFM 5.

[2]The plate-filter method, while rarely in use, is acceptable contingent on the correct application of equipment-cleaning protocols (NFM 3) and the project's data-quality objectives.

[21] USGS personnel can refer to internal communication, Water-Quality Information Notes 2009.10 and 2009.11. In addition, users of this *National Field Manual* are advised to check the NFM "Comments and Errata" Web page for recent and proposed protocol changes (*http://water.usgs.gov/owq/FieldManual/mastererrata.html*).

Plate-filter assemblies

Before 1994, the most common filtration assembly used for USGS studies for filtering inorganic samples was the nonmetallic backflushing plate-filter assembly designed to hold a 142-mm filter (fig. 2–12). Because this method allows greater exposure of the sample to the air, and because the equipment is time-consuming to field clean and quality assure, **this equipment no longer is recommended for routine filtering of inorganic samples (table 2–8)**. Information and instructions are provided below, however, because the plate-filter method might be necessary or useful for certain research-oriented studies, especially those that require filtration through a membrane with 0.2 µm or smaller pores and (or) a prerinse with nitric or other acid.

► Types of plate-filter assemblies available for inorganic samples include:

— Fluorocarbon polymer filtration assembly designed for 47-mm-diameter filters; can be used for inline filtering of inorganic or organic samples by using an appropriate filter membrane. The device is illustrated in the organic compounds section 2.2.3.B.

— Plastic pressure or vacuum filtration assembly for a 47-mm-diameter filter; used with either a hand vacuum pump or a peristaltic pump.

— Plastic backflushing assembly, available for 142-mm- and 293-mm-diameter filters (no longer in common use for USGS studies) (fig. 2–12).

► A smooth-tipped plastic forceps is needed to transfer the filter to the plate of the filter assembly. Kennedy and others (1976) give detailed instructions for use of the plate-filter assembly.

Figure 2–12. Nonmetallic backflushing plate-filter assembly for a 142-millimeter-diameter filter membrane. Illustration reproduced with permission of Pall Corporation.

2.2.3.B Organic Compounds

Filtering whole-water samples isolates suspended solid-phase substances from the aqueous phase, thus allowing for separate determinations of organic compounds in the solid and aqueous phases. Filtering also helps to preserve samples for organic determinations by removing microorganisms that could degrade compounds in the sample (Ogawa and others, 1981).

- ► Hydrophobic compounds are analytes that preferentially partition to particulate matter. Filtering concentrates particulate matter on the disk (filter), enhancing extraction efficiency and lowering analytical detection limits. This is especially useful for whole-water samples with small concentrations of suspended material and for which large volumes of sample (4 to 40 L) must be filtered to provide an analyzable mass of suspended materials.
- ► Hydrophilic compounds are analytes that are water soluble. Filtering is used to remove suspended material or other particulate matter from the water sample, to identify concentrations of dissolved analytes, and to remove any solid-phase substances containing constituents that could interfere with the analysis and that could be co-extracted with target analytes.

Use only equipment that is specified for the analyte schedule or analytical method of interest. Equipment needed to filter samples for determination of trace organic compounds, such as pesticides, is described in detail in Sandstrom (1995).[22] Equipment and components used for filtering whole-water samples for trace organic determinations should be made of materials (a) that will not contaminate the sample or sorb analytes, and (b) that can withstand organic cleaning solvents without being damaged. Such materials include stainless steel or aluminum, fluorocarbon polymer, glass, and nonporous ceramics (hard-fused microcrystalline alumina).

- ► **Avoid using plastics, rubber, oils, and other lubricants because their use can result in sample contamination, analytical interference, and (or) sorptive losses.**
- ► In contrast, some new analytical techniques, such as tandem mass spectrometry, are very selective and are not affected by interferences from leaching of plastics; consequently, specified high-purity plastic components can be used for the collection of samples for methods that use this analytical technique (for example, LC-MS/MS).

Valveless piston metering pump, tubing, and PTFE diaphragm pump head

The valveless piston metering pump consists of a pump head with a reciprocating piston driven by a 12-volt direct current (DC), variable-speed motor (fig. 2–13). It has a delivery rate of up to 500 mL per minute.

- ► The pump head and all wetted parts are constructed of ceramic, fluorocarbon polymer, or stainless steel components, which are resistant to organic solvents and thus appropriate for use when collecting samples for pesticides and many other organic compounds.
- ► These pumps can tolerate some suspended materials in the sample being pumped, but large concentrations of suspended materials can cause excessive wear of pump parts and strain on the pump's motor.
- ► The ceramic piston and shaft of these pumps will break if motor amperage exceeds 4 amps. To avoid this, either a 4-amp DC circuit breaker connected in-line with the pump power line, or an alternating to direct current converter with a 4-amp maximum output should be used.

[22] Contact the USGS National Water Quality Laboratory for additional information about this method (*http://nwql.usgs.gov/mrdp.shtml?MRDP*).

The pump and filtration assembly are connected by 1/4-in.-diameter convoluted fluorinated ethylene polypropylene (FEP) tubing (fig. 2–14) with appropriate fittings. The convoluted tubing does not crimp when bent and is available only in fixed lengths with smooth ends.

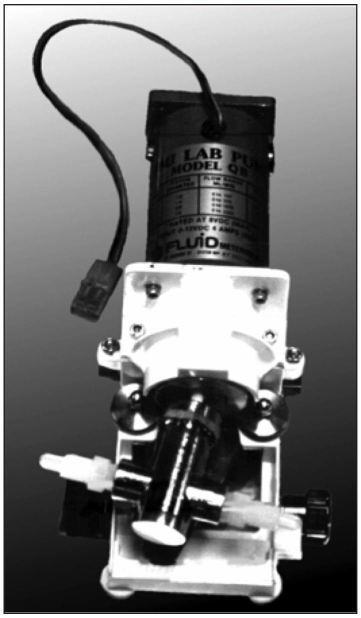


Figure 2–13. Valveless piston metering pump. Photograph by B.A. Bernard, U.S. Geological Survey.

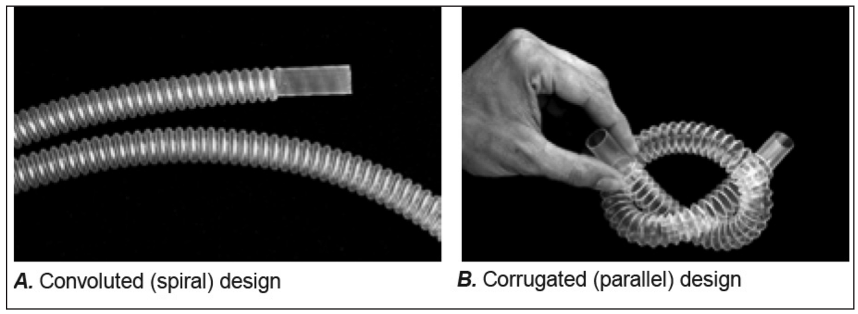


Figure 2–14. Flexible fluorinated ethylene polypropylene (FEP) tubing showing the (*A*) convoluted design and (*B*) corrugated design. Published with permission of Cole-Parmer Instrument Company: *A*, Copyright 1992. *B*, Copyright 1987. Cole-Parmer does not warrant these illustrations to be current, accurate, or suitable for any purpose.

When an alternative to the metering pump is necessary, a peristaltic pump fitted with a polytetrafluoroethylene (PTFE)-diaphragm pump head can be used (fig. 2–15). This system has a diaphragm through which repeated compression and decompression motions transfer the sample (similar to the action of piston pumps); sample water is sealed off from the outside, entering through an inlet check valve during decompression and exiting through an outlet check valve during compression.

- ► All the wetted components are constructed of PTFE and glass.
- ► The diaphragm (membrane) pump commonly is driven hydraulically and has a delivery rate of up to 800 mL/min.

Figure 2–15. Polytetrafluoroethylene diaphragm pump head. Photograph by D.A. Evans, U.S. Geological Survey, 2013. Photograph copyright© Cole-Parmer, published with permission.

Filtration equipment: samples of organic compounds for routine and DAI LC-MS/MS analyses and samples of organic carbon

Various types of devices are used routinely for filtration of samples to be analyzed for organic compounds. Selection of the filtration device depends on the analysis to be requested or the field method selected. Samples for organic-compound analyses are filtered through 0.7-um pore size media (see section below titled "Filter-membrane material").

Plate-filter assemblies are available for filters with disk diameters ranging from 13 to 293 mm. The 47-mm PFA filter holder delivers sample in-line from the source to the sample container. The assembly diameter selected is determined by the sample volume to be filtered, by the concentration of suspended materials in the sample, and by the method for delivering sample to the filtration unit. For example, the 25-mm Savillex pressure-filtration assembly (described more fully in the section below on DOC filtration) was developed specifically for water samples to be analyzed for dissolved and particulate organic carbon.

Samples to be filtered for analysis of organic compounds by direct-aqueous injection liquid chromatography tandem mass spectrometry (DAI LC-MS/MS) are processed using a syringe-filtration method (table 2–9).

► **Trace organic compounds.** Filter-holder assemblies commonly used for filtering wastewater, pharmaceutical, hormone, and some pesticide samples include either the three-legged aluminum (or stainless steel) plate-filter assembly (fig. 2–16*A*) or the PFA in-line filter-holder assembly (fig. 2–16*B*). The aluminum plate-filter assembly consists of two machined aluminum or stainless-steel plates (designed to contain a 142-mm-diameter filter) held together by locking bolts or a locking ring.

— The plates have fluorocarbon polymer-coated silicone or Viton® O-rings set in grooves to seal the filtration assembly. A stainless-steel screen on the lower plate supports the filter. A valve is built into the upper plate to exhaust trapped air. Connectors are built into the center of the top and bottom plates so that inlet and outlet fluorocarbon polymer tubing can be attached.

— O-rings should be inspected for cracks and abrasions every time they are cleaned and should be replaced when appropriate.

— The PFA in-line filter-holder assembly with a Tefzel® ETFE clamp nut holds a 47-mm-diameter glass fiber filter (GF/F) (0.7-µm nominal pore size). (Similar assemblies currently are available from commercial manufacturers such as Savillex, Cole-Parmer, and Berghof.)

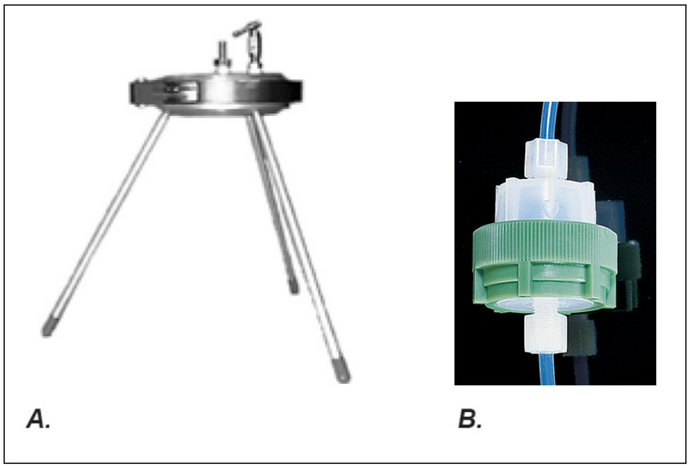


Figure 2–16. Examples of filter-holder assemblies: (*A*) Aluminum plate-filter assembly for a 142-millimeter-diameter filter GF/F disk and (*B*) Perfluoroalkoxy (PFA) filter holder for a 47-millimeter-diameter filter (Cole-Parmer EW-06103-13 PFA inline filter holder shown). Photographs published with permission: *A,* GeoTech Environmental Equipment, Inc. and *B* , Cole-Parmer Company (photograph copyright© Cole-Parmer), published with permission.

► **Organic compounds by DAI LC-MS/MS analysis.** Samples for analysis of organic compounds using direct aqueous injection (DAI LC-MS/MS)[23] may be filtered using an inline 25-mm disposable syringe filter unit (syringe filter), as explained below.[24] Filtration devices and other equipment made of plastic components generally are not to be used to process water-sediment samples for the determination of organic compounds; however, the syringe filter with plastic components has been approved and is an efficient and technically appropriate option for a specific DAI LC-MS/MS analysis. For detailed information regarding syringe filter, syringe, blunt needle, and other equipment needed for the syringe filtration process, and on how to connect the syringe filter to the syringe, refer to NFM 5, version 3.0 or later, or contact the USGS National Water Quality Laboratory (*http://nwql.usgs.gov/mrdp.shtml?MRDP)*.

— The disposable syringe-tip filter consists of a 25-mm-diameter GF/F membrane with a graded multifilter (GMF)[25], nominal 0.7-µm pore diameter, enclosed in a polypropylene housing with Luer inlet and outlet fittings (table 2–9; fig. 2–17*A*). **The syringe filter is discarded after a single use.**

— A disposable 20-mL syringe constructed of high-purity polypropylene and polyethylene is used to contain the sample and provide pressure to push the sample through the filter (table 2–9; fig. 2–17*B*). **The syringe is discarded after a single use.**

[23] Direct aqueous injection-liquid chromatography/tandem mass spectrometry.

[24] Alternatively, either a plate-filter assembly or PFA inline filter-holder assembly can be used, as described above in the bulleted item "Trace organic compounds."

[25] The graded multifilter (GMF) is a prefilter consisting of a coarse top layer of borosilicate glass microfibers meshed with a fine bottom layer.

— A blunt stainless-steel needle, 2 in. long, with Luer connector (needle), is used to withdraw sample into the syringe.

— The 25-mm filter unit is appropriate for the DAI LC-MS/MS methods because the required volume of filtered sample is only 10 mL.

Table 2–9. Equipment needed for filtration of water samples for analysis by DAI LC-MS/MS.

[DAI LC-MS/MS, direct aqueous injection-liquid chromatography/tandem mass spectrometry; NFSS, National Field Supply Service; GF/F, glass fiber filter; mm, millimeter; µm, micrometer; mL, milliliter; HSW®, Henke Sass Wolf Norm-Ject® sterile Luer-Lock syringe; NWQL, National Water Quality Laboratory; in., inch]

Item	NFSS Catalog Number	Description
Syringe filter	Q762FLD	Disposable syringe-tip filter, GF/F, 25-mm diameter, 0.7µm nominal pore diameter, polypropylene housing (Whatman 6890-2507 "GF/F with glass microfiber membrane")
Syringe	Q763FLD	Disposable syringe, 20 mL, with Luer-Lock outlet, high-purity polyethylene with polypropylene plunger, free of rubber, latex, and silicone oil (HSW® Norm-Ject®).
Blunt needle	Q764FLD	Stainless-steel needle, 1 in. long, with Luer fitting and blunt tip (NFSS catalog number Q764FLD).
DAI LC-MS/MS kit	Q765FLD	Kit includes the syringe filter, syringe, blunt needle, and 20-mL glass amber vial. (The 40-mL vial in which 20 mL of sample is collected is being replaced with a 20-mL vial that requires only 10 mL of sample. Contact NWQL if further clarification is needed.)

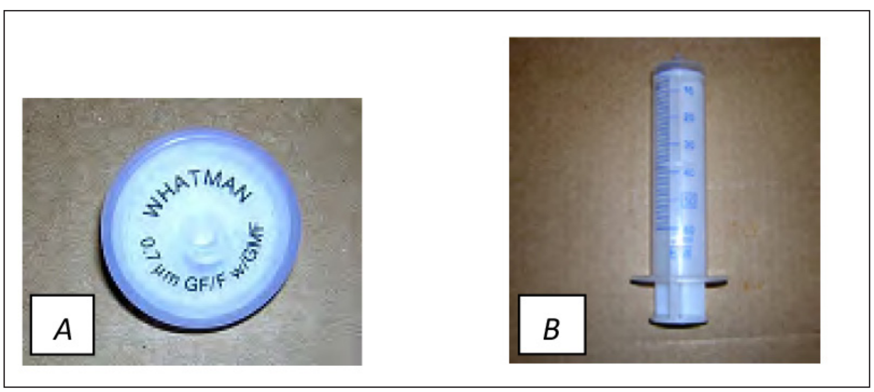


Figure 2–17. Syringe-tip filter and syringe for processing samples for analysis by DAI LC-MS/MS: *(A)* 25-millimeter disposable syringe-tip filter disk (National Field Supply Service (NFSS) catalog number Q762FLD) and *(B)* 20-milliliter disposable syringe with Luer-Lock outlet (NFSS catalog number Q763FLD). (A 1-inch blunt-tip stainless-steel needle with Luer fitting (NFSS catalog number Q764FLD) is not shown). Photographs from U.S. Geological Survey collection.

► **Dissolved organic carbon (DOC), total particulate carbon (TPC), particulate inorganic carbon (PIC), and total particulate nitrogen (TPN).** Depending on the types of analyses for dissolved organic carbon to be performed on the sample, **DOC samples** are processed through either (1) a Savillex DOC 25 fluorocarbon pressure filtration unit[26] with a baked 25-mm, 0.7-micron pore size GF/F disk, loaded on a 25-mm stainless steel or polysulfone filter-support screen, or (2) one of the disposable filters—either the large-capacity Versapor® capsule filter or the 19.6-cm^2 capacity Thermopor® disk filter (NFM 5.2.2.C). **Samples for TPC and TPN analyses** must be processed either through the Savillex pressure filtration assembly or a vacuum filtration assembly (fig. 2–18*A* and *B*), loaded with a baked 25-mm, 0.7-micron pore size GF/F disk on a 25-mm stainless steel screen.

- — Either a hand-pressure pump or a peristaltic pump fitted with clean tubing can be used to move the TPC, TPN, and PIC sample through the filtration assembly.
- — A peristaltic or submersible groundwater pump can be used to move the DOC sample through the capsule filter.
- — A detailed description of the methods and equipment needed for the analysis of carbon samples can be found in NFM 5.2.2.C, “Procedures for processing samples for carbon analysis.” See also the equipment lists provided in section 2.4.

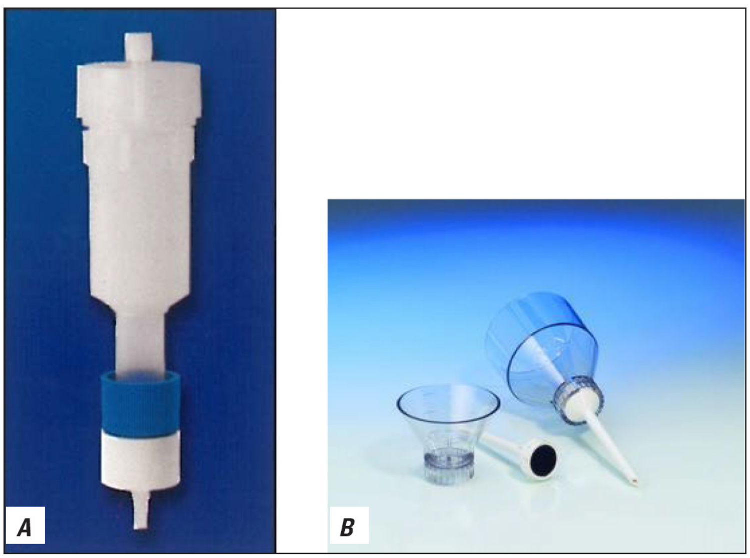


Figure 2–18. Filtration assemblies used to process samples for analysis of total particulate carbon and nitrogen: *(A)* Savillex DOC 25-mm fluorocarbon pressure assembly, and *(B)* Pall® Life Sciences, Inc. small-capacity (left) and large-capacity (right) polysulfone vacuum assemblies. Phographs published with permission: A, courtesy of Savillex Corporation; B. courtesy of Pall Corporation.

Filter-membrane material

Tortuous-path depth filters made of borosilicate glass microfibers are used to filter most samples to be analyzed for organic compounds because the material is considered inert for its intended use, can withstand organic solvents, and can withstand laboratory preparation (being baked at 450 °C). **Filter membranes made of cellulose, polycarbonate, or polyethersulfone polymers commonly are used to process**

[26] Part number for the “Savillex U.S. Geological Survey – DOC 25 configuration” is Savillex part #401-61-25-53-60-2.

samples for the determination of nutrients and other inorganic constituents. These are not suitable for filtering samples for the determination of most organic compounds, mainly because they are not resistant to the organic solvents used to preclean sampling and processing equipment. DOC samples, however, may be processed through the disposable capsule filter) (NFM 5), if study objectives permit.

- ► For most organic analytes, use GF/F (glass-microfiber filters) with a 0.7-µm nominal pore size that have been baked at 450 °C for at least 2 hours.[27]
  - — The 25-mm syringe-tip GF/F disk used for DAI LC-MS/MS sample analysis is not baked at 450 °C but is field rinsed prior to use.
  - — The 25-mm GF/F disk is used in the Savillex and vacuum filtration assemblies (see section 2.2.3.A.).
- ► Use only filters without binders. (Acrylic resin binders might leach from the filter and contaminate samples, or might not be completely combusted when baked at 450 °C.)

2.2.4 Pump Tubing and Tube Connectors

Pump tubing refers to the sample lines that are used with various pumps to collect and process groundwater and surface-water samples. Tubing connectors join the tubing to pumps, filters, or other sections of tubing that may be of the same or different diameter or material. The tubing and connectors for surface-water samples usually are consistent in material and diameter. The tubing and connectors for groundwater samples can vary according to the type of well to be sampled and the data quality objectives. Tubing and connections for groundwater may be used to pump water from the well or to connect to groundwater wells having preinstalled pumps. Field personnel are cautioned to **evaluate possible artifacts in a sample associated with pump tubing and tubing connectors and connections**.

When connecting to an existing supply well with a garden-hose type connection, the disposable, one-use only “Tuff-Lite” adapter (garden hose connection kit, part # CSK001) available from One Stop Shopping can be adapted to one-half inch NPT (National Pipe Thread Taper) standard threads to which project-appropriate fittings and tubing can be connected.

- ► Tubing connectors and connections that contact the sample should be made of inert material, to the extent possible. Stainless-steel connections should be the highest grade available (SS 316). If flexible copper, aluminum, or stainless-steel tubing is used for chlorofluorocarbon (CFC) sampling, it should be refrigeration grade. Such fittings ordinarily are delivered with coatings of machining lubricants, which must be removed by cleaning before use.
  - — Greaseless fittings can be specified and ordered on the open market.
  - — For filtering groundwater samples that are pumped directly from the well to a filtration assembly, **fluorocarbon polymer tubing ordinarily is preferred and recommended**.
  - — Fluorocarbon polymer, silicone, C-Flex® pump tubing commonly are used with portable submersible pumps and with peristaltic or metering pumps. Use of a fluorocarbon polymer material generally is recommended because fluorocarbon polymers are relatively inert with respect to many inorganic and organic analytes (table 2–10).

[27] USGS personnel can obtain baked, quality-assured 142-mm-, 47-mm-, and 25-mm-diameter GF/F disks and quality-assured 25-mm syringe-tip filters from One Stop Shopping.

► Silicone tubing is suitable when sampling for inorganic analytes only, **and only after appropriate cleaning** (see NFM 3).

— Measurable concentrations of silica (0.09 to 0.24 mg/L) have been detected in blank samples passed through silicone tubing (Horowitz and others, 1994). These concentrations are likely to be problematic only if low-ionic-strength water is being sampled or if the concentrations are unsuitable to meet the data-quality requirements of the study.

— Silicone tubing is not designed for use with acids.

— Silicone tubing is gas permeable and very sorptive of organic compounds.

► C-Flex® tubing is made from a thermoplastic elastomer and is suitable for use when sampling for all inorganic analytes and DOC, but not for other organic compounds.

— C-Flex® tubing is not compatible with alcohols or organic solvents, and therefore cannot be used when sampling for organic analytes. DOC is an anomaly because organic solvents are a source of contamination for DOC analysis.

— C-Flex® tubing is relatively resistant to acid. Acid resistance is important because dilute hydrochloric acid is required for most equipment-cleaning procedures, especially for decontamination of equipment used for sampling inorganic analytes (see NFM 3).

— C-Flex® tubing is less permeable to gas than silicone tubing.

► Fluorocarbon polymer tubing is recommended when sampling for most inorganic and organic analytes. Fluorocarbon polymer tubing is available in corrugated and convoluted, as well as in straight-wall configurations (fig. 2–14).[28]

— Fluorocarbon polymer tubing is available that is customized to the shape of the pump head.

— Convoluted fluorocarbon polymer tubing is flexible and easy to handle. Attach convoluted tubing to each end of the premolded tubing.

— Fluorocarbon polymer tubing sheathed in another plastic is available at lower cost and can be a good alternative for one-time use or short-term use and cleaning cycles.

- The fluorocarbon polymer liner may twist, constrict, and crack within its sheathing, such that a smooth flow of water is impeded.

- A fluorocarbon polymer tubing liner sheathed in another plastic requires frequent inspection to ensure that the liner has not cracked, allowing sampled water to pass between the liner and plastic sheathing.

[28] The convoluted tubing usually is available in fixed lengths with smooth surfaces at the ends, whereas the corrugated tubing is produced in alternating ribbed and smooth sections.

► Polyvinyl chloride (PVC) tubing (Tygon®) is suitable for inorganic samples only and must be appropriately cleaned prior to contact with inorganic samples.

— PVC tubing can be washed with dilute acid.

— PVC tubing has the lowest gas permeability of any peristaltic pump tubing.

— When used with a peristaltic pump, PVC tubing has a shorter life than silicone, C-Flex®, or Norprene®.

— **PVC tubing may leach plasticizers.**

► Nylon, polyethylene (PE), and polypropylene are all inexpensive, rigid tubing that can withstand high pressure and are relatively impermeable to gases and moisture. PE and polypropylene are suitable for sampling inorganic analytes. Nylon tubing is more resistant to organic compounds than other plastic tubing, but to date has not been tested as a potential source of trace-element or organic-compound contamination.

► Norprene® tubing is made from a thermoplastic elastomer (a polypropylene base with USP mineral oil) and **is suitable only when sampling for inorganic analytes**. It must be appropriately cleaned prior to contact with samples collected for inorganic analysis. (Norprene® tubing has the longest life of any manufacturer-recommended tubing material.) Norprene tubing®:

— Can be washed with dilute acid.

— **May leach USP mineral oil.**

— Is acceptable for use with a peristaltic pump.

— The gas permeability of Norprene® tubing is lower than that of silicone tubing and greater than that of PVC tubing.

Table 2–10. Common varieties and characteristics of fluorocarbon polymer tubing.

Varieties of Fluorocarbon Polymer Tubing.	Characteristics of Fluorocarbon Polymer Tubing.
FEP (fluorinated ethylene polypropylene)	• Most transparent • Best abrasion resistance • High flexibility • Least expensive of the Teflon® varieties
PFA (perfluoroalkoxy)	• Less transparent than FEP • Virtually nonporous (nonpermeable) • Most expensive of the Teflon® varieties
PTFE (polytetrafluoroethylene)	• Least transparent; milky to white • High flexibility • Midpriced between FEP and PFA
Kynar® (polyvinylidene fluoride)	• Translucent • Low flexibility • Less expensive than the Teflon® varieties
Tefzel® (Ethylene tetrafluoroethylene)	• Withstands higher pressure than Teflon® • Most expensive

2.3 Field Vehicles

Water samples should be processed within vehicles that are designed, designated, prepared, and dedicated for that purpose. If multiple-use vehicles are used for water-quality work, then use of portable processing and preservation chambers is mandatory, and additional quality-control samples should be collected to document that the quality of the data has not been compromised. **Contamination of the sample for target analytes is much more likely when multiple-use vehicles are used for the collection of water-quality data.**

Whether using a field vehicle dedicated for water-quality work or a multi-use vehicle, every effort should be made to keep the work area clean and to eliminate sources of sample contamination, as is emphasized in the examples listed below.

- Containers of blank water, solvents, buffers, standards, and other chemical substances should be properly labeled, dated, secured, and stored in a manner that prevents accidental spills. Some solutions may need to be stored separately to protect them from contamination.
- Keep metallic objects, such as surface-water and groundwater sampling support equipment, out of the inorganic sample-processing and -preservation area.
- Install a dustproof barrier between the vehicle's cab and the sample-processing and -preservation area.
- Cover metallic surfaces (cabinets or shelving that cannot be replaced) with plastic sheeting in areas where samples will be processed for the analysis of inorganic constituents and cover all work surfaces with heavy-duty aluminum foil in areas where samples will be processed for the analysis of organic constituents.
  - Keep the sheeting free of spills and dust.
  - Replace sheeting on a routine basis (as suitable for the site environment) and whenever it cannot be cleaned completely.
- Store chemical substances so that chemical fumes will not enter the sample-processing and -preservation area. Containers of solvents, blank waters, and liquid waste should be stored in separate areas or compartments.
- If transporting a nitrogen tank, ensure that the tank is fastened securely to the vehicle with a bracket. Brackets specially designed for gas tanks/cylinders can be obtained from companies that sell gas-supply equipment.

For additional discussions about recommendations and requirements for field vehicles, refer to Horowitz and others (1994) and Koterba and others (1995).

CAUTION! Store acids, bases, and solvents in separate storage areas so that the chemicals cannot mix if a spill occurs (NFM 9).

2.4 Checklists for Equipment and Supplies

Examples of checklists for equipment and supplies commonly used to collect and process water samples are provided in tables 2–11 through 2–18 to aid field personnel when selecting equipment for a water-quality field trip. These checklists are not intended to be exhaustive and should be modified to meet specific study needs. Many of the items listed are explained in greater detail in other NFM chapters, as indicated. Refer to other chapters of the NFM for lists of equipment and supplies for field measurements (NFM 6), biological indicators (NFM 7), and bottom-material samples (NFM 8). **Field equipment must be cleaned and tested before commencing with field work (NFM 3).**

Remember to test backup equipment and bring it to the field in good operating condition.

Table 2–11. Suggested support equipment for surface-water sampling.

[A detailed description of the various types of support equipment is beyond the scope of this manual; refer to Corbett and others (1943), Buchanan and Somers (1969), and Rantz and others (1982)]

Cranes		
Type		**Maximum recommended weight of sampler (pounds)**
	Type A	100
	Type E	30,000
	Bride board	50
	Other (add to checklist)	
Crane bases		
Type		**Maximum recommended weight of sampler (pounds)**
	Three-wheel	100
	Four-wheel	150

Miscellaneous	
	Battery or hydraulic power motor system for B-56 or E-53 reel
	Hanger bars, connectors, and pins for connecting sampler to cable
	Counterweights for four-wheel crane base
	Safety equipment (flotation jacket, cable cutter, bridge safety plan, traffic cones, and warning signs)
	Vertical transit rate pacer (US VTP-99)
	Variable speed reel drive system for B-56 or E-53 reel (batteries, spare belts)
	Handlines or ropes for operating weighted bottle sampler, VOC sampler, or DH 95, or DH 2
	Plastic coated wading rod for DH-81
	Other (add to checklist)

Table 2–11. Suggested support equipment for surface-water sampling.—Continued

[A detailed description of the various types of support equipment is beyond the scope of this manual; refer to Corbett and others (1943), Buchanan and Somers (1969), and Rantz and others (1982)]

Reels[1]						
	Reel	**Cable diameter (inches)**	**Maximum weight (pounds)**	**Cable capacity (feet)**	**Brake**	**Operation type**
	A-55	0.084 0.10	50 100	95 80	No	Hand
	B-56	0.10 0.125	150 200	144 115	Yes	Hand or power
	E-53	0.10 0.125	150 300	206 165	Yes	Power
	Other (add to checklist)					

[1]Selection of a type of reel should be based primarily on the maximum cable length needed and the weight of the sampler that must be supported.

Table 2–12. Suggested support equipment for groundwater sampling.

Groundwater support equipment	
	Handline or manual/power reel with line
	Tripod assembly with manual or power reel
	Wellhead guide for flexible sample line to pump
	Wheeled carts to transport portable sampling equipment
	Energy source for reels and pumps (batteries, compressor, or generator)
	Extension cords
	Other (add to checklist)

Table 2–13. Sample-collection equipment for surface water and groundwater.

[NFM, *National Field Manual for the Collection of Water-Quality Data*]

Sample collection equipment: surface water (refer to NFM 4)	
	Weighted bottle (plastic or stainless steel), handline, and bottle
	US DH-95 and US D-95 (plastic dipped) • Bottle (1 liter) • Nylon or fluorocarbon polymer nozzle[1] (3/16, 1/4, or 5/16 inch) and cap
	US DH-81 (handle and collar) • Nylon or fluorocarbon polymer nozzle[1] (3/16, 1/4, or 5/16 inch) and cap • Plastic or fluorocarbon polymer bottle (1 liter)
	US DH-2, US D-96, US D-96-A1, and US D-99 (plastic dipped) • Nylon or fluorocarbon polymer nozzle[1] (3/16, 1/4, or 5/16 inch) • Polyethylene or perfluoroalkoxy (PFA) bag • Extra tailfin section, nozzles, adapters, sampler head, and so forth • Bag sampler intake efficiency requires: ○ Graduated pitcher or cylinder (2 or 4 L) ○ Stop watch
	Crane with 3- or 4-wheel base and counterweights
	Reel, hanger bars, and pins
	Current meter/ADCP for US DH-95, US D-95, US DH-2, US D-96, US D-96-A1, and US D-99
	Bridge board and reel
	Plastic sheeting with weighted corners to cover bridge rail, 2 millimeters thick
	Vertical transit rate pacer
	Biochemical oxygen demand (BOD) sampler
	Volatile organic compound (VOC) sampler
	Thief sampler
	Pumping sampler(s)
	Other (add to checklist)
Sample collection equipment: groundwater (refer to NFM 4)	
	Positive-displacement submersible pump, discharge line, and reel
	Water-supply-well sample line and garden-hose threaded adaptor
	Thief-type sampler (for example, bailer, single or double-check valve, and bottom-emptying device)
	Suction-lift pump (peristaltic or centrifugal)
	Antibacksiphon device

Table 2–13. Sample-collection equipment for surface water and groundwater.—Continued

[NFM, *National Field Manual for the Collection of Water-Quality Data*]

Sample collection equipment: groundwater (refer to NFM 4)	
	Sample-water manifold (to split sample water flow)
	Flowthrough chamber for field-measurement electrodes (pH, conductivity, dissolved oxygen, water temperature, oxidation/reduction)
	Tubing, appropriate for type of pump and target analytes
	Tubing connectors and "Tuff-Lite" adapters (compatible with tubing material and target analytes)
	Water-level measuring tape (steel or electric) and bleach/water solution or disinfectant wipes (commercially available). For electric tapes, be sure to check with the manufacturer before exposing the tape and tape housing to the bleach or other solvent solution. Follow the detailed instructions for disinfecting and subsequent rinsing of well tapes given in NFM 3 and updated in the Comments and Errata for NFM 3, dated 11/21/2005 (*http://water.usgs.gov/owq/FieldManual/mastererrata.html*)
	Water-level indicator (blue chalk for steel tape)
	Weight (to attach to water-level measuring tape or sample line). Do not use a lead weight; use stainless steel or other relatively noncontaminating material.
	Power source for pump or reel; batteries for electronic sounder
	Graduated bucket (to measure rate of discharge) and stopwatch
	Containers (for disposal of purge water)
	Flow controller (for sampling pump)
	Plastic sheeting, 2 millimeters or thicker
	Other (add to checklist)

[1]Use only nozzles purchased from the U.S. Geological Survey Federal Interagency Sedimentation Project.

Table 2–14. Sample-processing equipment and supplies.

[NFM, *National Field Manual for the Collection of Water-Quality Data*; DAI LC-MS/MS, direct aqueous injection liquid-chromatography/tandem mass spectrometry; OGW, organic-grade water; L, liter; mm, millimeter; µm, micrometer; in., inch; g, gram; mL, milliliter]

	Sample splitters (refer to NFM 5)
	Churn splitters • Plastic churn splitter, 8 L or 14 L, modified spigot and funnel (NFM 2.2.1.A) (inorganic analytes) • Fluoropolymer churn splitter, 8 L or 14 L (organic and (or) inorganic analytes), modified spigot • Extra fluoropolymer churn spigot, nylon screws and o-rings
	Churn carrier
	Cone splitter • Splitting chamber for cone splitter • Bull's-eye bubble level and shims for cone splitter
	Large clear plastic bags: protective • Covering for transporting clean churn splitter or cone splitter • Covering for sample processing and preservation chambers
	Subsample bottle kits for whole-water samples
	Other: Gloves (nitrile, powderless, disposable)
	Filtration systems for inorganic-constituent filtration (refer to NFM 5)
	Peristaltic pump and batteries
	Pump tubing for groundwater and peristaltic pump (refer to section 2.2.4, table 2–10)
	Filtration devices • Filter units, disposable capsule filter, "high-capacity" Versapor® membrane, 0.45-µm pore size • Disk filter, small capacity, Thermopor® membrane, 0.45-µm pore size
	Filter membranes for nondisposable (plate-filter) filtration assemblies (various diameters, pore sizes, and materials); plate-type filtration assemblies; forceps, plastic or ceramic (to handle filter membranes)
	Subsample bottle kits (for filtered inorganic samples)
	Inorganic grade blank water (IBW) (obtained by USGS personnel from One Stop Shopping)
	Deionized water (DIW), Water Science Center-produced and quality assured)
	Gloves (powderless, disposable, nitrile)
	Other (add to checklist)
	Filtration systems for organic-compound filtration (refer to NFM 5)
	Plate-filter assembly • Aluminum or stainless steel (for 13-, 142-, or 293-mm-diameter filter disk) • PFA filter holder (for 25-mm or 47-mm-diameter filters)
	Filter disk, borosilicate glass fiber (GF/F); 0.7-µm pore size, baked. (Select diameter: 293 mm, 142 mm; 13 mm, 25 mm; 47 mm, as required)
	Pump, ceramic piston valveless metering, with fluorocarbon polymer convoluted tubing or groundwater pump tubing, and batteries. (Alternatively, peristaltic pump with FTPE diaphragm pump head: alternative to valveless metering pump, as appropriate for project needs and data-quality requirements.)

Table 2–14. Sample-processing equipment and supplies.—Continued

[NFM, *National Field Manual for the Collection of Water-Quality Data*; DAI LC-MS/MS, direct aqueous injection liquid-chromatography/tandem mass spectrometry; OGW, organic-grade water; L, liter; mm, millimeter; µm, micrometer; in., inch; g, gram; mL, milliliter]

Filtration systems for organic-compound filtration (refer to NFM 5)	
	DAI LC-MS/MS kit (refer to table 2–9) that includes: • Disposable syringe-tip filter, GF/F, 25-mm diameter, 0.7 µm, polypropylene housing • Disposable syringe, 20 mL, HSW® Norm-Ject® with Luer-lock outlet, high-purity polyethylene with polypropylene plunger • Stainless-steel blunt-tip needle, 1 in. long, with Luer fitting • 20-mL glass amber vial
	Organic carbon: Savillex fluorinated ethylenepropylene pressure-filtration assembly and 25-mm stainless steel or polysulfone filter support screen. (Refer also to section 2.2.3.B for use of the disposable capsule or disk filter for dissolved organic carbon sample analysis, listed above under “Filtration systems for inorganic-constituent filtration”)
	Subsample bottle kits
	Volatile/pesticide-grade blank water (VPBW) (obtained by USGS personnel from One Stop Shopping)
	Pesticide-grade blank water (PBW) (obtained by USGS personnel from One Stop Shopping)
	Deionized, charcoal-filtered organic-grade water (OGW), Water Science Center-produced and quality assured
	Forceps (stainless steel, ceramic, or Teflon-coated)
	Other (add to checklist)
Miscellaneous processing equipment and supplies: inorganic and organic sampling	
	Sample processing chamber; supply of transparent plastic covers (bags) for portable chamber and disposable powderless gloves to handle equipment
	Gloves, powderless, disposable, made of nitrile or other chemical-resistant material (as required by the intended application)
Filtration system for carbon analysis (refer to NFM 5)	
	Fluorocarbon-polymer filtration assembly and baked glass-microfiber filter disks (GF/F) (25-mm, 0.7-µm pore size)
	Disposable capsule filter for dissolved organic carbon sample analysis (if consistent with study protocols and objectives)
	Hand pressure or peristaltic pump
	C-flex tubing with inline 0.2-µm air filter
	Cylinder (graduated, glass)
	Holding stand, ring, and medium three-prong clamp
	Forceps, stainless steel
	Whirl-Pak bags (6 ounce and 18 ounce)
	Aluminum foil squares
	Cooler and ice
	Organic-grade water
	Power source for pump (battery, generator, other)
	Other: Gloves (powderless, disposable, nitrile)

Table 2–14. Sample-processing equipment and supplies.—Continued

[NFM, *National Field Manual for the Collection of Water-Quality Data*; DAI LC-MS/MS, direct aqueous injection liquid-chromatography/tandem mass spectrometry; OGW, organic-grade water; L, liter; mm, millimeter; µm, micrometer; in., inch; g, gram; mL, milliliter]

	Solid-phase extraction (SPE) system (refer to NFM 5)
	Valveless piston metering pump (ceramic) (with fluorocarbon polymer convoluted tubing)
	Fluorocarbon polymer tubing, 1/8-in. outside diameter
	Variety of tubing fittings, adaptors, connectors, and unions
	Portable balance, 1 to 6,000 g
	Graduated glass cylinders
	Beaker (plastic, 1,000 mL)
	Spike mixture and micropipette kit
	Surrogate mixture and micropipette kit
	SPE column (C-18); checklist and reporting form
	Methanol (pesticide grade), ascorbic acid, sodium chloride, and pesticide-grade organic water, all in fluorocarbon polymer dispenser bottles
	Gloves (powderless, disposable, nitrile)
	Stopwatch
	Aluminum foil
	CFCs, dissolved gases SF_6, $^3H/^3He$, and low-level VOCs)
	Consult the USGS Reston Chloroflurocarbon Laboratory at http://water.usgs.gov/lab/ for sample-collection or –processing equipment for CFCs and dissolved gases (N_2, Ar, Co_2, CH_4, O_2, He-4), SF_6, $_3H/_3He$, and low-level VOCs.
	Passive diffusion bag (PDB) samplers[1] for investigating selected volatile organic compounds in groundwater (see NFM 5)
	1- to 2-ft-long low-density polytheylene (LDPE) lay-flat tubes
	Polyethylene mesh (sleeve for PDB)
	Deionized water (used to initially fill the PDB before deployment)
	Weighted line or fixed pipe (to hold PDB in place in well)
	Cable ties or stainless steel spring clamps (to hold PDB to weighted line or fixed pipe)
	Heat source (to seal ends of PDB)

[1]Vroblesky (2001b) includes photographs of sampling equipment and deployment.

Table 2–15. Sample-preservation equipment and supplies.

[NFM, *National Field Manual for the Collection of Water-Quality Data*; *N*, normal]

Preservation equipment and supplies (refer to NFM 5)	
	Preservation chamber(s)
	Chamber covers (large, transparent bags)
	Waste containers for spent preservative ampoules (uniquely dedicated for each chemical used)
	Chemical reagents (such as nitric, hydrochloric, and sulfuric acids) and project requirements for sample preservation for the analytes targeted and analytical method selected. *Note that although several analytes might require the same type of acid preservative, the normality, volume, and grade specified by the laboratory may differ; it is important to follow the explicit laboratory directives concerning the chemical treatment of a sample, including handling, storage, and expiration date of the preservative.*
	Nitric acid (HNO_3): 7.57 to .7*N*, Ultrex grade
	6*N* ultrapure hydrochloric acid vial (for mercury sample)
	Sulfuric acid (H_2SO_4): • 4.5*N* for nutrients and carbon samples • 18*N* for chemical oxygen demand (COD) and phenol samples
	Hydrochloric acid (HCl) for volatile organic compound sample
	Phosphoric acid/cupric sulfate
	Sodium hydroxide (NaOH)
	Ascorbic acid
	Zinc acetate
	Phytoplankton kit
	Radon kit
Preservation equipment and supplies (refer to NFM 5)	
	Cooler, ice or chilling agent, 12-volt freezer or dry ice for chlorophyll
	Other: For example, apron, goggles, gloves (powderless, disposable nitrile)

Table 2–16. Cleaning and quality-control sampling equipment and supplies.

[NFM, *National Field Manual for the Collection of Water-Quality Data*; FEP, fluorinated ethylene polypropylene]

General cleaning equipment and supplies (refer to NFM 3)	
	Basins or standpipes (clear or white plastic, fluorocarbon polymer, stainless steel)
	Brushes (nonmetallic, clear or white)[1]
	Detergent, laboratory phosphate-free (0.1 to 2 percent by volume)
	Tap water
	Deionized water, produced in a Water Science Center laboratory or equivalent (ASTM International Type 1) (Office of Water Quality Technical Memorandum 92.01), distilled water purchased from commercial supplier

Table 2–16. Cleaning and quality-control sampling equipment and supplies.—Continued

[NFM, *National Field Manual for the Collection of Water-Quality Data*; FEP, fluorinated ethylene polypropylene]

General cleaning equipment and supplies (refer to NFM 3)	
	Wash bottles
	Material Safety Data Sheet (MSDS) for each chemical to be used
	Sealable plastic bags (without color closure strips) • Large plastic storage bags
	Other safety equipment; for example: • Laboratory coat or apron • Gloves • Eyewash station • Acid spill kit; solvent spill kit • Safety shower
Inorganic constituents	
	Hydrochloric acid, analytical grade (5 percent by volume)
	Neutralization container and marble chips
	Wash bottle (for hydrochloric acid)
	Inorganic-grade blank water (IBW)[2] (National Water Quality Laboratory Technical Memorandum 1992.01)
	Large plastic bags (clear or white)
	Plastic sheeting (clear or white)
Organic compounds	
	Methanol, pesticide grade[3]
	Waste container, methanol[3]
	Waste container for buffers and standards
	Wash bottle, for methanol (FEP-grade fluoropolymer)[3]
	Aluminum foil
	Fluorocarbon polymer bags/sheeting
	Pesticide- or volatile-grade blank water (PBW or VPBW)[2]
	Deionized water, district-produced or equivalent (ASTM International Type 1) and quality assured

[1]Restaurant-supply stores are an excellent source for these types of brushes.

[2]USGS personnel should obtain blank water from the "One Stop Shopping" Web site using the following item numbers: IBW - Q378 FLD; PBW - N1590 or N1600; VPBW - N1580 or N1570

[3]Methanol supplies must not be used or stored where contact is possible with samples or equipment dedicated for the analysis of organic carbon.

Table 2–17. Shipping equipment and supplies.

[NFM, *National Field Manual for the Collection of Water-Quality Data*]

Shipping equipment and miscellaneous shipping supplies (refer to NFM 5[1])	
	Coolers (1- to 5-gallon sizes)
	Boxes (sturdy)
	Packing material (foam sleeves, bubble wrap), ice
	Large plastic bags (for lining coolers and boxes)
	Sample-bottle labels
	Analytical Services Request (ASR) form, return address label, and account number
	Sealable plastic bag for forms and return address label
	Tape (fiber reinforced)
	Shipping label (forms)

[1] The additional equipment needed for shipping chain of custody samples is not included on this table.

Table 2–18. Field-measurement and miscellaneous field supplies.

[NFM, *National Field Manual for the Collection of Water-Quality Data*; DO, dissolved oxygen; NIST, National Institute of Standards and Technology; USGS, U.S. Geological Survey]

Field-measurement and miscellaneous field supplies (refer to NFM 6)	
Field Measurements	
	Instruments for measurement of barometric pressure, water temperature, dissolved oxygen, specific electrical conductance, pH, redox, alkalinity, turbidity, and other water properties (Refer to each section in NFM 6.)
	Barometer (NFM 6.2) (most DO meters include an internal barometer)
	Calibration buffers and standards (NFM 6.2, 6.3, 6.4, 6.5, 6.7)
	Digital counter for alkalinity titration (NFM 6.6)
	Buret (NFM 6.6)
	Beakers
	Volumetric pipettes (have a backup supply of various capacities)
	Magnetic stirrer
	Titrant (NFM 6.6)
	Titrant cartridges (NFM 6.6)
	Titrant delivery tubes (NFM 6.6)
	Thermometers and (or) thermistors (NFM 6.1), NIST-certified or NIST-traceable
Miscellaneous Equipment and Supplies	
	Printout or online access to relevant sampling procedures and USGS field protocols
	Emergency contact information for field personnel: names, phone numbers, e-mail addresses, etc.

Table 2–18. Field-measurement and miscellaneous field supplies.—Continued

[NFM, *National Field Manual for the Collection of Water-Quality Data*; DO, dissolved oxygen; NIST, National Institute of Standards and Technology; USGS, U.S. Geological Survey]

Field-measurement and miscellaneous field supplies (refer to NFM 6)—Continued	
Miscellaneous Equipment and Supplies—Continued	
	Bound notebook (logbook) and ballpoint pen (indelible ink, non-smudge)
	Laptop or tablet computer with power adapter
	Thumb drive for data backup
	Field folder(s) with station, site, and well information and permission form
	Field documentation forms
	Calculator and extra batteries
	Watch
	Tagline
	Discharge measurement equipment
	Hip boots
	Chest waders
	Rain gear
	Personal flotation device
	Traffic safety vest, cones, signs, warning lights
	First aid kit
	Highway emergency kit
	Tool kit
	Tape (electrical, fiber, fluorocarbon polymer, other)
	Plastic-coat spray
	Fire extinguisher
	Flashlight with extra batteries
	Backup batteries for sampling devices
	Keys to sampling site, security locks, and vehicle (extra set)
	Weather report
	Field trip itinerary (copy to supervisor); sampling and safety plans, Job Hazard Analysis form
	Satellite phone or cellular phone
	Camera with extra batteries, memory card, etc.
	Work gloves

Table 2–18. Field-measurement and miscellaneous field supplies.—Continued

[NFM, *National Field Manual for the Collection of Water-Quality Data*; DO, dissolved oxygen; NIST, National Institute of Standards and Technology; USGS, U.S. Geological Survey]

Field-measurement and miscellaneous field supplies (refer to NFM 6)—Continued	
Miscellaneous Equipment and Supplies—Continued	
	Shovel, ice chisel/auger
	Boat, motor, gasoline, oil, paddle, oars
	Drinking water
	Soap (antibacterial)
	Sunscreen (wash hands thoroughly after application; do not use a spray application or aerosol)
	Insect repellent. Instead of a DEET repellent, try (a) oil of lemon eucalyptus or (b) picaridin: (see *http://en.wikipedia.org/wiki/Icaridin*; *http://wwwnc.cdc.gov/travel/yellowbook/2014/chapter-2-the-pre-travel-consultation/protection-against-mosquitoes-ticks-and-other-insects-and-arthropods*). Additional insect-repellent information from U.S. Environmental Protection Agency: *http://cfpub.epa.gov/oppref/insect/* (accessed April 29, 2014).
	Paper towels (lint free)
	Safety plan(s) (NFM 9)
	Map(s); Global Positioning System (GPS)-capable device
	Locations of and phone numbers for hospitals and other emergency facilities (police, fire department, animal control, etc.) (NFM 9)
	USGS photo identification should be with all field personnel at all times in the field.
	Direct current/alternating current (DC/AC) power inverter
	Other (add to checklist)

Conversion Factors, Selected Terms and Symbols, and Abbreviations

Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
inch (in.)	25.4	millimeter (mm)
square inch (in^2)	645.16	square millimeter (mm^2)
foot (ft)	0.3048	meter (m)
foot per second (ft/s)	0.3048	meter per second (m/s)
gallon (gal)	3.785	liter (L)
pound, avoirdupois (lb)	0.4536	kilogram (kg)

SI to Inch/Pound

Multiply	By	To obtain
meter (m)	3.281	foot (ft)
meter per second (m/s)	3.281	foot per second (ft/s)
centimeter (cm)	0.3937	inch (in.)
micrometer (µm)	3.9372×10^{-5}	inch (in.)
millimeter (mm)	0.03937	inch (in.)
square centimeter (cm^2)	0.155	square inch (in^2)
liter (L)	0.2642	gallon (gal)
milligram per liter (mg/L)	0.5841	grains per gallon
milliliter (mL)	0.0338	ounce, fluid (oz)
milliliter (mL)	2.64×10^{-4}	gallon (gal)
milligram (mg)	3.527×10^{-5}	ounce, avoirdupois (oz)
gram (g)	0.03527	ounce, avoirdupois (oz)
kilogram (kg)	2.205	pound (lb)

Water and air temperature are given in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by use of the following equation:

$$°F = 1.8(°C) + 32$$

Concentrations of chemical constituents in water are given either in milligrams per liter (mg/L) or micrograms per liter (µg/L).

Selected Terms

Analyte (target analyte). “Substances being determined in an analysis” (from Bennett, 1986). The term “target analyte” is used in this report to refer to any chemical or biological substance for which concentrations in a sample will be determined. Target analyte does not include field-measured properties such as temperature, conductivity, dissolved-oxygen concentration, pH, Eh, alkalinity, color, or turbidity.

Fluorocarbon polymers and fluoropolymers. Fluorocarbon polymers (polyfluorocarbons) or fluoropolymers are composed of monomers (smallest repeating compound segment of a polymer) consisting of carbon, fluorine, hydrogen, and, for one polymer, oxygen. The fluoropolymers have tradenames that include, for example, Teflon® and Tefzel® (ethylene tetrafluoroethylene) (products of the DuPont Company) and Kynar® (a polyvinylidene fluoride, a product of the Atofina Chemicals Company). Common types of fluoropolymers include FEP (fluorinated ethylene polypropylene), PFA (perfluoroalkoxy), PTFE (polytetrafluoroethylene), and PVDF (polyvinylidene fluoride). Each fluorocarbon polymer has different chemical and physical properties; however, all are relatively nonreactive chemically at ambient temperatures and do not leach monomers.

Trace element(s). For the purpose of this report and to maintain consistency with common usage, the term “trace element(s)” is used to refer to metals and other elements such as arsenic, antimony, selenium, and tellurium that usually are present in natural surface-water and groundwater systems in concentrations less than 1 mg/L (modified from Hem, 1985). Common usage of this term, as defined above, is inexact and not rigorous with respect to the aqueous chemistry discipline.

Whole water. Water as sampled from its source and not subjected to filtration or other phase-separation process. Common synonymous terms include: raw (water) sample and unfiltered (water) sample.

Selected Symbols

~	approximately
>	greater than
≤	less than or equal to
±	plus or minus

Abbreviations

BOD	biochemical oxygen demand
CFC	chlorofluorocarbon
DAI	direct aqueous injection
DAI LC-MS/MS	direct aqueous injection-liquid chromatography/tandem mass spectrometry)
DC	direct current
DIW	distilled/deionized water DOC dissolved organic carbon
DOC	dissolved organic carbon
ETFE	ethylene-tetrafluorethylene
FEP	fluorinated ethylene polypropylene
FISP	Federal Interagency Sedimentation Project of the U.S. Geological Survey
gal/min	gallon per minute
GF/F	glass fiber filter, sometimes referred to as glass microfiber filters (GMF)
GMF	graded glass microfiber prefilter, consisting of a coarse top layer of borosilicate glass microfibers meshed with a fine bottom layer
GPS	Global Positioning System
HIF	USGS Hydrologic Instrumentation Facility, Stennis Space Center, Mississippi
IBW	inorganic-grade blank water (water that is laboratory-certified to be free of specified inorganic analystes within the given analytical detection or reporting levels)
L/min	liter per minute
LC/MSMS	liquid chromatography-tandem mass spectrometry
LDPE	low-density polyethylene
mL/min	milliliter per minute
NFM	*National Field Manual for the Collection of Water-Quality Data*
NFSS	National Field Supply Service
NPT	National Pipe Thread Taper
NWQL	USGS National Water Quality Laboratory
OGW	organic-grade water produced and analyzed in a USGS Water Science Center laboratory
PBW	pesticide-grade blank water (water that is laboratory-certified to be free of specified pesticide compounds within given analytical detection or reporting levels
PDB	passive diffusion bag sampler

PE	polyethylene
PFA	perfluoroalkoxy
PIC	particulate inorganic carbon
PTFE	polytetrafluoroethylene
PVC	polyvinyl chloride
PVDF	polyvinylidene fluoride
SPE	solid-phase extraction
SS	stainless steel
TPC	total particulate carbon
TPN	total particulate nitrogen
USGS	U.S. Geological Survey
USP	United States Pharmacopeia
VOC	volatile organic compound
VPBW	volatile/pesticide grade blank water (water that is laboratory-certified to be free of specified volatile and pesticide compounds within given analytical detection or reporting levels)

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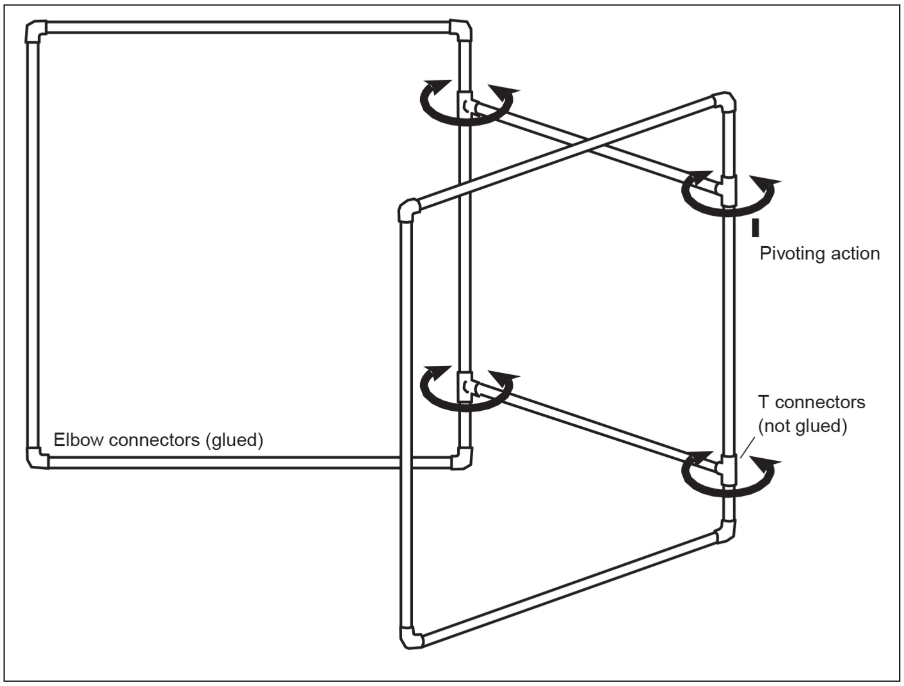
Appendix: Construction of a Collapsible Sample-Processing/ Preservation Chamber.



This frame can be pulled apart at the four joints that are left unglued and will swivel or fold at these joints. Schedule 40 polyvinyl chloride pipes can be used for greater rigidity. The dimensions of a chamber depend on its use (processing or preservation) and the space available in the field vehicle.