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Interagency Field Manual for the Collection of Water-Quality Data

Open-File Report 00–213

U.S. Department of the Interior
U.S. Geological Survey

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Compiled by Dee L. Lurry and Christine M. Kolbe

U.S. GEOLOGICAL SURVEY
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In cooperation with the U.S. Environmental Protection Agency

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U.S. DEPARTMENT OF THE INTERIOR

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CONTENTS

FIGURES

TABLES

APPENDICES

CONVERSION FACTORS, ABBREVIATIONS, AND ACRONYMS

Abbreviation	From	Multiply by	To	Abbreviation
		Length		
in.	inches	2.5	centimeters	cm
ft	feet	30	centimeters	cm
ft	feet	0.3048	meters	m
yd	yards	0.9	meters	m
mi	miles	1.609	kilometers	km
		Area		
in^2	square inches	6.5	square centimeters	cm^2
ft^2	square feet	0.0929	square meters	m^2
yd^2	square yards	0.8	square meters	m^2
mi^2	square miles	2.59	square kilometers	km^2
ac	acres	4,047	square meters	m^2
ac	acres	0.4	hectares	ha
		Volume		
pt	pints	0.47	liters	L
qt	quarts	0.95	liters	L
gal	gallons	3.8	liters	L
gal/min	gallons per minute	6.309×10^{-5}	cubic meters per second	m^3/s
ft^3	cubic feet	0.0283	cubic meters	m^3
yd^3	cubic yards	0.76	cubic meters	m^3
cfs or ft^3/s	cubic feet per second	0.0283	cubic meters per second	m^3/s
cfs or ft^3/s	cubic feet per second	0.646	million gallons per day	Mgal/d

Abbreviation	From	Multiply by	To	Abbreviation
Mgal/d	million gallons per day	0.0438	cubic meters per second	m^3/s
Mgal/d	million gallons per day	1.547	cubic feet per second	cfs or ft^3/s
		Temperature		
^oF	degrees Fahrenheit	5/9 (^oF-32)	degrees Celsius	^oC
		Concentration		
ppm	parts per million	1	milligrams per liter	mg/L
		Length		
cm	centimeters	0.4	inches	in.
m	meters	3.281	feet	ft
m	meters	1.1	yards	yd
km	kilometers	0.6214	miles	mi
		Area		
cm^2	square centimeters	0.16	square inches	in^2
m^2	square meters	10.76	square feet	ft^2
m^2	square meters	1.2	square yards	yd^2
km^2	square kilometers	0.3861	square miles	mi^2
m^2	square meters	0.0002471	acres	ac
ha	hectares (10,000 m^2)	2.5	acres	ac
		Volume		
mL	milliliters	0.03	fluid ounces	fl oz
L	liters	2.1	pints	pt
L	liters	1.06	quarts	qt
L	liters	0.26	gallons	gal
m^3	cubic meters	35.31	cubic feet	ft^3
m^3	cubic meters	1.3	cubic yards	yd^3
m^3/s	cubic meters per second	35.31	cubic feet per second	cfs or ft^3/s
m^3/s	cubic meters per second	22.821	million gallons per day	Mgal/d
		Temperature		
^oC	degrees Celsius	9/5 (^oC+32)	degrees Fahrenheit	^oF
		Concentration		
mg/L	milligrams per liter	1	parts per million	ppm

Abbreviations

ft/s, foot per second
g, gram
gal/min, gallon per minute
g/L, gram per liter
in., inch
L/min, liter per minute
µg/L, microgram per liter (equivalent to parts per billion)
µm, micrometer
meq/L, milliequivalent per liter
mg/L, milligram per liter (equivalent to parts per million)
mL, milliliter
mm, millimeter
µS/cm, microsiemens per centimeter
N, normality
ppb, parts per billion (equivalent to microgram per liter)
ppm, parts per million (equivalent to milligram per liter)

Acronyms

ADEQ, Arizona Department of Environmental Quality

ANC, acid-neutralizing capacity

ASTM, American Society for Testing and Materials

BOD, biochemical oxygen demand

BOR, U.S. Bureau of Reclamation

CFC, chlorofluorocarbon

CH/DH, clean hands/dirty hands

CNA, Comisión Nacional del Agua

CPR, cardiopulmonary resuscitation

CRWQCB, California Regional Water Quality Control Board

DIW, deionized water

DO, dissolved oxygen

DOC, dissolved organic carbon

DPD, *N*,*N*-diethyl-*p*-phenylenediamine

DQO, data-quality objective

EDI, equal-discharge increment

EWI, equal-width increment

FAS, ferrous ammonium sulfate

FISP, Federal Interagency Sedimentation Project

GIS, geographic information system

GPS, global positioning system

IBWC, International Boundary and Water Commission

IPT, inflection point titration

ITFM, Intergovernmental Task Force for Water-Quality Monitoring

MF, membrane filtration

MPN, most probable number

MRL, minimum reporting level

MSDS, Material Safety Data Sheets

NGO, nongovernmental organizations

PAO, phenylarsineoxide

PCB, polychlorinated biphenyls

PFD, personal flotation device

PVC, polyvinyl chloride

QA/QC, quality assurance/quality control

SOC, suspended organic carbon

TNRCC, Texas Natural Resource Conservation Commission

TOC, total organic carbon

USEPA, U.S. Environmental Protection Agency

USGS, U.S. Geological Survey

VCF, vertical at centroid of flow

INTERAGENCY FIELD MANUAL FOR THE COLLECTION OF WATER-QUALITY DATA

Compiled by Dee L. Lurry[1] and Christine M. Kolbe[2]

INTRODUCTION

Along the United States-Mexico border region, numerous Federal, State, and local agencies; nongovernmental organizations (NGO); and researchers collect water-quality data for many purposes. The water community uses a number of documented and undocumented procedures, some of which have specific data-quality objectives (DQO) and data-information objectives. This mix of procedures results in uncertainties by data users as to data validity and quality. These uncertainties limit the use of the data by the U.S. Environmental Protection Agency (USEPA); International Boundary and Water Commission (IBWC) United States and Mexico; U.S. Geological Survey (USGS); State environmental agencies; NGOs; and the public, as well as their counterparts in Mexico.

The USEPA, IBWC, USGS, and Texas Natural Resource Conservation Commission (TNRCC) have been working cooperatively to establish a Water-Quality Monitoring Council for the international reach of the Rio Grande (Río Bravo). A similar effort is occurring along the western international boundary with interested partners including the U.S. Bureau of Reclamation (BOR), Arizona Department of Environmental Quality (ADEQ), and the California Regional Water Quality Control Board (CRWQCB). As of February 1997, the partners agreed to work towards greater cooperation, specifically:

1. to revise the 1977 Joint Report of IBWC Engineers as specified in IBWC Minute No. 289;
2. to implement a binational Intergovernmental Task Force for Water-Quality Monitoring (ITFM) workgroup by inviting the participation of cooperators from Mexico;
3. to review and revise each agency's existing monitoring network to reduce interagency redundancy;
4. to develop a bilingual manual for water-quality monitoring that would describe various field methods used for sampling water, aquatic biology, and sediment, and for assessing stream habitat; and selection of methods on the basis of DQOs, representativeness, and limitations;
5. to establish a common, easily accessible water-quality database; and
6. to hold joint training programs in water-quality monitoring and data management.

Part of the fourth goal—to develop a field manual for water-sample-collection methods—will be accomplished with the publication of this manual.

[1] U.S. Geological Survey.

[2] Texas Natural Resource Conservation Commission.

Purpose and Scope

The purpose of this interagency manual is to document/compile field water-sample-collection methods (water column only) commonly used by various "participating" agencies for assessing the water quality of international and transboundary rivers. These agencies include the USEPA-Regions VI and IX, IBWC, USGS, BOR, and State regulatory agencies. This document is intended to provide an objective assessment of the benefits and limitations associated with each sampling method to enable the collector to select the field procedure that is most appropriate for the respective agency's needs or individual project's DQOs. This manual covers only water-column sampling of ambient waters of rivers, streams, lakes, and reservoirs. This manual also is not intended to replace agency-specific, detailed guidelines or sampling instructions provided by the USEPA, IBWC, USGS, BOR or State agencies for various water-quality projects. Users of this manual are advised to contact water-quality personnel within their agency for final determinations on sampling procedures, techniques, and protocols. The development of new and improved field techniques is a continuing process. Therefore, this manual might not contain the most recent information after it is printed and distributed. The user should review their agency protocols if there are any questions.

Field Manual Review and Revision

This interagency manual has been reviewed and revised by the following participants: Forrest B. John, USEPA-Region VI; Yusuf Farran and Yvette McKenna, IBWC; and Lloyd Woosley, USGS. Editorial and technical reviews were completed by USGS personnel. Reviews and opportunities to comment were afforded to the Comisión Nacional del Agua (CNA) through the IBWC, Mexican Section. The use of any trade names or materials in this manual does not constitute an endorsement of the product or material by any participating agencies.

Acknowledgments

The preparation of this document was made possible by the USEPA. The information included in this manual is based on existing agency manuals, various reference documents, and a broad spectrum of colleague expertise. The manual compilers wish to thank the following individuals for their contributions: Delores Williams, USGS, manuscript preparation and Clarence E. Ranzau, USGS, photographer.

PLANNING FOR WATER-QUALITY SAMPLING

The quality of water in streams and rivers commonly is determined by selected chemical and physical analysis of water samples collected to represent the water body. Factors to be considered in selecting a sampling method include: (1) the accuracy of sampling necessary to satisfactorily represent the water-quality constituents of interest

so that the specific sampling or data-information objectives can be achieved, and (2) the costs of alternative sampling methods.

The principal sampling methods for determining water quality in flowing water can be classified as

(1) surface grab sampling in which samples are collected in an open container from a single point at, or near, the water surface, and (2) cross sectionally integrated, flow-weighted composite ("integrated") sampling using depth-integrating, nozzled samplers that fill isokinetically. Isokinetic sampling means there is no change in stream velocity as the water enters the sampler intake.

This manual contains sampling methods or techniques that can be selected on the basis of various DQOs as defined in tables 1 and 2. For this manual, these DQOs are associated with data-information objectives linked to constituent groups and where they occur in the water column or phase (table 1). The data-information objectives are defined by the purpose for sampling water quality such as determining compliance with applicable water-quality standards, identifying trends, and so forth. For example (referring to table 1), if nutrients are the constituent group to be examined or sampled for, and gross detection (G) is the data-information objective, then the phase sampled should be W (whole water, which includes dissolved constituents and suspended sediment), and (referring to table 2) DQO I is the key to determining the suggested sampling method. Table 2 defines DQO I as gross detection at a point in a river/stream/lake/reservoir and indicates the sample collector should obtain a qualitative grab sample. Table 2 also includes some of the benefits and limitations of the various sampling methods qualified by factors such as costs, potential for contamination, and appropriate quality-control (QC) investment.

Table 1. Data-quality objectives associated with data-information objectives for occurrence of constituents

[D, dissolved; W, whole water (includes dissolved constituents and suspended sediment); TMDL, total maximum daily load; SS, total suspended sediment; SVOC, semivolatile organic compounds]

Constituent group	Data-information objective	Phase or occurrence of constituent	Data-quality objective (table 2)
Major inorganics/common ions (including total dissolved solids and specific conductance)	PDWS[1], SWQS[2], trends	D, W	II or IV
Nutrients and biochemical oxygen demand	G[3], load (TMDL) Trends	W D, W	I II or IV
Trace metals and other minor elements	PDWS[1] AL[4], HH[5] Load	W D W or D and SS	II, III, IV, or V III or V IV, V, custom SS
SVOCs	AL[4], load, HH[5]	W or SS	V or custom SS
Soluble pesticides	PDWS[1], AL[4], HH[5] Load	D D	III or V V
Bacteria	G[3] PDWS[1], CR[6]	W W	I II or IV
Field parameters (temperature, pH, alkalinity, and dissolved oxygen)	G[3] SWQS[2], AL[4]	W W	I II
Organochlorines	AL[4], load, HH[5]	W or SS	V or custom SS
Suspended sediment	Load, AL[4]	W or SS	IV
Toxicity	AL[4], SWQS[2], G[3]	W	II or IV

[1] Public drinking water standards.

[2] Surface-water-quality standards.

[3] Gross detection/screening.

[4] Aquatic life protection.

[5] Human health protection.

[6] Contact recreation use.

Table 2. Data-quality objectives

No.	Data-quality objective (DQO)	Sampling method		Benefits and limitations
		Precision/ accuracy level	Sample type	
I.	Gross detection at a point in a river/stream/lake/ reservoir	Qualitative	Grab	Very inexpensive; real-time; limited regulatory use; high potential for environmental contamination; requires least rigorous quality-control measures
II.	Detection at a point in a river/stream/lake/ reservoir	ppm[1]	Grab	Less costly than DQO III, IV, and V; high potential for environmental contamination; applicable for dissolved phase and bacteria at well-mixed sites; requires more rigorous quality-control measures than DQO I but less rigorous than DQO III, IV, and V
III.	Low-level detection at a point in a river/stream/ lake/reservoir	ppb[2]	Grab	More costly than DQO I and II; low potential for environmental contamination; applicable for dissolved phase and bacteria at well-mixed sites; requires more rigorous quality-control measures than DQO I, II, and IV
IV.	Detection in a representative cross section of a river/stream/lake[3]/reservoir[3]	ppm[1]	Cross sectional[4]	More costly than DQO I, II, and III; high potential for environmental contamination; applicable for any phase and bacteria at any site; requires more rigorous quality-control measures than DQO I and II but less rigorous than DQO III and V
V.	Low-level detection in a representative cross section of a river/stream/lake[3]/reservoir[3]	ppb[2]	Cross sectional	Most expensive; low potential for environmental contamination; applicable for any phase and bacteria at any site; requires the most rigorous quality-control measures

[1] Parts per million (ppm) accuracy is equivalent to milligrams per liter.

[2] Parts per billion (ppb) accuracy is equivalent to micrograms per liter.

[3] Representative lake or reservoir samples should be obtained by collecting depth-integrated samples with a thief-type or pumping sampler.

[4] Cross sectional as used in this manual denotes a depth-integrated sample composited from various cross sections of the stream channel.

Before sampling begins, a sampling plan should be designed to address the objectives of a water-quality project or program. A sampling plan should include specifics about sampling locations or sites, methods and techniques, number of samples, kinds of samples including: volume of water, filtered or whole, preservatives and holding times, number and kinds of quality assurance/quality control (QA/QC) samples, and desired DQOs. Water-quality sampling can be expensive and time-consuming. Sampling plans help assure that sampling results are error free and meet the objectives of the water-quality project or program. For official guidelines and sampling plan components required by various State and Federal agencies, the user should consult those agencies.

Additional resources available to assist personnel with water-quality sampling plans and execution include but are not limited to:

(1) Federal Interagency Sedimentation Project (FISP) is an independent, interagency project created to unify the research and development of activities of Federal agencies involved in fluvial sediment studies. Research conducted by FISP has expanded to include development of sample-analysis methods, development of automatic in-place analyzers, and techniques and equipment for sampling water quality in streams and rivers. Equipment and techniques of FISP are the standards used by most Federal, State, and local governments and private organizations collecting sediment samples in the United States. The FISP catalog can be accessed electronically on the World Wide Web at http://fisp.wes.army.mil/Catalog%20Index.htm

(2) The National Water-Quality Monitoring Council's purpose is to coordinate and provide guidance and technical support for the voluntary implementation of recommendations presented in "The Strategy for Improving Water-Quality Monitoring in the United States," by government agencies and the private sector (Intergovernmental Task Force on Monitoring Water Quality, 1995). The USGS and USEPA serve on the National Council with the U.S. Department of Commerce/National Oceanic and Atmospheric Administration, the Tennessee Valley Authority, the U.S. Army Corps of Engineers, the U.S. Department of Agriculture, the U.S. Department of Energy, and the U.S. Fish and Wildlife Service. The National Council is the permanent successor to the ITFM.

(3) World Wide Web pages of Federal agencies such as USGS Office of Water Quality and USEPA Office of Water, Office of Wetlands, Oceans, and Watersheds may be accessed electronically at http://water.usgs.gov/owq/ and http://www.epa.gov/OWOW/index.html

Site Selection

If previous sampling sites can be reactivated and used in current plans, they should be considered. Historical water-quality data from these previous sites can provide useful data to the current data-collection effort. If a sampling plan calls for new water-quality sampling sites to be selected, a number of factors should be considered. New sampling sites should be positioned at or near USGS or IBWC gaging stations whenever possible so that stream

discharge can be related to water-quality constituents. If no gaging stations are near the chosen site, discharge measurements should be made at the time of sampling. Consider whether samples can be obtained throughout the entire year at all discharges. If the site is inaccessible during parts of the year, it might not be suitable for the project or program needs. Sampling sites in a river should be located upstream from a confluence in sections where the channel is smoothest, straightest, accessible, and uniform in depth. Avoid locating sites directly above or below confluences or point sources to minimize problems with backwater or poorly mixed flows. Determine if the river or stream is homogenous at the proposed site by measuring temperature, pH, dissolved oxygen (DO), or conductivity at regular intervals and depths across the channel to test the degree of mixing. Because most water bodies are not completely homogenous, the representativeness of samples depends on the equipment and collection method used. Consider the influence of errors that might be encountered during sampling because of turbulence, velocity gradients, and other physical factors that affect the water-sediment mixture. To determine the best site for sample collection, one must consider which site will produce the most representative sample with the least amount of error introduced in obtaining that sample. More details about establishment of a new sampling site are included in the "Preparing for Water-Quality Sampling" section.

A representative sample is one that accurately reflects the chemical composition and the biological and physical characteristics of the whole stream at the sampling point at an instant. Representative samples also reflect changes that occur in ambient water passing a sampling point. Therefore, enough samples must be distributed in time and space to represent those changes.

Once the sampling sites have been determined, the sample collector or project chief must conduct the research and communication to gain legal access to the site(s). Permission to legally access the site and/or erect any construction to facilitate sampling should be obtained in formal writing. This ensures that all owners or operators of the property have communicated their acceptance of the intent to visit and sample on a predetermined basis as outlined in the sampling plan and agree to any necessary construction. Legal access for some Federal, State, or county officials or designated contractors can range from verbal consent to administrative search warrants. Check with your agency regarding its guidelines or requirements on this topic. Establish a good relationship with property owners by offering a copy of the sampling plan and analysis results. Be sure to notify local environmental and health agencies of sampling plans and activities and solicit their advice and expertise. Their local and technical expertise could provide valuable insight.

When sampling international and transboundary rivers along the United States-Mexico border, personnel should always contact the IBWC for directions and requirements for sampling along the international boundary. In some areas along the border, safety issues can be a concern, and the U.S. Border Patrol should always be contacted when devising a sampling plan. Often they are the most knowledgeable about local conditions that could affect the safety

of the sampling personnel. All precautions should be taken to ensure sampling personnel can accomplish their job in a safe manner.

PREPARING FOR WATER-QUALITY SAMPLING

Four factors are crucial to successful and accurate sample collection—personal health and safety, collecting a representative sample, quality control of overall sampling process, and complete and accurate records. Personal health and safety recommendations are included in the "Safety" section below. Collecting a representative sample has been introduced and will be discussed again. Quality control will be reviewed in the "Quality-Assurance Plans and Quality-Control Samples" section. Record keeping will be discussed in this section.

Site Establishment

The basic steps in establishing a new site include locating and describing the sampling station in the data records or database by physical positioning, determining station coordinates, and photographing the station. The location and identification number of a water-quality sampling site should be accurately marked on a USGS topographic quadrangle. Drawing site sketches which show roads, buildings, and other landmarks not on the topographic maps helps locate remote sites for others. Establishing and documenting a new sampling site (if necessary) should be the first step in record keeping.

Finding the physical location could be necessary if the sampling site is not shown on a map. Establish the location of the site by measuring the horizontal distance between the sampling site and other physical features, transfer that distance to a map, and mark the location. Reference features on topographic quadrangles may be roads, buildings, power lines, and water bodies. Methods and devices used to measure distances, in order of decreasing accuracy are: (1) triangulation, (2) electronic distance measurer, (3) tape measure, (4) hip-chain distance measurer, (5) distance measuring wheel, (6) range finder, (7) global positioning system (GPS) (depending on accuracy or sensitivity), (8) pacing, and (9) vehicle odometer.

Station/sampling site coordinates in degrees, minutes, seconds, and fractions of seconds of latitude and longitude should be determined as accurately as practically feasible. Ways to determine coordinates, from least to most expensive, include: using topographic quadrangles, professional land surveying, and digitizing from maps using geographic information system (GIS) technology and/or using portable GPS devices.

Station sites should be photographed on a regular basis for site documentation. On the first visit to the site, take enough photos to establish a complete photo record of the site and its surrounding. Take photos from established and constant photo points such as large trees or boulders. Describe these photo points in the field notes and improvise landmarks (for example, with a pile of rocks) if naturally occurring ones are not available. Include a

person in the photo to show scale. Ideally, two photos should be taken of the site—one from upstream of the sample point looking downstream at the sample point and the other from downstream of the sample point looking upstream at the sample point. Take additional photos if you notice any significant change in the site area. The photographs taken over the lifetime of the site should help document the physical influences and changes that could impact water quality (Arizona Water Resources Research Center, 1995, p. 10–13).

Field Folders/Field Measurements

The use and maintenance of field folders ensures that all necessary information about the sampling site can be found at all times in one single file. Using field folders as a repository for all information pertinent to the operation of a surface-water-quality sampling station/site is a common practice in some agencies. A field folder should contain most if not all of the following information when feasible: associated data or historical information from other databases maintained by Federal, State, and local agencies; land-use information, including aerial photographs; published and unpublished reports; studies and data; geologic maps; and water-table contour maps. An extensive checklist is included in Appendix A.

Field notes are important to the sample-collection process because they are often the only written record of field measurements. Recorded field measurements, site observations, and variances from standard sampling procedures are important documentation for QA/QC and data interpretation. These records could be offered as official and legal documents and should be as legible and complete as possible. Field measurements and observations recorded with indelible ink during each visit to an individual station can include but are not limited to the following:

1. Station name
2. Identification number
3. Sampling data
4. Sampling time
5. Sample collector's name(s)
6. Sample purpose
7. Measured field properties and constituents and values:
    a. Temperature (water and air)
    b. pH
    c. Dissolved oxygen (measured at center of flow whenever possible)
    d. Specific conductance
8. Instantaneous discharge/gage height at the beginning and end of sampling
9. Interim gage heights if substantial changes occur during sampling
10. Sampling conditions such as:
    a. Location (for example, wading, bridge)

b. Site (for example, open channel, pool) and stream use
c. Method/equipment used

11. Stage conditions and biological activity
12. Weather—current and recent precipitation
13. Water appearance, unusual odors
14. Miscellaneous notes including cross-sectional measurements, watershed or instream activities
15. Sample types collected—chemical/biological/quality assurance
16. Tag or tracking numbers for samples shipped to laboratory
17. Blank water lot numbers, bacteria counts, and any missing parameters

Field measurements are the determinations of physical properties or chemical constituents that are measured onsite, as close as possible in time and space to the media being sampled. Measurements of water temperature, pH, alkalinity, DO, and specific conductance could change dramatically within a few minutes or hours after sample collection. Therefore field measurements of these properties are required if representative results of in-stream conditions are to be obtained. Field measurements, field notes on sampling methods or equipment used, site observations, and calibration information should be recorded on field forms for later reference. These field forms or notes may vary in format.

Instrument logbooks also should be used to track instrument performance, maintenance, and calibration. These logbooks should be maintained and reviewed before each field trip. The operation and calibration of all field instruments (including back-up meters and electrodes) should be checked to ensure that all are in good working condition. Test each instrument (meter and sensors) before leaving for the field. Practice your measurement technique if the instrument or measurement is new to you. Make field measurements only with calibrated instruments. Calibrate instruments according to manufacturer guidelines or operations manual.

Before making field measurements, sensors must be allowed to equilibrate to the temperature of the water being monitored. Allow at least 60 seconds (or follow the manufacturer guidelines) for sensors to equilibrate with sample water. Sensors have equilibrated adequately when instrument readings have stabilized. Record the median of the final three or more readings as the value to be reported for that measurement point. When field measurements are made with a multiparameter instrument, it is preferable to place the sonde in the water body to be sampled and allow it to equilibrate in the DO mode while the streamflow is measured. Field measurements should be made in-place if possible (at the centroid of flow) if the stream visually appears to be completely mixed from bank to bank. In-place measurement is necessary to avoid changes in chemical properties of anoxic water. Subsample measurements are necessary for alkalinity determinations. Flowcharts of general in-place and subsample field-measurement procedures are shown in figures 1 and 2.

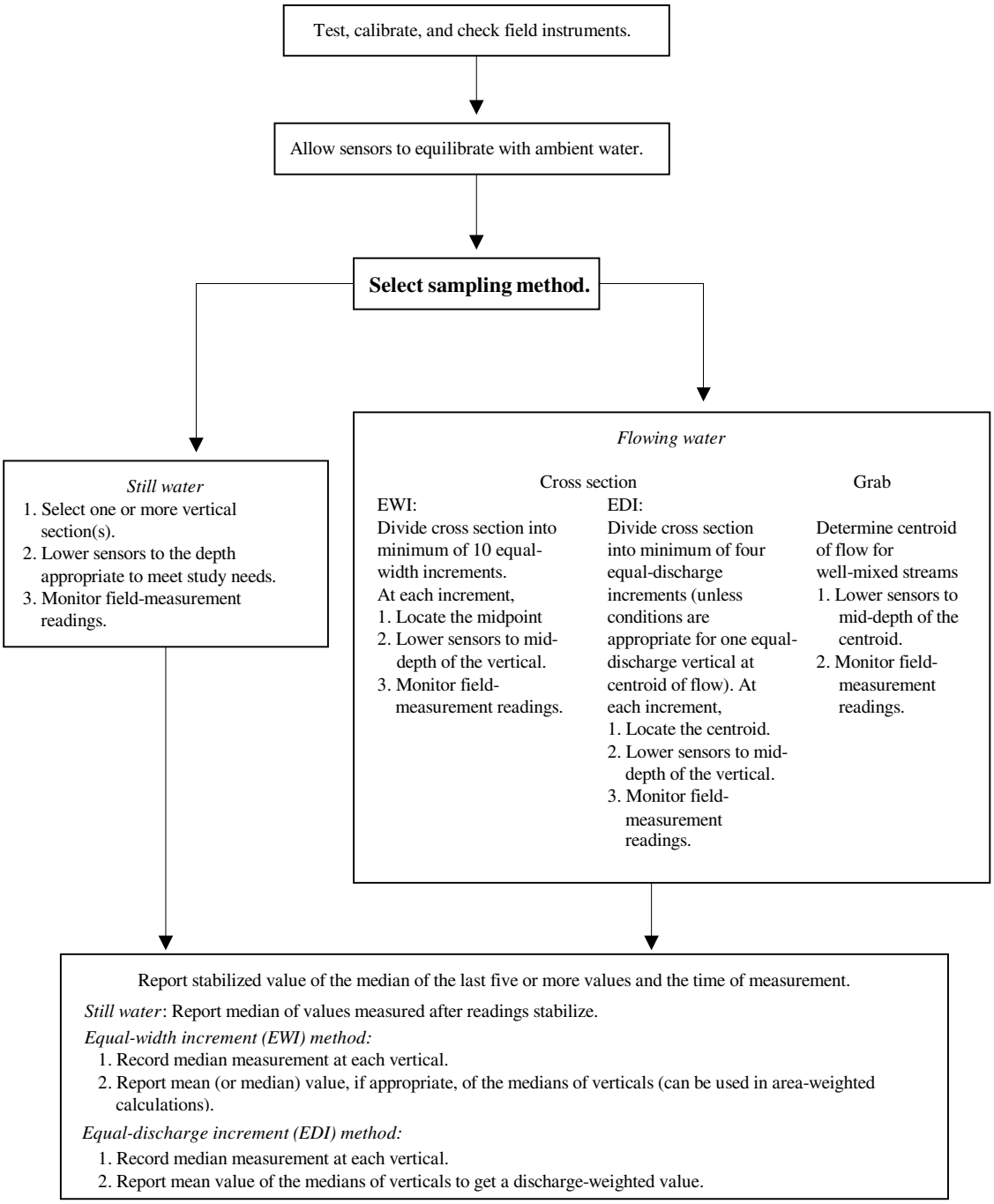


Figure 1. In-place field-measurement procedures (from Wilde and Radtke, 1998).

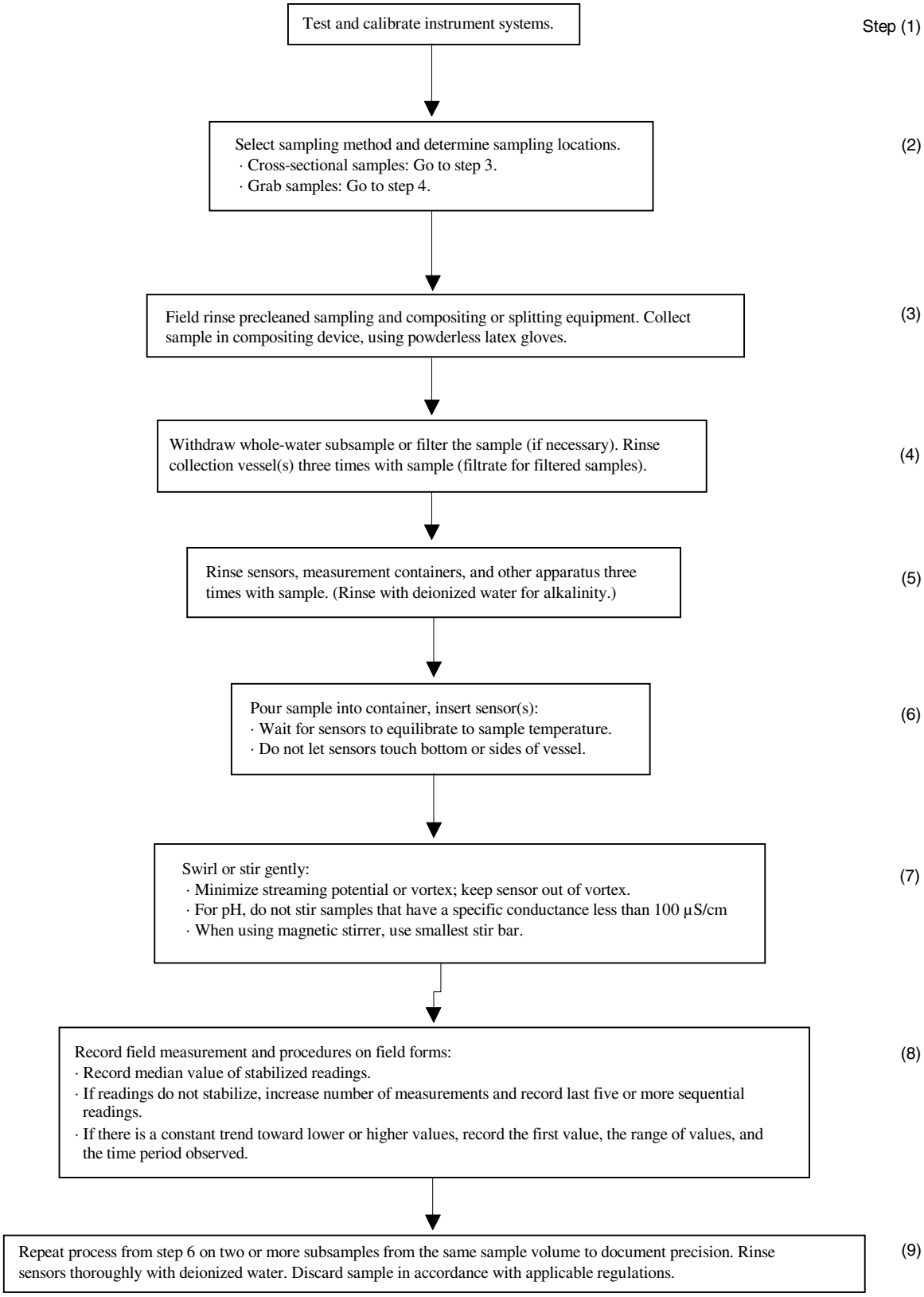


Figure 2. Sub-sample field-measurement procedures for conductivitity, pH, and alkalinity (from Wilde and Radtke, 1998).

If the water depth for a grab sample is less than 1.5 ft, field measurements should be made at a depth equal to one-third of the water depth measured from the water surface. If the water depth at the sampling point is greater than 1.5 ft but less than 5 ft, temperature, pH, DO, and specific conductance should be measured at 1 ft below the surface. If the water depth at the sampling point exceeds 5 ft, a vertical profile of temperature, pH, DO, and specific conductance should be made using a multiparameter instrument. When it is not possible to do a profile of field measurements, these measurements should be reported at a water depth of 1 ft. When sampling reservoirs, bays or estuaries, and barge or ship channels that are 5 to 9 ft deep, measurements should be recorded at depths of: 1 ft below the surface, mid-depth, and 1 ft above the bottom. For the same water bodies that are 10 ft or greater in depth, measurements should be recorded at 1 ft below the surface and at each 5-ft interval below the surface. If the distance from the last measurement to the bottom is greater than 5 ft, take a measurement at 1 ft above the bottom. If the distance is equal to or less than 5 ft, do not take another measurement. If the total depth exceeds 60 ft in reservoirs, intervals can be extended to 10 ft. All intervals should be equal. In coastal ship channels that are 10 ft or greater in depth, measurements should be recorded at 1 ft below the surface and at each 10-ft interval below the surface. If the distance from the last measurement to the bottom is greater than 5 ft, take a measurement at 1 ft above the bottom. If the distance is equal to or less than 5 ft, do not take another reading.

Streamflow

For sites where a flow measurement is necessary, always measure flow, read the USGS or IBWC flow gage, or obtain a flow value at a later date from the USGS or IBWC. Measure and record flow after recording visual observations. Do not collect water samples in the area disturbed during a flow measurement. At sites with a USGS or IBWC flow gage, observe and record the gage height to the nearest hundredth of a foot in the field logbook. Contact the office responsible for the gage and obtain the flow (in cubic feet per second) that corresponds to the gage height. If there is any doubt about the accuracy of the gage-height reading, sampling personnel should measure the flow if possible. USGS gage heights can be measured by one of the three methods: staff gage, wire weight, or bubble gage. Staff gages are black and white steel plates with the appearance of large measuring tapes bolted to a stable structure. Gradations in feet, tenths of a foot, and two-tenths of a foot should be recorded (where the water level hits the gage) to the nearest hundredth of a foot. Wire-weight gages house a weight attached by wire cable to a graduated reel (gradations are tenths and hundredths of a foot) with a counter at one end. The weight should be lowered to touch the surface of the water (causing a slight ripple). At that position, the counter value should be recorded to the nearest whole number and the point indicated by the stylus on the graduated reel to the nearest hundredth of a foot. The wire-weight gage could be a movable type to accommodate braided streams. If the gage needs to be moved, use the correction value on the bridge near the repositioned gage location.

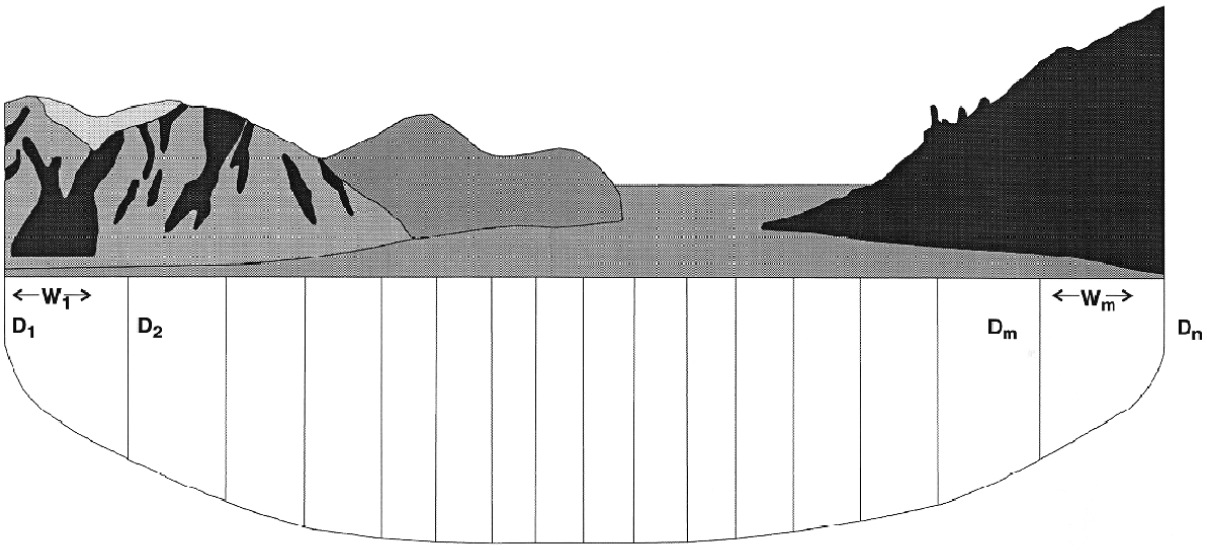
Bubble gages are installed in USGS gage houses, which are locked with a USGS key. The bubble gage uses a data logger attached to a pressure transducer system to indicate gage height in feet. Gage houses can also contain stilling wells with staff gages on the inside wall of the well. If no nearby USGS flow gages can be accessed to determine streamflow, personnel should measure flow. A summary description of the USGS conventional current-meter flow-measurement procedure is included here for general guidance (mid-section method to determine discharge). A current-meter measurement is the summation of the products of individual subsection areas of the stream cross section and their respective average velocities. In the mid-section method of computing a flow measurement, it is assumed that the velocity sample at each vertical represents the mean velocity in the individual subsection areas.

Flow-measurement equipment required includes: (1) current meter or flowmeter, (2) top-setting wading rod (marked in tenths of a foot), and (3) tape measure or tagline (marked in tenths of a foot). The current meter or flowmeter brands or equivalent can be: Marsh-McBirney electronic, Montedoro-Whitney electronic, Price pygmy (with timer and beeper), Price meter, or Type AA (with Columbus weight).

The first step in streamflow measurement is selecting a cross section across the total width of the stream. Select a straight reach where the streambed is uniform and relatively free of boulders and aquatic growth. The flow should be uniform and free of eddies, dead water near banks, and excessive turbulence. If necessary and possible, modify the measuring cross section to provide acceptable conditions by building dikes to cut off dead water or removing rocks, weeds, and debris in the reach of the stream 1 to 2 m upstream from the cross section. After modifying a streambed, allow the flow to stabilize before starting the flow measurement. Determine the width of the stream by stringing a measuring tape from bank to bank at right angles to the direction of flow. Next, determine the spacing or width of the verticals. Space the verticals so that no subsection has more than 5 or 10 percent of the total discharge within it (according to agency guidelines). If the stream width is less than 5 ft, use vertical spacing widths of 0.5 ft. If the stream width is greater than 5 ft, the minimum number of verticals is 10 or 25 (according to agency guidelines). The preferred number of verticals is 20 to 30. At the first vertical in a stream greater than 2.5 ft deep, face upstream (stand at least 1.5 ft downstream and off to one side of the flow sensor) and lower the velocity meter to the channel bottom; record its depth, then raise the meter to 0.8 and 0.2 of the distance from the stream surface, measure the water velocities at each level, and average them. The top-setting wading rod allows the user to easily set the sensor at 0.8 and 0.2 of the total depth by using the markings on the rod. Each single mark represents 0.10 ft, each double mark represents 0.50 ft, and each triple mark represents 1.00 ft. If the depth is less than 2.5 ft, only one measurement is required at each vertical measurement section, at 0.6 of the total depth.

The wading rod should be kept vertical and the flow sensor kept perpendicular to the tape rather than perpendicular to the flow while measuring velocity with an electronic flowmeter. When using a pygmy meter, the instrument should be perpendicular to the flow. Move to the next vertical and repeat the procedure until you reach the opposite

bank. Once the velocity, depth, and distance of the cross section have been determined, the mid-section method can be used for determining the discharge (formula in fig. 3). Compute the discharge in each increment by multiplying the averaged velocity or single velocity in streams less than 2.5 ft deep in each increment by the increment width and averaged depth (or single depth in streams less than 2.5 ft deep). (Note that the first and last increments are located at the edge of the stream and have a depth and velocity of zero.) Add the discharges for each increment to compute total stream discharge. Record the flow in liters (or cubic feet or cubic meters) per second in your field book.



$$Q = \left(\frac{D_1 + D_2}{2}\right)\left(\frac{V_1 + V_2}{2}\right)W_1 + \ldots + \left(\frac{D_m + D_n}{2}\right)\left(\frac{V_m + V_n}{2}\right)W_m$$

Q = discharge, D = depth, V = velocity, W = width (Rantz and others, 1982).

Figure 3. Stream cross section illustrating mid-section method to determine discharge.

Temperature

Field measurements of temperature should include both air-temperature and water-temperature readings. Because of possible environmental contamination if broken, mercury-filled thermometers should not be used. Field temperatures should be determined using a thermistor. A thermistor is an electrical device made of a solid semiconductor that has a high temperature coefficient of resistivity. Thermistor calibration should be checked in the laboratory or office using an American Society for Testing and Materials (ASTM) thermometer. Air-temperature readings should be made by placing a dry thermistor in a shaded area protected from strong winds, but open to adequate air circulation. Avoid areas that might have radiant heat such as near metal walls or sides of vehicles.

Allow the thermistor to equilibrate 3 to 5 minutes before recording the temperature. Water temperatures should represent the mean temperature of the stream at the time of the observation. A horizontal and vertical cross-section profile will determine the variability, if any. Streams with highly variable temperature profiles should have several readings averaged to use as the mean, and those variations should be documented. Streams with fairly uniform temperatures (less than 2 ºC variance 95 percent of the time) generally will have one measurement that can be made and reported as the stream temperature. In wadeable streams, stand so that a shadow is cast upon the site for the temperature measurement. Hold the thermistor or probe by its top and immerse it in the water. Allow it to stabilize for at least 1 minute, then read and record the temperature to the nearest 0.1 ºC without removing from the water. When temperature cannot be measured in-stream, it should be measured in the container used for the collection of water samples. The following conditions must be met when measuring temperature from a container.

- The container must be large enough to allow full immersion of the thermistor or probe.
- The container must be brought to the same temperature as the water before it is filled.
- The thermistor or probe must be placed in the container immediately, before the temperature changes.
- The container must be shaded from direct sunlight and strong breezes before and during temperature measurement.
- The thermistor or probe must be allowed to equilibrate for at least 1 minute before temperature is recorded.
- After these measurements are made, this water should be discarded and another sample of water should be drawn for the water samples to be sent to the laboratory.

pH

Calibrate the pH sensor according to manufacturer directions. The pH function should be calibrated each day of use for multiparameter instruments. To detect any drift in instrument reading during the course of sampling, postcalibration often is recommended.

In-Place Method

Preferably, pH is measured directly in-stream at the depth(s) specified earlier in this section. Allow the pH probe to equilibrate for at least 1 minute before pH is recorded to the nearest 0.1 standard unit.

Subsample Method

If pH cannot be measured in-stream, it should be measured in the container used for water-sample collection. The precautions that must be taken when using a container to make field measurements of pH are the same as those specified in the “Temperature” section above.

If the pH-meter value does not stabilize in several minutes, out-gassing of carbon dioxide or hydrogen sulfide, or settling of charged clay particles might be occurring (Wells and others, 1990).

- If out-gassing is suspected as the cause of meter drift, collect another water sample, immerse the pH probe, and read the pH at 1 minute.
- If suspended clay particles are the suspected cause of meter drift, allow the sample to settle for 10 minutes, then read the pH in the upper layer of sample without agitating the sample. With care, pH can be measured accurately to the nearest 0.1 standard unit.

Alkalinity

Measuring alkalinity in the field is useful because it can be used to check the cation-anion balance of a solution. When all major cations and anions have been determined, the sum of the cations, in milliequivalents per liter, should equal the sum of the anions expressed in the same units. In almost all natural waters, alkalinity can be assigned entirely to bicarbonate and carbonate, two of the three major anions. Alkalinity, which refers to the acid-neutralizing capacity (ANC) of solutes in a water sample, is reported in equivalents (or milliequivalents or microequivalents) per liter and consists of the sum of titratable carbonate and noncarbonate chemical species in a filtered water sample. Alkalinity and concentrations of bicarbonate, carbonate, and hydroxide species are determined using either the inflection point titration (IPT) method or the Gran function plot method to analyze the titration data. The IPT method is adequate for most waters and study needs. The IPT and Gran methods require electrometric titration of a sample with incremental additions of sulfuric acid (H_2SO_4) of specified normality. A digital titrator is popular because it is more convenient and less fragile than a buret and keeps the acid in a virtually closed system. The following equipment and supplies are used for alkalinity digital titrations:

1. pH meter with automatic temperature compensator; calibrated electrode
2. Thermometer, calibrated
3. Stirrer, magnetic with Teflon™ stir bars, or glass stir rods
4. Volumetric pipets, class A—25, 50, and 100 mL
5. Pipet squeeze bulb or pump
6. Sample bottle, 500 mL
7. Beakers—50, 100, and 150 mL
8. Titrant solution, sulfuric acid solution (pre-filled cartridges are commercially available for 0.1600*N* or 1.600*N* solutions)

Note: Most natural waters require 0.1600*N* acid, and common sample volumes are 50 or 100 mL in 100 or 150 mL beakers, respectively.

The following steps summarize alkalinity titration procedures:

- Calibrate pH system.
- Collect representative sample; filter subsamples for alkalinity.
- Field-rinse sample bottles with sample (or filtrate).
- Fill bottles completely and cap tightly; maintain sample at ambient water temperature until titration.
- Rinse electrodes, sensors, beaker, stir bar, and delivery tube with deionized water (DIW).
- Place small-size stir bar in beaker.
- Select and record titration method, subsample volume, and titrant normality.
- Digital system: Assemble titrator, bleed delivery tube, and set counter to zero.
- Buret system: Fill clean, dry buret with titrant—purge trapped air bubbles.
- Pipet appropriate volume of sample into beaker.
- Place beaker on stirrer; insert electrodes and temperature sensor (away from bottom or sides).
- Stir gently—do not splash; minimize vortex.
- Record initial time, pH, temperature, sample volume, normality, and counter reading if using digital system.
- Add titrant, stir for 15 to 20 seconds, read and record pH.
- Repeat until titration is complete.

If pH is greater than 8.1, titrate slowly (to determine carbonate species) in small increments, to less than 8.1 pH.

Slowly add titrant in replicate increments no greater than 2 to 3 digital counts until pH of the sample is about 8.0, to determine the carbonate inflection point. Record pH and digital counter reading after each addition of the titrant. Larger increments can be used for samples containing high carbonate concentrations.

If pH is less than 8.1, titrate rapidly, in large increments, to pH of 5.5 (for specific conductance less than 100 µS/cm) and pH not less than 5.0 in carbonate systems. Continue titration in small increments to 4.0 pH.

If pH is less than 5.0, titrate cautiously, in increments of 1 to 3 digital counts from pH 5.0 to 4.0. The most sensitive part of the titration is between pH 4.8 and 4.3 for many natural waters. Titrate to lower pH if noncarbonate contribution is large.

Compute alkalinity in the field using the following equation:

$$\text{Alkalinity (meq/L)} = \frac{\text{mL}_{\text{acid}} \times N\ (\text{meq/mL}_{\text{acid}}) \times 1{,}000\ (\text{mL/L})}{\text{mL}_{\text{sample}}}.$$

To determine concentrations of carbonate alkalinity and contributing species, plot the change in pH divided by the change in digital counts against the digital counts of the titrant or the tabulate the change in pH divided by the

change in digital counts. The factors and equations used for the 0.1600*N* titrant cartridges (commonly used for natural systems) are as follows:

(Note: milliliters of acid used is shown as digital counts for Hach^{TM} titrator)

$$\text{Alkalinity (meq/L)} = \frac{B\,(D3)\,(C_{acid})}{mL_{sample}},$$

$$\text{Carbonate (mg/L as } CO_3) = \frac{A\,(D1)}{mL_{sample}},$$

$$\text{Bicarbonate (mg/L as } HCO_3) = \frac{(B - 2A)\,(D2)}{mL_{sample}},$$

$$\text{Hydroxide (mg/L as OH)} = \frac{(A - C)\,(D4)}{mL_{sample}}, \text{and}$$

$$\text{Alkalinity (mg/L as } CaCO_3) = \frac{B\,(D3)}{mL_{sample}},$$

where

mL_{sample} = volume of the sample, in milliliters,

A = digital count from the initial pH to the inflection point near 8.3,

B = digital count from the initial pH to the inflection point near 4.5,

C = digital count from the inflection point near 8.3 to the inflection point near 4.5,

D = digital titration factor, and

C_{acid} = concentration of the acid.

D1 for 0.1600*N* titrant = 12.0; D2 = 12.2; D3 = 10.0; and D4 = 3.4. (Note: D can be recomputed by powers of 10 depending on the normality of the titrant from 1.600*N* to 0.01600*N*; for example, D1 for 1.600*N* titrant would be 120, and so forth.)

Dissolved Oxygen

Dissolved oxygen (DO) is the oxygen freely available in water. DO can be measured either by the Winkler tritration method or with a DO meter, preferably in place at the depth(s) specified earlier in the "Field Folders/Field Measurements" section. Refer to instrument manual for specific calibration requirements.

Multiprobe Instrument

Calibrate the DO sensor on the multiprobe instrument. The DO probe must equilibrate for at least 90 seconds before DO is recorded to the nearest 0.1 mg/L. Care must be taken at profile stations to ensure that the reading is stable for each depth. Because DO takes the longest to stabilize, record this parameter after temperature, pH, and specific conductance. If the DO probe has an operable, automatic stirrer attached, the DO probe does not have to be

manually stirred. However, if the probe is not equipped with an automatic stirrer, manual stirring must be maintained by raising and lowering the probe at a rate of 1 ft/s without agitating the water surface. If the stream velocity at the sampling point exceeds 1 ft/s, the probe membrane can be pointed upstream into the flow and manual stirring can be avoided (Wells and others, 1990). To detect any drift in instrument readings during the course of sampling, postcalibration often is recommended.

Winkler Titration Method

If the electronic DO probe is inoperable, DO should be measured by Winkler titration (Texas Natural Resource Conservation Commission, 1997). A Winkler titration kit includes:

- Two 300-mL biochemical oxygen demand (BOD) bottles with stoppers (may substitute a 300-mL Erlenmeyer flask for titration).
- One sewage sampler.
- Manganous sulfate powder pillows.
- Alkaline-iodide-azide reagent powder pillows.
- Sulfamic acid powder pillows.
- 10-mL pipettes; 200- or 250-mL graduated cylinder.
- 0.025*N* phenylarsineoxide (PAO) (replace annually or as needed in field kit).
- Stable starch reagent indicator solution. (Starch solution is stable for 1 month under field conditions. It should be renewed from stock, which is stable for up to 1 year in refrigerator.)
- Scissors or knife for opening powder pillows.

The following steps summarize Winkler titration procedures:

1. Collect a sample for titration by placing a 300-mL BOD bottle in a sewage sampler and lowering the top of the sewage sampler to a depth of 1 ft.
2. The sewage sampler will fill in 30 to 45 seconds.
3. The sampler is filled with water when it ceases bubbling.
4. The sewage sampler should not be withdrawn until it has filled completely.
5. The sampler should be carried upright until the BOD bottle is removed.
6. Carefully remove the BOD bottle from the sewage sampler.
7. The bottle should be filled to the top of the lip.
8. Gently pour the upper 3 to 4 mL of water out of the flared mouth of the bottle.
9. Add the contents of one manganous sulfate powder pillow to the full bottle.
10. Add the contents of one alkaline-iodide-azide reagent powder pillow to the full bottle.
11. Incline the bottle slightly and recap with a glass stopper in a quick, twisting thrust.

12. Do not allow air bubbles to be trapped in the bottle. Sometimes this can be accomplished by just touching the top of the liquid with the stopper tip and then dropping it into position.
13. Invert the bottle at least 25 times to mix completely and then set the bottle aside out of direct sunlight.
14. A brown flocculent indicates the presence of DO. Allow the flocculent to settle halfway down the bottle (approximately 5 minutes).
15. Invert the bottle another 25 times and let the flocculent settle once again. The flocculent will settle very slowly in sea water, which requires a minimum of 2 minutes reaction time. Results will not be affected if the flocculent refuses to settle or if some of the reagent powder does not dissolve.
16. When the flocculent has settled after the second inversion so that the upper one-third of the bottle is clear, or after waiting 2 minutes, add the contents of one sulfamic acid powder pillow.
17. Recap and gently invert the bottle another 25 times until all the flocculent has disappeared. The solution should be clear and straw-colored in appearance. The intensity of the yellow color is related directly to the original concentration of DO in the sample. A clear, pale solution indicates a very low DO concentration. A dark, clear, yellow solution indicates a high DO concentration.

Samples prepared with the addition of sulfamic acid can be stored for 4 hours before completion of the Winkler titration. Samples can be stored for a maximum of 6 hours in the dark if the bottle is stored at the temperature of collection or water-sealed by putting water around the lip and kept at 10 to 20 °C (American Public Health Association, 1995).

As soon as the precipitate has completely dissolved as a result of acidification, the sample is ready to titrate.

18. Use a clean, graduated cylinder to transfer 200 mL of the solution to a 300-mL BOD bottle or Erlenmeyer flask.
19. Place the flask on a magnetic stirrer, if this equipment is available. Otherwise, use a pipet and bulb, swirling the sample by hand.
20. Stir the sample at a moderate rate without aerating the sample. Titrate with 0.025*N* PAO until the solution is pale straw-yellow in color.
21. Add 1 to 2 mL of stable starch reagent and note the blue color, which indicates the presence of iodine. A few drops should give the blue indicator color (not gray). If more than 1 or 2 mL are needed to produce the color, the sample titration results should be rejected and the starch solution replaced.
22. Continue the titration just until the blue color disappears. Do titration against a white background. This step requires either continuous stirring or vigorous swirling to ensure that the titration endpoint is accurate. Disregard the reappearance of the blue color after a few minutes.

The total volume (in milliliters) of PAO used in the titration is equal to the DO concentration, expressed in milligrams per liter. The DO concentration from the titration should be recorded to the nearest 0.1 mg/L. For a 200-

mL sample, the volume of titrant added is directly proportional to the DO concentration in milligrams per liter. To compute DO for a sample greater or less than 200 mL, use the following formula:

$$\text{DO (mg/L)} = \frac{200}{\text{sample volume x titrant added (in mL)}}.$$

Corrections to Dissolved Oxygen Measurements Made With Dissolved Oxygen Meters

Some DO meters report measurements that are not compensated for salinity. Field DO measured with meters that are not salinity compensated and that are measured in waters with specific conductance exceeding 1,800 µS/cm, must be corrected. This correction is made by multiplying the field DO concentrations by a correction factor, which is computed from the following formula:

$$F = 1 - \frac{[0.003439 + 0.361]}{(22.1 + T)^2} \times \frac{C}{1{,}000},$$

where

F = adjustment factor;

T = water temperature in degrees Celsius; and

C = specific conductance in microsiemens per centimeter,

$$\text{Corrected DO} = \text{field DO} \times F.$$

The sample collector should record the corrected DO concentration.

Specific Conductance

Preferably, specific conductance is measured directly in-stream at the depth(s) specified in the previous section, “Field Folders/Field Measurements.” Calibrate the conductivity meter in the lab or field as indicated by agency guidelines. Standards of known conductivity are required for calibration of multiprobe instruments. Conductivity standards should be high enough to encompass expected stream conductivities. This can be obtained from historical data or general knowledge of an area. Allow the conductivity probe to equilibrate for at least 1 minute before specific conductance is recorded to three significant figures (if the value exceeds 100). The primary physical problem in using a specific conductance meter is entrapment of air in the conductivity probe chambers, which is indicated by unstable specific conductance values fluctuating to as much as 100 µS/cm. The entrapment of air can be minimized by slowly, carefully placing the probe into the water; when the probe is completely submerged, move it through the water quickly to release any air bubbles. To detect any drift in instrument readings during the course of sampling, postcalibration often is recommended.

If specific conductance cannot be measured in-stream, it should be measured in the container used for collection of water samples using the precautions outlined in the “Temperature” section.

Chlorine Residual

Chlorine residual should be analyzed on samples collected downstream of chlorinated effluent discharges or in areas where the presence of chlorine is suspected. Chlorine has an effect on fecal coliform samples, BOD, cyanide, and pesticides/herbicides. If chlorine is present in samples to be analyzed for BOD, cyanide, or pesticides/herbicides, the samples must be treated with sodium thiosulfate to remove the chlorine. Chlorine residual should be analyzed on a grab sample using the *N*,*N*-diethyl-*p*-phenylenediamine (DPD)-ferrous ammonium sulfate (FAS) titration or using the DPD colorimetric procedure.

Chlorine residual DPD-FAS titration procedure:

A standard solution of FAS must be made up fresh monthly and stored in a cool, dark place. It is recommended that small amounts of the standard solution be carried into the field and replaced daily. The following is the procedure for making FAS:

Make a small amount of (1:3) sulfuric acid (H_2SO_4) by adding 5 mL of concentrated H_2SO_4 to 15 mL of water in a 200-mL beaker. CAUTION: ALWAYS ADD ACID TO WATER. A large beaker is required so that the heat generated by the mixing of acid to water will dissipate. This solution can be stored in an amber glass bottle.

In a 1,000-mL volumetric flask, add approximately 500 mL of distilled water and then add 1 mL of (1:3) H_2SO_4. Add 1.106 g of FAS crystals to this solution. After the crystals are completely dissolved, add enough distilled water to bring the volume to exactly 1,000 mL. Transfer the FAS solution to a dark plastic bottle. Invert the bottle several times to mix the solution. Store in a cool, dark place.

Analysis for Chlorine Residual

Measure 100 mL of sample in a graduated cylinder and transfer to a 250-mL Erlenmeyer flask or beaker. Add the contents of four DPD powder pillows for total chlorine analysis. If chlorine is present, a red or pink color should develop. High chlorine residuals might produce a temporary red color followed by a yellow color. If this occurs, perform the analysis using a smaller volume of sample diluted to 100 mL with distilled water.

Fill a pipette with FAS and titrate until the red color disappears. Record the volume of FAS used. Disregard the reappearance of the pink color after a few minutes.

If manganese is present in the sample, it will interfere with the chlorine residual analysis and must be corrected. Collect the same volume of sample (100 mL) and add 0.5 mL of sodium arsenite solution (5 g/L) and four DPD powder pillows for total chlorine analysis. Wait 3 minutes, then titrate until the red color disappears and record the volume of FAS used.

To compute the chlorine residual, use the following formula:

$$\text{mg/L of total chlorine} = \text{mL FAS used} \times 100 \text{ mL of sample used.}$$

Fecal Indicator Bacteria

Fecal indicator bacteria are used to assess the quality of water because they are not typically disease causing but are correlated to the presence of several waterborne disease-causing organisms (pathogens). The concentration of indicator bacteria (the term “indicator bacteria” is used synonymously with fecal indicator bacteria in this document) is a measure of water safety for contact recreation or for consumption. The identification and enumeration of indicator bacteria measure the sanitary quality of water.

To collect samples for indicator bacteria in flowing streams, dip the sample container (sterile, unrinsed) to a depth of about 4 in. with the open end facing upstream. Push the mouth of the container upstream at this depth until the container is nearly full. The mouth of the container should at all times be upstream of the sample collector, sampling apparatus, and any disturbed sediments. To collect samples for bacteria in reservoirs and coastal waters, dip the container to a depth of about 4 in. The mouth of the container should be pushed at this depth away from the boat, sample collector, sampling apparatus, and any disturbed sediment. Leave enough airspace (5 to 10 mL) in the top of the sample container to help mix the sample when it is shaken just before filtration. Bacteriological samples should be collected at the same locations as field measurements and water-quality samples.

Always use a sterile container such as a new Whirlpak bag or precleaned (autoclaved) plastic or glass bottle to collect the sample. Immediately chill samples in an ice chest or refrigerator at 1 to 4 °C. Do not freeze samples. Begin analyses as quickly as possible, preferably within 1 hour but not more than 6 hours after sample collection, to minimize changes in indicator bacteria density.

The membrane filtration (MF) and most probable number (MPN) methods are used for the identification and enumeration of indicator bacteria. For general use, the MF method is preferable to the MPN method because it is easy to do, does not require a formal laboratory setting, and can be used to process samples in the field. Portable incubators that run off car batteries are available for analyzing fecal coliform samples in the field. MF analysis requires several types of media and reagents, which are dependent on the indicator. The necessary media and reagents include sterile buffered water (buffer), agar- or broth-based selective and differential growth media, and media and reagents for additional biochemical identification. Buffer is used to dilute samples and to rinse the MF apparatus and utensils. It can be purchased from laboratories of use. Culture media (usually available in premeasured packages or ampules) can be obtained from certain laboratories or supply companies. Follow instructions for storage and use.

The following steps summarize the MF method:

- Filter a minimum of two subsamples of different volumes from each sample collected. The objective is to filter a volume that will result in the optimum number of 20 to 60 fecal coliform colonies on the filter. The volume(s) filtered will depend on the source of the sample(s). The more contaminated the sample, the smaller the volume filtered. This is the reason for multiple subsamples. If possible, check historical data for an idea of expected fecal coliform concentrations.
- Prepare petri dishes according to agency guidelines with m-FC media. This media is a broth formulated to promote the growth of fecal coliform organisms. It contains rosolic acid to inhibit growth of nonfecal organisms and aniline blue dye to stain the fecal colonies blue. A minimum of two petri dishes per sample plus one petri dish for a blank are needed.
- Label the top and bottom of each petri dish with the appropriate station identifier and number of milliliters of sample to be filtered. The top label is convenient when filtering the sample, and the bottom label is convenient when the samples are inverted in the incubator. The bottom label is also a good idea if the lid is somehow separated from the bottom. If samples are run on successive days, it might also be helpful to add the date.

Note: Always refrigerate bacterial media until it is expired and avoid exposure to warm temperatures in a vehicle.

- As recommended by more experienced personnel, filter the least contaminated samples first.
- Assemble the filtration equipment apparatus and connect the vacuum pump. Rinse the filter assembly thoroughly with buffer by pulling several rinses through the filter apparatus. This will remove traces of alcohol and formaldehyde generated by the sterilization procedure.
- Place a sterile, 0.45-μm membrane filter on the filter apparatus using sterilized forceps. Sterilize forceps each time before they are used to move the filter. Forceps are sterilized by dipping the tips into methanol, then burning the methanol off. The flame merely burns off the methanol, the methanol acts as the disinfectant. The forceps should grasp the filter near outside edge without touching the area covered by the filtered sample.
- Wet the filter with a few milliliters of buffer to aid the distribution of the bacteria onto the filter.
- If the sample volume to be filtered is less than 10 mL, add at least 10 to 50 mL of buffer to the filter funnel.
- Shake the sample vigorously 25 times and quickly pipet the desired volume into the filter funnel. Bacteria are associated with particles in the water, and the vigorous shaking breaks up the particles and disperses the bacteria.
- Apply a moderate vacuum to filter the sample.
- Rinse the filter funnel twice with buffer.
- Release the vacuum from the filter apparatus and remove the filter from the filter apparatus to the appropriately labeled petri dish.

- Place a new filter on the filter apparatus and repeat the filtration steps with another subsample of the same sample.
- Reassemble the filter apparatus without a filter and rinse the filter apparatus thoroughly (a minimum of three rinses) with buffer between each sample.
- Repeat the MF method with each additional sample. Discard the used pipette and use a new, sterile pipette for each additional sample.
- Place the labeled petri dishes UPSIDE DOWN in an incubator set at an incubation temperature of 44.5 °C. When the dishes are upside down, condensation does not form on the lid, and the pad (if used) is less likely to dry out. Record the beginning incubator temperature on the field sheets or in the field logbook.

The following sterilization procedure is best performed when filtering is finished for the day. If the apparatus has been sterilized in this manner before storage, this step does not need to be done at the beginning of the next filtering exercise.

- Remove the stainless-steel beaker from the filter assembly. Saturate the asbestos wick around the base of the filter assembly with methanol. Ignite the methanol on the asbestos wick and allow the wick to burn for 30 seconds.
- Place the stainless-steel beaker tightly over the filter assembly and leave the beaker in place for 15 minutes or until the next time the apparatus is used. The oxygen is consumed by the burning, and formaldehyde gas is produced by incomplete combustion. About 15 minutes of contact time is necessary to ensure sterilization.

To run a blank, follow the same procedure as above but use about 20 mL of buffer. The blank helps monitor the effectiveness of the method. If colonies appear on the blank, all data from samples that were filtered at the same time as the blank should be discarded. A minimum of one blank should be run per group of samples analyzed.

Record the volumes of samples filtered each time, the time and the date the samples were collected and filtered, and the initial temperature of the incubator. Incubate the fecal coliform samples for 22 to 24 hours at 44.5 °C ± 0.2 °C. At the end of the incubation period, record the incubator temperature and the time the samples were removed from the incubator.

The field sheets or field logbook should contain the following information about the bacteriological analyses:

1. Sampling station number and location
2. Date and time of sample collection
3. Volume of sample filtration
4. Number of fecal coliform colonies counted on each filter
5. Pertinent observations; for example, confluent growth, abnormal coloration
6. Incubator temperature at beginning and end of incubation period

7. Date and time of filter removal from incubator
8. Initials of individual preparing and analyzing samples

Count and record the number of individual, distinct, round, blue colonies on each filter. Counting colonies is preferably accomplished with a dissecting microscope or a hand-held magnifying lens. The ideal number of colonies on the plate is 20 to 60. Often in the summer months, a pink, thermophilic bacteria can overgrow the coliform colonies. The only way to cope with this is to reduce the volume filtered to about 5 mL.

Occasionally, the culture plate will produce many very small blue colonies that range in size from 1/50 to 1/10 of the size of coliform colonies. Do not count these "pretenders." Compute the density of fecal coliform bacteria in the original samples and record the value as the number of cols./100 mL. For ideal plate counts, report bacteria density by the following guidelines:

1st sample $\frac{20 \text{ cols.}}{5 \text{ mL}}$ 2nd sample $\frac{55 \text{ cols.}}{20 \text{ mL}} = \frac{75 \text{ cols.}}{25 \text{ mL}}$

$\frac{75 \text{ cols.}}{25 \text{ mL}} = \frac{3 \text{ cols.}}{1 \text{ mL}} = \frac{300 \text{ cols.}}{100 \text{ mL}}$. (Report this density.)

For counts where one sample has less than ideal colony counts (20 to 60 cols.), report the density computed from the plate with 20 to 60 cols. For plate counts less than 20 cols., compute and report a combined fecal coliform density for the sample. For example:

$$\frac{0 \text{ col.}}{10 \text{ mL}} + \frac{3 \text{ cols.}}{20 \text{ mL}} = \frac{3 \text{ cols.}}{30 \text{ mL}} = \frac{0.1 \text{ col.}}{1 \text{ mL}} \times 100 \text{ mL} = \frac{10 \text{ cols.}}{100 \text{ mL}}.$$

For plate counts greater than 60 cols., make the following evaluations:

If you can make an accurate count of discrete fecal coliform colonies on one or both filters, compute and report the density of the colonies. Usually when the density on the filter exceeds 100 cols., competition for space and nutrients suppresses growth, giving erroneously low counts. Thus the count should be expressed as 'greater than' whatever the count reveals. If growth is confluent, report a minimum estimated value by assuming a count of 60 cols. on the basis of the smallest volume filtered (Myers and Wilde, 1997).

If no colonies appear on the plates, report a value, dependent upon the volume filtered, that represents the method detection limit. Combine the two volumes filtered to maximize the sample size. Report the fecal coliform density as less than the value computed by this procedure, using the symbol "<" for less than the detection limit.

The fecal coliform test is performed according to a universally standard procedure. The data are useful only for comparison to other data obtained using the same procedure or to standards criteria. If the test cannot be performed successfully, then no result should be reported. However, the field sheet or field logbook should indicate by notes

(interference by competing organisms, exceeded holding time, exceeded incubation time, and so forth) that the test was attempted.

Sampling equipment should be assembled, checked, and calibrated just before a sampling trip. This includes assuring that every piece of equipment that might be needed is available, the equipment is in good working order, power supplies/batteries are fresh, and meters hold their calibrations. If meters or equipment are in questionable shape, bring along a replacement. An extensive checklist of sampling equipment and supplies is listed in Appendix B. Always clean and/or decontaminate equipment before use. Consult with your agency about cleaning procedures for various sampling protocols and their respective analytical accuracy requirements such as parts per million and parts per billion. To avoid cross contamination during transport to the sampling site(s), wrap inorganic equipment in plastic and organic equipment in aluminum foil.

Safety

Before attempting to collect water-quality samples, be aware of the applicable health and safety requirements. Often, samples are collected at contaminated sites or in remote, rugged country far from immediate medical attention. For these and other safety concerns, field personnel should consider the following recommendations:

1. Receive prior training in first aid and cardiopulmonary resuscitation (CPR). This training is available in most cities from the Red Cross. Receive prior training in the use and handling, transport, storage, and disposal of chemicals at a level appropriate for the types of chemicals likely to be encountered. Before handling any chemicals, refer to Material Safety Data Sheets (MSDS);
2. Consult with your personal safety officer;
3. Never go alone into the field;
4. Determine the location of the nearest hospital, clinic, or physician beforehand;
5. Receive the appropriate immunizations. Vaccinations for tetanus, hepatitis B, and typhoid fever are recommended when working near contaminated waters;
6. Notify others of your itinerary and who to contact in case of an emergency;
7. Take precautions against hunters, poisonous reptiles, poisonous plants, rodents, small mammals, sudden floods, heat exhaustion, sun exposure, and other environmental conditions that would negatively affect your health and safety;
8. Carry identification. In addition, if possible, take a cellular telephone or two-way radio;
9. Be aware of all bridge safety regulations. Check with your agency for specific bridge sampling protocols or guidelines. Wear personal flotation devices (PFDs) when in or over water;
10. When handling sample preservatives such as acid, always wear splash-proof goggles and non-contaminating gloves.

Water-Quality Sample-Collection Equipment

The selection of water-quality sample-collection equipment is dependent on and should be appropriate to the desired DQOs and their respective suggested methods as outlined in tables 1 and 2. If a grab sample is suggested, select a nonisokinetic sampler on the basis of physical/environmental/mechanical constraints and safe operation of the equipment. If a cross-sectional sample is suggested, select isokinetic samplers on the basis of safety and physical/environmental/mechanical constraints. Appendix C contains general guidelines for selecting sampling equipment on the basis of construction material and target analyte(s). If you are sampling for the presence of heavy metals, do not use samplers with metal components. When sampling for organics, avoid using samplers with plastic components, as the plastic may adsorb and contaminate the samples. Do not forget to decontaminate equipment before use. Once the equipment is decontaminated, wrap inorganic equipment in plastic and organic equipment in aluminum foil for transport to the site.

Generally water-quality samplers are either isokinetic or nonisokinetic. Isokinetic means the sampler operates in such a way that the water-sediment mixture moves into the sampler with no change in velocity as it leaves the ambient flow and enters the sampler intake. Isokinetic depth-integrating samplers (used for cross-sectional sampling) are either hand-held samplers or cable-and-reel samplers. Appendix D lists various isokinetic samplers and their operational ranges, which are based on maximum velocity and depth available from FISP. Figure 4 shows several types of water-quality sampling equipment.

A detailed discussion of water and suspended-sediment samplers is given in Edwards and Glysson (1998). Nonisokinetic samplers (used for grab sampling) include open-mouth samplers, such as hand-held bottles, disposable bailers, buckets, or cubitainers; weighted bottles; and BOD and volatile organic compound (VOC) samplers. Thief-type samplers, such as the Kemmerer or Van Dorn, are used to collect instantaneous discrete (point) samples primarily from lakes, reservoirs, and bays and estuaries. Single-stage samplers such as the U–59 and U–73 were designed to obtain suspended-sediment samples from streams at remote sites or from streams where rapid changes in stage make it impractical to use a conventional isokinetic depth-integrating sampler. Automatic pumping samplers that have fixed-depth intake(s) sometimes are used to collect samples at remote sites; from ephemeral, small streams; or from urban storm drains where stage rises quickly.

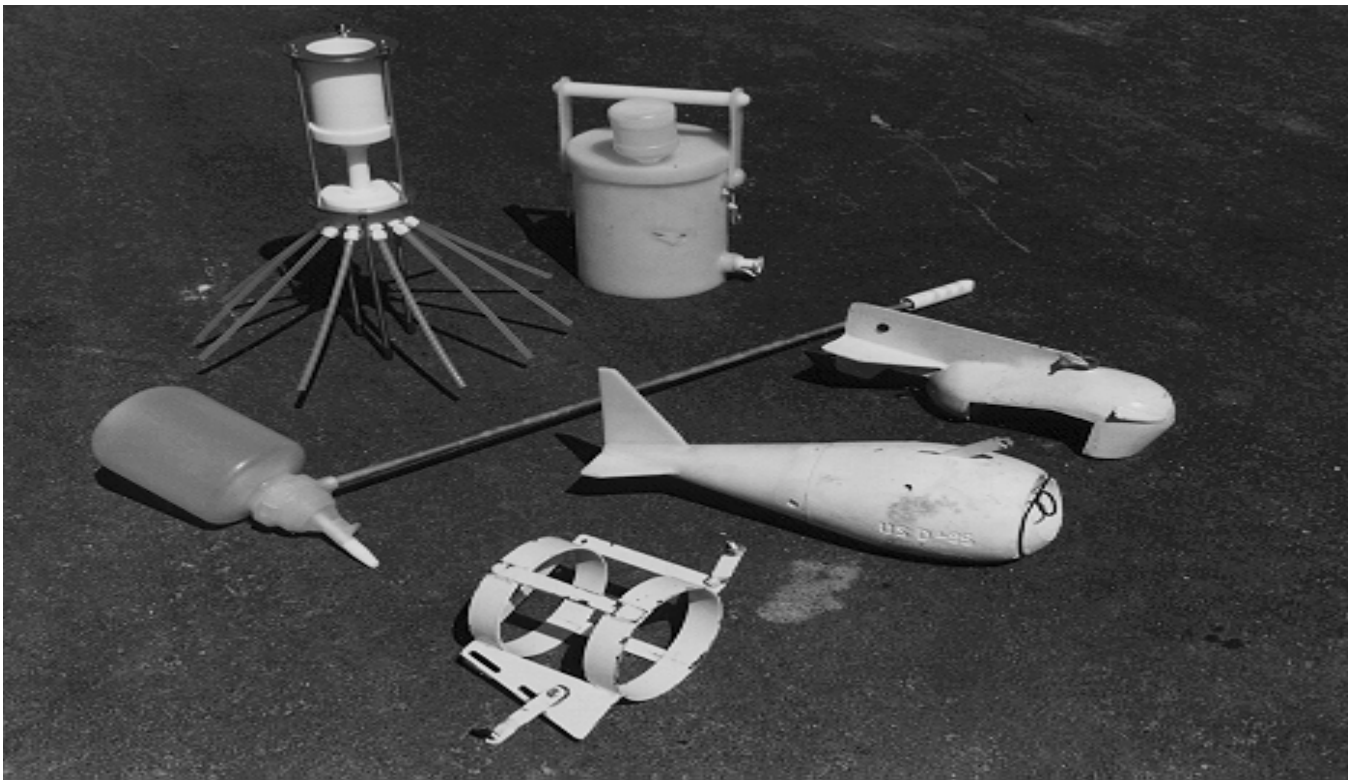


Figure 4. Water-quality sampling equipment (clockwise from center background) (1) churn splitter, (2) DH–76, (3) D–95, (4) frame sampler, (5) DH–81, and (6) cone splitter.

Equipment Decontamination

The goal of equipment cleaning is equipment decontamination—the removal from new equipment of residues from construction and machining and the removal of substances adhering to equipment from previous exposure to environmental and other media. Equipment used for sampling (sample collection, processing, and handling) must be cleaned before being used. The level of cleaning with extensive soaking and rinsing is dependent on the analytical precision level required in the sampling plan.

A brief overview of the major steps of equipment cleaning is included in this manual. More specific equipment cleaning procedures should be obtained from the sample collector's agency. Most standard procedures require that all sampling equipment is cleaned before use; that equipment is recleaned directly after sample collection before use at the next site to avoid cross contamination between sampling sites; and that field-rinsing of equipment with the water to be sampled, which is not appropriate for all equipment, does not replace cleaning or decontamination procedures.

Before assembling cleaning materials and supplies, determine the materials that the equipment is constructed of (for example, metal, glass, or plastic) and the chemical analytes for which the equipment will be used. For inorganic analytes use cleaning supplies composed of uncolored or white polypropylene, polyethylene, or some other suitable nonmetallic material. Do not use cleaning supplies that can leach metals if equipment will be used for collecting and processing samples to be analyzed for metals and metalloids. For organic analytes use cleaning supplies composed of metal, glass, or polyfluorocarbon materials. Do not use cleaning supplies that can leach organic substances if equipment will be used for collecting and processing samples to be analyzed for organic compounds. Appendix E lists basic cleaning items typically used for cleaning field equipment for water-quality sampling. If possible, prepare separate sets of precleaned equipment for use at each site. Return heavily contaminated equipment to the office for rigorous cleaning before reuse instead of field cleaning. Generally the sequence for cleaning equipment for sampling organic and/or inorganic analytes can be summarized as follows: detergent wash; tap/DIW rinse; check equipment for metal parts; no metal—acid soak; metal parts—DIW soak; methanol rinse; and air dry.

The following detailed equipment cleaning procedures currently (1999) are used for "clean" protocols including "clean hands/dirty hands" (CH/DH) techniques with cross-sectional depth-integrated sampling:

- Use of gloves, which are changed between each step.
- Soak the equipment and tubing for 30 minutes in Liquinox (0.2-percent solution) or another phosphate-free detergent; scrub the equipment and tubing with a nonmetallic, noncolored brush (except for the organic carbon filtration unit unless deemed necessary because of exposure to high concentrations of organic carbon).
- Thoroughly rinse the equipment and tubing with tap water.
- Soak for 30 minutes in a solution of 5-percent hydrochloric acid (HCl) (trace element free) any equipment that comes into contact with the dissolved trace element sample (the sampling equipment and the churn or cone splitter, if used, plus the Teflon™ tubing); do not expose any metal components of the cone splitter to acid.
- Rinse the equipment three times with DIW.
- Rinse with a small amount of methanol (pesticide grade) any equipment that comes into contact with the dissolved pesticide sample (the sampling equipment and the glass carboy or cone splitter, if used, plus the Teflon™ tubing).
- Rinse the organic carbon filtration unit and sampling equipment with a final rinse of organic-free water
- Allow everything to air dry completely.
- Use Teflon™ tape to protect areas of the sampling equipment and Teflon™ tubing that will come in contact with the sample; place the equipment and tubing in a sealable double plastic bag or other container for storage and transport.

- Wrap the filtration units for pesticides and organic carbon with aluminum foil or place the units in a Teflon™ bag and store in a sealable container.
- Rinse all inorganic sample bottles three times with DIW and then fill the bottles halfway with DIW for transport to the field.

COLLECTING WATER-QUALITY SAMPLES

Sampling Methods

The following sections describe grab sampling and cross-sectional sampling as currently implemented by various State and Federal water-quality monitoring agencies. The protocols most widely accepted at this time, especially when using the parts-per-billion analytical levels, require the use of clean sampling procedures. These sampling procedures help to reduce (to the extent feasible given current resources) the amount of contamination introduced when collecting water-quality samples in the field. "Clean" sampling procedures involve (1) using equipment that is constructed of noncontaminating materials and that has been cleaned rigorously before field work and between field sites; (2) handling equipment in a manner that minimizes contamination; (3) collecting, processing, and handling samples in a manner that prevents contamination; and (4) routinely collecting quality-control (QC) samples.

Clean Hands/Dirty Hands Techniques

"Clean" sampling procedures, including CH/DH techniques, are required when collecting inorganic samples for metals and other trace elements. Clean sampling procedures are recommended for all other sampling, to the extent that is reasonable, but particularly when the target analyte could be subject to contamination from field or laboratory procedures at a level that could exceed DQOs for reporting and interpretation. CH/DH techniques separate field duties and dedicate one individual as "clean hands" to tasks related to direct contact with the sample. These techniques are summarized below:

1. CH/DH techniques require two or more people working together.
2. At the field site, one person is designated as "clean hands" (CH) and a second person as "dirty hands" (DH). Although specific tasks are assigned at the start to CH or DH, some tasks overlap and can be handled by either as long as contamination is not introduced into the samples.
3. Both CH and DH wear appropriate noncontaminating, disposable, powderless gloves during the entire sampling operation and change gloves frequently, usually with each change in task (wearing multiple layers of gloves allows rapid glove changes).
4. CH takes care of all operations that involve equipment that comes into contact with the sample; for example, CH:

- Handles the surface-water sample bottle.
- Handles the discharge end of the surface-water sample tube or line.
- Transfers the sample to the churn/cone splitter.
- Prepares a clean workspace (inside vehicle).
- Sets up the processing and preservation chambers.
- Sets the equipment (for example, the sample bottles and the filtration and preservation equipment) inside the chambers.
- Works exclusively inside the chambers during collection, processing, and preservation.
- Changes the chamber covers as needed.
- Sets up the field-cleaning equipment and cleans the equipment.

5. DH takes care of all operations that involve contact with potential sources of contamination; for example, DH:

- Works exclusively exterior to the processing and preservation chambers.
- Prepares and operates the sampling equipment, including the pumps and discrete samplers, peristaltic pump switch, pump controller, and manifold system.
- Operates the cranes, tripods, drill rigs, vehicles, or other support equipment.
- Handles the generator or other power supply for samplers.
- Handles the tools, such as hammers, wrenches, keys, locks, and sample-flow manifolds.
- Handles the single or multiparameter instruments for field measurements.
- Handles the churn carrier, including the outer protective bags.
- Handles the stream-gaging or water-level equipment.
- Sets up and calibrates the field-measurement instruments.
- Measures and records the water levels and field measurements.

Metal and Trace Element Sampling

The following field practices are recommended when sampling for metals and trace elements:

1. Think contamination: be aware of and record the potential sources of contamination at each field site.
2. Wear appropriate noncontaminating, disposable, powderless gloves.

- Change gloves before each new step during sample collection and processing.
- Avoid hand contact with contaminating surfaces (such as equipment, coins, and food).

3. Use equipment constructed of materials that are relatively inert with respect to targeted analytes. Metal samplers must be epoxy-coated to prevent trace element contamination.

4. Use only equipment that has been cleaned according to prescribed procedures. See the equipment cleaning procedures in the "Preparing for Water-Quality Sampling" section of this manual. Sample processing equipment should be kept covered (when not dispensing samples).
5. Field-rinse the equipment only as directed. Some equipment for some analytes should not be field-rinsed.
6. Use correct sample-handling procedures:

- Minimize the number of sample-handling steps.
- Use CH/DH techniques as required for parts-per-billion trace element sampling.
- Adapt CH/DH techniques for all sample types, as required to obtain data of known quality.
- Train for and practice field techniques under supervision before collecting water samples on your own.

7. Collect and process samples in a clean enclosure such as a dedicated water-quality field vehicle or field processing chamber. Metallic objects, dirt, oil residue, engine exhaust, and food can all be sources of contamination. Simple processing chambers can be fashioned from a polyvinyl chloride (PVC) framework and a clear plastic bag.
8. Filter samples for dissolved trace elements and metals as soon as practical after collection. Use a disposable, tortuous path, capsule filter (effective pore size of 0.45 µm). The USEPA uses a Gelman Supor, model no. 12175 (15-mm diameter or larger), or an equivalent model. A variable speed, battery-operated pump fitted with a peristaltic pump head that forces the sample through Tygon™ or Teflon™ tubing is recommended. Filtered samples should be preserved with (1+1) ultra-pure nitric acid (HNO_3) to a pH of 2.0 or less. Normally, 3 mL of (1+1) acid per liter should be sufficient to preserve the sample. Ultra-pure nitric acid is available in 2-mL polypropylene vials.
9. Collect a sufficient number of appropriate types of QC samples. QC samples should be reviewed to determine if cleaning procedures are sufficient and contamination has been minimized.
10. Follow a prescribed order of sample collection and processing.

Specific details regarding grab and depth-integrated sample-collection methods, preservation, storage, and handling requirements are summarized in tables 3 and 4. The basic techniques of obtaining the water samples are outlined in the grab sampling and cross-sectional sampling sections that follow.

Grab Sampling

Grab samples are indicated in table 2 for DQOs I, II, and III. A grab sample, as explained in an earlier section, is collected in an open container from a single point at or near the stream/river/lake/reservoir surface. Grab samples can be collected with a suspended or hand-held polypropylene (Nalgene™) 5-gal container, disposable bailer, or narrow, open-mouth bottle. If the grab sample is collected by hand-held methods, the sample collector should wade to where the sample will be collected (preferably at the centroid of flow or mid-channel) and immerse a hand-held narrow-mouth bottle. Water samples should be collected before any other work is done at a site. If other work (for

example, sediment-sample collection, flow measurement, or biological/habitat assessment) is done before the collection of water samples, a representative sample will be difficult to collect from a disturbed stream. The sample collector should stand downstream of the bottle while it is being filled. Care must be taken to avoid collecting particulates that are resuspended as the result of wading. Various examples of grab samples include dip, discrete, and pump samples. Dip samples typically are collected by dipping the collection container (of appropriate noncontaminating material) into the upper layer of the water body. Discrete or point samples are collected by either (1) lowering a sampler to a specified depth and then collecting a sample by opening and closing the sampler or (2) using a single-stage sampler, which fills when stream stage rises to a predetermined height. Thief-type samplers and some pumps are the samplers most often used to collect samples by method 1. Although these samplers are designed primarily to sample still waters, they can be adapted to slowly flowing water. Single-stage samplers used in method 2 include the U–59 and are useful at stations on flashy streams or at other locations where it is difficult to reach a station to manually collect samples. Pump samples typically are collected with suction lift or submersible pump systems designed to collect water-quality samples. Pump systems can be portable or permanently installed and automated for sampling.

For a routine water-quality sample where near-surface water is representative of the water mass, a water sample can be collected by directly immersing the container beneath the water surface to a depth of 1 ft. A bucket can be used to collect a sample if the mixed surface layer is very shallow or accessible only from a bridge. If a bucket is used, extreme care should be taken to avoid contaminating the sample with debris from the rope and bridge. Care must be taken also to rinse the bucket between stations. In slow-moving rivers, reservoirs, and estuaries, the depth of the mixed layer can be determined from field measurements by locating the thermocline or an abrupt change in specific conductance. In tidally-influenced water bodies, the mixed surface layer is defined as that part of the water column from the surface to the depth at which the specific conductance is 6,000 µS/cm greater than the specific conductance at the surface. For mixed surface-layer samples (depth greater than 1 ft), pre-rinse one of the following sampling devices at least once with native water before using: submersible pump tube, Kemmerer, or Van Dorn. A minimum volume of 3 L should be collected from each site. Sample containers do not have to be rinsed with site water. Care should be taken at all times during sample collection, handling, and transport to prevent exposure of the sample to direct sunlight. Information on sample processing, preservation, and holding times for the grab sampling method, including information on dissolved metals in water, is listed in table 3.

Table 3. Summary of grab sampling method and preservation, storage, and handling requirements

[mL, milliliter; L, liter; °C, degrees Celsius; conc., concentrated; <, less than; >, greater than; g, gram; FAS, ferrous ammonium sulfate; µm, micrometer; CH/DH, clean hands/dirty hands; ft, foot; VOC, volatile organic compound; BTEX, benzene, toluene, ethylbenzene, xylenes; qt, quart; gal, gallon; DIW, deionized water]

Property or constituent	Container(s)	Sample volume (mL)	Preservation	Maximum holding time	Procedure(s)
Water samples					
Routine water sample (3 containers: 2 unpreserved, 1 preserved with H_2SO_4)					
Alkalinity	Quart or 1-L plastic or glass	100	Cool to 4 °C, dark	14 days	Label containers before collection with a unique sample identifier number, station location, date, and sample type. Place an **X** on the container lid to identify the acidified sample. Pre-rinsing containers with ambient water is not necessary. Fill each container with ambient water by submerging container about 1 ft below the surface mid-stream until filled. Place sample on ice immediately. Acidify the **X** container as soon as possible. Place on ice and ship as soon as possible. *It is preferable that samples be filtered in the field or laboratory as soon as possible. **If nitrite and nitrate are analyzed by ion chromatography, acidification is not required. For other methods of analysis, preserve with H_2SO_4 to pH <2 for a holding time of 28 days. ***According to "Standard Methods," samples should be filtered as soon as possible, and filters can be stored frozen for 21 to 30 days. Other authorities state filtered samples can be stored indefinitely.
Total suspended sediment, suspended sediment	do.	400	do.	7 days	
Chloride (Cl^-)	do.	100	do.	28 days	
Sulfate (SO_4^{2-})	do.	100	do.	28 days	
Orthophosphate phosphorus (PO_4-P)	do.	150	do.	Filter ASAP*; 48 hours until analysis	
Nitrite + nitrate (NO_2 + NO_3)**	do.	150	do.	28 days	
Ammonia (NH_3)	do.	150	1 to 2 mL conc. H_2SO_4 to pH <2 and cool to 4 °C, dark	28 days	
Total phosphorus	do.	150	do.	28 days	
Total organic carbon	do.	100	do.	28 days	
Chlorophyll *a* Pheophytin *a*	Quart or 1-L plastic or brown glass	1,000	Cool to 4 °C, dark	Filter within 48 hours Filters may be stored frozen for 30 days***	
Nitrite	do.	50	Cool to 4 °C, dark	48 hours	
Total dissolved solids	do.	250	Cool to 4 °C, dark	7 days	
Hardness	Quart or 1-L plastic or glass	250	Unfiltered, cool to 4 °C, dark, OR Filtered 2 mL conc. H_2SO_4 or HNO_3 to pH <2; cool to 4 °C, dark	48 hours 6 months	

Table 3. Summary of grab sampling method and preservation, storage, and handling requirements—Continued

Property or constituent	Container(s)	Sample volume (mL)	Preservation	Maximum holding time	Procedure(s)
Nonroutine water samples					
Oil and grease	Glass jar with Teflon™-lined lid rinsed with hexane or methylene chloride	1,000	2 mL conc. H_2SO_4 to pH <2; cool to 4 °C, dark	28 days	
Phenols	Glass jar with Teflon™-lined lid	1,000	2 mL conc. H_2SO_4 to pH <2; cool to 4 °C, dark	28 days	
Cyanide	Quart or 1-L plastic	1,000	2 mL 1:1 NaOH added to pH >12; 0.6 g ascorbic acid if residual chlorine present. Cool to 4 °C, dark	14 days	
Biochemical oxygen demand	Gallon plastic	>4,000	Cool to 4 °C, dark; add 1 g FAS crystals per liter if residual chlorine present	48 hours	
Chemical oxygen demand	Quart or 1-L plastic	110	2 mL conc. H_2SO_4 to pH <2; cool to 4 °C, dark	28 days	
Metals in water					
Dissolved (except Hg)	HNO_3-cleaned quart plastic bottle	1,000	Filter at sampling site with 0.45-µm in-line filter into ultra-pure HNO_3 preacidified container to pH <2	6 months	Dissolved metals (includes hexavalent chromium) Put on **powder-free** latex gloves using CH/DH technique: Assemble pump, tubing, and filter. Immerse intake tubing directly into water 1 ft and pump about 500 mL of ambient water to flush tubing and filter. Fill precleaned, preacidified container with 600 to 1,000 mL of filtrate leaving some headspace. Total metals Put on **powder-free** latex gloves using CH/DH technique: Assemble pump and tubing without filter. Immerse intake tubing directly into water 1 ft and pump about 500 mL of ambient water to flush tubing. Fill precleaned, preacidified container with 600 to 1,000 mL of sample leaving some headspace.
Dissolved mercury	do.	1,000	Filter at sampling site with 0.45-µm in-line filter into ultra-pure HNO_3 preacidified container to pH <2	28 days	
Total (except Hg)	do.	1,000	Preacidified container with 5 mL ultra-pure HNO_3 to pH <2	6 months	
Total mercury (Hg)	do.	600	Preacidified container with 5 mL ultra-pure HNO_3 to pH <2	28 days	
Hexavalent chromium (filtered)	Plastic or glass	600	Cool to 4 °C, dark	24 hours; must notify lab in advance	

Table 3. Summary of grab sampling method and preservation, storage, and handling requirements—Continued

Property or constituent	Container(s)	Sample volume (mL)	Preservation	Maximum holding time	Procedure(s)
Organics/pesticides in water					
Volatile organic compounds (VOC)	Two 40-mL VOC vials	80	Cool to 4 ºC, dark; or 2 to 4 drops HCl to pH <2, cool to 4 ºC, dark for BTEX	14 days	
Organics Pesticides and herbicides Organophosphorus pesticides Organochlorine pesticides Chlorinated herbicides Semivolatile organic compounds	1-qt glass jar with Teflon™-lined lid per sample type; must be pre-rinsed with hexane, acetone, or methylene chloride	1,000 Each sample type requires 1,000 mL in a separate container	Cool to 4 ºC, dark If chlorine is present, add 0.1 g sodium thiosulfate	7 days until extraction	Label each container before collection with tag number/unique sample identifier number, station location, date, and "ORGANICS-Organophosphorus Pesticides or Organochlorine Pesticides, or Chlorinated Herbicides" or "SEMIVOLATILES" (depending on sample type). Fill quart jar(s) to the top. Put in the dark and on ice.
Biological samples					
Toxicity in water	Two 1-gal glass or plastic	8,000	Cool to 4 ºC, dark	7 days	Label containers before collection with station location, date, and sample type. Open cubitainers by pulling apart. Pre-rinsing cubitainers with ambient water is not necessary. Fill each container with ambient water by submerging container about 1 ft below the surface mid-stream until filled. Place on ice and ship as soon as possible.

Table 3. Summary of grab sampling method and preservation, storage, and handling requirements—Continued

Quality-assurance samples
Field duplicates
Represent the variability introduced during sampling, preservation, and handling. Collected on a 5- to 10-percent basis, depending on specific program requirements. Collect two sets of routine water samples at the same location, sequentially, using the same methods. The samples are handled, stored, shipped, and analyzed using identical procedures. This applies to all cases of routine surface-water collection procedures, including in-stream grab samples, bucket grab samples from bridges, pumps, and other water- or sediment-sampling devices. Each set of samples has a separate tag number. Submit both sets of water samples to the same laboratory for analysis; LABEL RFA tag as a DUPLICATE.
Trip blanks
One set of DIW samples is submitted for VOC samples only. DIW blanks are prepared in the laboratory, transported to the field, and preserved (as required) along with other samples. The trip blank demonstrates that the containers and sample handling did not introduce contamination.
Metals blanks
Dissolved metals
To assess contamination of dissolved metals in water samples, FIELD SAMPLE BLANKS are submitted to the laboratory for every sampling trip. Blanks are collected at the last station of a sampling trip or sampling day. DIW is obtained from the laboratory. 1,000 mL of metals-free DIW that has been drawn through a new filter will be submitted as a blank. Flush tube and filter with 500 to 1,000 mL of metals-free DIW. Routine procedure described for collecting dissolved metals in water will be followed. Label container with DISSOLVED METALS BLANK and a separate sample tag number (the same RFA tag is used for both dissolved and total metals in water samples); LABEL RFA tag as a BLANK.
Total metals
To assess contamination of total metals in water samples, FIELD SAMPLE BLANKS are submitted to the laboratory for every sampling trip. Blanks are collected at the last station of a sampling trip or sampling day. DIW is obtained from the laboratory. 1,000 mL of metals-free DIW that has been drawn through a clean tube will be submitted as a blank. Flush tube with 500 to 1,000 mL of metals-free DIW. Routine procedure described for collecting total metals in water will be followed. Label container with TOTAL METALS BLANK and sample tag number (the same RFA tag is used for both dissolved and total metals in water samples); LABEL RFA tag as a BLANK.

Cross-Sectional Sampling

Cross-sectional sampling (used in this manual to denote cross sectionally integrated, flow-weighted composite) is achieved by using depth-integrating, nozzled samplers that fill isokinetically. An isokinetic sampler operates in such a way that the water-sediment mixture moves into the sampler with no change in speed and direction (velocity) as the water enters the sampler intake. This sampling method ensures that the sediment concentration in the water-sediment mixture in the sampler and the sediment concentration in the stream are equal. An isokinetic sampler is lowered through a vertical (the center of each increment or part of the stream cross section) at a predetermined transit rate. The transit rate (the rate at which the sampler is lowered and raised) is mainly a function of the sampler nozzle diameter, volume of sampler container, stream velocity, and sampling depth. The transit rate must be kept constant during sampler descent and ascent through a vertical. Three different sampling methods based on the use of isokinetic samplers are the single vertical at centroid of flow (VCF) method, the equal-discharge increment (EDI) method, and the equal-width increment (EWI) method. These methods will be summarized in this section. The centroid of flow is the point in the increment at which discharge is equal on both sides. The number of increments needed to collect a discharge-weighted sample at a site is related primarily to how stringent the DQOs are and how well mixed or homogenous the stream is with respect to the physical, chemical, and biological characteristics (variation) of the cross section. Information on sample processing, preservation, and holding times for the cross-sectional depth-integrated sampling method is listed in table 4.

Table 4. Summary of cross-sectional depth-integrated sampling method and preservation, storage, and handling requirements

[mL, milliliter; ºC, degrees Celsius; *N*, normality; CH/DH, clean hands/dirty hands; DIW, deionized water; EDI, equal-discharge increment; EWI, equal-width increment; ss, suspended sediment; mg/L, milligram per liter; µm, micrometer; L, liter; mm, millimeter; DOC/SOC, dissolved organic carbon/suspended organic carbon; <, less than; >, greater than; BOD, biochemical oxygen demand; g, gram; FAS, ferrous ammonium sulfate; cm, centimeter]

Property or constituent	Container(s)	Sample volume (mL)	Preservation	Maximum holding time	Procedure(s)
Water samples					
Routine water samples (depth-integrated sample volumes for inorganics and DOC/SOC are composited into splitting device)					
Specific conductance, pH, turbidity	Unfiltered sample volumes for bottles are dispensed from churn or cone splitters	250	No preservatives/not necessary to chill	6 months	Before field collection, all equipment is cleaned in office/laboratory according to CH/DH techniques given in this manual. Label bottles with site identification number, station name, date, time, and sample designation code. Rinse all inorganic sample bottles three times with DIW, then fill halfway with DIW for transport to the field. Rinse all sampling equipment and splitting devices thoroughly three times with native water before collecting first sample. Collect required volume of water by appropriate methods (cross sectional (EDI/EWI) or centroid of flow) using CH/DH techniques. Composite depth-integrated samples into either churn or cone splitter. For streams where ss concentrations are 2,000 mg/L or greater, cone splitter is recommended. Filter required amounts (with 0.45-µm capsule filter preconditioned with 1 L DIW) for dissolved trace elements, nutrients, major ions, and alkalinity. Place sample on ice immediately. Ship as soon as possible. DOC/SOC sample is filtered in stainless-steel barrel filter unit using a 47-mm-diameter silver filter pre-conditioned with organic-free DIW. *Filtered SOC volumes vary with concentration of ss as follows: <30 mg/L-filter 250 mL; ss 30 to 300 mg/L-filter 100 mL; ss 300 to 1,000 mg/L-filter 30 mL; and ss >2,000 mg/L-filter 10 mL. Carefully remove SOC silver filter, fold in half with sediments inside, and place in plastic petri dish, record filtrate volume on dish, and place in sealable plastic bag.
Alkalinity, fluoride, chloride, sulfate, vanadium	Filtered sample volumes are pumped from the splitting device through capsule filter	500	do.	6 months	
Orthophosphate phosphorus (PO_4-P)	Filtered sample volumes dispensed through capsule filter into brown polyethylene bottle		Cool to 4 ºC, dark	Ship to laboratory immediately for analysis. 48 hours	
Nitrite + nitrate ($NO_2 + NO_3$)	do.	125	do.	28 days	
Ammonia (NH_3) + organic N	do.		do.	28 days	
Ammonia (NH_3) + organic N	do.		do.	28 days	
Nitrite (NO_2)	do.		do.	48 hours	
Ammonia (NH_3) + organic N	do.		do.	28 days	
Ammonia (NH_3) + organic N, total phosphorus	Unfiltered sample volumes dispensed from splitter	120	1 mL 4.5*N* H_2SO_4 and cool to 4 ºC, dark	Ship to laboratory immediately for analysis. 28 days	
Dissolved organic carbon (DOC)	Pre-baked amber glass bottle, not pre-rinsed	5–120	Cool to 4 ºC, dark	Filter on-site	
Suspended organic carbon (SOC)	do.	10–250*	do.	Filters may be stored frozen for 30 days	

Table 4. Summary of cross-sectional depth-integrated sampling method and preservation, storage, and handling requirements—Continued

Property or constituent	Container(s)	Sample volume (mL)	Preservation	Maximum holding time	Procedure(s)
Nonroutine water samples					
Biochemical oxygen demand (BOD)	BOD bottle with stopper	300	Cool to 4 ºC, dark; add 1 g FAS crystals per liter if residual chlorine present	48 hours	
Trace elements in water					
Dissolved trace elements—aluminum, antimony, arsenic, barium, beryllium, boron, cadmium, chromium, cobalt, copper, iron, lead, lithium, manganese, molybdenum, nickel, selenium, silver, strontium, uranium, vanadium, zinc	Rinse bottles with 25 to 50 mL of filtered native water	250	Filter at sampling site with 0.45-µm capsule filter, acidify with HNO_3 Teflon™ ampules	6 months	Clean all equipment using cleaning process given in this manual. Collect sample with the same protocols as used to collect other depth-integrated samples. Sampling equipment, splitter, and Teflon™ tubing should be soaked for 30 minutes in 5-percent HCl solution. Filter required sample volume with in-line 0.45-µm capsule filter (preconditioned with 1 L of DIW). Use 25 to 50 mL of filtered sample to rinse trace element bottle (fill to the top of the lower lip of the 250-mL bottle). Fill designated sample bottle only to top of upper lip of sample bottle for a total volume filter of about 250 mL.
Organics/pesticides in water					
Organics	Sample is filtered and dispensed into a 1-L baked amber glass bottle	1,000	Cool to 4 ºC, dark	7 days until extraction	Pre-rinse filter (142-mm plate) with at least 100 mL of native water. Filter with baked glass fiber filter (0.7-µm pore size). Collect about 1 L filtered sample without pre-rinsing bottle, leaving 2 cm of headspace in bottle. Determine exact volume of filtered sample by subtracting tare weight from weight of filled sample bottle. Rinse all equipment/tubing in contact with pesticide sample with pesticide-grade methanol.
Pesticides and herbicides	do.	1,000	Cool to 4 ºC, dark. If chlorine is present, add 0.1 g sodium thiosulfate	7 days until extraction	

Table 4. Summary of cross-sectional depth-integrated sampling method and preservation, storage, and handling requirements—Continued

Quality-assurance samples
Laboratory/field equipment blanks
Laboratory equipment blanks are required for both inorganics (dissolved metals and nutrients) and organic carbon. They are required by the inorganic protocol to be collected at least once per year for equipment that is used to collect low-level samples for inorganic constituents. Laboratory equipment blanks are generated in the laboratory to verify that cleaning and maintenance of equipment is adequate to prevent contamination of native water when collecting an environmental sample. Two field equipment blanks are required for both inorganics and organic carbon, and one is required for pesticides at least once per year. A field equipment blank is a blank solution that is generated under actual field conditions and is subjected to the same aspects of sample collection, field processing, preservation, transportation, and laboratory handling as the environmental samples. Field equipment blanks should be prepared immediately before collecting and processing a native-water sample at a selected site and should be prepared using either inorganic- or organic-free blank water, but not both, at the same site.
Inorganic equipment blanks
Collect two initial samples of source solution, one for each schedule if necessary. After initial rinsing with blank water, fill the sampler and pour the water through the nozzle into a sample bottle for the dissolved trace element blank. Pour the remainder of the blank water from the sampler into the churn splitter; refill the sampler and repeat until the churn contains about 5 L of water; pump an aliquot of blank water from the churn splitter, using the routine pumping system, into a sample bottle for the dissolved trace element pump blank. Pump two aliquots of blank water from the churn splitter through the preconditioned filtration system into two sample bottles for the filtered nutrients and dissolved trace element field equipment blanks. Preserve all samples as required; submit only the final field equipment blank samples (filtered nutrients and dissolved trace elements) to the laboratory and store the remainder of the samples for later analyses, if necessary
Organic equipment blanks
Collect two initial samples (1 L and 125 mL) of source solution, one for each schedule, if necessary. Rinsing of the sampler should simulate as closely as possible the field rinsing that occurs before collection of environmental samples. After initial rinsing, fill the sampler with blank water and pour the water through the nozzle into the glass carboy; refill the sampler and repeat until the carboy contains at least 2 to 3 L of water; pump an aliquot of blank water from the glass carboy through the preconditioned pesticide filtration system for the pesticide equipment blank. Refill the sampler and pour another 2 to 3 L of blank water into the churn splitter; collect an aliquot through the churn spigot and pump through the preconditioned DOC/SOC filtration system; after conditioning the filter with 100 mL, filter an additional 100 mL and submit the filtrate and the filter for the DOC/SOC equipment blank.

Single Vertical at Centroid of Flow Method

The VCF method uses one centroid of flow for the stream cross section, and therefore, only one vertical is sampled. Consequently for appropriate use of this method, the cross section should be well mixed vertically and laterally with respect to concentrations of target constituents. The following steps should be followed to use the VCF method:

1. Measure discharge along the cross section to be sampled. Space the verticals to provide about 25 to 30 subsections or increments.
2. Locate the centroid of flow (the point in the stream where the discharge is equal on both sides) directly from the discharge measurement sheet OR
3. Construct an equal-discharge increment (EDI) curve by plotting cumulative discharge or cumulative percentage of discharge against cross-section width (in feet from right streambank). The centroid of flow (as determined by the EDI curve) would be located at the cross-section width where 50 percent of the discharge crosses the plotted line.
    a. If the stream channel is stable at the cross section to be sampled, then EDI curves of cumulative discharge at various stages can be based on historical discharge measurements. The location of centroids can be determined from these EDI curves so that discharge measurements do not have to be made before each sampling. EDI curves require occasional verification by comparison to recent discharge measurements.
    b. Examine the cross section for uniformity of appearance.
4. Measure the cross-sectional variation of field measurements (temperature, pH, DO, and specific conductance) at sites that have sampling history. Generally these field parameters should be measured at no less than 10 evenly spaced increments about 1 ft below the water surface. Record and review variations along the cross section. If values of field measurements differ by less than 5 percent and show that the stream is well mixed both along the cross section and from top to bottom, a single vertical of flow can be used.
5. Evaluate data from steps 1-4 to decide if the VCF method is appropriate. If discharge, field-measurement, or chemical-analysis data do not confirm that the cross section is well mixed vertically and laterally, use either the EDI or the EWI method.
6. If the VCF method is appropriate, go to the “Equal-Discharge Increment Method” section and follow step 3 to select the transit rate and step 4 to collect samples.

Equal-Discharge Increment Method

The objective of the EDI method is to collect a discharge-weighted sample that represents the entire flow passing through a cross section by obtaining a series of samples, each representing equal volumes of stream discharge. The EDI method requires that flow in the cross section be divided into increments of equal discharge. Equal-volume samples are collected at the centroid of each of the EDIs along the cross section. Samples are collected by passing the sampler through a vertical located at the centroid of each EDI. The sample collector should (1) use isokinetic,

depth-integrating sampling equipment (Appendix D), (2) use the same size sampler and nozzle at each of the verticals, (3) use the same constant transit rate during each ascent and descent in verticals, and (4) composite the samples from all verticals with the appropriate compositing equipment.

The following steps summarize the EDI method:

1. Prepare the field site.
    a. Upon arrival, set out safety equipment such as traffic cones and signs. Park the vehicle in a location and direction that will prevent sample contamination from vehicle emissions.
    b. Assemble the equipment needed and set up a clean workspace.

- To collect organic compound samples, use fluorocarbon polymer, glass, or metal for equipment components that are in direct contact with samples to be analyzed for organic compounds. Do not use plastics other than fluorocarbon polymers.
- To collect inorganic constituent samples, use fluorocarbon polymer or other relatively inert and uncolored plastics or glass for equipment components that are in direct contact with samples to be analyzed for inorganic constituents. Do not use metal or rubber components for trace element sampling.
- Collect bacteria samples (if required) using the filtration method described in the "Field Folders/Field Measurements" section of this manual.
    - Calibrate field instruments as recommended in instrument operations manuals.

2. Select the number and distribution of EDIs.

The number of EDIs selected for a sampling site is governed by factors described in the following steps and should not be determined arbitrarily.

    a. Visually inspect the stream from bank to bank and longitudinally, observing velocity, width, depth distribution, and apparent sediment and aquatic biota distribution along the cross section. Note and document the locations of stagnant water, eddies, backwater, reverse flows, areas of faster-than-normal flow, and piers or other obstructions along the cross section.
    b. Determine the stream width from a tagline or from distance markings on a bridge railing or cableway.
    c. At sites that have little sampling history: measure, record, and review the cross-sectional variation of field measurements (temperature, pH, DO, and specific conductance). Review the magnitude of the variations along the cross section.
    d. Measure discharge along the cross section for sampling or use existing EDI curves drawn from historical discharge measurements (if available).
    e. Determine the volume of discharge that will be represented in each EDI on the basis of DQOs for the study; the variation in discharge, field measurements, and stream-channel characteristics along the cross section; and the volume of sample required for analyses of target constituents.

f. Divide the cross section into EDIs.

- When determining the number of increments to be sampled, remember that the sample collected at the centroid of flow within each EDI must represent the mean discharge measured for that increment. If the mean discharge for that increment is not represented, the number of increments should be increased by decreasing the volume of discharge in each EDI until the mean discharge is represented.
- As a guide, a minimum of four sampling increments is recommended; the maximum number of increments is nine.

g. Locate of the centroid of flow within each EDI from discharge measurements as follows (the centroid of flow also can be located from previously constructed curves, as described later in the TECHNICAL NOTE):

- Construct a curve by plotting cumulative discharge or cumulative percentage of discharge against cross-section width, or
- Determine EDI locations using the discharge measurement sheet (produced in step 2d above) by following steps i–iv.

• Example:

i. If the stream cross section will be divided into five increments, divide stream discharge (determined in step 2d above) by 5 to determine the EDIs. For example, each increment equals 20 percent of discharge (100 percent/5 = 20 percent), thus equal increments of discharge.

ii. Locate the centroid of flow (the point at which discharge is equal on both sides) of the initial increment where cumulative discharge equals one-half the EDI (for example, 20 percent/2 = 10 percent). This also is the location of the first vertical at which a sample is collected.

iii. Locate each remaining (four in this example) centroid of flow by adding the next incremental discharge to the discharge at the previously sampled centroid and determining where that cumulative discharge occurs along the cross section.

iv. The EDI centroids will correspond to locations along the cross section where calculations in iii above indicate 10, 30, 50, 70, and 90 percent of the cumulative discharge along the cross section.

TECHNICAL NOTE: If the stream channel is stable at the cross section to be sampled, graphs of cumulative discharge or percentage of cumulative discharge at various stages can be based on historical discharge measurements. Location of EDI centroids can be determined from these graphs so that discharge measurements do not have to be made before each sampling. Linear interpolation based on discharge can be made between EDI curves. However, these EDI curves require occasional verification by comparison to recent discharge measurements.

3. Select the transit rate.

   a. Determine the sampling depth and the mean stream velocity at the centroid of each EDI.

   b. Determine the actual transit rate for each centroid that will yield samples of approximately the same volume, using sampling depth, mean stream velocity, and information in Appendix F.

Guidelines for selecting the EDI-sampling transit rate

- Collect samples of equal volumes at each centroid. This is required for the EDI method if the sample will be composited. Generally, to collect equal volumes, transit rates will vary from centroid to centroid.
- Keep the transit rate equal and directionally constant and within the isokinetic transit-rate range of the sampler (Appendix F) when collecting isokinetic samples at each centroid.
- DO NOT EXCEED the maximum transit rate. The maximum transit rate will have been exceeded if the minimum sample volume for the selected nozzle, bottle, and stream velocity is not collected. Exceeding the maximum transit rate will affect the concentration of particulates greater than or equal to 0.062 mm.
- Use the slowest transit rate possible, but make sure that the minimum transit rate is sufficiently rapid to keep the sampler from overfilling. (The sampler is overfilled when the water level in the bottle or bag is above the bottom of the nozzle when the sampler is held in the horizontal sampling position.)

4. Collect samples (the procedures are the same whether the sample collector is wading or using a reel-and-cable suspension method).

- Collect samples at EDI centroids as many times as necessary to ensure collection of sufficient sample volume for analysis if the sample is to be composited. For composite samples, care must be taken to obtain the same total volume from the vertical at each EDI centroid if more than one traverse is made at each centroid. This ensures that the composited cross-sectional sample will be proportional to flow at the time of sampling.
- Remember to stay within the isokinetic transit-rate range of the sampler at each vertical. If stream velocity is less than the isokinetic transit-rate range of the sampler, a discharge-weighted sample still can be obtained by collecting equal volumes at each vertical; however, this sample will not be isokinetic.

   a. Read and record the starting gage height from the staff gage or wire weight if available. Instantaneous discharge (relative to gage height at streamflow-gaging stations) routinely is stored with water-quality data to calculate loads. Move the sampling and support equipment to the centroid of the first increment to be sampled. Field-rinse the sampling equipment and record the sampling start time.

   b. Lower the sampler at the predetermined constant transit rate until a slight contact is made with streambed.

- Do not pause upon contact with the streambed. Raise the sampler immediately at a constant transit rate to complete the vertical traverse. The descending transit rate does not have to equal the ascending transit rate, but each rate must be equal and directionally constant and within the isokinetic transit-rate range of the sampler.

- Take care not to disturb the streambed by bumping the sampler onto it; bed material might enter the nozzle, resulting in erroneous data.
- Ensure that the sampler is not overfilled. Overfilling results in enrichment of the sample with heavy particulates because of secondary circulation of water through the sampler (from the nozzle through the air exhaust). This enrichment could result in an artificially increased suspended-sediment concentration and bias particle-size distribution toward heavier and larger particulates.

  a. Inspect each bottle or bag-type sampler, looking for overfilling and the presence of anomalously large amounts of particulates that might have been captured because of excessive streambed disturbance during sample collection. If either of these conditions is noted, discard the sample (make sure no residual particulates are left in the container) and resample.
  b. Ensure that the sampler is not underfilled. Underfilling results in a sample that is not isokinetically collected because the maximum transit rate has been exceeded. The minimum volume must be collected to ensure that the sample is isokinetic.
  c. Depending on DQOs, process and (or) analyze the samples collected at each vertical as either a separate sample, as a composite with other subsamples collected along the cross section, or split the samples for further processing. If the total volume of samples to be collected will exceed the operational capacity of the churn splitter, decrease the number of increments or use an appropriate sampler with a smaller bottle or with a bag with a smaller nozzle. When transferring the sample from the sampler bottle or bag to the splitter, ensure that all particulates in the sampler are transferred with the water.

- Remove the sampler cap.
- Swirl the sample gently to keep the particulates suspended.
- Quickly pour the sample into the sample splitter.

  d. Move the equipment to the next vertical.

- Determine the transit rate for this vertical that will yield the same volume as for the previous EDI centroid.
- Repeat the procedures in steps 4b through 4e.
- Repeat this procedure at the remaining verticals along the cross section.

  e. Record the following information after all samples have been collected:

- Sampling end time.
- Ending gage height.
- All field observations and any deviations from standard sampling procedures.

5. Process the samples as appropriate. This step includes removing necessary volumes of water from the compositing device for filtering or dispensing into the required sampler bottles. After filling the bottles

specified for the scheduled analyses, add the necessary preservatives and package the bottles appropriately for shipment to the laboratory.

6. Clean the equipment as appropriate.

- If the sampler will not be reused during a field trip, rinse the components with DIW before they dry and place the sampler in a plastic bag for transporting back to the office laboratory for cleaning.
- If the sampler will be reused, clean it at the sampling site while it is still wet.
- Collect a field blank, if required, after the sampling equipment has been cleaned in the field.

Equal-Width Increment Method

For the EWI method, the stream cross section is divided into a number of EWIs. Samples are collected by lowering and raising the sampler through the water column at the center of each EWI. The combination of the same constant transit rate used to sample at each vertical and the isokinetic characteristic of the sampler results in a discharge-weighted sample that is proportional to total streamflow.

The following steps summarize the EWI method:

1. Prepare the field site
    a. Upon arrival, set out safety equipment such as traffic cones and signs. Park the vehicle in a location and direction that will prevent sample contamination from vehicle emissions.
    b. Assemble the equipment and set up a clean workspace.

- To collect organic compound samples, use fluorocarbon polymer, glass, or metal for equipment components that are in direct contact with samples to be analyzed for organic compounds. Do not use plastics other than fluorocarbon polymers.
- To collect inorganic constituent samples, use fluorocarbon polymer or other relatively inert and uncolored plastics or glass for equipment components that are in direct contact with samples to be analyzed for inorganic constituents. Do not use metal or rubber components for trace element sampling.
- Collect bacteria samples (if necessary) using the filtration method described in the “Field Folders/ Field Measurements” section of this manual.
- Calibrate field instruments as recommended in instrument operations manuals.

2. Select the number and width of EWIs.
    a. Visually inspect the stream from bank to bank and longitudinally, observing velocity, width, depth distribution, and apparent sediment and aquatic biota distribution in the cross section. Note and document the locations of stagnant water, eddies, backwater, reverse flows, areas of faster-than-normal flow, and piers or other obstructions along the cross section.
    b. Determine the stream width from a tagline or from distance markings on a bridge railing or cableway.

c. At sites that have little sampling history, measure, record, and review the cross-sectional variation of field measurements (temperature, pH, DO, and specific conductance). Review the magnitude of the variations along the cross section.

d. Determine the width of the increment or the distance between verticals. To determine the width of each equal increment, divide the stream width by the number of verticals necessary to collect a representative sample. The number of increments must be a whole number. Increment width is based on DQOs for the study and on the variation in discharge, field measurements, and stream-channel characteristics along the cross section. For all but very wide and shallow streams, a minimum of 10 and a maximum of 20 verticals usually is sufficient.

- Collect the sample at the center of each EWI (the vertical). This sample should approximately represent the mean discharge for that increment.
- If the sample does not appear to represent the mean discharge for that increment, decrease the width of the increment until the mean discharge is approximate. This will increase the number of increments sampled.
- Locate the verticals at the center of each remaining EWI along the cross section.
- Make slight adjustments to sampling locations, if necessary, to avoid sampling where the flow is affected by a pier or some other obstruction.
    - Example:

i. If a stream 56 ft wide has been divided into 14 increments of 4 ft each, the first sampling vertical would be 2 ft from the water's edge and subsequent verticals would be at 6 ft, 10 ft, 14 ft, and so forth.

ii. Even if streamflow is divided, as in a braided channel, EWIs must be identical from channel to channel, and the same constant transit rate must be used at each vertical.

3. Select the transit rate.

a. Refer to Appendix F for guidelines for determining the isokinetic transit rates for collecting isokinetic, depth-integrated samples. Unless the mean velocity is actually determined, use the trial-and-error method to determine the minimum transit rate.

b. Locate the EWI that has the largest discharge (the largest product of depth times velocity) by sounding for depth and either measuring or estimating velocity. At the vertical for this increment, use of the minimum transit rate results in the maximum allowable filling of the sampler bottle or bag during one vertical traverse.

c. Determine the minimum transit rate at this vertical for the size of the sampler nozzle and bottle or bag that will be used.

d. Approximate the mean velocity (in feet per second) of the vertical by timing a marker as it travels a known distance. Divide the distance (in feet) by the time (in seconds) and multiply by 0.86.

e. Make sure that the transit rate does not exceed the maximum allowable transit rate to be used at any of the remaining verticals along the cross section. This can be determined by sampling the slowest and shallowest increment with any substantial flow. If the minimum sample volume is not collected at this vertical, then the EWI method cannot be used at this cross section to collect a discharge-weighted sample.

- The descending and ascending transit rates must be constant in each direction and must be the same at each vertical along the cross section.
- The maximum transit rate must not be exceeded at any of the verticals.
- The minimum transit rate must be sufficiently rapid to keep the sampler from overfilling. (The sampler is overfilled when the water level in the bottle or bag is above the bottom of the nozzle when the sampler is held in the horizontal sampling position.)
- The same size sampler nozzle and bottle must be used at all verticals along the cross section.
- The total volume collected must not exceed the recommended volume for the churn splitter used to composite the sample.
- If the transit rate exceeds the maximum allowable rate, use the EDI method instead of the EWI method.

4. Collect samples (the procedures are the same whether the sample collector is wading or using the reel-and-cable suspension method; the same sampler bottle or bag can be used for all verticals in the cross section).
   a. Move to the first vertical (the midpoint of the first EWI near the edge of the water) and field-rinse the equipment.
   b. Record the start time and gage height.
   c. Lower the field-rinsed sampler at the predetermined constant transit rate until a slight contact is made with the streambed.

- Do not pause upon contact with the streambed. Raise the sampler immediately at a constant transit rate to complete the vertical traverse.
- Take care not to disturb the streambed by bumping the sampler onto it; bed material might enter the nozzle, resulting in erroneous data.
- Ensure that the sampler is not overfilled. Overfilling results in a sample that is not isokinetic and that could be enriched with heavy particulates because of secondary circulation of water through the sampler (from the nozzle through the air exhaust). This enrichment could result in an artificially increased suspended-sediment concentration and bias particle-size distribution toward heavier and larger particulates.
- Ensure that the sampler is not underfilled. Underfilling results in a sample that is not isokinetically collected because the maximum transit rate has been exceeded. The minimum volume must be collected to ensure that the sample is isokinetic.
- If the required volume cannot be collected, use the EDI method for discharge-weighted samples.

d. Inspect each bottle or bag-type sampler, looking for overfilling and the presence of anomalously large amounts of particulates that might have been captured because of excessive streambed disturbance during sample collection. If either of these conditions is noted, discard the sample (make sure no residual particulates are left in the container) and resample.

e. Move the sampling equipment to the next vertical. Maintain the established transit rate. The sample volume can vary considerably among verticals. Samples can be collected at several verticals before emptying the sampler, as long as the maximum sample volume in a bottle or bag-type sampler has not been exceeded.

f. Continue to the next vertical until no more samples can be collected without overfilling the sampler. Empty the sampler into a field-rinsed compositor or splitting device and repeat the sample collection procedure until samples have been collected at all verticals.

- If the total sample volume to be collected will exceed the operational capacity of the churn splitter, use the EDI method.
- When transferring the sample from the sampler bottle or bag to the splitter, ensure that all particulates in the sampler are transferred with the water. Remove the sampler cap. Swirl the sample gently to keep the particulates suspended and quickly pour the sample into the sample splitter.
- Collect as many samples at the EWI verticals as necessary to ensure that an adequate sample volume is collected as required for analysis, but sample at each vertical an equal number of times. (The composite cross-sectional sample will remain proportional to flow at the time of sampling.)

g. Record the following information after all samples have been collected:

- Sampling end time.
- Ending gage height.
- All field observations and any deviations from standard sampling procedures.

5. Process the samples as appropriate.

6. Clean the equipment as appropriate.

- If the sampler will not be reused during a field trip, rinse the components with DIW before they dry and place the sampler in a plastic bag for transporting back to the office laboratory for cleaning.
- If the sampler will be reused, clean it at the sampling site while it is still wet
- Collect a field blank, if required, after the sampling equipment has been cleaned in the field.

Processing Cross-Sectional Samples

Cross-sectional samples typically are composited to produce a water-quality sample that is representative of the total stream discharge at the sampling station. This compositing can be accomplished by depositing each sample

volume from each vertical into a churn splitter—a polyethylene container that slowly stirs the composited sample with a polypropylene disk. Because the churn splitter requires 3 to 8 L of composited water, verticals in a narrow stream may need to be sampled more than once. All verticals should be sampled the same number of times to retain the representativeness of the sample to the stream. It is also important to churn while drawing sample aliquots from the splitter. Do not use a churn splitter to composite samples collected for VOCs, organic carbon, oil and grease, pesticides, herbicides, or bacteria, because the plastic components have the potential for adsorbing and contaminating the samples. Instead use glass containers for sampling these constituents with the grab-sampling method.

The choice of using the parts-per-million/milligrams-per-liter protocol or the parts-per-billion/micrograms-per-liter protocol is based on the minimum reporting level (MRL) required in the sampling plan. Most analytical work and most Federal drinking-water regulations are reported in micrograms per liter. The parts-per-billion protocol with its extremely low MRLs requires certain field practices, such as the CH/DH technique, appropriate cleaning/handling of sampling equipment, and rigorous and appropriate QC sampling and planning to ensure minimum contamination occurs during the entire water-quality sampling and processing procedure.

Some constituents require different sampling methods than others. Always check with the laboratory that will perform the analyses about container type and volume, preservation, and holding times. Clear descriptions of selected constituents, preservatives, and holding times should be included in the sampling plan before samples are collected. The current properties and constituents, preservatives, and holding times for both grab and depth-integrated sampling methods are listed in tables 3 and 4.

Samples should be wrapped and packed in containers so that they are received unbroken at the laboratory. Record all identification numbers on the field notes or field logbook. Communicate with the laboratory about the sample delivery time and method of shipment. Follow necessary procedure, complete the required forms, and retain copies so that samples can be tracked after shipment.

Quality-Assurance Plans and Quality-Control Samples

Assuring the validity of environmental data or QA is accomplished by collecting QC samples, reviewing and analyzing QC data, and making adjustments to data-collection procedures on the basis of the results. Because environmental sampling is done in a relatively uncontrolled manner subject to many variables, large sources of error may exist. Therefore, measures of control over the collection of water-quality samples are crucial for answering any questions regarding the validity of the data. QA plans should contain planned and systematic procedures necessary to provide confidence that the data will satisfy established requirements for quality. Detailed information about QA/QC samples can be found throughout the literature and within specific agencies responsible

for water-quality data collection. This section gives a review of the types of QC samples commonly required in QA plans.

Blank solutions or “blanks” are solutions (DIW or rinse water) that are laboratory certified to have target constituent concentrations that are less that the method detection limits. These solutions are used to develop specific types of blank samples. Equipment blanks are blank solutions that are processed through all equipment used for collecting and processing an environmental sample. Once analyzed, the blanks indicate the effectiveness of cleaning of field equipment. Equipment blanks should be collected after sampling the station with the highest contamination. Field blanks are containers of DIW that are subjected to the same aspects of sample collection, field processing and preservation, transportation, and laboratory handling as environmental samples. Field blanks are used to check for contamination in the laboratory and for cross contamination during the collection and shipment of samples. Trip or travel blanks are containers of DIW that are put in the same type of bottle as used for environmental samples and are kept with the set of sample bottles both before and after sample collection. These blanks are used to detect contamination that occurs during sample transport or storage or in the laboratory. Replicate samples are used to assess the performance in those parts of the procedure that are replicated. Replicate samples are collected in a manner such that the samples are thought to be essentially identical in composition. Many types of replicate samples are possible, and each might yield slightly different results in a dynamic hydrologic setting. Split replicates sent to separate laboratories are used to ensure that results from the different laboratories are comparable. Split replicates sent to the same laboratory are used to measure the variability of the laboratory. Concurrent or sequential replicates are used to ensure that samples collected with different samplers or by different sampling methods are comparable. Spike samples are samples that have known concentrations of specific constituents added in such a manner as to minimize the change in the matrix of the original samples. Spike samples are used to verify the method performance for either accuracy or recovery. Accuracy data reflect the best results that can be expected at the time the samples were analyzed, and recovery data reflect bias from an environmental sample matrix.

Most QA plans and QC samples take into account the following:

- Equipment blanks should be collected annually or whenever new equipment is used.
- Field conditions could require blanks or other QC samples not previously planned for.
- All field QC samples should be collected on the same day that environmental samples are collected. The same equipment should be used for both types of samples.
- Preservatives from the same lot number should be used for the environmental and associated samples. The preservative lot number should be recorded.
- QC samples should be labeled appropriately.
- Results of QC analyses should be stored in a separate database.

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GLOSSARY

Accuracy - The degree of agreement of a measured value with the true or expected value of the quantity of concern (Taylor, 1987). The concept of accuracy includes both bias and precision.

Analyte (target analyte) - "Substances being determined in an analysis" (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 parameters such as temperature, pH, DO, or conductivity.

Alkalinity - The acid-neutralizing capacity of a solution. Alkalinity indicates how much change in pH will occur with the addition of moderate amounts of acid. Because alkalinity of most natural waters is composed almost entirely of bicarbonate and carbonate ions, determinations of alkalinity can provide accurate estimates of concentrations of these ions. Bicarbonate and carbonate ions are among the dominant anions present in natural waters thus alkalinity measurements provide information about major ion relations and evolution of water chemistry.

Ambient - The natural conditions that would be expected to occur in waters unaffected or not influenced by human activities.

Bias - Systematic error inherent in a method or caused by some artifact or idiosyncrasy of the measurement system. The error can be positive (indicating contamination) or negative (indicating loss of analyte concentration) (Taylor, 1987).

Biochemical oxygen demand (BOD) - A measure of the amount of oxygen consumed by biological processes breaking down organic matter.

Centroid (as used to designate a special case of stream-sampling location for the EDI method) - The vertical in the increment at which the discharge is equal on both sides.

Centroid (of entire cross section) of flow - The vertical in the stream cross section at which the discharge is equal on both sides.

Chemical oxygen demand (COD) - A measure of the oxygen required to oxidize all compounds in water, both organic and inorganic.

Chloride (Cl) - One of seven major ions in most natural waters; element that dissolves from rock materials. The following contribute to an increase in chloride levels: aridity, return drainage from irrigation, sewage, drainage from oil wells, salt springs, and industrial waste. Increased levels of chloride will heighten the corrosive effects of water; combined with sodium, causes a salty taste.

Clean hands/dirty hands (CH/DH) - A field practice that requires two people to obtain and process water-quality samples to reduce contamination at the parts-per-billion level. One sampling person is designated as clean hands (CH) and the other is designated as dirty hands (DH). CH handles only equipment that touches the water sample, and DH handles all the equipment that could be a source of contamination. Both personnel are outfitted with multiple layers of powderless, latex gloves that can be removed at various stages in sampling and sample processing.

Clean sampling procedures - Sampling protocols used when analyzing samples at the parts-per-billion level.

Composite sample - Water sample collected from different locations of a stream cross section.

Conductivity - See specific conductance.

Constituent - An essential part: component, element. Serving to form, compose, or make up a unit or whole.

Contact recreation - Recreational activities that involve a substantial risk of ingesting water, including wading by children, swimming, water skiing, diving, and surfing.

Contamination (of water) - Change of ambient water composition by the addition of biological or chemical substances as a result of human activity or natural processes. Addition of such substances can be detrimental to the quality of the water resource.

Data quality - Refers to the properties of the measurement such as precision, bias, detection limit, and other relevant measures.

Data-quality requirements - The subset of data-quality objectives (DQOs) that pertains specifically 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.

Depth integration - A method of sampling at every point throughout a given depth (the sampled depth) whereby the water-sediment mixture is collected isokinetically so that the contribution from each point is proportional to the stream velocity at the point. This process yields a sample that has properties that are discharge weighted over the sampled depth (American Society for Testing and Materials, 1990).

Dissolved (D) - Refers to constituents that exist in true chemical solution in a water sample; as a convenient operational definition used by agencies that collect water data, the term “dissolved” commonly is used to refer to constituents in a representative water sample passed through a 0.45-µm filter membrane for inorganic analysis or a 0.7-µm glass fiber filter for organic analysis.

Dissolved oxygen (DO) - The oxygen freely available in water. Adequate DO is necessary for the life of fish and other aquatic organisms. About 3 to 5 mg/L or ppm is the lowest limit for support of fish life over a long period of time.

Effluent - Something that flows out or waste material (such as smoke, liquid industrial refuse, or sewage) that is discharged into the environment, especially as a pollutant.

Estuary - Regions of interaction between rivers and near-shore ocean waters where tidal action and river flow create a mixing of freshwater and saltwater. These areas can include bays, mouths of rivers, salt marshes, and lagoons. These brackish water ecosystems shelter and feed marine life, birds, and wildlife.

Filtered - Pertains to constituents in a water sample passed through a filter membrane of specified pore diameter, most commonly 0.45 µm or less for inorganic analytes and 0.7 µm for organic analytes.

Ion - An atom or group of atoms that carries a positive or negative electric charge as a result of having lost or gained one or more electrons.

Isokinetic sampling - Collecting a sample in such a way that the water-sediment mixture moves with no change in velocity as it leaves the ambient flow and enters the sampler intake (American Society for Testing and Materials, 1990).

Load - The mass of a material entering a system over a certain time period (pounds per day or kilograms per day).

Maximum contaminant level (MCL) - The maximum permissible level of a contaminant in water delivered to any user of a public water system. Maximum contaminant levels are enforceable standards.

Metals - Any of a class of chemical elements that have a luster and can conduct heat and electricity. In water quality, these elements (in high enough concentrations) can be considered toxic. Common examples include copper, chromium, lead, mercury, and zinc.

Method detection limit (MDL) - The minimum concentration of a substance that can be identified, measured, and reported with 99-percent confidence that the analyte concentration is greater than zero; determined from analysis of a sample in a given matrix containing the analyte.

Minimum reporting level (MRL) - The smallest measured concentration of a constituent that can be reliably reported using a given analytical method. In many cases, the MRL is used when documentation for the MDL is not available.

Nutrients - Elements or compounds that are essential for animal and plant growth. The term generally is applied to nitrogen and phosphorus in wastewater but also is applied to other essential and trace elements.

Normality, *N* (equivalents/L) - The number of equivalents of acid, base, or redox-active species per liter of solution. Example: a solution that is 0.01 *F* in HCl is 0.01 *N* in H^+.

Organics - Shortened term used to refer to manmade organic chemicals made up primarily of carbon, hydrogen, and oxygen. Common examples include pesticides, solvents such as methanol and acetone, and polychlorinated biphenyls (PCB). PCBs are chemical compounds often used as coolants or insulators in electrical transformers.

Organochlorines - Synthetic organic compounds that contain chlorine. A generally used term referring to compounds that contain mostly or exclusively carbon, hydrogen, and chlorine. Examples are DDT, chlordane, and lindane; PCBs; and some solvents that contain chlorine.

pH - Represents the negative base-10 logarithm of hydrogen ion activity of a solution in moles per liter; a measure of the acidity (pH less than 7) or alkalinity (pH greater than 7) of a solution.

Precision - The degree of mutual agreement characteristic of independent measurements as the result of repeated application of the process under specified conditions (Taylor, 1987).

Secchi disk transparency - A method of measuring (in meters) the turbidity of a water body by averaging the depths below the surface that a Secchi disk disappears from view when lowered and reappears when raised.

Sediment - Solid material that originates mostly from disintegrated rocks and is transported by, suspended in, or deposited from water. Solid material includes chemical and biochemical precipitates and decomposed organic sediment that are influenced by such environmental factors as degree of slope of basin, length of slope, soil characteristics, land use, and quantity and intensity of rainfall.

Semivolatile organic compounds (SVOC) - A group of synthetic organic compounds that are solvent-extractable and can be determined by gas chromatography/mass spectrometry. SVOCs include phenols, phthalates, and polycyclic aromatic hydrocarbons (PAH).

Specific conductance - A measure of the ability of water to conduct an electrical current. The measure is used as a surrogate for the amount of dissolved solids or salt content in the water.

Sulfate (SO_4) - A form of sulfur; one of seven major ions in most natural waters.

Total - Pertains to the constituents in an unfiltered, representative water-suspended-sediment sample. This term is used only when the analytical procedure ensures measurement of at least 95 percent of the constituent present in both dissolved and suspended phases of the sample. Knowledge of the expected form of the constituent in the sample, as well as the analytical methodology used, is required to judge when the results should be reported as "total."

Total dissolved solids (TDS) - A measure of dissolved materials in water that indicates salinity. For many purposes, TDS concentration is a major limitation on the use of water.

Toxicity - The degree of health risk (causing death, disease, or birth defects) posed to living organisms.

Transit - The movement of the sampler from the water surface to the streambed or from the streambed to the water surface.

Turbidity - The measure of the scattering effect that suspended solids have on light; the higher the intensity of scattered light, the higher the turbidity.

Quality assurance (QA) - A system of protocols and procedures (such as sampling at the right place and (or) time using the correct equipment and techniques) implemented to meet expected standards of quality needed to fulfill study objectives and control unmeasurable components of a study.

Quality control (QC) - A system of activities (such as collection of blank or replicate samples) whose purpose is to control the quality of environmental data by generating a set of data that will be used to estimate the magnitude of the bias and variability that result from the procedures used to obtain the data.

Variability - Random error in independent measurements as the result of repeated application of the process under specific conditions.

Vertical - A vertical line of observation within an increment from the water surface to the streambed.

Volatile organic compounds (VOC) - A compound that has high vapor pressure and low water solubility. VOCs typically are industrial solvents, constituents in petroleum fuel products, or by-products produced by chlorination in water treatment.

Whole water (W) - Pertains to the constituents in solution after an unfiltered representative water-suspended-sediment sample is digested (usually using a dilute acid solution). Complete dissolution of particulate matter often is not achieved by the digestion treatment, and thus, the determination represents something less than the “total” amount (that is, less than 95 percent) of the constituent present in the dissolved and suspended phases of the sample. For inorganic determinations, digestions are performed in the original sample container to ensure digestion of material absorbed on the container walls. To achieve comparability of analytical data, equivalent digestion procedures would be required of all laboratories performing such analyses because different digestion procedures are likely to produce different analytical results.

Appendix A. Field-folder checklist for water-quality stations

Check-list	Item
	Station description
	• Location of gaging station (if one is present)
	• Location of sampling sites: high and low streamflows
	• Hydrologic and geologic sections
	• Name of landowner, tenant, or other responsible party
	• Site access instructions (for example, call owner or site operator before arrival at site, obtain key to unlock security gate)
	• Photographs to document site conditions
	Maps to site (State and local)
	Profiles of cross section of stream channel at sampling locations(s)
	• Stream-bottom geometry
	• Physical and field measurements
	Safety information
	• Nearest emergency facilities
	• Phone numbers (home) of supervisor
	• Traffic condition and traffic plan showing where to park, placement of flags and cones
	• Location of power lines
	• Environmental hazards, such as weather and animals
	Sampling schedule
	• Laboratory analyses to be requested and associated codes
	• When to collect samples (high or low flow)
	Bottle types needed for each analytical schedule
	Sampling instructions
	• Cumulative discharge curves at about 10-, 50-, and 90-percent duration
	• Velocity cross sections at about 10-, 50-, and 90-percent duration
	• Equipment to use at various flows
	• Flow-duration curve
	• Discharge rating curves and (or) tables
	Shipping instructions
	• Amount of ice to use
	• Mailing labels to and from laboratory
	• Location of nearest post office or shipping agent
	Surface-water field form and an example of completed form
	A tabulation sheet for each type of bacteria enumerated at the site (include example with date of sample, streamflow, volumes filtered, dilutions, plate counts)
	Plots of field-measured data (last 5–10 years of record); if a good enough relation exists to show outliers, include:
	• Specific conductance versus streamflow
	• Specific conductance versus alkalinity
	• Temperature versus time
	Statistical summary of historical water data
	• Seasonal, maximum-minimum values
	• Discharge-related maximum-minimum values
	Special equipment needed to address site-specific conditions
	• Sampling
	• Safety

Appendix B. Equipment list for water-quality sampling

[FISP, Federal Interagency Sedimentation Project; N, nutrients; M, major ions; T, trace element; O, organics; R, radiochemical; B, biological; in., inch; L, liter; PVC, polyvinyl chloride; µm, micrometer; mm, millimeter; MFS, membrane fiber specific; ºC, degrees Celsius; DOC/SOC, dissolved organic carbon/suspended organic carbon; VOC, volatile organic compound; mL, milliliter; *N*, normality; BOD, biochemical oxygen demand]

Check-list	Item	Source	Appropriate use
	Sampling equipment:		
	Depth-integrated		
❑	D–77 (standard) sampler, epoxy-coated for trace elements and metals	FISP	N,M,T,O,R,B
❑	Support for D–77, bridge boards, reels, cranes	FISP	
❑	Nylon or Teflon™ (for organics) nozzles, 3/16-, ¼-, 5/16-in.	FISP	N,M,T,O,R,B
❑	D–77, 3-L polypropylene bottle (one for each site)	FISP	N,M,T,R,B
❑	Plastic cap, for D–77/DH–81 bottle	FISP	N,M,T,R,B
❑	D–77, 3-L Teflon™ bottle	FISP	N,M,T,O,R,B
❑	Adapter for 3-L Teflon™ bottle	FISP	N,M,T,O,R,B
❑	Teflon™ cap, for D–77/DH–81 bottle	FISP	N,M,T,O,R,B
❑	3-L slotted plastic bottle (to be lined with Teflon™ or oven bag)	FISP	N,M,T,O,R,B (Teflon™) N,M,T,R,B (oven)
❑	8-L slotted bottle (to be lined with Teflon™ or oven bag)	Nalgene	N,M,T,O,R,B (Teflon™) N,M,T,R,B (oven)
❑	3-L Teflon™ bags	FISP	N,M,T,O,R,B
❑	8-L Teflon™ bags	Jensen Inert	N,M,T,O,R,B
❑	Reynolds oven bags, small (3-L sampler) and large (8-L sampler)	Grocery store	N,M,T,R,B
❑	Sounding weight(s) for frame sampler	FISP	N,M,T,O,R,B
❑	Current meter for frame sampler	FISP	
❑	Epoxy paint, for touching up trace element and metal samplers	FISP	N,M,T,O,R,B
❑	DH–81 collar	FISP	N,M,T,O,R,B
❑	Wading rod for DH–81, plastic covered	FISP	N,M,T,O,R,B
❑	DH–81, 1-L polypropylene bottle and cap (one for each site)	FISP	N,M,T,R,B
❑	DH–81, 1-L Teflon™ bottle	FISP	N,M,T,O,R,B

Appendix B. Equipment list for water-quality sampling—Continued

Check-list	Item	Source	Appropriate use
❑	Adapter for 1-L Teflon™ bottle	FISP	N,M,T,O,R,B
❑	Hand line	FISP	
❑	Plastic sheet for covering bridge rail and weights to hold sheet	Hardware store	N,M,T,O,R,B
❑	Churn splitter, 8-L polyethylene or 14-L polyethylene	BelArt	N,M,T,R
❑	Plastic bags for enclosing churn	Grocery, hardware store	N,M,T,R,B
❑	Plastic trash can for carrying churn	Hardware store	N,M,T,R,B
	Grab/others		
❑	Weighted-bottle sampler (nonmetallic or epoxy-coated)	FISP	N,M,T,R,B
❑	Thief-type samplers; for example, Van Dorn or Kemmerer	Scientific supply	To collect depth-discrete samples in lakes and ponds
❑	Bottles for weighted-bottle sampler		N,M,T,O,R,B
❑	Plastic rope for weighted-bottle sampler	Hardware store	N,M,T,O,R,B
❑	Pumping sampler(s)	Scientific supply	
❑	Other	Scientific supply	
❑	1-L cubitainer	Scientific supply	
	Sample processing equipment:		
❑	Processing and preservation chamber—PVC framework	Parts from hardware or building supply store	N,M,T,O,R,B
❑	Plastic bags (clear) for covering chambers	Grocery, hardware, or building supply store	N,M,T,O,R,B
❑	Disposable, powderless vinyl gloves	Local scientific supply stores	N,M,T,O,R,B
❑	Capsule filters (disposable, tortuous path), 0.45-µm pore size	Local scientific supply stores	N,M,T,R
❑	142-mm plate filter(s) (plastic)	GeoTech	N,M,T,R
❑	142-mm membrane filters (MFS)	Local scientific supply stores	N,M,T,R
❑	Stainless-steel forceps for handling filters	VWR, Millipore, Cole-Parmer, or other scientific supply	N,M,O,R,B
❑	142-mm aluminum filter holder	GeoTech	O
❑	Glass fiber filters, 142-mm diameter/0.7-µm pore size, baked at 450 °C	Local scientific supply stores	O
❑	Peristaltic pump	Cole-Parmer	N,M,T,R

Appendix B. Equipment list for water-quality sampling—Continued

Check-list	Item	Source	Appropriate use
❑	Foot switch for pump	Cole-Parmer	N,M,T,O,R
❑	Ceramic head pump	Fluid Metering	N,M,T,O,R
❑	Silicon pump tubing (one for each site)	Local scientific supply stores	N,M,T,R
❑	Teflon™ tubing, fluorinated ethylene propylene (FEP) lined	Cole-Parmer or other scientific supply	N,M,T,O,R,B
❑	Silver filter, 47-mm diameter/0.45-µm pore size (for DOC/SOC)	Local scientific supply stores	O
❑	Stainless-steel, pressure-type filtration unit	Millipore	O
❑	Teflon™, pressure-type filtration unit	Savillex Corp.	O
❑	Petri dishes for silver filters	Local scientific supply stores	O
❑	Forceps (plastic- or Teflon™-coated)	PGC Scientifics	N,M,T,O,R
	Equipment cleaning:		
❑	Liquinox (0.2-percent)/alconox nonphosphate detergent	Local scientific supply stores	N,M,T,O,R,B
❑	Hydrochloric acid for cleaning (trace element free grade) (dilute to 5 percent by volume for use)	VWR or other scientific supply	N,M,T,O,R
❑	Deionized water (DIW) for rinsing	Local scientific supply stores	N,M,T,O,R,B
❑	Clear plastic containers or basins for soaking equipment	Nalgene, BelArt	N,M,T,O,R,B
❑	Nonmetallic brushes for cleaning, baby toothbrush for nozzles	Grocery store	N,M,T,O,R,B
❑	Pipet jar or nonmetallic tube for cleaning pump	VWR, Cole-Parmer, or other scientific supply	N,M,T,O,R,B
❑	Ziplock bags for storing cleaned equipment (noncolored closure)	Grocery store	N,M,T,R,B
❑	Pesticide-grade methanol (for organics sampling) (Burdick & Jackson)	Scientific Products	O
❑	Wash bottles for deionized water (DIW) and acid (safety labeled)	VWR, BelArt, Cole-Parmer, or other scientific supply	N,M,T,O,R,B
❑	Wash bottle, Teflon™ for methanol	Cole-Parmer or other scientific supply	O
❑	Paper wipes, paper towels, oil sorbent pads	Local scientific supply stores	N,M,T,O,R,B
❑	Aluminum foil, heavy duty	Local scientific supply stores or grocery store	
❑	Inorganic-free blank water	Laboratory supply	N,M,T,R
❑	Pesticide (organic-free) blank water	Laboratory used for analytical work	N,M,T,O,R
❑	Volatile organic compound (VOC) blank water	Laboratory used for analytical work	VOC

Appendix B. Equipment list for water-quality sampling—Continued

Check-list	Item	Source	Appropriate use
	Sample containers:		
❑	250-mL acid-rinsed bottles, clear cap	Laboratory supply	M,T
❑	125-mL brown bottles	Laboratory supply	N
❑	250-mL plain plastic bottles, black cap	Laboratory supply	M
❑	500-mL plain plastic bottles	Laboratory supply	N,M,T (bottom material)
❑	250-mL glass bottles for mercury	Laboratory supply	Mercury
❑	125-mL glass bottles, amber (baked) for organic carbon	Laboratory supply	TOC,DOC
❑	1-L glass bottles, clear (baked)	Laboratory supply	O
❑	1-L glass bottles, amber (baked)	Laboratory supply	O, Stable isotopes
❑	Septum vials	Laboratory supply	VOC
❑	250-mL Teflon™ bottles	Laboratory supply	T,O
❑	Caps with polypropylene liners for bottles	Laboratory supply	N,M
❑	Foam sleeves for glass bottles	Laboratory supply	T,O,R,VOC
❑	Mesh bags for sample bottles	Laboratory supply	N,M,T,O,R,B
	Sample preservation:		
❑	Nitric acid vials (2-mL), ~7.7*N* Ultrex™ ultra-pure	Laboratory supply	T
❑	Potassium dichromate ampules	Laboratory supply	Mercury
❑	1-mL sulfuric acid ampules	Laboratory supply	BOD, oil and grease
❑	1- or 2-mL nitric acid ampules		
❑	Ampule breaker	With some ampules	N,T,R
❑	Ice with shipping coolers	Local sources	
❑	Disposal bottles for used ampules		N,T,R

Appendix B. Equipment list for water-quality sampling—Continued

Check-list	Item	Source	Appropriate use
	Field measurement:		
❑	Data collection/field forms/notebook	Specific to agency	
❑	Thermometer (nonmercury) or thermistor	Scientific supply	
❑	pH meter with instruction manual and calibration/maintenance logbook	Many sources	
❑	pH probe (plus backup probe)	Many sources	
❑	Filling solution for pH probe	Use type recommended by manufacturer	
❑	Hach digital titrator or burette	Scientific supply	
❑	Cartridges for titrator or H_2SO_4 solution for burette	Scientific supply	
❑	Battery-operated stirrer, magnetic	Many sources	
❑	Teflon™-coated stir bars	Cole-Parmer, PGC, or other scientific supply	
❑	Stir bar retriever	Cole-Parmer, PGC, or other scientific supply	
❑	Specific conductance meter with instruction manual and calibration/ maintenance logbook	Many sources	
❑	Specific conductance probe or cups	Use type recommended by meter manufacturer	
❑	Dissolved oxygen meter with instruction manual and calibration/maintenance logbook	Many sources	
❑	Dissolved oxygen probe (plus backup probe)	Many sources	
❑	Cable for dissolved oxygen probe	Many sources	
❑	Calibration chamber for dissolved oxygen meter	Scientific supply	
❑	Dissolved oxygen probe maintenance kit (membranes and o-rings)	Many sources	
❑	Pocket barometer	Scientific supply	
❑	Multiprobe instrument (Hydrolab, YSI, or other brand)	Hydrolab, YSI, or other scientific supply	
❑	pH buffers (4.0, 7.0, 10.0)	Scientific supply	
❑	Small cups for pH buffers	Scientific supply	
❑	Specific conductance standards to bracket expected conditions	Scientific supply	
❑	Turbidimeter	Scientific supply	

Appendix B. Equipment list for water-quality sampling—Continued

Check-list	Item	Source	Appropriate use
	Bacteria:		
❑	Bacteria kits (fecal coliform, total coliform)	Scientific supply	B
❑	Petri dishes	Scientific supply	B
❑	Hot plate/stirrer	Cole-Parmer, VWR, or other scientific supply	B
❑	Teflon™-coated stir bars	Cole-Parmer, VWR, or other scientific supply	B
❑	Lab thermometer	Scientific supply	B
❑	Glass beakers for preparing media	Many sources	B
❑	1-, 10-, 25-mL sterile pipets	Scientific supply	B
❑	47-mm, 0.45-µm gridded, sterile, membrane filters	Scientific supply	B
❑	47-mm, 0.65-µm gridded, sterile, membrane filters	Scientific supply	B
❑	Stainless-steel (sterile) or disposable filter unit(s)	Millipore	B
❑	Hand pump	Scientific supply	B
❑	Buffered water	Scientific supply	B
❑	Dilution bottles	Scientific supply	B
❑	Incubators (with electrical cords)	Millipore	B
❑	Alcohol lamp	VWR or other scientific supply	B
❑	Forceps for bacteria filters	Scientific supply	B
❑	Autoclave bags	Cole-Parmer or other scientific supply	B
❑	Autoclave	VWR or other scientific supply	B
❑	Anitibacterial soap	Drug store	B
❑	Microscope or magnifier	Cole-Parmer, VWR, or other scientific supply	B
	Safety:		
❑	Waders/hip boots/cleats	Many sources, internet catalogues available online	
❑	Life jacket	Many sources, internet catalogues available online	
❑	Rain gear	Many sources, internet catalogues available online	
❑	Hat, sunscreen, sunglasses	Many sources, internet catalogues available online	

Appendix B. Equipment list for water-quality sampling—Continued

Check-list	Item	Source	Appropriate use
❑	Drinking water	Many sources, internet catalogues available online	
❑	Safety cones	Many sources, internet catalogues available online	
❑	Tool box with basic tools including graphite lubricant (not oil or WD–40), stopwatch, calculator		
❑	Safety vest	Many sources, internet catalogues available online	
❑	“Men Working” signs	Many sources, internet catalogues available online	
❑	First-aid kit, knife	Many sources, internet catalogues available online	
❑	Fire extinguisher, leather gloves	Many sources, internet catalogues available online	
❑	Spill kits	VWR, Lab Safety, BelArt, or other scientific supply	
❑	Eye wash	Cole-Parmer, Lab Safety, BelArt, or other scientific supply	
❑	Protective goggles or face mask	Cole-Parmer, Lab Safety, BelArt, or other scientific supply	
❑	Container with lid for glove disposal	Cole-Parmer, Lab Safety, or other scientific supply	
❑	Laminated list of emergency phone numbers		
❑	Safety carrier for acid bottles	Cole-Parmer, Lab Safety, BelArt, or other scientific supply	
❑	Apron, lab coat	Cole-Parmer, VWR, BelArt, or other scientific supply	
❑	Flashlight and spare batteries	Grocery, hardware, drug store	
❑	Antibacterial soap	Drug store	
❑	Two-way radio/cellular phone	Electronics store	
	General supplies:		
❑	Government/agency ID and/or business cards, field forms		
❑	Authorization for access to sampling site, keys/security codes for gates or locks		
❑	Waterproof pens, markers, pencils, mailing labels, shipping coolers		
❑	Masking tape, rubber bands		
❑	Camera with film		
❑	Topographic maps/aerial photos/global positioning system (GPS)		

Appendix C. General guidelines for selecting equipment on the basis of construction material and target analyte(s)

[√, generally appropriate for use shown; Si, silica; Cr, chromium; Ni, nickel; Fe, iron; Mn, manganese; Mo, molybdenum; $^{3}H/^{3}He$, tritium/helium-3; CFC, chlorofluorocarbon; B, boron]

Construction material for sampling equipment		Target analyte(s)	
Material	**Description**	**Inorganic**	**Organic**
Plastics[1]			
Fluorocarbon polymers[2] (several varieties available for differing applications)	Chemically inert for most analytes	√ (potential source of fluoride)	√ (sorption of some organics)
Polypropylene	Relatively inert for inorganic analytes	√	**Do not use**
Polyethylene (linear)	Relatively inert for inorganic analytes	√	**Do not use**
Polyvinyl chloride (PVC)	Relatively inert for inorganic analytes	√	**Do not use**
Silicone	Very porous. Relatively inert for most inorganic analytes	√ (potential source of Si)	**Do not use**
Metals			
Stainless-steel 316 (SS–316)	SS–316—metal having the greatest corrosion resistance. Comes in various grades. Used for submersible pump casing	√ (potential source of Cr, Ni, Fe, and possibly Mn and Mo) **Do not use** for surface water unless encased in plastic	√ Do not use if corroded[33]
Stainless-steel 304	Similar to SS–316 but less corrosion resistant	**Do not use**	√ Do not use if corroded[3]
Other metals—brass, iron, copper, aluminum, galvanized and carbon steels	Refrigeration-grade copper or aluminum tubing are used routinely for collection of $^{3}H/^{3}He$ and CFC samples	**Do not use** (except as noted for isotopes)	√ Routinely used for CFCs. Do not use if corroded[3]
Glass			
Glass, borosilicate (laboratory grade)	Relatively inert. Potential sorption of analytes	√ Potential source of B and Si	√

[1] Plastics used in connection with inorganic trace element sampling should be uncolored or white.
[2] Includes materials such as Teflon™, Kynar™, and Tefzel™, which are relatively inert for sampling inorganic or organic analytes.
[3] Corroded/weathered surfaces are active sorption sites for organic compounds.

Appendix D. Sampler designations and characteristics

[Plastic dip-coated (PDC) versions of all samplers are available for collecting trace metal samples. in., inches; lb, pounds; ft/s, feet per second; ft, feet; --, not applicable]

Sampler designation (US)	Construction material	Sampler dimensions			Nozzle distance from bottom (in.)	Suspension type	Maximum velocity (ft/s)	Maximum depth (ft)	Sampler container size		Intake size (in.)
		Length (in.)	Width (in.)	Weight (lb)					Pint	Quart	
DH–75P	Cadmium-plated	9.25	4.25	1.5	3.27	Hand-held rod	6.6	16	X	--	3/16
DH–75Q	Cadmium-plated	9.25	4.25	1.5	4.49	Hand-held rod	6.6	16	--	X	3/16
DH–75H	Cadmium-plated	9.25	4.25	1.5	--	Hand-held rod	6.6	--	2 L		3/16
DH–59[1]	Bronze	15	3.5	22	4.49	Handline	5.0	19	X	--	1/8
DH–59[1]	Bronze	15	3.5	22	4.49	Handline	5.0	16	X	--	3/16
DH–59[1]	Bronze	15	3.5	22	4.49	Handline	5.0	9	X	--	¼
DH–76[1]	Bronze	17	4.5	22	3.15	Handline	6.6	16	--	X	1/8
DH–76[1]	Bronze	17	4.5	22	3.15	Handline	6.6	16	--	X	3/16
DH–76[1]	Bronze	17	4.5	22	3.15	Handline	6.6	16	--	X	¼
DH–81	Plastic	[2]6.5	3.2	.5	4	Hand-held rod	8.9	15	([3])	--	3/16
DH–81	Plastic	[2]6.5	3.2	.5	4	Hand-held rod	8.9	15	([3])	--	¼
DH–81	Plastic	[2]6.5	3.2	.5	4	Hand-held rod	8.9	14	([3])	--	5/16
D–49	Bronze	24	5.25	62	4	Cable and reel	6.6	19	X	--	1/8
D–49	Bronze	24	5.25	62	4	Cable and reel	6.6	16	X	--	3/16
D–49	Bronze	24	5.25	62	4	Cable and reel	6.6	9	X	--	¼
D–74	Bronze	24	5.25	62	4.06	Cable and reel	6.6	[4]19, [5]16	X[6]	X	1/8
D–74	Bronze	24	5.25	62	4.06	Cable and reel	6.6	[4]19, [5]16	X[6]	X	3/16
D–74	Bronze	24	5.25	62	4.06	Cable and reel	6.6	[4]19, [5]16	X[6]	X	¼
D–74	Aluminum	24	5.25	42	4.06	Cable and reel	5.9	[4]19, [5]16	X[6]	X	1/8
D–74	Aluminum	24	5.25	42	4.06	Cable and reel	5.9	[4]19, [5]16	X[6]	X	3/16
D–74	Aluminum	24	5.25	42	4.06	Cable and reel	5.9	[4]19, [5]16	X[6]	X	¼
D–77	Bronze	29	9	75	7	Cable and reel	7.2	15	3 L		5/16
D–77	Aluminum	29	9	42	7	Cable and reel	3.3	15	X[6]	X	1/8
D–95	Bronze	28.5	6	65	4.5	Cable and reel	ND[7]	15	([3])	--	3/16
D–95	Bronze	28.5	6	65	4.5	Cable and reel	ND[7]	15	([3])	--	¼
D–95	Bronze	28.5	6	65	4.5	Cable and reel	ND[7]	14	([3])	--	5/16
P–61[1]	Bronze	28	7.34	105	4.29	Cable and reel	16.6	[4]180, [5]120	X[6]	X	3/16
P–63	Bronze	37	9	200	5.91	Cable and reel	6.6	[4]180, [5]120	X[6]	X	3/16
P–72[1]	Aluminum	28	7.34	41	4.29	Cable and reel	5.3	[4]72.2, [5]50.9	X[6]	X	3/16

[1] Not appropriate for trace element sample collection, quality-control sample plan recommended for non trace element sampling.
[2] Without sample bottle attached.
[3] Any size bottle with standard mason jar treads.
[4] Depth using pint sample container.
[5] Depth using quart sample container.
[6] Pint milk bottle can be used with adapter sleeve.
[7] To be determined.

Appendix E. Supplies for cleaning field equipment for water-quality sampling activities

[ACS, American Chemical Society; DIW, deionized water; µS/cm, microsiemens per centimeter at 25 degrees Celsius; L, liter; cm, centimeter; PBW, pesticide-free blank water; VPBW, volatiles/pesticide-free blank water; PVC, polyvinyl chloride]

Item	Description/comments
Acid[1]	Hydrochloric: ACS trace element grade (5 percent by volume). Nitric; ACS trace element grade (10 percent by volume)
Aluminum foil	Heavy duty, for covering work surface and cleaned equipment
Bags, plastic or polyfluorocarbon	Recyclable trash bags recommended for large equipment storage. Sealable bags with uncolored closure strips, various sizes.
Basins	One wash basin for each cleaning solution; white or uncolored. Plastic, nonleaching. (Stainless steel is required for methanol and can be used for equipment for organic-compound sampling.)
Brushes and sponges	Noncolored; plastic components needed for inorganic work
Deionized water (DIW)	Recommended maximum conductivity, 1 µS/cm
Detergent	Nonphosphate laboratory (for example, Liquinox)
Disposable gloves	Vinyl or latex (latex or nitrile for use with methanol), nonpowdered, assorted sizes
Inorganic-free blank water	Blank water prepared and/or quality assured by the analyzing laboratory with certificate of analysis; required for blank samples
Jerricans or carboys, one for use as neutralization container	For waste solutions and rinsate. Neutralization container; 25- to 30-L, polyethylene
Methanol	Pesticide grade
Neutralization materials	Marble landscape chips (1- to 2-cm recommended)[2]
Organic-free pesticide-free (PBW), or volatiles/ pesticide-free (VPBW) blank water[3]	Blank water prepared and/or quality assured by the analyzing laboratory; required for blank samples. Use PBW and/or VPBW according to study analytical requirements
Safety equipment	Goggles, chemical spill kit, apron
Standpipes for submersible pump	Plastic or glass; for example, pipette jars or capped PVC casing; one standpipe labeled for blank water and each cleaning solution
Tap water	If quality is questionable, substitute DIW. Tap water is more effective for rapid removal of detergent residue
Tissues (for example, Kimwipes)	Laboratory grade, lint-free, extra large, for cleanup
Wash (dispenser) bottles	Labeled to indicate contents (for example, ACID, DIW, TAP). Polyfluorocarbon bottle needed for methanol
Waste container, methanol	Designated for flammable liquid, to contain used methanol

[1] Hydrochloric acid is required if nitrogen species will be analyzed; otherwise, nitric acid is acceptable.

[2] Agricultural limestone, soda ash, baking soda, and crushed shells are not recommended (Horowitz and others, 1994).

[3] Use only laboratory certified organic-free water and inorganic-free water.

Appendix F. Isokinetic transit rates

[Transit rates in feet per second; depth is water depth; full, fills bottle; 10º tip, fills bottle with no spillage up to a 10º down tip of the nozzle from horizontal; fastest, fastest allowable rate for isokinetic sampling]

Depth (feet)	Rate	Mean stream velocity (vertical feet per second)												Volume (milliliters)	
		1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	6.00	7.00	8.00	9.00	Maximum 10º minimum	Minimum
1-liter bottle, 1/4-inch nozzle															
1	Full	0.03	0.04	0.05	0.06	0.06	0.07	0.08	0.09	0.11	0.13	0.15	0.17	1,050	918
1	10º tip	0.04	0.05	0.06	0.07	0.08	0.10	0.11	0.12	0.15	0.17	0.19	0.22	798	667
1	Fastest	0.22	0.29	0.37	0.44	0.51	0.59	0.66	0.73	0.88	1.03	1.17	1.32	132	
2	Full	0.06	0.07	0.09	0.11	0.13	0.15	0.17	0.18	0.22	0.26	0.29	0.33	1,050	806
2	10º tip	0.07	0.10	0.12	0.15	0.17	0.19	0.22	0.24	0.29	0.34	0.39	0.44	798	555
2	Fastest	0.24	0.32	0.40	0.48	0.56	0.63	0.71	0.79	0.95	1.11	1.27	1.43	243	
3	Full	0.08	0.11	0.14	0.17	0.19	0.22	0.25	0.28	0.33	0.39	0.44	0.50	1,050	710
3	10º tip	0.11	0.15	0.18	0.22	0.25	0.29	0.33	0.36	0.44	0.51	0.58	0.65	798	458
3	Fastest	0.26	0.34	0.43	0.51	0.60	0.68	0.77	0.85	1.02	1.19	1.36	1.54	340	
4	Full	0.11	0.15	0.18	0.22	0.26	0.29	0.33	0.37	0.44	0.52	0.59	0.66	1,050	626
4	10º tip	0.15	0.19	0.24	0.29	0.34	0.39	0.44	0.48	0.58	0.68	0.77	0.87	798	375
4	Fastest	0.27	0.36	0.46	0.55	0.64	0.73	0.82	0.91	1.09	1.28	1.46	1.64	423	
5	Full	0.14	0.18	0.23	0.28	0.32	0.37	0.41	0.46	0.55	0.64	0.74	0.83	1,050	553
5	10º tip	0.18	0.24	0.30	0.36	0.42	0.48	0.54	0.61	0.73	0.85	0.97	1.09	798	301
5	Fastest	0.29	0.39	0.49	0.58	0.68	0.78	0.87	0.97	1.17	1.36	1.55	1.75	497	
6	Full	0.17	0.22	0.28	0.33	0.39	0.44	0.50	0.55	0.66	0.77	0.88	0.99	1,050	488
6	10º tip	0.22	0.29	0.36	0.44	0.51	0.58	0.65	0.73	0.87	1.02	1.16	1.31	798	236
6	Fastest	0.31	0.41	0.52	0.62	0.72	0.82	0.93	1.03	1.24	1.44	1.65	1.86	562	
7	Full	0.19	0.26	0.32	0.39	0.45	0.52	0.58	0.64	0.77	0.90	1.03	1.16	1,050	430
7	10º tip	0.25	0.34	0.42	0.51	0.59	0.68	0.76	0.85	1.02	1.19	1.36	1.52	798	178
7	Fastest	0.33	0.44	0.55	0.65	0.76	0.87	0.98	1.09	1.31	1.53	1.74	1.96	620	
8	Full	0.22	0.29	0.37	0.44	0.52	0.59	0.66	0.74	0.88	1.03	1.18	1.32	1,050	378
8	10º tip	0.29	0.39	0.48	0.58	0.68	0.77	0.87	0.97	1.16	1.36	1.55	1.74	798	126
8	Fastest	0.34	0.46	0.57	0.69	0.80	0.92	1.03	1.15	1.38	1.61	1.84	2.07	672	

[1] Additional transit rate and reel rate tables may be obtained from the U.S. Geological Survey Office of Water Quality at http://water.usgs.gov/owq/

Appendix F. Isokinetic transit rates[1]—Continued

Depth (feet)	Rate	Mean stream velocity (vertical feet per second)												Volume (milliliters)	
		1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	6.00	7.00	8.00	9.00	Maximum 10° minimum	Minimum
10	Full	0.28	0.37	0.46	0.55	0.64	0.74	0.83	0.92	1.10	1.29	1.47	1.66	1,050	288
10	10° tip	0.36	0.48	0.61	0.73	0.85	0.97	1.09	1.21	1.45	1.69	1.94	2.18	798	37
10	Fastest	0.38	0.51	0.63	0.76	0.89	1.01	1.14	1.27	1.52	1.78	2.03	2.28	761	
12	Full	0.33	0.44	0.55	0.66	0.77	0.88	0.99	1.10	1.32	1.55	1.77	1.99	1,050	214
12	10° tip														
12	Fastest	0.42	0.55	0.69	0.83	0.97	1.11	1.25	1.39	1.66	1.94	2.22	2.50	836	
14	Full	0.39	0.52	0.64	0.77	0.90	1.03	1.16	1.29	1.55	1.80	2.06	2.32	1,050	152
14	10° tip														
14	Fastest	0.45	0.60	0.75	0.90	1.05	1.20	1.36	1.51	1.81	2.11	2.41	2.71	898	
15	Full	0.41	0.55	0.69	0.83	0.97	1.10	1.24	1.38	1.66	1.93	2.21	2.48	1,050	124
15	10° tip														
15	Fastest	0.47	0.63	0.78	0.94	1.10	1.25	1.41	1.57	1.88	2.19	2.50	2.82	926	
1-liter bottle, 5/16-inch nozzle															
1	Full	0.04	0.06	0.07	0.09	0.10	0.12	0.13	0.14	0.17	0.20	0.23	0.26	1,049	918
1	10° tip	0.06	0.08	0.09	0.11	0.13	0.15	0.17	0.19	0.23	0.26	0.30	0.34	800	668
1	Fastest	0.34	0.46	0.57	0.69	0.80	0.92	1.03	1.15	1.38	1.61	1.84	2.07	132	
2	Full	0.09	0.12	0.14	0.17	0.20	0.23	0.26	0.29	0.35	0.40	0.46	0.52	1,049	806
2	10° tip	0.11	0.15	0.19	0.23	0.26	0.30	0.34	0.38	0.45	0.53	0.60	0.68	800	557
2	Fastest	0.37	0.50	0.62	0.74	0.87	0.99	1.12	1.24	1.49	1.74	1.98	2.23	243	
3	Full	0.13	0.17	0.22	0.26	0.30	0.35	0.39	0.43	0.52	0.60	0.69	0.78	1,049	709
3	10° tip	0.17	0.23	0.28	0.34	0.40	0.45	0.51	0.57	0.68	0.79	0.91	1.02	800	460
3	Fastest	0.40	0.53	0.67	0.80	0.93	1.07	1.20	1.33	1.60	1.87	2.13	2.40	340	
4	Full	0.17	0.23	0.29	0.35	0.40	0.46	0.52	0.58	0.69	0.81	0.92	1.04	1,049	626
4	10° tip	0.23	0.30	0.38	0.45	0.53	0.60	0.68	0.75	0.91	1.06	1.21	1.36	800	376
4	Fastest	0.43	0.57	0.71	0.86	1.00	1.14	1.28	1.43	1.71	2.00	2.28	2.57	424	
5	Full	0.22	0.29	0.36	0.43	0.50	0.58	0.65	0.72	0.86	1.01	1.15	1.29	1,049	552
5	10° tip	0.28	0.38	0.47	0.57	0.66	0.75	0.85	0.94	1.13	1.32	1.51	1.70	800	303
5	Fastest	0.46	0.61	0.76	0.91	1.06	1.21	1.37	1.52	1.82	2.13	2.43	2.73	497	

Appendix F. Isokinetic transit rates[1]—Continued

Depth (feet)	Rate	Mean stream velocity (vertical feet per second)												Volume (milliliters)	
		1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	6.00	7.00	8.00	9.00	Maximum 10° minimum	Minimum
6	Full	0.26	0.35	0.43	0.52	0.60	0.69	0.78	0.86	1.04	1.21	1.38	1.55	1,049	487
6	10° tip	0.34	0.45	0.57	0.68	0.79	0.91	1.02	1.13	1.36	1.58	1.81	2.04	800	238
6	Fastest	0.48	0.64	0.81	0.97	1.13	1.29	1.45	1.61	1.93	2.26	2.58	2.90	562	
7	Full	0.30	0.40	0.50	0.60	0.71	0.81	0.91	1.01	1.21	1.41	1.61	1.81	1,049	429
7	10° tip	0.40	0.53	0.66	0.79	0.92	1.06	1.19	1.32	1.58	1.85	2.11	2.38	800	180
7	Fastest	0.51	0.68	0.85	1.02	1.19	1.36	1.53	1.70	2.04	2.38	2.73	3.07	620	
8	Full	0.35	0.46	0.58	0.69	0.81	0.92	1.04	1.15	1.38	1.61	1.84	2.07	1,049	377
8	10° tip	0.45	0.60	0.75	0.91	1.06	1.21	1.36	1.51	1.81	2.11	2.42	2.72	800	128
8	Fastest	0.54	0.72	0.90	1.08	1.26	1.44	1.62	1.80	2.16	2.51	2.87	3.23	672	
10	Full	0.43	0.58	0.72	0.86	1.01	1.15	1.29	1.44	1.73	2.01	2.30	2.59	1,049	287
10	10° tip	0.57	0.75	0.94	1.13	1.32	1.51	1.70	1.89	2.26	2.64	3.02	3.40	800	38
10	Fastest	0.59	0.79	0.99	1.19	1.39	1.59	1.78	1.98	2.38	2.77	3.17	3.57	762	
11	Full	0.47	0.63	0.79	0.95	1.11	1.27	1.42	1.58	1.90	2.22	2.53	2.85	1,049	219
11	10° tip														
11	Fastest	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00	2.40	2.80	3.20	3.60	830	
12	Full	0.52	0.69	0.86	1.04	1.21	1.38	1.55	1.73	2.07	2.42	2.76	3.11	1,049	143
12	10° tip														
12	Fastest	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00	2.40	2.80	3.20	3.60	906	
13	Full	0.56	0.75	0.94	1.12	1.31	1.50	1.68	1.87	2.24	2.62	2.99	3.37	1,049	68
13	10° tip														
13	Fastest	0.60	0.80	1.00	1.20	1.40	1.60	1.80	2.00	2.40	2.80	3.20	3.60	981	
3-liter bottle, 5/16-inch nozzle															
2	Full	0.03	0.04	0.05	0.06	0.07	0.09	0.10	0.11	0.13	0.15	0.17	0.19	2,830	2,118
2	10° tip	0.04	0.05	0.06	0.07	0.09	0.10	0.11	0.12	0.15	0.17	0.20	0.22	2,461	1,749
2	Fastest	0.13	0.17	0.21	0.25	0.30	0.34	0.38	0.42	0.51	0.59	0.68	0.76	712	
3	Full	0.05	0.06	0.08	0.10	0.11	0.13	0.14	0.16	0.19	0.22	0.26	0.29	2,830	1,837
3	10° tip	0.06	0.07	0.09	0.11	0.13	0.15	0.17	0.18	0.22	0.26	0.29	0.33	2,461	1,468
3	Fastest	0.14	0.18	0.23	0.27	0.32	0.36	0.41	0.46	0.55	0.64	0.73	0.82	993	

Appendix F. Isokinetic transit rates[1]—Continued

Depth (feet)	Rate	Mean stream velocity (vertical feet per second)												Volume (milliliters)	
		1.50	2.00	2.50	3.00	3.50	4.00	4.50	5.00	6.00	7.00	8.00	9.00	Maximum 10° minimum	Minimum
4	Full	0.06	0.09	0.11	0.13	0.15	0.17	0.19	0.21	0.26	0.30	0.34	0.38	2,830	1,593
4	10° tip	0.07	0.10	0.12	0.15	0.17	0.20	0.22	0.25	0.29	0.34	0.39	0.44	2,461	1,224
4	Fastest	0.15	0.20	0.24	0.29	0.34	0.39	0.44	0.49	0.59	0.68	0.78	0.88	1,237	
5	Full	0.08	0.11	0.13	0.16	0.19	0.21	0.24	0.27	0.32	0.37	0.43	0.48	2,830	1,379
5	10° tip	0.09	0.12	0.15	0.18	0.21	0.25	0.28	0.31	0.37	0.43	0.49	0.55	2,461	1,010
5	Fastest	0.16	0.21	0.26	0.31	0.36	0.42	0.47	0.52	0.62	0.73	0.83	0.94	1,451	
6	Full	0.10	0.13	0.16	0.19	0.22	0.26	0.29	0.32	0.38	0.45	0.51	0.58	2,830	1,190
6	10° tip	0.11	0.15	0.18	0.22	0.26	0.29	0.33	0.37	0.44	0.52	0.59	0.66	2,461	820
6	Fastest	0.17	0.22	0.28	0.33	0.39	0.44	0.50	0.55	0.66	0.77	0.88	0.99	1,641	
7	Full	0.11	0.15	0.19	0.22	0.26	0.30	0.34	0.37	0.45	0.52	0.60	0.67	2,830	1,021
7	10° tip	0.13	0.17	0.21	0.26	0.30	0.34	0.39	0.43	0.52	0.60	0.69	0.77	2,461	652
7	Fastest	0.18	0.23	0.29	0.35	0.41	0.47	0.53	0.58	0.70	0.82	0.93	1.05	1,809	
8	Full	0.13	0.17	0.21	0.26	0.30	0.34	0.38	0.43	0.51	0.60	0.68	0.77	2,830	870
8	10° tip	0.15	0.20	0.25	0.29	0.34	0.39	0.44	0.49	0.59	0.69	0.79	0.88	2,461	501
8	Fastest	0.18	0.25	0.31	0.37	0.43	0.49	0.55	0.62	0.74	0.86	0.99	1.11	1,960	
9	Full	0.14	0.19	0.24	0.29	0.34	0.38	0.43	0.48	0.58	0.67	0.77	0.86	2,830	734
9	10° tip	0.17	0.22	0.28	0.33	0.39	0.44	0.50	0.55	0.66	0.77	0.88	0.99	2,461	365
9	Fastest	0.19	0.26	0.32	0.39	0.45	0.52	0.58	0.65	0.78	0.91	1.04	1.17	2,096	
10	Full	0.16	0.21	0.27	0.32	0.37	0.43	0.48	0.53	0.64	0.75	0.85	0.96	2,830	610
10	10° tip	0.18	0.25	0.31	0.37	0.43	0.49	0.55	0.61	0.74	0.86	0.98	1.10	2,461	241
10	Fastest	0.20	0.27	0.34	0.41	0.48	0.54	0.61	0.68	0.82	0.95	1.09	1.22	2,220	
12	Full	0.19	0.26	0.32	0.38	0.45	0.51	0.58	0.64	0.77	0.90	1.02	1.15	2,830	396
12	10° tip	0.22	0.29	0.37	0.44	0.52	0.59	0.66	0.74	0.88	1.03	1.18	1.32	2,461	26
12	Fastest	0.22	0.30	0.37	0.45	0.52	0.60	0.67	0.74	0.89	1.04	1.19	1.34	2,435	
14	Full	0.22	0.30	0.37	0.45	0.52	0.60	0.67	0.75	0.90	1.05	1.19	1.34	2,830	215
14	10° tip														
14	Fastest	0.24	0.32	0.40	0.48	0.57	0.65	0.73	0.81	0.97	1.13	1.29	1.45	2,615	
15	Full	0.24	0.32	0.40	0.48	0.56	0.64	0.72	0.80	0.96	1.12	1.28	1.44	2,830	135
15	10° tip														
15	Fastest	0.25	0.34	0.42	0.50	0.59	0.67	0.76	0.84	1.01	1.18	1.34	1.51	2,695	

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