

# Guidelines for Field-Measured Water-Quality Properties

Chapter 6.0 of  
Section A, National Field Manual for the Collection of Water-Quality Data  
**Book 9, Handbooks for Water-Resources Investigations**



Techniques and Methods 9–A6.0

Version 1.1, July 17, 2023

Supersedes USGS Techniques of Water-Resources Investigations,  
Book 9, Chapter A6.0, Version 2.0

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

**Cover:** Measurement of field parameters in Furnace Spring, Shenandoah National Park, Virginia.  
Photograph by Gerolamo Casile, U.S. Geological Survey.

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## Contents

Abstract.....	1
1.0 Introduction.....	1
2.0 Quality Assurance.....	2
2.1 Records.....	2
3.0 Performing Field Measurements.....	3
3.1 Surface Water.....	5
3.1.1 Summary of Surface-Water Sampling Methods.....	5
3.1.2 In Situ Field-Measurement Procedures.....	9
3.1.3 Subsample Field-Measurement Procedures.....	9
3.2 Groundwater.....	9
3.2.1 Summary of Well-Purging Protocols.....	15
3.2.2 Direct Field-Measurement Procedure Using a Flow-Through Cell/Chamber.....	17
3.2.3 Subsample Field-Measurement Procedures.....	19
Acknowledgments.....	19
Selected References.....	21

## Figures

6.0-1. In situ field-measurement procedures for surface water.....	10
6.0-2. Subsample field-measurement procedures for conductivity, pH, and alkalinity of surface water.....	11
6.0-3. Sketch of a manifold and flow-through cell/chamber used during well purging and sample collection.....	12
6.0-4. Example of a field form for recording measurements during well purging.....	13
6.0-5. Photographs of a flow-through cell/chamber for use with multiple sensors, shown without sensors installed; and a flow-through cell for a multiparameter sonde.....	14
6.0-6. Field-measurement procedures for groundwater performed by using downhole and flow-through cell/chamber systems.....	18
6.0-7. Subsample field-measurement procedures for conductivity, pH, and alkalinity of groundwater.....	20

## Tables

6.0-1. Stabilization criteria for recording direct field measurements.....	3
6.0-2. Example of field notes for a discharge-weighted conductivity measurement.....	7
6.0-3. Example of field notes for an area-weighted conductivity measurement.....	8

## Conversion Factors

U.S. customary units to International System of Units

<b>Multiply</b>	<b>By</b>	<b>To obtain</b>
gallon (gal)	3.785	liter (L)
pound, avoirdupois (lb)	0.4536	kilogram (kg)

International System of Units to U.S. customary units

<b>Multiply</b>	<b>By</b>	<b>To obtain</b>
kilogram (kg)	2.205	pound, avoirdupois (lb)
liter (L)	0.2642	gallon (gal)
liter (L)	61.02	cubic inch (in <sup>3</sup> )
milligram (mg)	$3.527 \times 10^{-5}$	ounce, avoirdupois (oz)
milliliter (mL)	0.0338	ounce, fluid (oz)
milliliter (mL)	$2.642 \times 10^{-4}$	gallon (gal)

Temperature is reported in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by use of the following equation:

$$^{\circ}\text{F} = 1.8(^{\circ}\text{C}) + 32$$

Specific conductance is reported in microsiemens per centimeter at 25 degrees Celsius ( $\mu\text{S}/\text{cm}$  at 25 °C).

## Abbreviations and Symbols

ANC	acid-neutralizing capacity
Eh	measure of the oxidation-reduction potential of a solution
L	liter
$\mu\text{S}/\text{cm}$	microsiemens per centimeter (reported at 25 °C)
mg/L	milligram per liter (equivalent to parts per million [ppm])
NFM	National Field Manual for the Collection of Water-Quality Data (USGS)
NFOA	National Field Quality Assurance program (USGS)
NFSS	National Field Supplies Service—also referred to as “One-Stop Shopping” (USGS)
NWIS	National Water Information System (USGS)
NWIS-TS	NWIS time-series data—NWIS database for continuous water data (USGS)
pH	negative base-10 logarithm of the hydrogen ion activity (unitless)
QA	quality assurance
QC	quality control
QW	quality of water
QWDATA	Quality of Water Database (USGS NWIS database for discrete water data)

USGS	U.S. Geological Survey
>	greater than
≥	greater than or equal to
<	less than
≤	less than or equal to

## Requirements and Recommendations

As used in the U.S. Geological Survey (USGS) “National Field Manual for the Collection of Water-Quality Data” (NFM), the terms “**required**” and “**recommended**” have the USGS-specific meanings described below:

- The terms “**require**,” “**required**,” and “**requirements**” in reference to USGS protocols indicate that USGS Water Mission Area (WMA) policy has been established on the basis of research or consensus of the technical staff, and has been reviewed by water-quality specialists and other professionals having the appropriate expertise. Technical memorandums and other documents that define USGS WMA policy are cited in the NFM. USGS field personnel are instructed to use required equipment and procedures as described in the NFM. Departure from or modifications to stipulated requirements, if necessary for accomplishing specific data-quality requirements or study objectives, must be independently quality assured and documented (Office of Water Quality Technical Memorandum [2002.13](#)—U.S. Geological Survey, 2002).
- The terms “**recommend**,” “**recommended**,” and “**recommendation**” indicate that, on the basis of research or consensus, there are several acceptable alternatives to a given procedure or equipment selection in the NFM. Relevant technical memorandums and publications pertinent to such recommendations are cited in the NFM to the extent that such documents are available. Specific requirements, data-quality objectives, or other constraints of a project may affect the choice of recommended equipment or procedures. Selection from among the recommended alternatives should be based on referenced research and sound field judgment, and reasons for the selection must be documented. Departures from or modifications to the recommended procedures must be independently quality assured and documented (Office of Water Quality Technical Memorandum [2002.13](#)—U.S. Geological Survey, 2002).



# Chapter 6.0. Guidelines for Field-Measured Water-Quality Properties

By U.S. Geological Survey

## Abstract

The “National Field Manual for the Collection of Water-Quality Data” (NFM) provides guidelines and procedures for U.S. Geological Survey (USGS) personnel who collect data used to assess the quality of the Nation’s surface-water and groundwater resources. This chapter, NFM A6.0, provides guidance and protocols for the measurement of field parameters on site, which include the selection of measurement points and methods for measurement in groundwater and surface water and procedures for measurement and reporting. It updates and supersedes USGS Techniques of Water-Resources Investigations, book 9, chapter A6.0, version 2.0, by Franceska D. Wilde. Field parameters are routinely measured when water samples are collected, are often measured continually at USGS streamgages, and are regularly measured during laboratory and field experiments. The field methods for measuring field parameters described in this chapter are applicable to most natural waters.

Before 2017, the NFM chapters were released in the USGS Techniques of Water-Resources Investigations series. Effective in 2018, new and revised NFM chapters are being released in the USGS Techniques and Methods series; this series change does not affect the content and format of the NFM. More information is in the general introduction to the NFM (USGS Techniques and Methods, book 9, chapter A0) at <https://doi.org/10.3133/tm9A0>. The authoritative current versions of NFM chapters are available in the USGS Publications Warehouse at <https://pubs.er.usgs.gov/>. Comments, questions, and suggestions related to the NFM can be addressed to [nfm@usgs.gov](mailto:nfm@usgs.gov).

## 1.0 Introduction

The “National Field Manual for the Collection of Water-Quality Data” (NFM) is the official and citable protocol for the collection of water-quality data by the Water Mission Area (WMA) of the U.S. Geological Survey (USGS). The NFM provides guidelines and procedures for USGS personnel who collect data for water quality in surface water and groundwater, with detailed, comprehensive, and citable procedures.

National USGS program and project personnel who collect water-quality data, as well as those in USGS Water Science Centers and including those conducting projects supported by the USGS Cooperative program, are mandated to use protocols provided in the NFM (USGS Office of Water-Quality Technical Memorandum 2002.13—U.S. Geological Survey, 2002). Formal training, as provided in the USGS class “Field Water-Quality Methods for Groundwater and Surface Water,” and field apprenticeships supplement the information provided in the NFM and are needed to collect unbiased, high-quality data.

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**The USGS National Field Manual provides detailed, comprehensive, and citable procedures for monitoring the quality of surface water and groundwater. Formal training and field apprenticeships supplement the information provided in the NFM.**

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Chapter A6.0 provides guidance and protocols for the on-site measurement of water-quality field parameters, which include the selection of sites and methods for making measurements in groundwater and surface water and procedures for reporting. It updates and supersedes USGS Techniques of Water-Resources Investigations, book 9, chapter A6.0, version 2.0, by Franceska D. Wilde. Field parameters are routinely measured when water samples are collected, are often measured continually at USGS streamgages, and are regularly measured during laboratory and field experiments.

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**FIELD MEASUREMENTS<sup>1</sup>: Determinations of physical or chemical properties that must be measured on site, as close as possible in time and space to the sampling of the medium.**

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On-site measurement is necessary to preserve sample integrity and ensure data accuracy for the following field measurements: water temperature, dissolved-oxygen (DO)

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<sup>1</sup>The term “field measurements,” as used in the National Field Manual, is synonymous with “field properties” and “field parameters,” terms that are used commonly in environmental water-quality literature.

## 2 Chapter A6.0. Guidelines for Field-Measured Water-Quality Properties

concentration, specific electrical conductance (SC), pH, reduction-oxidation potential (redox/ORP), alkalinity and acid-neutralizing capacity (ANC)<sup>2</sup>, and turbidity.<sup>3</sup> The field methods for measuring field parameters described in this chapter are applicable to most natural waters.

USGS guidelines for continuous monitoring of selected field measurements are described in Wagner and others (2006). Specific guidance for the use of multiparameter instruments—instruments for which the individual field-measurement sensors are combined into a sonde and deployed to the water body for in situ measurements—is provided in NFM A6.8.

Before 2017, the NFM chapters were released in the USGS Techniques of Water-Resources Investigations series. Effective in 2018, new and revised NFM chapters are being released in the USGS Techniques and Methods series; this series change does not affect the content and format of the NFM. More information is in the general introduction to the NFM (USGS Techniques and Methods, book 9, chapter A0) at <https://doi.org/10.3133/tm9A0>. The authoritative current versions of NFM chapters are available in the USGS Publications Warehouse at <https://pubs.er.usgs.gov/>. Comments, questions, and suggestions related to the NFM can be addressed to [nfm@usgs.gov](mailto:nfm@usgs.gov).

## 2.0 Quality Assurance

Adherence to standard U.S. Geological Survey (USGS) quality-assurance protocols is required, and quality-controlled procedures are to be incorporated into every USGS data-collection effort to monitor water quality. Quality assurance of the data collected includes the timely and accurate documentation of field information in electronic and (or) paper records, as well as second- or third-party auditing of such records. Included in these records of quality-control data for field measurements are the records of replicate measurements. Training in measurement techniques and the collection of quality-control data is essential to the consistency of the field-measurement procedures.

### 2.1 Records

Recordkeeping is the responsibility of all field personnel. Electronic and (or) paper records must be established and maintained for each uniquely identified sampling location to

<sup>2</sup>Alkalinity/acid-neutralizing capacity (ANC) is a field analysis, not a direct field measurement; however, the analysis is performed routinely during the same field trip in which the other field-measurements are made. In this section, the term “alkalinity” is used when referring to either alkalinity or ANC.

<sup>3</sup>Each of these field measurements is discussed in detail in the following chapters of the National Field Manual: temperature (NFM A6.1), dissolved oxygen (NFM A6.2), specific electrical conductance (NFM A6.3), pH (NFM A6.4), reduction-oxidation potential (NFM A6.5), alkalinity and acid-neutralizing capacity (NFM A6.6), and turbidity (NFM A6.7).

permanently document field activities, measurement readings, instrument calibration, and any other information needed to meet programmatic or regulatory requirements (see NFM A1 and A4 for detailed information about records).

- For every field visit, instrument-performance information and the field-measurement data are transcribed onto paper and (or) electronic field and analytical request forms by the data collector. Much of the documentation process should be completed at the field site. Records should be checked independently by a field partner and (or) data administrator. Additional field forms, such as chain-of-custody or land-use forms, may be required, depending on project needs.
- USGS personnel are encouraged to use electronic instead of paper field notes to increase efficiency and minimize transcription errors. [Office of Water Quality Technical Memorandum 2016.09](#) recommends that all water-quality records be collected electronically wherever feasible and specifies requirements for electronic records.
- A separate paper or electronic log book must be maintained for each field instrument or replaceable sensor where instrument repair, maintenance, and calibration history information is recorded. The log book travels with the instrument. The pages of the instrument log book should be prenumbered consecutively. Do not skip or tear out pages. Water-resistant paper is recommended. Log books are available to USGS personnel through One-Stop Shopping at the USGS internal website <https://1stop.usgs.gov> (item Q609FLD).
- Use a blue or black indelible ballpoint pen to write on paper forms and in log books. Use of a pencil is not acceptable; felt-tipped pens (for example, Sharpie® markers) should not be used, and could compromise the quality of data for samples collected for measurement of volatile organic compounds.
- Fill out the forms as completely as possible. Erroneous or mistaken entries should be crossed out with one line and initialed.
- The conventions used to report field-measurement data are described at the end of each field-measurement chapter of the NFM. Stabilization criteria for recording direct field measurements are given in table 6.0–1.
- Final or reported field-measurement values for USGS studies are to be entered into the following parts of the National Water Information System (NWIS):
  - **QWDATA**: Contains discrete (noncontinuous) field-measurement data in addition to results of laboratory analyses.

**Table 6.0–1.** Stabilization criteria for recording direct field measurements.

[±, plus or minus; °C, degrees Celsius; ≤, less than or equal to; μS/cm, microsiemens per centimeter at 25 °C; >, greater than; unit, standard pH unit; mg/L, milligrams per liter; FNU, formazin nephelometric units; TU, turbidity units; %, percent]

Standard direct field measurement <sup>1</sup>	Stabilization criteria <sup>2</sup> (Variability should be within the range shown for five or more measurements)
<b>Temperature</b>	
Thermistor	±0.2 °C
<b>Specific electrical conductance</b>	
≤100 μS/cm	±5 μS/cm
>100 μS/cm	±3%
<b>Dissolved oxygen</b>	
Optical/luminescent sensors	±0.2 mg/L
<b>pH:</b>	
Meter displays to 0.01	±0.1 unit
<b>Turbidity<sup>3</sup></b>	
≤100 FNU (or other TU)	±0.5 TU or ±5%, whichever is greater
>100 FNU (or other TU)	±10%

<sup>1</sup>Eh is not considered to be a routine or direct field measurement (see National Field Manual (NFM) A6.5). Alkalinity and acid-neutralizing capacity determinations require a titration procedure and are not considered direct measurements.

<sup>2</sup>Refer to NFM A6.8 for similar criteria when using multiparameter instruments. For continuous monitors, consult Wagner and others (2006).

<sup>3</sup>Multiparameter instruments used for most in situ turbidity applications contain single-beam infrared wavelength turbidity sensors and are reported in FNU. Check the Excel spreadsheet at [https://pubs.usgs.gov/twri/twri9a6/twri9a67/twri9a\\_turbidity\\_codes\\_5-2012.xlsx](https://pubs.usgs.gov/twri/twri9a6/twri9a67/twri9a_turbidity_codes_5-2012.xlsx) to determine the appropriate turbidity unit of measure; consult NFM A6.7 for detailed guidance on turbidity measurement and instrumentation.

- **AQUARIUS:** Contains automated, continuous water data, all groundwater level data, and information for discrete samples.

### 3.0 Performing Field Measurements

Field measurements should represent, as closely as possible, the ambient physical and chemical properties of the surface-water or groundwater system at the time of sampling. Properties of temperature, DO concentration, and Eh are required to be measured directly (in situ) in the water body where possible. Other properties such as pH, conductivity, and turbidity are recommended to be measured in situ or from a sample withdrawn from the source, depending on the type of equipment selected for field measurements. Alkalinity determination requires titration on a measured volume of subsample. These properties are required to be measured at the field site.

**Expertise:** Collecting data for USGS studies requires training, practice, and a knowledge of required and recommended protocols.

- **Training:** Field personnel must complete USGS water-quality courses. Fundamental training for performing water-quality field activities in accordance with USGS protocols and standard procedures includes a two-week Field Water-Quality Methods class (QW1028). Other foundational training includes Water-Quality

Principles (QW1022), Water Quality Instrumentation; Operation, Calibration, and Maintenance (USGS–W–16–322), Statistical Methods for Environmental Data Analysis (QW1075), Quality-Control Sample Design and Interpretation (QW2034), and Water-Quality Toolbox for NWIS Users (QW1297). These classes provide a practicum for the knowledgeable execution of field and office project activities and help to ensure proper management and valid interpretation of the data being collected.

- **National Field Quality Assurance Program (NFQA):** All field personnel, including non-USGS employees, who collect field-measurement data that are entered into NWIS are required to participate annually in the NFQA Program (<https://qsb.usgs.gov/nfqa/onlineResources.php?page=overView>, accessed May 14, 2020), which evaluates the proficiency of personnel in measuring pH, SC, and alkalinity (or ANC).

**Equipment:** A variety of single-parameter and multiparameter instruments that use various technologies to measure the same water property and that require different calibration, maintenance, and measurement methods is available for field measurements.

- **Single-parameter instruments:** Single-parameter instruments include, for example, stand-alone temperature sensors; DO, SC, and pH meters; and turbidimeters. The protocols and procedures that

## 4 Chapter A6.0. Guidelines for Field-Measured Water-Quality Properties

pertain to these instruments are a primary focus of NFM A6.1 through NFM A6.7. Single-parameter instruments are selected according to project needs and convenience, or when required because site conditions do not allow use of a multiparameter instrument, or for the purpose of instrumenting a flow-through cell or chamber.

- **Multiparameter instruments:** Multiparameter instruments have measurement sensors that fit into the body of a sonde. Measurements made with the sonde can be performed either by submerging the sensors of the sonde in surface water or groundwater, or by pumping a sample in line from its source to an air-tight cell/chamber into which the sonde fits.

Field teams must determine whether the instruments and methods to be used will produce data of the type and quality required to fulfill study needs as well as USGS requirements. Check the appropriate chapter of the NFM for the required and recommended methods and equipment, instructions for measurement and quality-control procedures, and guidelines for troubleshooting and data reporting. Keep the following in mind while determining the type of instrumentation and methods to use for a water-quality study:

- Become familiar with the instructions and precautions provided by the manufacturers of the instruments to be used. Field personnel are encouraged to contact instrument manufacturers for answers to technical questions about the operation of their instrument. Apparent conflicts between USGS protocols and a manufacturer's instructions should be identified and resolved by consulting a water-quality specialist.
  - Field instruments are constantly being improved or replaced by newer technology that typically is unique in some aspect to the manufacturer of the instrument. Personnel should be knowledgeable about emerging technologies that can improve the quality and efficiency of their field activities.
  - Make field measurements only with properly calibrated instruments. Instruments are required to be calibrated before each field trip and checks are required at field sites for most instruments.
  - If the instrument or measurement is new to you, practice your measurement technique with a mentor who has current experience and is up to date with USGS field-method protocol and procedures.
  - Review the instrument log book(s) before leaving for the field site to ensure that problems previously encountered have been resolved and that the appropriate instrument and site maintenance were performed.
- Backup instruments and batteries should be readily available and in good working condition.
- Performance:** Be aware of sampling and field or other conditions that could introduce bias to the determination of field-measurement values. Execute field measurements in a manner that avoids or minimizes bias from data-collection activities.
- Check instrument precision and accuracy (variability and bias) periodically while at a field site; precision and accuracy may vary depending on the instrument used, sampling conditions, and the expertise of personnel.
  - Long-standing USGS standard procedure is to allow sensors to equilibrate to the temperature of the water being monitored to the extent possible before making field measurements, as is appropriate for the instrument in use. Sensors have equilibrated adequately when instrument readings have stabilized—that is, when the variability among consecutive measurements does not exceed an established criterion. The USGS criteria for stabilized field readings are defined operationally in table 6.0–1 for a set of about five (or more) consecutive measurements.
- The natural variability inherent in surface water or groundwater at the time of sampling generally falls within the stability criteria given in table 6.0–1 and reflects the accuracy that should be attainable with a properly calibrated instrument.
- **Surface water:** Allow at least 60 seconds (or follow the manufacturer's guidelines) for sensors to equilibrate with sample water. Take instrument readings until the stabilization criteria in table 6.0–1 are met. Record the median of the final three or more readings as the value to be reported for that measurement point (section 3.1).
  - **Groundwater:** Begin recording measurements after sensors have equilibrated with purge water. Take instrument readings until the stabilization criteria in table 6.0–1 are met and the required number of well volumes of groundwater have been purged. Record the median of the final five or more readings as the value to be reported for that site (section 3.2).
  - For sites at which variability exceeds the criteria shown in table 6.0–1, allow the instrument a longer equilibration time and record additional measurements. To determine the value to be reported for that measurement point, either use the median of the final five or more measurements recorded, or apply knowledge of the site and professional judgment to select the most representative of the final readings and document in field notes how the decision was made.

### 3.1 Surface Water

Field measurements must accurately represent the physical or chemical properties of the surface water being studied. In order to collect data that represent water conditions at the time of sampling, it is necessary to correctly locate the point(s) of measurement, select equipment appropriate to site conditions and study needs, and use appropriate methods to make accurate field measurements. Water temperature, DO concentration, and Eh are required to be measured directly within the water body (in situ) where possible. Other properties, such as pH, conductivity, and turbidity, are recommended to be measured in situ but may be measured in a subsample of a composite or grab sample, as appropriate for the study.

#### 3.1.1 Summary of Surface-Water Sampling Methods

Standard USGS procedures for locating points of sample collection and sample-collection methods for surface-water sampling are detailed in NFM A4. **This section (3.1.1) provides an abbreviated description of surface-water isokinetic sampling methods, and should not be used without a detailed understanding of the method as given in NFM A4.** The quality and interpretation of the field-measurement data collected also depend on the equipment with which samples are withdrawn, composited, and subsampled. Guidance for equipment selection is detailed in NFM A2. **Familiarity with the USGS protocols and standard procedures prescribed in these chapters of the National Field Manual is the responsibility of all USGS water-quality field personnel.**

Typically, the point or points at which field measurements are made correspond to the location(s) at which samples are collected for laboratory analysis (NFM A4). The decision to use grab-sampling methods or isokinetic sampling methods is based on the characteristics of the water body to be sampled or monitored and on study objectives.

- **Still-water conditions** are found in storage pools, lakes, and reservoirs. Field measurements typically are made in situ at multiple locations and depths. The location, number, and distribution of measurement points are determined according to study objectives.
- Measurements made at discrete depths through the water column must not be averaged or reported as a median value that represents the entire vertical section (vertical).
- Report the value selected to represent each point measured in the vertical individually by assigning a unique time to each measurement in the vertical.
- **Flowing-water conditions** are found in perennial and ephemeral streams. The location and the number of field measurements depend on stream conditions and study

objectives. Generally, a single set of field-measurement data is used to represent an entire stream cross section at a sampling site. This practice can be useful when calculating chemical loads.

- To obtain data representative of the section, the variability of discharge and field measurements across the stream must be known.
- An exploratory field-measurement profile across a section of a stream can be used to estimate the magnitude of variation along the cross section.
- A field-measurement profile also can be useful—especially at new or poorly documented sites—to determine which isokinetic method (equal-discharge increment (EDI) or equal-width increment (EWI)) should be used for sampling.
- The final points of measurement are determined according to whether the EDI or EWI method will be used. Make individual measurements at a number of equally spaced verticals along the cross section and at multiple depths within each vertical. Alternatively, consult previous records for the site to determine historical measurement points and methods.

To locate measurement points:

1. Check the cross-sectional profile data of the stream site to determine the variability of discharge per unit width of the stream and of field-measurement values across the section.
  - Make individual measurements at several equally spaced verticals along the cross section and at multiple depths within each vertical—or consult previous records for the site.
  - Make in situ field measurements for the profile.
  - Field-measurement profiles of stream variability are needed for low- and high-flow conditions and should be verified at least every 2 years or as study objectives dictate.
2. Select the EDI or EWI method to locate points of measurement (refer to NFM A4 to select and execute the appropriate method).
  - If stream depth and velocities along the cross section are relatively uniform, use EWI.
  - If stream depth and velocities along the cross section are highly variable, use EDI.
  - In a small stream, typically less than 5 feet (ft) in width, that is well mixed, a single point at the centroid of flow may be used to represent the cross section. The stream is considered well mixed if the

variability of field-measurement values noted in the cross-sectional profile is negligible—for example, within the stabilization criteria given in table 6.0–1 in addition to best professional judgment of what is reasonable for the field site. The centroid of flow is defined as the point in the increment at which discharge in that increment is equal on both sides of the point.

### Equal-Discharge Increments (EDI)

The stream cross section is divided into increments of equal discharge. Field measurements can be made in situ at the centroid of each increment or by collecting an isokinetic, depth-integrated sample at the centroid of each increment and determining the value either for each sample or for a composite of the samples. These methods result in measurements that are discharge weighted (Edwards and Glysson, 1999).

Knowledge of streamflow distribution in the cross section is required to select verticals at which measurements will be made or subsamples collected. Streamflow distribution can be based on the long-term discharge record for the site or on a discharge measurement made just prior to sample collection. Divide the stream into a minimum of four increments. Additional increments could be needed for a stream site that is poorly mixed.

To divide the cross section into increments of equal discharge:

The following discussion summarizes the steps needed to apply the EDI method and should not be used without an understanding of the method and the detailed instructions given in NFM A4.

1. Visually inspect the stream from bank to bank, observing velocity, width, depth distribution, and the apparent distribution of sediment and aquatic biota in the cross section. Note the location of stagnant water, eddies, backwater, reverse flows, areas of faster than normal flow, and piers or other obstructions.
2. If the channel and the control governing the stage are stable, historical streamflow data can be used to determine the measurement locations. If the channel is unstable or if no historical data are available, make a discharge measurement and preliminary field measurements across the selected section of channel.
  - a. From the available discharge data, either:
    - Construct a graph using cumulative discharge or cumulative percent of total discharge plotted against the cross-sectional width, or
    - Determine EDI sections directly from the discharge-measurements note sheet.
  - b. If profile values of pH, conductivity, temperature, and DO concentration differ by less than 5 percent

and show that the stream is well mixed both across the section and from top to bottom, a single measurement point at the centroid of flow can be used to represent field-measurement values for the cross section.

3. From the graph or measurement notes, determine the number and locations of EDIs and the centroids (the far midpoints) of those increments.

**EXAMPLE:** If five increments will be used, select points of measurement by dividing the total stream discharge by 5 to determine increment discharge; in this case, each EDI equals 20 percent of discharge. The first vertical is located at the centroid of the initial EDI, the point where cumulative discharge equals 10 percent of the total discharge. The remaining four centroids are found by adding each successive incremental discharge to the discharge at the initial EDI centroid. The values at the far midpoints also need to be calculated. The EDI centroids will correspond to points along the stream cross section where 10, 30, 50, 70, and 90 percent of the total discharge are accounted for.

When making field measurements:

1. Select either the in situ or subsample method and follow the instructions in 3.1.2 or 3.1.3.
  - **In situ method**—Go to the centroid of the first EDI. Using submersible sensors, measure at mid-depth (or multiple depths) within the vertical. Repeat at each vertical. The value recorded at each vertical should be the median of values observed within approximately 60 seconds after sensor(s) have equilibrated with streamwater.
  - **Subsample method**—Collect an isokinetic, depth-integrated sample at the centroid of each EDI, emptying the increment sample into a compositing device. Measure field parameters either in the sample collected at each increment or in a subsample taken from the composite of all the increment samples.
2. The final field-measurement value is the mean of the in situ or individual increment-sample value for all the EDI verticals in the section (the composite subsample yields a single value). Use a median value for pH. For pH, recording a median value ensures that the reported pH value represents a true measurement rather than a computed measurement, and avoids the mathematical procedure required to compute a mean pH by using logarithmic operations. Enter the data on the field forms.
 

**EXAMPLE:** Table 6.0–2 shows an example of how mean conductivity measured in situ is calculated using the EDI method.

  - In the example, the correct value for the discharge-weighted mean conductivity is 163  $\mu\text{S}/\text{cm}$ , calculated

**Table 6.0–2.** Example of field notes for a discharge-weighted conductivity measurement.

[ft/s, feet per second; ft, feet; ft<sup>2</sup>, square feet; ft<sup>3</sup>/s, cubic feet per second; μS/cm, microsiemens per centimeter at 25 degrees Celsius; LEW, left edge of water; –, not available; REW, right edge of water]

Equal discharge increment	Percent of flow in increment	Mean velocity, in ft/s	Width of increment, in ft	Depth of increment, in ft	Area of increment, in ft <sup>2</sup>	Increment discharge, in ft <sup>3</sup> /s	Median conductivity <sup>1</sup> , in μS/cm
LEW	0	–	–	–	–	–	–
1	20	2.0	22	5.7	125	250	185
2	20	2.2	11	10.4	114	250	170
3	20	2.3	9	12.0	109	250	155
4	20	3.9	5	12.8	64	250	155
5	20	3.4	10	7.4	74	250	150
REW	0	–	–	–	–	–	–

<sup>1</sup>Calculation of conductivity: mean of median conductivity measurements ( $\frac{815}{5}$ ) = 163 μS/cm

as 815 divided by 5 (the sum of the recorded median values divided by the number of median measurements). This mean value should be entered into the QWDATA database as a calculated value.

- Note that the median conductivity at the midpoint of the center centroid of flow (increment 3) would have been reported as 155 μS/cm; if conductivity had been measured near the left edge of the water (increment 1), the conductivity would have been reported as 185 μS/cm.

### Equal-Width Increments (EWI)

The stream cross section is divided into increments of equal width. In situ field measurements are made at the midpoint of each increment. Area-weighted concentrations can be computed from these measurements (table 6.0–3). Subsample field measurements are made in discrete samples that typically are withdrawn from a composite sample collected with an isokinetic sampler and an isokinetic, depth-integrating method. The volume of the isokinetic sample must be proportional to the discharge in each increment, and measurements in subsamples taken from the compositing device result in discharge-weighted values. Knowledge of the streamflow distribution in the cross section is not required.

To divide the cross section into increments of equal width:

The following discussion summarizes the steps needed to apply the EWI method and should not be used without an understanding of the method and the detailed instructions given in NFM A4.

1. Visually inspect the stream from bank to bank, observing velocity, width, depth distribution, and the apparent distribution of sediment and aquatic biota in the cross section. Note the location of stagnant water, eddies,

backwater, areas of faster than normal flow, and piers or other obstructions.

2. Determine stream width by using a tagline or from station markings on bridge railings or cableways.
3. Divide the section into increments of equal width on the basis of flow and stream-channel characteristics along the cross section, field-measurement variability from the cross-section profile, and data objectives for the study. This interval width will govern the number of verticals used, and it also applies to streams in which flow is divided (for instance, a braided channel).
4. Locate the midpoint of the first vertical at a distance of one-half the selected increment width from the edge of the water. Locate other measurement verticals at the centers of the remaining increments.

**EXAMPLE:** In a stream 60 ft wide that has been divided into 15 increments of 4 ft each, the first measurement vertical would be 2 ft from the water's edge, and subsequent verticals would be at 6, 10, and 14 ft, and so forth, from the starting point at the water's edge.

- In streams 5 ft wide or greater, a minimum of 10 equal-width increments is recommended.
- In streams less than 5 ft wide, use as many increments as is practical, but they must be equally spaced and a minimum of 3 inches (in.) apart.

When making field measurements:

1. Select either the in situ or the subsample method and follow the instructions in section 3.1.2 or 3.1.3.
  - In situ method— Go to the centroid of the first EWI. Using submersible sensors, measure at mid-depth (or

multiple depths) within the vertical. Repeat this procedure at each vertical. The value recorded at each vertical should be the median of values observed within approximately 60 seconds after the sensor(s) have equilibrated with streamwater.

- Subsample method— Collect an isokinetic, depth-integrated sample at the centroid of each equal-width increment, emptying the increment sample into a compositing device. Measure field parameters either in the sample collected at each increment or in a subsample taken from the composite of all the increment samples.
2. The final field-measurement value is the mean of the in situ or individual increment-sample value for all the EWV verticals in the section (the composite subsample yields a single value). Use a median value for pH. Recording a median value for pH ensures that the reported value represents an actual measurement rather than a computed measurement, and avoids the mathematical procedure required to compute a mean pH by using logarithmic operations. Enter the data on the field forms.

**EXAMPLE:** Table 6.0–3 shows an example of an area-weighted median measurement for conductivity measured in situ.

- In the example, the area-weighted median conductivity equals 130  $\mu\text{S}/\text{cm}$ .
- To calculate an area-weighted median, multiply the area of each increment by its corresponding field measurement, sum the products of all the increments, and divide by total cross-sectional area.
- Note that if the conductivity reported were selected at mid-depth of the vertical of centroid of flow (section 10), it would have been reported as 125  $\mu\text{S}/\text{cm}$ ; if the conductivity reported were near the left edge of the water, it would have been reported as 150  $\mu\text{S}/\text{cm}$ .
- The final field-measurement value typically is calculated as the mean of the values recorded at all EWV increments, resulting in an area-weighted mean. Use a median value for pH.

**Table 6.0–3.** Example of field notes for an area-weighted conductivity measurement.

[ft, feet; LEW, left edge of water; ft<sup>2</sup>, square feet; SC, conductivity (specific electrical conductance);  $\mu\text{S}/\text{cm}$ , microsiemens per centimeter at 25 degrees Celsius; —, not available; REW, right edge of water]

Section number	Cumulative percent of flow in section	Vertical location, in ft from LEW	Width of section, in ft	Depth of vertical, in ft	Area of section, in ft <sup>2</sup>	Median SC <sup>1</sup> , in $\mu\text{S}/\text{cm}$	Product of median SC and area
LEW	0	0	—	—	—	—	—
1	2	2	4	1.0	4.0	150	600
2	4	6	4	2.0	8.0	145	1,160
3	6	10	4	2.6	10.4	145	1,508
4	10	14	4	3.2	12.8	140	1,792
5	16	18	4	3.5	14.0	135	1,890
6	22	22	4	4.0	16.0	130	2,080
7	28	26	4	4.5	18.0	130	2,340
8	34	30	4	5.4	21.6	125	2,700
9	42	34	4	6.0	24.0	125	3,000
10	50	38	4	5.7	22.8	125	2,850
11	62	42	4	5.1	20.4	125	2,550
12	76	46	4	4.6	18.4	125	2,300
13	88	50	4	3.5	14.0	125	1,750
14	96	54	4	1.4	5.6	135	756
15	99	58	4	1.0	4.0	140	560
REW	100	60	—	—	—	—	—

<sup>1</sup>Calculation of SC: sum of values in last column divided by the total cross-sectional area ( $\frac{27,836}{214}$ ) = 130  $\mu\text{S}/\text{cm}$



- Alternatively, for EWI, if the area-weighted median most closely represents integrated stream chemistry, then the median can be reported instead of the mean, but be sure to document this decision on the field form and in the final data report if a parameter code for median values is not available in NWIS.

### 3.1.2 In Situ Field-Measurement Procedures

An in situ measurement (fig. 6.0–1), made by immersing a multiparameter sonde or one or more single-parameter field-measurement sensors directly into the water body, is used to determine a profile of variability across a stream section. Initially, equal-width increments or other defined, documented measuring points across the stream can be used. In situ measurement can be repeated if stream discharge is highly variable across the section and if measurement points need to be located at increments of equal discharge. Note that in situ measurements are point samples and therefore are not depth integrated.

- **In situ measurement is required (where possible) for determining temperature, DO concentration, and Eh.** In situ measurement is recommended for pH, conductivity, and turbidity. The alkalinity determination can be made only on a stirred subsample contained in a vessel but is recommended to be performed on site. Field measurements made in anoxic water are required to be made in situ.

### 3.1.3 Subsample Field-Measurement Procedures

Subsamples (discrete samples that have been withdrawn from a sample-compositing device or point sampler) contained in a measurement vessel open to the atmosphere can yield useful data for conductivity, pH, turbidity, and alkalinity as long as conditions are amenable and correct procedures are followed. Anoxic conditions can cause field measurements made by using the subsample method to be invalid. Subsample field measurements should be completed as soon as possible after sample collection, minimizing temperature changes and exposure to the atmosphere (fig. 6.0–2). Remember that measurements of water temperature, DO concentration, and Eh cannot be made using a subsample and are required to be made in situ.

## 3.2 Groundwater

Field measurements in groundwater must accurately represent the physical and chemical properties of the water in the formation (aquifer) at the time of data collection. This typically requires purging the well of standing water while monitoring field parameters. However, the purge procedures applied depend on the type of well from which sample water will be withdrawn (for example, a public-supply, domestic, or

monitor well), well-construction and aquifer characteristics, and study objectives. The final field-measurement values to be recorded for a groundwater site are determined toward the end of the purging process. Consult NFM A4 for additional guidance on well purging and USGS protocols and standard procedures for groundwater withdrawal at wells.

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#### TECHNICAL NOTE:

Well purging removes standing water from a well. Purging reduces chemical and biochemical artifacts caused by well installation, inadequate well development, well-construction materials, or infrequent pumping (ASTM International, 2018). Purging also serves to rinse and condition sampling equipment with the ambient groundwater to be sampled.

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Groundwater can be withdrawn from wells by using submersible or above-ground pumps, or bailers or similar discrete-volume samplers (for example, syringe or Kemmerer samplers). Well type, construction, sampling objectives, target analytes, and site conditions can constrain the equipment selected. The method of groundwater withdrawal that will be used and how it will be employed also depend on those parameters (well type, construction, etc.) listed previously. NFM A2 provides detailed information on equipment for groundwater withdrawal and sample collection at wells.

The pumping mechanism can affect the degree to which certain measurements represent true groundwater properties. For example, pumps that introduce turbulence or heat to the water column can result in nonrepresentative values of DO concentration and temperature. The pump should produce a smooth, solid stream of water with no air or gas bubbles and without pump cavitation during sample withdrawal and field measurements. The pump discharge can be split by a manifold sampling system (fig. 6.0–3) to allow measurements to be taken and recorded on a form (fig. 6.0–4) or electronic record system.

- A positive-displacement submersible pump (portable or dedicated) is recommended for sampling at wells with depth to water greater than 28 ft (at sea level).
- A peristaltic pump often is a desirable choice for obtaining samples collected from wells at a depth of 28 ft or less (depending on altitude of the site), but the water pumped with this or other suction-lift pumps should not be used when measuring DO, Eh, or other properties that could be modified by placing a negative pressure on the water, which can cause volatilization of dissolved gases and volatile organic compounds.
- When a large volume of water must be purged, a dual-pump system can be used. If the depth to water is less than 28 ft (depending on the altitude of the site), either position a submersible pump downhole and a centrifugal pump at the surface or use two submersible pumps. An inflatable packer system set above the pump

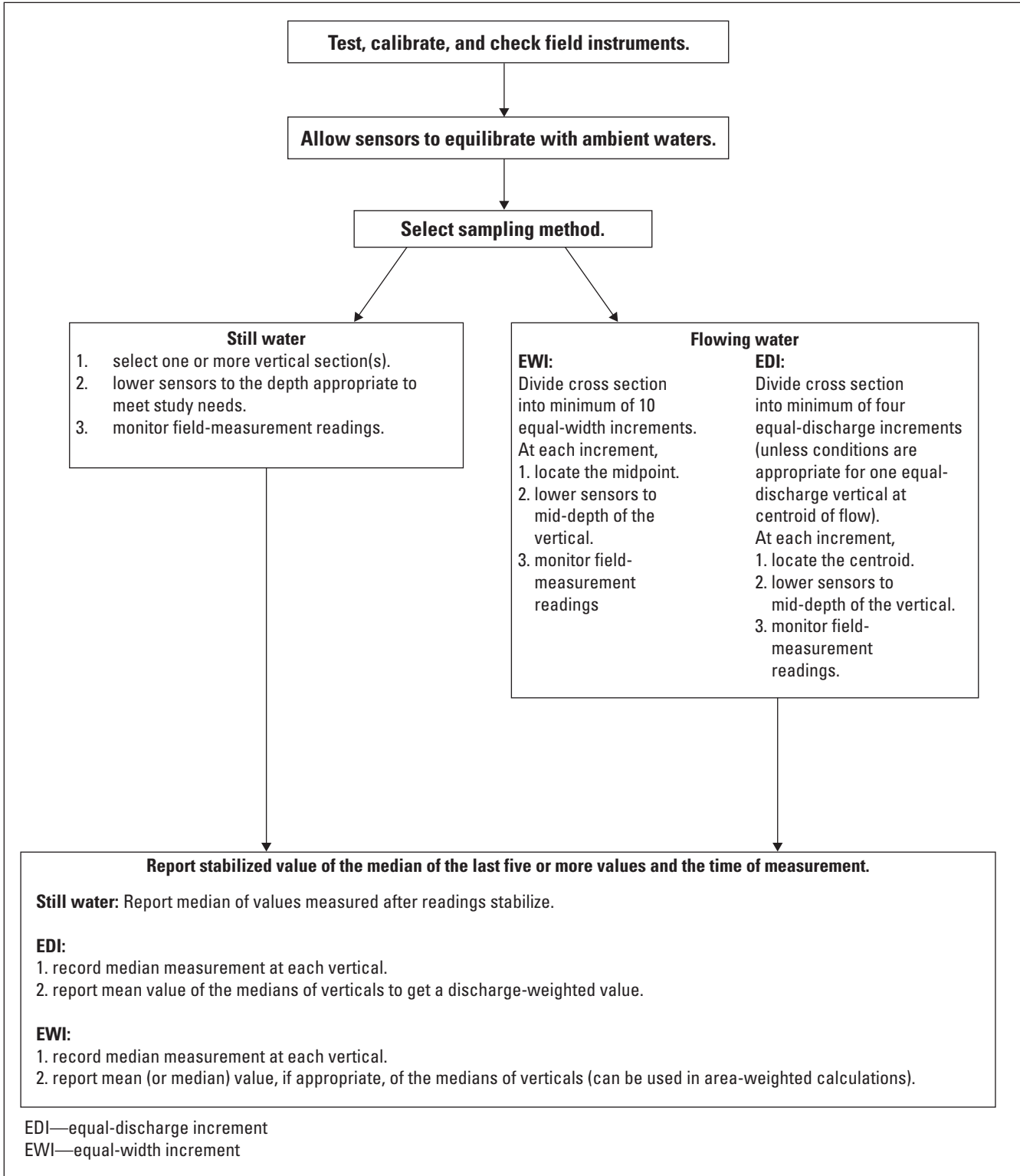
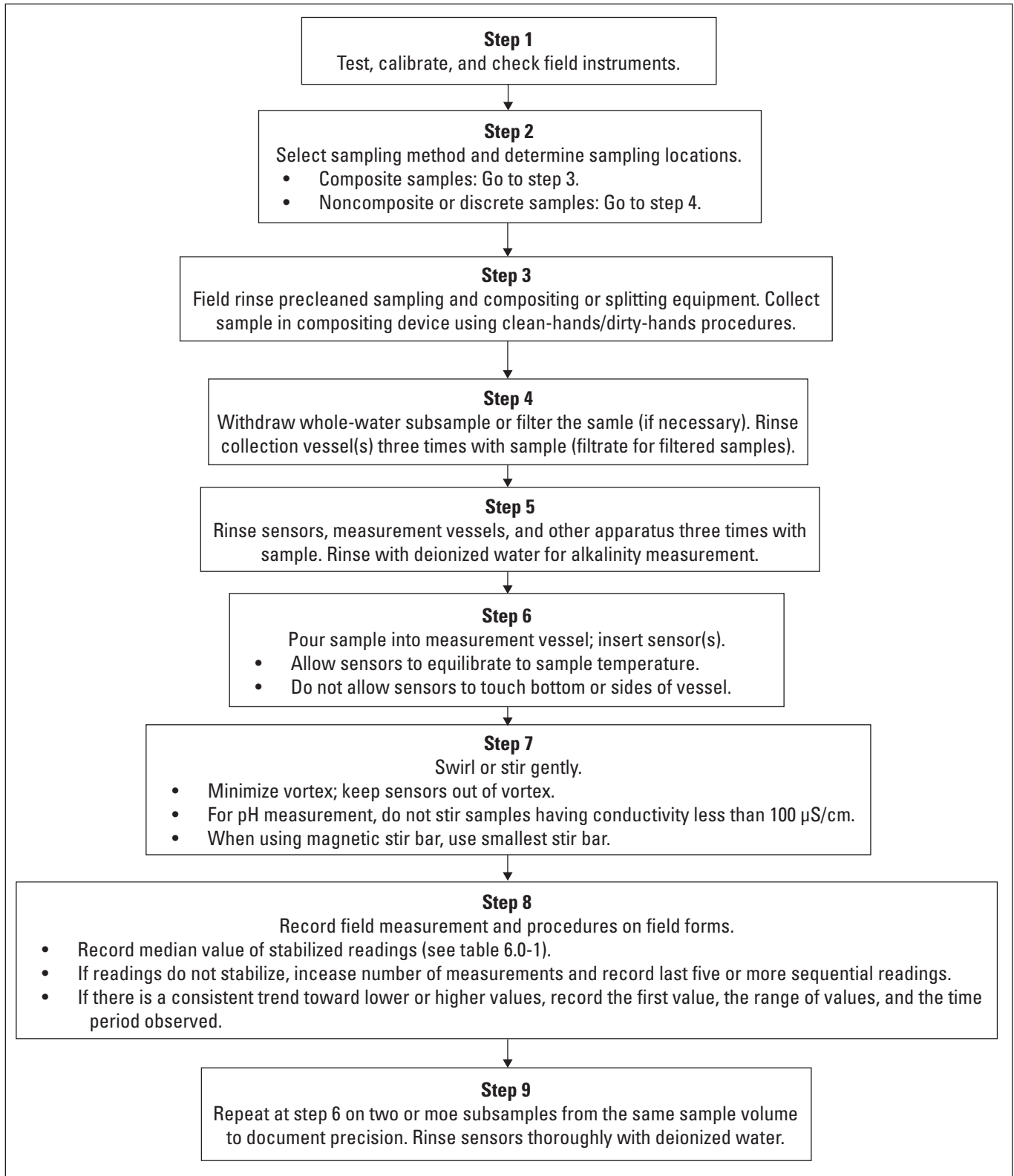
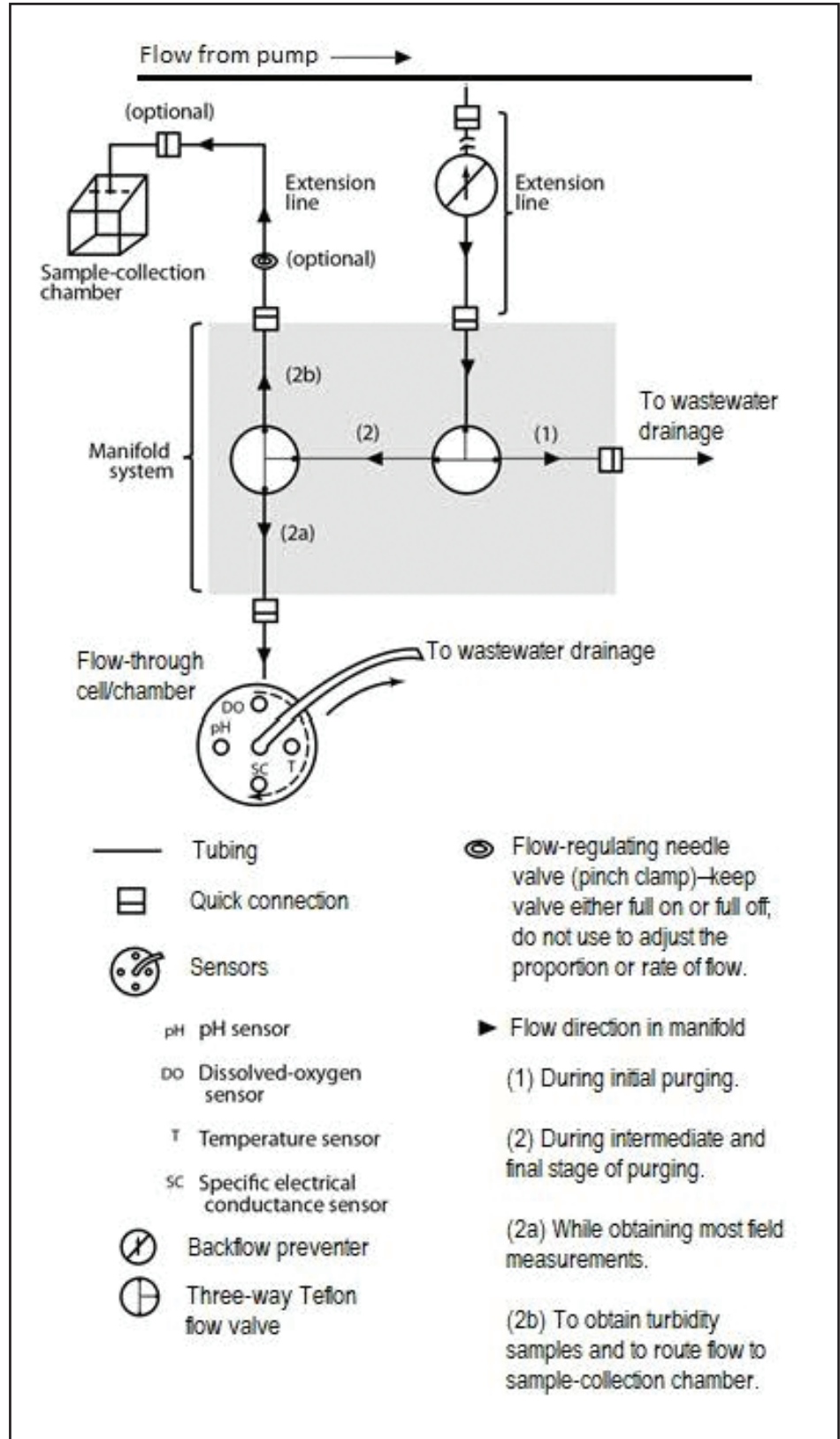


Figure 6.0–1. In situ field-measurement procedures for surface water.



**Figure 6.0–2.** Subsample field-measurement procedures for conductivity, pH, and alkalinity of surface water. ( $\mu\text{S}/\text{cm}$ , microsiemens per centimeter at 25 degrees Celsius)



**Figure 6.0-3.** Sketch of a manifold and flow-through cell/chamber used during well purging and sample collection.



can be used to reduce the volume and time required for purging; this procedure can be especially useful in deep wells or if regulations require that purge water be contained (see NFM A4 for additional information).

- Bailers are not recommended for purging because they have limited use for routine field-measurement determinations and are inefficient for well purging. The bailed sample must be decanted to obtain subsamples for field measurements, exposing the sample to atmospheric conditions. Therefore, water subsampled from a bailed sample may not be used for measurements of DO concentration, Eh, and water temperature. The action of the bailer being deployed downhole can introduce atmospheric gases and particulates into the water column, also resulting in biased turbidity and other field measurements.

Groundwater is sampled for field measurements in one of three ways:

1. **Inline-flow procedure:** By pumping formation water through a manifold system (fig. 6.0–3) inline to a flow-through cell or chamber (fig. 6.0–5) containing measurement sensors.
2. **Downhole or in situ procedure:** By deploying measurement sensors downhole.
3. **Subsample procedure:** By subsampling water collected from a discrete-volume sampler (for example, a bailer), and making measurements on the subsample(s).

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#### Recommended:

- Use a positive-displacement submersible pump for groundwater withdrawal.
  - Use in-line flow with a flow-through cell/chamber for field measurements.
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Inline-flow and in situ procedures are direct-measurement methods (section 3.2.2) in contrast to the indirectly measured subsample method (section 3.2.3). For most field applications, using inline-flow procedures with a flow-through cell/chamber system is recommended and most efficient.

The measurement system selected can be constrained by the type of well being sampled and its accessibility. General well types and considerations are—

- **Supply wells**—Downhole access for a pump or sensors might be limited or impossible at public- or domestic-supply wells, and sample-water access may be located near the well head or from a tap (for drinking-water studies). The flow-through cell/chamber field-measurement system (inline-flow procedure) should be used in this case.
- The standard three-volume purging protocol may not be appropriate. (Consult “Exceptions to the standard purging procedure” in NFM A4.)
- Identify equipment permanently installed in or at the well (such as a pump) that can affect the logistics and quality of the field measurements.



**Figure 6.0–5.** Photographs of (A) a flow-through cell/chamber for use with multiple sensors, shown without sensors installed; and (B) a flow-through cell for a multiparameter sonde. (Photographs from (A) Geotech Environmental Equipment, Inc., accessed February 13, 2020, at [http://www.geotechenv.com/flowblock\\_monitoring\\_system.html](http://www.geotechenv.com/flowblock_monitoring_system.html), and (B) YSI Inc., accessed February 13, 2020, at <https://www.ysi.com/accessory/id-005083/5083-flow-cell>.)

- The field-measurement system should be connected to the supply plumbing inline before or as it bypasses holding tanks, back-flow pressure tanks, flow meters, or chemical treatment systems.
  - **Monitor wells**—At wells that allow downhole access, it is necessary to determine the depth interval at which measurements will be made or from which water will be withdrawn for field measurements. Selection of the sampling-depth interval depends on how the well was constructed and the sampling design of the study. Record the depth at which the pump intake is set within a given screened or open interval.
  - The standard three-volume purging protocol typically is appropriate. (Consult NFM A4 before field work begins; the summary in section 3.2.1 does not include all the information needed to ensure adequate performance.)
  - Either direct-measurement or subsample procedures can be used at monitor wells, depending on study needs and sampling objectives. If samples for laboratory analysis will be collected, use of the flow-through cell/chamber system (inline-flow procedure) is recommended in order to avoid possible sample contamination from use of a downhole sensor system or bailer.
2. Option (a) is generally preferred and constitutes what is termed in this report the “inline-flow procedure.” Options (b) and (c) constitute what is termed in this report the “downhole (in situ) procedure.” Option (d) is termed in this report the “subsample procedure.”
  3. Check the identification number of the well and the well depth to verify that the well is the correct one intended for data collection or sampling. Review the record of water levels, pumping history, and field-measurement variability (if available) of the well, and prepare the necessary field forms (for example, the well-purging record, national or study field form, analytical service request form, and chain-of-custody record). Record the type of equipment being used.
  4. Lay plastic sheeting around the well to prevent contaminating the equipment. Unlock the well housing or top of the protective casing and remove the well cap. Set up the field-measurement system, paying attention to the sequence in which sensors are inserted into the flow-through chamber with respect to water flow. The sensor configuration may not be important depending on the sensors used. Figure 6.0–3 illustrates a typical flow system, including a sample-collection manifold, through which water is directed either to waste, to the flow-through cell/chamber, or to the sample-collection chamber. To adjust the direction of flow, a flow-regulating needle valve or ball valve should be kept either full on or full off, and should not be used to adjust either the proportion or rate of flow during purging. Use of the pump speed controls is the preferred way to adjust the amount of flow during purging of a monitor well.
  5. Review the purging history of the well, particularly the field-measurement data previously recorded. This practice can save time and help determine the appropriate procedures and length of time over which the well should be purged.

### 3.2.1 Summary of Well-Purging Protocols

The standard USGS well-purging protocol is to remove three or more well casing volumes of water while monitoring the water level and the stabilization of field parameters as a function of time, pumping rate, and the volume of water being removed (see NFM A4). Routine field measurements include pH, temperature, conductivity, DO concentration, and turbidity. Inherent in the purging procedure is an assumption that stabilization of field parameters indicates that the water being discharged from the well represents ambient formation water. Field personnel should examine this assumption for each well, using their knowledge of the well and aquifer hydraulics. Field experience, an understanding of the effects of hydrologic and geochemical conditions, and knowledge of data-collection and data-quality requirements are necessary to determine the most representative field-measurement values.

Before purging begins:

1. Select and set up the field-measurement system most appropriate to the requirements for the data-collection effort. Options include—
  - a. A transparent, air-tight flow-through chamber, holding the sensors of single-parameter instruments or a multiparameter sonde. The flow-through chamber is connected to tubing through which the sample is pumped directly from the well to the measurement chamber (examples are given in figure 6.0–5).
  - b. A multiparameter instrument without the flow-through chamber, deployed downhole in the well.
  - c. Single-parameter meters with sensors that allow for downhole submergence.
  - d. Single-parameter meters or a multiparameter instrument with sensors immersed in subsamples collected from a discrete-volume sampler.

**To purge a monitor well** (assuming that the well will be pumped and that a flow-through cell/chamber system and water-level sensor will be used):

1. Measure and record the depth to static water level (fig. 6.0–4). Instructions for water-level measurement are given in NFM 4.

2. Calculate and record the well volume by using the information in figure 6.0–4. Note that the depth to the static water level, the well depth, and the inside casing diameter must be known to calculate the well volume.
  - Calculate the volume of water in the well casing by using the height of the water column from the static water level to the bottom of the well and the casing diameter.
  - Include an estimate of the volume of water stored in the annular space between the casing and the borehole wall by using knowledge of the borehole diameter.
3. Lower a submersible pump followed by a water-level sensor to the desired location of the pump intake. The final pump-intake position always is located at the point of sample collection. Lower the equipment slowly and smoothly to avoid stirring up particulate matter.
  - Position the pump intake between 3 ft (about 0.9 meter (m)) below the static water surface and a minimum distance above the top of the open/ screened interval of 10 times the well diameter (for example, 20 in. for a 2-in. well diameter) if the sample is to be integrated over the entire screened or open area of the aquifer. The location of the intake depends on the study objectives, well construction, and the type of equipment used. Unless the intended sampling interval can be isolated adequately, locating the intake at a point within a well screen or open borehole will result in extracting a sample that includes water from the entire screened or open interval (Varljen and others, 2006; Reilly and Gibs, 1993).
  - The water-level sensor should be a maximum of 1 ft (about 0.3 m) below the static water surface.
4. Start the pump. Gradually increase and (or) adjust the pumping rate to limit drawdown to between 0.5 and 1.0 ft (about 0.15 to about 0.3 m, or as determined by project objectives and the well dynamics).
  - If the final intake position is above the screened or open interval, the final pumping rate should be about 500 milliliters per minute (mL/min). Try to keep drawdown to a maximum of 1 ft.
  - If the pump speed and intake position are fixed, as in a well with a dedicated pump, control the rate of flow for field measurements through the flow-splitting valve(s).
  - Monitor the water level as purging progresses. Ideally, drawdown will be at a steady state, ideally less than 1 ft, with the water level remaining above the top of the open or screened interval.
5. Purge a minimum of three well volumes or the purge volume dictated by study objectives (consult NFM A4 for detailed guidance on exceptions to the standard three-well-volume purging procedure).
  - Monitor values for field parameters sequentially and at regular time intervals throughout purging (fig. 6.0–4). The frequency of these measurements depends on the purging rate, which in turn is a function of well depth, well diameter, and aquifer transmissivity.
  - If required by Federal, State, or local regulations, contain purge water as directed.
6. As the third or last well volume is purged, slowly adjust the purge rate to the pumping rate to be used during sampling (500 mL/min). Do not halt or suddenly change the pumping or flow rate during the final phase of purging or while sampling.
  - Record field measurements at regular time intervals, about 3 to 5 minutes apart.
  - Check the last three to five or more measurement values for each field parameter against the criteria for field-measurement stabilization in table 6.0–1.
  - Determine final field-measurement values.
  - If the stabilization criteria are met—report the median value.
  - If the stabilization criteria are not met—consult the study requirements and objectives. Extend the purging time if readings still do not stabilize; report the median value of the last five or more sequential measurements and document problems encountered and how they were resolved.

**To purge a supply well** (assuming that a flow-through cell/chamber will be used):

A supply well that is in regular service and that is being pumped continuously or that has been operating long enough to have had three casing volumes of water removed within several hours of sample collection does not require removal of three well volumes. Before withdrawing a sample or measuring field parameters in this case, flush three tubing volumes of sample water through the tubing and monitor measurement values. If a supply well is not in continuous use and needs to be purged, a summary of the procedure is as follows.

  1. If access is possible, determine or estimate and record the depth to static water level (fig. 6.0–4). Instructions for water-level measurement are given in NFM 4.
  2. Calculate and record the well volume using the information on figure 6.0–4. Note that the depth to the static water level, well depth, and the inside casing diameter must be known to calculate the well volume.



- Calculate the volume of water in the well casing by using the height of the water column from the static water level to the bottom of the well and the casing diameter.
  - Include an estimate of the volume of water stored in the annular space between the casing and the borehole wall by using knowledge of the borehole diameter.
3. Select the location and method of tubing hookup to the well and connect the sample tubing as close as possible to the wellhead.
    - There must be no water-storage tanks, pressurization tanks, or chemical-disinfection or water-treatment systems connected inline between the pump and the tap/faucet to which the sample tubing will be connected.
    - Select a faucet without an aerator or obtain written permission to remove the aerator (replace the aerator after sampling).
  4. Regulate the flow through the sample tubing by using a manifold with a needle valve, if possible. An optional needle valve can be used to regulate flow at a supply well where the sample line is intersecting only a portion of the total flow from the pump.
    - Open additional valves or taps/faucets to ensure that system pressure stays low enough to allow the pump to operate continuously and reduce the possibility of backflow stored in ancillary plumbing lines.
    - The pump should produce a smooth, solid stream of water with no air or gas bubbles.
  5. Purge three well volumes, or the purge volume dictated by the pumping status of the well, or by the sampling objectives if the well has not been pumped recently.
  6. Throughout purging, monitor and record field-measurement readings (fig. 6.0–4).
  7. When the final field measurements are recorded—
    - Record field measurements at regular time intervals, about 3 to 5 minutes apart.
    - Check the last three to five or more measurement values for each field parameter against the criteria for field-measurement stabilization in table 6.0–1.
    - Determine the final field-measurement values.
    - If the stabilization criteria are met—report the median value.
    - If the stabilization criteria are not met—consult the study requirements and objectives. Extend the

purging time if readings still do not stabilize; report the median value of the last five or more sequential measurements and document problems encountered and how they were resolved.

### 3.2.2 Direct Field-Measurement Procedure Using a Flow-Through Cell/Chamber

Direct field measurements are those that are performed—

- By pumping water from the well, inline, directly to a flow-through cell or chamber instrumented with single parameter instrument sensors or a multiparameter instrument.
- Downhole, using individual submersible sensors or a multiparameter sonde (in situ measurement procedure).

Ambient groundwater temperature, conductivity, DO concentration, pH, Eh, and turbidity can be determined by using direct or indirect measurement procedures, but use of the in situ procedure can have more limitations and, to avoid sample contamination, should not be used if pumped samples will be collected for water-quality analysis.

#### Inline-Flow (Flow-Through Cell/Chamber) Procedure

A flow-through cell/chamber is an air-tight, transparent vessel with either leak-proof ports to accommodate individual sensors or a leak-proof fixture to hold a multiparameter sonde. Photographs of flow-through cells are shown in figure 6.0–5. Several types of flow-through cell/chamber systems are available and can be designed for a specific measurement or simultaneous measurements. Figure 6.0–3 is a diagram of a flow-through cell system and figure 6.0–6 shows the steps for inline-flow measurement of field parameters using a flow-through cell/chamber system.

All sensors must be calibrated and checked at the field site before use, as described in the relevant chapters of the NFM (chapters A6.1 through A6.8) and according to the manufacturer's guidelines for the instrument in use. When using a flow-through cell/chamber system, install the cell/chamber inline from the pump and as close to the wellhead as possible.

- Keep the cell/chamber, field-measurement instruments and the tubing off the ground and shaded from direct sunlight. Keep the tubing as short as possible.
- For a system in which individual sensors are to be installed in the chamber, install the pH sensor downstream from the conductivity sensor. Turn on the pump; direct initial flow to waste to avoid introducing sediment into the chamber.
- For a multiparameter instrument system, place the sonde into the cell provided by the manufacturer, according to the manufacturer's instructions.

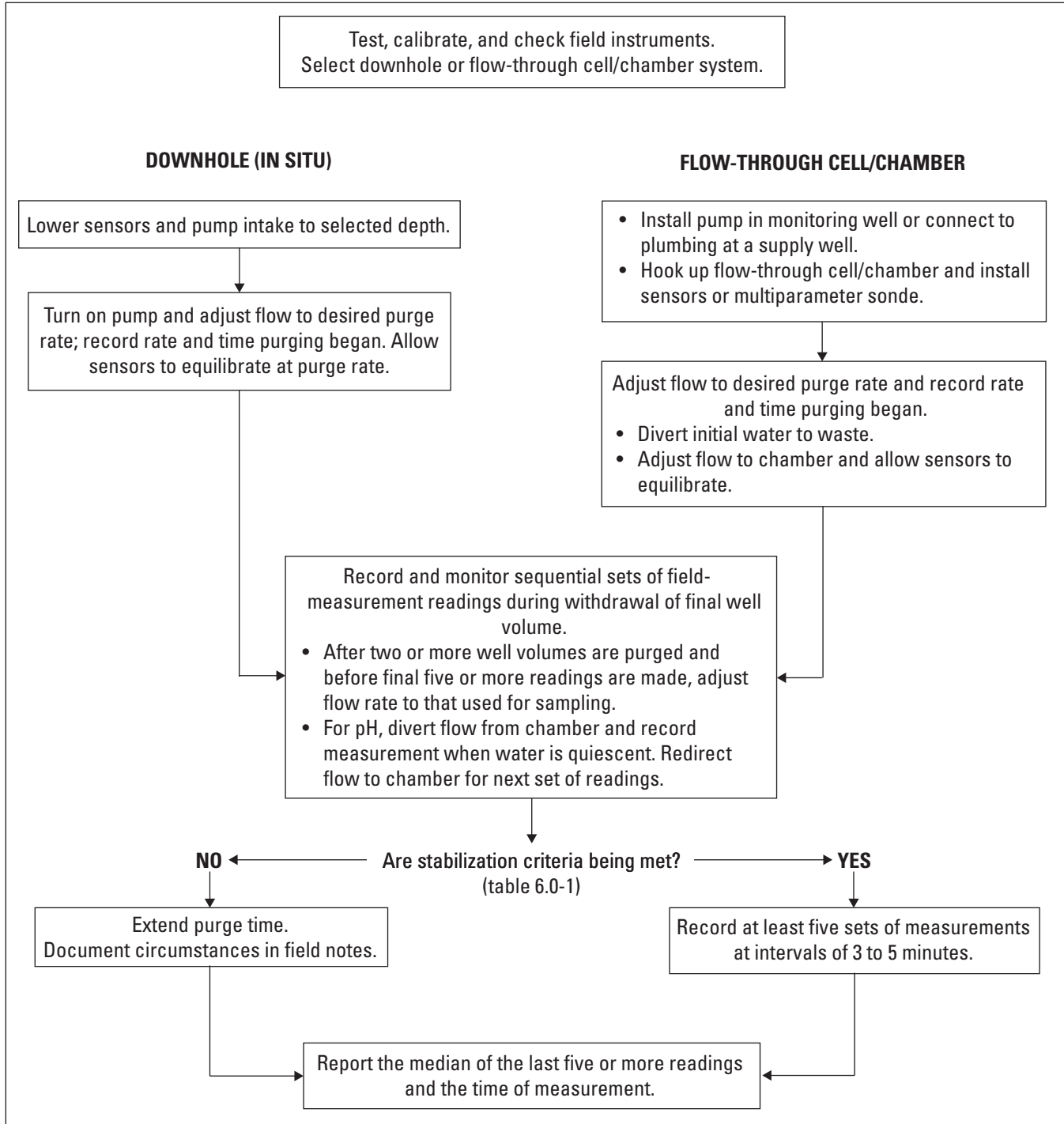


Figure 6.0-6. Field-measurement procedures for groundwater performed by using downhole and flow-through cell/chamber systems.

- Adjust the flow into the chamber so that a constant stream of water is maintained at the rate required for measurements. Correct any back-pressure conditions; tilt the chamber if necessary to expel trapped air or any gas bubbles that form.

### Downhole (In Situ) Procedure

When deploying sensors or a multiparameter sonde downhole, it is recommended that groundwater be pumped to flow past downhole sensors in order to obtain values representative of the depth interval being sampled. Because of this constraint, the downhole method may not be practical at wells with dedicated pumps or when working in small-diameter wells. Figure 6.0–6 shows the steps to be used for downhole measurement of field parameters.

- The depth at which sensors are located depends on study objectives. If a sample is to represent groundwater that is integrated over the screened interval, locate sensors approximately 1 ft above the screened interval in a 2-in.-diameter well and below the pump intake.
- Remove downhole sensors from the well before collecting samples for chemical analysis to prevent these instruments from affecting sample chemistry. Note that the process of removing these instruments and replacing the pump causes disturbances in the well that can affect the quality of samples subsequently collected for chemical analysis (Puls and others, 1991; Kearl and others, 1992; Puls and Powell, 1992). For this reason, the inline flow method using a flow-through cell/chamber is recommended when a well will be pumped and sampled.

### 3.2.3 Subsample Field-Measurement Procedures

Subsamples or discrete samples are aliquots of sample collected from a nonpumping sampling device such as a bailer, a thief sampler, or a syringe sampler. Measurements of field parameters made in discrete or nonpumped samples are more vulnerable to bias from changes in temperature, pressure, turbidity, and concentrations of DO and other gases than measurements made by using inline-flow or in situ measurement procedures.

- Subsamples must not be used for reported measurements of temperature, DO concentration, Eh, or turbidity without value qualifiers and comments indicating that the measurements are estimated and made on a subsample.

- Subsamples can be used to determine ambient groundwater conductivity, pH, and alkalinity and other carbonate species.
- Subsample procedures must not be used for any field-measurement determination if the groundwater conditions are reducing or anoxic unless the sample is decanted and measurements are made within a chamber or glove box filled with an inert gas (for example, ultrapure nitrogen or argon gas).

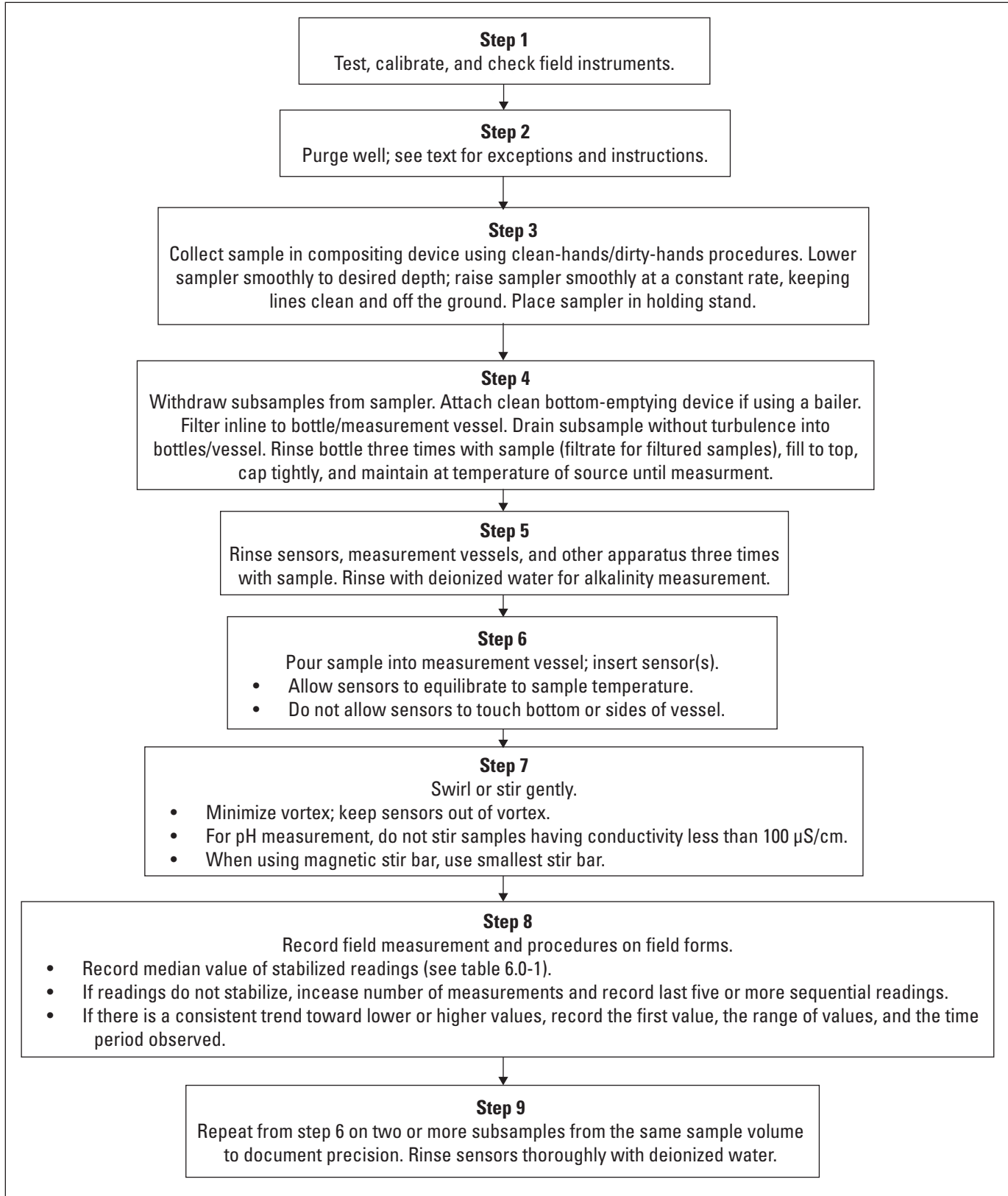
Figure 6.0–7 shows the steps for measurement of field parameters on a bailed or other nonpumped sample. Use of bailers with double (top and bottom) check valves and a bottom-emptying device is recommended. To shield the sample from atmospheric contamination, make measurements within a collection chamber or glove box.

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**Figure 6.0–7.** Subsample field-measurement procedures for conductivity, pH, and alkalinity of groundwater. (µS/cm, microsiemens per centimeter at 25 degrees Celsius)

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