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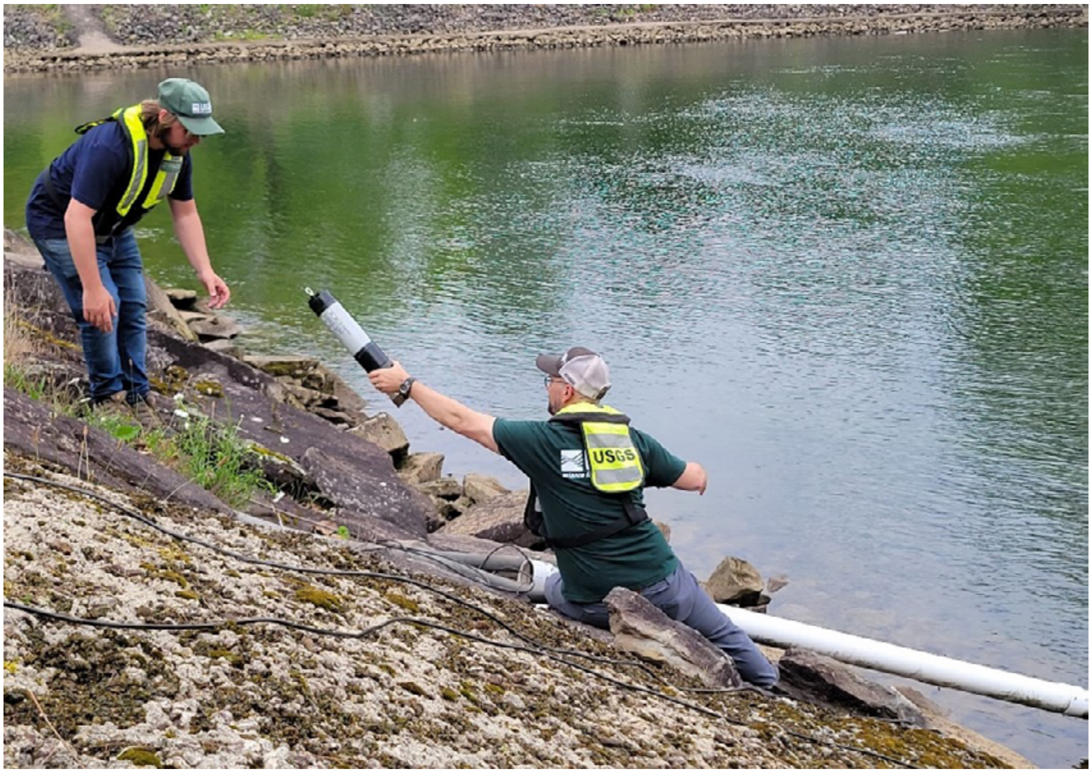
Use of Multiparameter Instruments for Routine Field Measurements

Chapter 6.8 of
Section A, National Field Manual for the Collection of Water-Quality Data
Book 9, Handbooks for Water-Resources Investigations



Techniques and Methods 9–A6.8
Version 1.1, June 2025

Supersedes USGS Techniques of Water-Resources Investigations,
Book 9, Chapter A6.8, Version 1.1

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

Cover Photo. Servicing a multiparameter instrument at Youghiogheny River Lake Dam near Confluence, Pennsylvania. Photograph by Allison Casile, U.S. Geological Survey.

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U.S. Geological Survey, Reston, Virginia

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Conversion Factors

U.S. customary units to International System of Units

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

International System of Units to U.S. customary units

Multiply	By	To obtain
gram (g)	0.0353	Ounce, avoirdupois (oz)
liter (L)	0.2642	gallon (gal)
liter (L)	61.02	cubic inch (in^3)
milligram (mg)	3.527×10^{-5}	ounce, avoirdupois (oz)
milliliter (mL)	0.0338	ounce, fluid (oz)
milliliter (mL)	2.642×10^{-4}	gallon (gal)

Temperature is reported in degrees Celsius (°C), which can be converted to degrees Fahrenheit (°F) by use of the following equation: °F = 1.8(°C) + 32

Specific conductance is reported in microsiemens per centimeter at 25 degrees Celsius (µS/cm at 25 °C).

Abbreviations and Symbols

Eh	measure of the oxidation-reduction potential of a solution
L	liter
µS/cm	microsiemens per centimeter at 25 degrees Celsius
mg/L	milligrams per liter (equivalent to parts per million [ppm])
NFM	National Field Manual for the Collection of Water-Quality Data (USGS)
NWIS	National Water Information System (USGS)
pH	negative base-10 logarithm of the hydrogen ion activity (unitless)
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 A6.8. Use of Multiparameter Instruments for Routine Field Measurements

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 A6.8, provides guidance and protocols for the use of multiparameter instruments for routine field measurements, which includes storage and maintenance of equipment, calibration, troubleshooting, and procedures for measurement and reporting. It updates and supersedes USGS Techniques of Water-Resources Investigations, book 9, chapter A6.8, version 1.1, by Jacob Gibs, Franceska D. Wilde, and Heather A. Heckathorn. The use of multiparameter instruments for conducting field measurements has become routine. The methods described here are specific to the use of multiparameter instruments. The field methods 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.

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.

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.

Chapter A6.8 provides guidance and protocols for the use of multiparameter instruments for routine field measurements, which includes storage and maintenance of equipment, calibration, troubleshooting, and procedures for measurement and reporting. It updates and supersedes USGS Techniques of Water-Resources Investigations, book 9, chapter A6.8, version 1.1, by Jacob Gibs, Franceska D. Wilde, and Heather A. Heckathorn. The use of multiparameter instruments for conducting field measurements has become routine. The methods described here are specific to the use of multiparameter instruments. Additional information on measuring specific water-quality parameters (temperature, dissolved-oxygen concentration, specific conductance, pH, oxidation-reduction potential, alkalinity, turbidity) is available in the other chapters of chapter A6 of the NFM. The field methods 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

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1.1 Overview of Multiparameter Instruments

The miniaturization of sensors and other technological advances in electronics have resulted in water-quality instruments that house multiple sensors capable of making simultaneous readings of various field measurements in environmental waters. With the use of these multiparameter instruments, field measurements can be determined in considerably less time than that generally required when using multiple single-parameter instruments (table 6.8–1). This chapter, NFM A6.8, addresses the short-term or discrete-measurement use of portable multiparameter instruments. Refer to Wagner and others (2006) for information about long-term or continuous-monitor deployment.

MULTIPARAMETER INSTRUMENT: An electronic instrument that contains sensors (each specific to the measurement of a given physical, chemical, or biological property) that are bundled in a single housing (a sonde).

NFM chapter A6.8 describes requirements and recommendations that have been developed for routine U.S. Geological Survey (USGS) field studies. The instrument manufacturer is, however, the primary source of information about the maintenance and use of a specific instrument. The protocols and recommendations described in this chapter are meant to complement and enhance the manufacturer's guidelines, providing the level of quality assurance for which USGS data are held accountable. USGS personnel should identify any discrepancies between the requirements and recommendations described in the NFM and the instructions provided by the instrument manufacturer. The more stringent procedures typically should be used. Personnel should discuss discrepancies with their water-quality specialist and may send any questions to nfm@usgs.gov.

2.0 Equipment and Supplies

Multiparameter instruments are available for discrete measurements made during a site visit or for deployment at a stream, lake, reservoir, well, or other environmental setting, and their sondes or bodies are suitable for use in water that is fresh, brackish, saline, or contaminated. Housings (the sonde) of multiparameter instruments are available in a range of diameters from about 4 inches (in.) (10 centimeters [cm]) to less than 2 in. (5.1 cm). Small-diameter sondes can be used for downhole measurements in wells, but may have more limited wiper and sensor capability than the larger diameter sondes (because fewer ports are available for sensors). Depending on the manufacturer, some instruments can store measurements to internal or removeable memory in a format compatible with a hand-held display, laptop computer, tablet, database input file, or typical cell phone. Many instruments are operated by applications run on tablets or cell phones and communicate by using wireless communication protocols. Instruments may be powered by their own internal batteries or through cables connected to external devices, such as wireless communicators, hand-held displays, or laptop computers.

The use of multiparameter instruments for field measurements has become routine. Advances in technology and design are expanding the sensor capabilities of multiparameter instruments and are improving the utility of the instruments. The procedures required for the maintenance, calibration, and use of these instruments can change over time as a result of technological changes. Users must stay current with respect to how their instrument operates and is maintained. Sensors

Table 6.8–1. Advantages and limitations of multiparameter instruments for field use.

Advantages	Limitations
The time needed to measure and record multiple field parameters at one time is reduced.	One system (inside the sonde) is responsible for recording all parameters, which would cause the loss of all parameter values upon failure.
Measurements can be made in situ instead of in samples removed from the source water.	Backup field instruments (single parameter or multiparameter) are recommended to prevent data loss.
Measurements made in situ are likely more representative than measurements made in samples removed from their source.	Purchase costs for multiparameter instruments are higher than those for single-parameter instruments.
Instruments can store data, either in a display device or to internal memory.	Calibration may require use of a greater volume of standards for rinsing than that needed for single-parameter instruments.

for the determination of water temperature, specific electrical conductance (SC), pH, dissolved-oxygen (DO) concentration and turbidity are commonly bundled in sondes used for USGS water-quality studies. Permanent sensors for measuring barometric pressure (for use with a DO sensor), water depth (either vented or unvented), and location (global positioning systems) either are standard equipment with many multiparameter instruments or can be added at extra cost. Nonpermanent sensors for measuring oxidation-reduction potential (Eh), fluorescence[1], velocity, and concentrations of nitrate, ammonia, ammonium, chloride, and chlorophyll can be added to many sondes through use of sensor ports. The types and number of sensors that can be bundled in a given sonde depend on the number of ports available in an instrument model, typically four to seven. When selecting a sensor, consult the manufacturer's recommendations and specifications for the instrument, taking into consideration the environmental conditions to be encountered, the data-quality objectives of the study, and the specific benefit of a particular sensor technology that could be applicable to the anticipated field conditions.

Table 6.8–2 lists the equipment specifications required when making field measurements with a multiparameter instrument. Table 6.8–3 lists the specifications for calibration solutions required when using multiparameter instruments. The requirements in tables 6.8–2 and 6.8–3 may be modified to fit specific project needs. Ancillary supplies and equipment needed to measure field properties with multiparameter instruments (table 6.8–4) are the same as or similar to those required for the calibration and maintenance of single-parameter instruments, and are discussed in detail in the individual field-measurement chapters (NFM chapters A6.1 through A6.7).

[1]Fluorescence sensors indicate different algal pigment concentrations; see NFM chapter A7.4 and Booth and others (2023) for additional information.

2.1 Equipment Transport

Multiparameter instruments have become more robust with time, but the sensors can easily be damaged if handled improperly. Some sensors require storage and transportation in a wet/moist environment, whereas others do not, check the manufacturer's recommendations. Sondes should not be exposed to extreme heat or cold. Transport in a case that is designed to protect the equipment following the manufacturer's recommendations is best. For transportation and storage, use a padded case that protects the sonde from shock. The padding should be of a type that will not absorb water. Hard-sided cases should be equipped with a vent so that internal pressure can equalize with that of the atmosphere. Do not expose the case to direct sunlight in order to avoid solar heating of the equipment inside.

Table 6.8–2. Specifications for multiparameter instruments.

[±, plus or minus; mV, millivolt; −, minus; +, plus; °C, degrees Celsius; SC, specific electrical conductance; µS/cm, microsiemens per centimeter at 25 °C; DO, dissolved oxygen; mg/L, milligram per liter; NFM, USGS National Field Manual for the Collection of Water-Quality Data; nm, nanometer; ORP, oxidation-reduction (redox) potential; mm Hg, millimeter of mercury]

Sensor[1]	Specifications
pH and millivolt	Range of at least 2 to 12, preferably 0 to 14, pH units. Accuracy, ±0.1 pH units. Resolution, ±0.01 pH units. Millivolt readout—accuracy, ±0.1 mV.
Temperature	Range, of at least –5 to +45 °C. Accuracy, ±0.2 °C.
SC	Accuracy, the greater of ±5 percent of reading or ±2 µS/cm.
DO	Optical sensor (luminescent-sensor method)—range 0.01 to 20 mg/L. Accuracy, ±0.1 mg/L.
Turbidity	Range and accuracy depend on the instrument type, manufacturer, and field conditions (see NFM A6.7). Choice of instrument depends on application. Most multiparameter-instrument turbidity sensors use a monochrome light source with a spectral output typically near infrared (780–900 nm), typically a light-emitting diode, and one detector at 90-degree orientation to the light source.
ORP	Accuracy, ±5 mV. For guidance on Eh measurements using the platinum electrode, refer to NFM A6.5 and the manufacturer's instructions.
Air pressure	Select instruments that incorporate an altimeter/barometer that measures to at least the nearest 1 mm Hg.

[1] Modify this list to meet the specific needs of the field effort

Table 6.8–3. Specifications for calibration solutions for multiparameter instruments.

[SDS, Safety Data Sheet; NFM, USGS National Field Manual for the Collection of Water-Quality Data; SC, specific electrical conductance; DO, dissolved oxygen; g, gram; L, liter; DIW, deionized water; ORP, oxidation-reduction (redox) potential; SDVB, styrene-divinylbenzene; ≤, less than or equal to; µm, micrometer]

Solution	Specifications
All sensor-calibration solutions	Keep the respective SDS guidance on hand in the laboratory and in the field. Dispose of waste according to local regulations, using a licensed disposal company, if necessary.
pH buffers	Standard buffers are pH 4, 7, and 10. Temperature-correction chart(s) supplied by the buffer manufacturer or distributor are required. See NFM A6.4.
SC standards	Choose the SC standard(s) nearest to and/or that bracket(s) the expected measurement or range. To field check the calibration, select additional standard(s) that bracket the expected sample SC. See NFM A6.3.
DO standard	Zero-DO solution. Dissolve 2 g of sodium sulfite in 1 L of DIW (prepared onsite or during the week of use). Zero-DO solution can be obtained commercially. See NFM A6.2.
ORP standard	ZoBell's solution. This solution contains cyanide and may be harmful if absorbed through skin, inhaled, or swallowed. Check the SDS for guidance on safe handling. See NFM A6.5.
Turbidity standard	Turbidity standards (Stablcal[1]) with various ranges are available commercially or from USGS One-Stop Shopping. Most sensor manufacturers recommend either formazin-based or SDVB-polymer standards for calibration. **Do not use gel or solid verification standards for calibrating instruments**. See NFM A6.7. • Turbidity-free water which is DIW filtered through a ≤0.2-µm membrane filter. • Formazin stock suspension can be obtained commercially.

[1]Stablcal is a registered trademark of Hach.

Table 6.8–4. Ancillary supplies related to multiparameter instruments.

[NFM, USGS National Field Manual for the Collection of Water-Quality Data; NIST, National Institute of Standards and Technology; µS/cm, microsiemens per centimeter at 25 degrees Celsius; ASTM, ASTM International Company; DO, dissolved oxygen; USGS, U.S. Geological Survey]

Equipment	Information and specifications
Flow-through cell/chamber	Standard flow-through cell/chamber, obtained from the manufacturer of the instrument. (Commonly used for groundwater or other water pumped from the water source to the airtight cell for measurement).
Extra sensors and meters	Single-parameter meters and sensors or a multiparameter instrument are recommended as backup. Refer to equipment lists and descriptions and instructions provided in NFM A6.1 through A6.7.
Calibration thermometer and barometer	NIST-certified or NIST-traceable. (see NFM A6.1 and A6.2 for USGS standard specifications).
Carrying case	Protective, insulated, case, vented, white or other reflective color, for transport and storage.
Logbook(s)	One per instrument or interchangeable sensor, for recording calibrations, maintenance, and repairs. Logbook travels with the instrument or sensor or is digitally accessible.
Deionized water	Maximum conductivity of 1 µS/cm (ASTM Type 2) for rinsing sensors, dispensed from a plastic bottle.
Paper tissues	Laboratory grades (for example, lint-free Kimwipes).
Towels, cloth or paper	For DO sensor calibration and checks, and general cleanup.
Brushes for equipment cleaning	Brushes of various sizes, but generally small and soft to prevent scratching the sensor(s) or other surfaces. Consult instrument manual.
Batteries and (or) battery pack(s)	Check that batteries are fully charged; bring spares.
Disposable gloves	Nitrile gloves, disposable, nonpowdered are available from USGS One-Stop Shopping.
Waste-disposal containers	Appropriate for safe containment of regulated substances and dedicated to use for the respective waste material (examples: ZoBell's solution, acid, and turbidity calibration solutions).

2.2 Instrument Maintenance and Storage

Each instrument requires a dedicated logbook that accompanies the instrument.

- A separate logbook in which instrument repair, maintenance, and calibration history information is recorded is required to be maintained for each field instrument or replaceable sensor that stores calibration information within the sensor's internal processor. The logbook should travel with the instrument or be accessible through electronic means. The pages of a paper instrument logbook should be prenumbered consecutively. Do not skip or tear out pages. Water-resistant paper is recommended. Paper logbooks are available to USGS personnel through One-Stop shopping (item Q609FLD).
- USGS personnel are encouraged to use electronic rather than paper field notes to increase efficiency and minimize transcription errors. Office of Water Quality Technical Memorandum 2016.09 recommends that all water-quality records, including logbooks, be collected electronically wherever feasible and specifies requirements for electronic records.
- Use a blue or black indelible ballpoint pen to write on paper forms and in logbooks. 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 analysis of volatile organic compounds.

The following recommendations pertain to maintenance of the multiparameter instrument that is used over discrete or short (attended) time intervals. For maintenance of instruments intended for long-term or unattended instrument deployment, refer to Wagner and others (2006) and the instructions provided by the manufacturer.

General care of multiparameter instruments:

- Do not leave instruments in vehicles during extremes in temperature. It is good practice to transport and store them in an insulated case or cooler.
- Routinely inspect cables for damage, and electronic connectors and sensor ports for corrosion.
- Inspect and clean the cable connection and sensor O-rings annually, at a minimum. Lubricate them lightly with silicone grease or Krytox. Replace any that are damaged.
- Store cables in a plastic container only after they are clean, dry, and neatly coiled (no tighter than 6-in-diameter coils). Use protective plugs when cable connectors are not in use. When they are in use, protect cables from abrasion or unnecessary tension.
- Make sure the instrument is running on software and firmware that is up to date. Check for updates from the manufacturer every 6 months at a minimum and follow the manufacturer's installation instructions.

Sensor and sonde care and maintenance:

- Rinse the sensors immediately after each use with deionized water (DIW).
- If the body of the multiparameter instrument (handheld display and sensors-containing sonde only, not the sensors) is particularly dirty or will be stored, clean it with a mild, nonphosphate detergent solution by using a small, nonabrasive brush or cotton swab or cloth, and follow with a thorough water rinse.
- Avoid using organic solvents or other corrosive solutions to clean the sensors unless indicated in guidance given by the manufacturer.
- Do not coat the sonde or sensors with protective or anti-fouling paint, except as specifically instructed by the manufacturer.
- Manufacturers may have instructions specific to their sensors—check the manufacturer's operating manual for each instrument that will be in use.

Wiper and wiper-brush maintenance:

- Inspect the wiper pad and (or) wiper brush for dirt, deterioration, and damage after each use of the instrument. (Not all instruments have a wiper or wiper-brush mechanism.)
- Check wiper pads for wear, excessive discoloration, and particle accumulation, and change the pads as needed. Check that the wiper arm is parking properly. Follow the manufacturer's guidance for conditions requiring changing the pads and for wiper maintenance.
- Warm soapy water and a soft toothbrush can be used to clean wiper-brush bristles. Rinse with DIW.
- Replace or recondition the wiper brush when it shows excessive splaying.

General storage recommendations for multiparameter instruments and instrument cases:

- For short-term storage, some sensors need a small amount of the storage solution added to the protective (transport) cap or calibration cup; check the manufacturer's instructions.

- For long-term storage (longer than 1 week), remove the internal batteries; however, be sure to check the instrument manual for guidance before removing the batteries. Check the instrument manual for recommendations on storage solutions and removal of the individual sensors for storage.

- Store multiparameter instruments in a carrying case or plastic container with closed-cell (nonabsorbent) foam cushion (for shock protection). Keep the instrument and case out of direct sunlight and protected against extremely hot or cold temperatures.

- Check sensor ports to be sure that either the ports have a properly installed sensor, or the empty ports are sealed with an appropriate plug. Sensors from which data are not being collected routinely can be removed from the sonde for safe storage. The temperature sensor should not be removed. All electrical connections must be clean, dry, waterproof, and protected from dust.

3.0 Calibration

Multiparameter instruments are required to be tested and the sensors calibrated or checked before each field use. Preferably, calibrations are done under laboratory or indoor conditions and are checked and verified in the field. Alternatively, if laboratory or indoor conditions are not available, instruments may be calibrated in the field. Before beginning the calibration or check process, ensure that the sensors are properly installed in the sonde and that the batteries are charged. The following guidelines apply generally to multiparameter instruments. Consult NFM chapters A6.1 through A6.7 for detailed instructions on calibrations and checks of individual parameters. The information in chapters A6.1 through A6.7 is the definitive information for calibration of instruments and is not replaced by the general guidance given here or by guidance found in previous versions of this chapter.

- Multiparameter instruments may require warm-up before calibration. Refer to the manufacturer's recommendations.

- The following order is recommended for performing parameter calibrations or checks of multiparameter instruments. This list is generally in the order of increasing ionic strength of the standards. Calibrating from low to high ionic strength should reduce the possibility that residual standards will bias subsequent calibrations if rinses between changes in solutions are not thorough. Rinsing the sensors three times with DIW between different standard solutions is required standard practice.

  1. **Temperature**—Use a NIST-certified or NIST-traceable digital thermometer or thermistor. See NFM A6.1 for specific procedures.

  2. **Specific electrical conductance (SC)**—See NFM A6.3 for specific procedures.

  3. **pH**—See NFM A6.4 for specific procedures.

  4. **Dissolved-oxygen concentration (DO)**—See NFM A6.2 for specific procedures.

  5. **Oxidation-reduction potential (ORP)**—See NFM A6.5 for specific procedures.

  6. **Turbidity**—See NFM A6.7 for specific procedures.

  7. **Ion-selective electrodes**—Followed by chlorophyll-fluorescence and other sensors.

- Calibration records must be maintained and entered into the appropriate instrument or sensor logbook and field form at the time of calibration or verification.

- Keep a hard or electronic copy of past field measurements in the field or site folder. These records contain vital information that can be referenced if performance questions arise. See NFM chapter A1 for more information on field forms and site folders.

- Follow the manufacturer's instructions on how to operate the instrument model and sensors being used. Make sure the units of measurement are set correctly in the instrument's software setup.

- Follow NFM guidance in chapters A6.1 through A6.7 for selection of standards, temperature ranges, rinsing procedures, and specific calibration procedures for each parameter. Note that generally standards are chosen that bracket the expected measurement or deployment range of measurements.

- Check sensor ports to ensure that sensors are properly installed or that empty ports are sealed. Sensors from which data are not being collected routinely can be removed from the sonde for safe storage. The temperature sensor should not be removed. All electrical connections must be clean, dry, waterproof, and protected from dust.

4.0 Measurement

The field-measurement procedures implemented depend on the type of water body being studied, onsite characteristics and conditions at the time of measurement, and the objectives and data-quality requirements of the study. The following guidelines apply generally to multiparameter instruments. Consult NFM chapters A6.0 through A6.7 for detailed instructions on measuring individual parameters. The information in chapters A6.0 through A6.7 is the definitive information for making measurements and is not replaced by either the general guidance here or the guidance in previous versions of this chapter. Allow time for the readings on the display to stabilize within the criteria shown in table 6.8–5. Record all required field measurements on the appropriate paper or electronic field forms, laboratory analytical request forms, logbooks, chain-of-custody logs, and other documentation that might be required for the study (see appendix 6.8–1 for an example of a field form). Note on the appropriate form(s) any onsite conditions that could have affected the quality of the data.

4.1 Surface Water

Field parameters are commonly measured within a cross section of a surface-water body to (1) help determine how well mixed the stream or river is, and consequently the sampling method to be used; and (2) determine the field-parameter values of the water body at the selected site. In situ use of a multiparameter instrument is a highly efficient means of obtaining surface-water field-parameter data. Considerations when using multiparameter instruments in surface water are listed in the following bullet points. For additional information on field measurements and sampling methods, see NFM A6.0 and NFM A4. For more information on measuring specific individual field parameters, see NFM A6.1 through NFM A6.7.

- Many instruments include a pressure transducer that produces a value for the depth of the sonde or the water level. For instruments without pressure transducers, the approximate depth of the sonde as it is lowered through the water column can be noted by placing incremental marks along the instrument cable, or the sonde can be connected to a pressure transducer. Depending on site conditions, the sonde might need to be weighted. Consult the manufacturer's instructions for proper weighting procedures.
- Wait a minimum of 60 seconds for the sensors and sonde body to reach thermal equilibrium with the water at each new measurement location. Some instruments require a longer equilibration time; check the manufacturer's recommendations.
- Plants or debris in the water can interfere with sensors or the guard around sensors, which can adversely affect sensor readings. If field conditions and quality-assurance protocols allow, adjust the locations of the measurements along the cross section or transect to avoid areas that will require stopping and cleaning plant growth, sediment, or debris from the sensors.

4.2 Groundwater

The stability of field-parameter values is monitored toward the end of well purging to help indicate when the water being withdrawn represents fresh formation water and when sample collection should begin (see NFM A6.0, NFM A4). The final field-parameter values typically are recorded after three or more well volumes have been purged and stability criteria have been met.

If the purpose of sampling is to obtain field measurements only, these data can be obtained in situ by deploying a multiparameter sonde into the well, followed by a submersible pump to draw water upward. If water-quality samples will be collected, pumping the water from the well to and through a flow-through cell that contains the instrument's sensors is another efficient method for collecting field-parameter data without having to remove and redeploy sampling equipment. Flow-through cells are typically supplied by the manufacturers

Table 6.8–5. Stabilization criteria for common field parameters.

[±, plus or minus; °C, degrees Celsius; SC, specific electrical conductance; ≤, less than or equal to; %, percent; µS/cm, microsiemens per centimeter at 25 degrees Celsius; >, greater than; DO, dissolved oxygen; mg/L, milligram per liter; TU, turbidity unit]

Sensor	Standard sensor stabilization criteria (Note that the actual accuracy of the sensor varies, depending on sensor model and manufacturer.)
Temperature	± 0.2 °C
Specific electrical conductance (SC)	± 5 µS/cm for SC ≤100 µS/cm, or ± 3% for SC >100 µS/cm
DO	± 0.2 mg/L
pH	± 0.1 pH units
Turbidity	± 0.5 TU or 5% of the measured value, whichever is greater, for turbidity ≤ 100 TU; or 10% of the measured value for turbidity >100 TU

of multiparameter instruments. Considerations when using multiparameter instruments in groundwater are listed in the following bullet points. For information on field measurements and sampling methods, see NFM A6.0 and NFM A4. For information on measuring specific individual field parameters, see NFM A6.1 through NFM A6.7.

- Connect all sampling-pump discharge-tubing fittings securely so that air does not enter the flow-through cell, as air can affect the accuracy and stability of the measurements.
- Shield the flow-through cell from direct sunlight to minimize changes in the temperature of the groundwater as it is withdrawn. Changes in temperature can affect the accuracy of other field-parameter measurements that rely on temperature corrections conducted within the sonde.
- Wait a minimum of 60 seconds for the sensors and sonde body to reach thermal equilibrium with the water before monitoring field-parameter values. Some instruments require a longer equilibration time; check the manufacturer's recommendations.
- Sediment accumulated in the flow-through cell can adversely affect the sensors of multiparameter instruments. Check to make sure that fittings and flows are oriented to minimize the build-up of sediment (if present) in the flow-through cell.

Field-measurement sensors must first be allowed to reach thermal equilibrium with the water body being sampled or monitored. This process can take from 60 seconds to several minutes or more, depending on the instrument and the initial and final temperature range.

5.0 Troubleshooting

Multiparameter instruments that perform poorly can be tested to determine the cause of the issue. The complexity of problems and tests may increase with the number of sensors installed on the sonde. Troubleshooting tests should be performed in a prescribed order depending on the types of sensors in use and the potential for sensor contamination. General troubleshooting tips are provided in table 6.8–6. Detailed guidance is available from the instrument's manufacturer. **Consult the manufacturer's user manual for the specific instrument being used.**

- If the display shows a warning message, do not use the instrument system until the error has been identified, understood, and corrected.
- Unless otherwise specified, sensor ports on the sonde body should be dry before sensors are replaced. Use compressed air or isopropyl alcohol to dry the ports. Before using solvents, such as isopropyl alcohol, be sure they are compatible with the sonde. When using isopropyl alcohol, gently shake the excess liquid from the port and allow sufficient time for the liquid to evaporate before installing the sensor.

WARNING: Alcohol and other solvents can damage certain types of plastics and o-rings and can destroy the sensing surface of the optical DO sensor.

6.0 Reporting

USGS personnel are instructed to record all field-parameter values on electronic or paper field forms, and to complete and submit information on Analytical Services Request forms of the USGS National Water Quality Laboratory (NWQL) or other laboratories to which samples will be submitted. Record the method (where applicable) that was used to make field measurements. Quality-control checks of the data should be made by a second party and compared for accuracy and consistency. Field-parameter values are required to be entered into NWIS. Recording and storage guidelines for field measurements are summarized in table 6.8–7.

Table 6.8–6. Troubleshooting tips for typical problems with multiparameter instruments.

[NIST, National Institute of Standards and Technology; NFM, USGS National Field Manual for the Collection of Water-Quality Data; DO, dissolved oxygen; SC, specific electrical conductance; ORP, oxidation-reduction (redox) potential]

Problem	Possible cause(s), corrective actions, and tips
Unstable readings	• Check for loose connections, low battery, or unstable wireless connection. • Unstable wireless connection; move sonde and handheld device closer together to stabilize connection or reset connection.
Display does not turn on	• Check that the batteries are installed properly and are fully charged. • Battery performance decreases with decreasing temperature. Carry spare batteries.
Display does not show readings; the readings seem to be wrong or are scrambled	• Check that the correct units are selected. • Inspect all connectors for moisture, dirt, damage, and loose connections. • Unstable wireless connection; move sonde and handheld device closer together to stabilize connection or reset connection.
Initial drifting of the readings	• Sensors not equilibrated to the water temperature. • Check that the sensors are appropriately submerged and at the required angle (if necessary). • Dislodge air bubbles from sensor surfaces.
Temperature reading is unstable or inaccurate	• Check for water in the port connector if present. • Check the temperature reading with a NIST-certified or NIST-traceable digital thermometer and replace the sensor if it does not meet accuracy standards. In some cases, only the manufacturer can replace a faulty temperature sensor.
Reading is unstable or inaccurate. For individual parameters see the appropriate NFM chapters: DO (see also NFM A6.2), SC (see also NFM A6.3), pH (see also NFM A6.4), ORP (see also NFM A6.5), turbidity (see also NFM A6.7)	• Examine the sensor for dirt or damage. Clean sensors according to the manufacturer's instructions. Replace damaged sensors and recalibrate. • Check the sensor connector for water; dry the connector and reinstall the sensor. • Allow sufficient time for the temperature sensor to equilibrate to the water temperature. • Check that the calibration solutions used were appropriate and not expired or subject to contamination. • Calibrations may have been rushed with inadequate rinsing of sensors. Check sensors and recalibrate if necessary. • Check pH reference junction; follow manufacturer's instructions for cleaning. If possible, replace the junction which may be part of a replaceable cap. • If the ZoBell solution check fails, was temperature dependence of the ZoBell solution accounted for? • The SC sensor must be fully immersed for proper calibration and sample measurement. There must be no bubbles in the cell compartment if present. • The turbidity sensor wiper must be clean, activated, and rotating properly. • Check the age and condition of the DO sensor cap and replace according to manufacturer's instructions if necessary.

Table 6.8–7. USGS guidelines for recording and storing field parameter values.

[NWIS, the National Water Information System; °C, degrees Celsius; SC, specific electrical conductance; ≥, greater than or equal to; <, less than; µS/cm, microsiemens per centimeter, DO, dissolved oxygen; mg/L, milligrams per liter; ORP, oxidation reduction (redox) potential; SHE, standard hydrogen electrode; mV, millivolt; FNU, formazin nephelometric unit; ppt, parts per thousand; psu, practical salinity units calculated from specific electrical conductance at 25 degrees Celsius]

Parameter	USGS reporting convention for NWIS[1]	Unit
Temperature	Nearest 0.01 depending on instrument precision	°C
SC	Three significant figures for SC ≥100, two significant figures for SC <100	µS/cm at 25 °C
DO	Nearest 0.01	mg/L
pH	Nearest 0.01, depending on instrument precision	pH standard units
ORP	Two significant figures, calculated relative to the SHE (do not report raw data). Record the temperature of the sample at the time of measurement.	mV
Turbidity	0 to <1, nearest 0.05 1 to <10, nearest 0.1 10 to <100, nearest 1 100 to <1,000, nearest 10 ≥1,000, nearest 50	FNU[2]
Salinity	<1 to <10, nearest 0.1 ≥10, nearest 1	ppt or psu

[1]It is USGS practice to enter values into NWIS that have more significant figures than are standard for reporting. The NWIS database has rounding built in for reporting. This practice eliminates user errors when reporting rounded values.

[2]Most multiparameter instruments used for USGS turbidity measurement contain single-beam infrared wavelength turbidity sensors and are reported in FNU. Check the Excel spreadsheet at http://water.usgs.gov/owq/turbidity_codes.xls to determine the appropriate turbidity unit of measure and NFM A6.7 for detailed information on turbidity measurement and instrumentation.

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Appendix 6.8–1. Example of a U.S. Geological Survey Field Form for Recording Sensor Calibrations and Field Measurements

NOTE: U.S. Geological Survey personnel are advised to use the most recent available version of the form shown in figure 6.8–01.01 and other field forms.

Calibrated by:__________________________ Location:_______________________ Station No. ___________________
Date:_________________ Time:______________

METER CALIBRATIONS and FIELD MEASUREMENTS

TEMPERATURE Meter make/model _________________ S/N _______________ Thermistor S/N ____________ Thermometer ID _________

Calibration criteria: ± 0.2 °C for thermistors

Local Meter

Lab Tested against NIST Thermometer/Thermistor? Y N Date: ___________________ ±___________ °C

Measurement Location: SINGLE POINT AT _______ ft DEEP STREAMSIDE _____ FT FROM LEFT RIGHT BANK VERTICAL AVG/MEDIAN OF _____ PTS

Field Readings # 1 ______ #2 ______ #3 ______ #4 ______ #5 ______ **MEDIAN**:_______ **ºC** Method Code ______ Remark ___ ___ Qualifier __

SPECIFIC CONDUCTANCE Meter MAKE/MODEL __________________ S/N ______________ Sensor ID __________________

Sample: CONE SPLITTER CHURN SPLITTER SINGLE POINT AT ______ ft DEEP VERTICAL AVG. OF _______ POINTS

LOCAL METER ID:_______________ AUTO TEMP COMPENSATED METER? Y N CORRECTION FACTOR APPLIES? Y N CORRECTION FAC-

Std Value µS/cm	Std Temp	SC Before Adj.	SC After Adj.	Vendor Lot No.	NWIS Parameter Code (see last page)	NWIS* Lot No.	Expiration Date

Calibration Criteria: ± 5 % for SC ≤100 µS/cm or 3% for SC >100 µS/cm ***NWIS Lot Numbers are available at: http://wwwnwql.cr.usgs.gov/qas.shtml?ConductivityStds_home**

Field readings #1_____ #2_____ #3_____ #4_____ #5 _____ **MEDIAN: _______ µS/cm** Method Code _______ Remark ___ ___ Qualifier ___ ___

pH Meter MAKE/MODEL ___________________ S/N ________________ Electrode ID _______________ Type: GEL LIQUID OTHER ________

Sample: FILTERED UNFILTERED CONE CHURN SPLITTER SINGLE POINT AT _______ ft DEEP VERTICAL AVG. OF ____ POINTS

pH BUFFER	BUFFER TEMP	THEO-RETICAL pH FROM TABLE	pH BEFORE ADJ.	pH AFTER ADJ.	SLOPE	MILLI-VOLTS
pH 7						
pH ___						
CHECK pH ___						

pH Buffer	Vendor Lot No.	NWIS* Lot No.	Expiration Date
pH 7 (99173)			
pH 10 (99171)			
pH 4 (99172)			

Calibration Criteria: ± 0.1 pH units, ± 0.3 if SC <75us/cm ***NWIS Lot Numbers are available at: http://wwwnwql.cr.usgs.gov/qas.shtml?Buffers_home**
Millivolts: pH 7 –10 to +10 , pH4 +165 to +195 mV, pH 10 –165 to –195 mV
Slope Acceptance Criteria: 95% to 102%

Field Readings #1_________ #2_________ #3_________ #4_________ #5 _________ **MEDIAN: _______ Units** Remark ___ ___ Qualifier ___

DISSOLVED OXYGEN Meter MAKE/MODEL __________________________________ S/N ________________________

Sensor Type: Amperometric Luminescent Spectrophotometer Sensor ID ____________________________Local Meter ID______________

Calibration Method: Air-Saturated Water Water-Saturated Air

Sample: SINGLE POINT AT _______ ft DEEP VERTICAL AVG. OF _____ POINTS BOD BOTTLE OTHER______________ Stirrer Used? Y N

Calibration Temperature ºC	Barometric Pressure mm Hg	DO Table Reading mg/L	Salinity Correc-tion Factor	DO Before Adjustment mg/L	DO After Adjust-ment mg/L

Zero DO Check __________mg/L Adj. to __________ mg/L Date: _______________

Thermister Check? Y N Date__________

Barometer Calibrated? N Y Date: ________________ Time: ________

Phase Degrees/Slope/Gain/Scale Factor (100%)_______________(Zero)_________

Calibration Criteria: ± 0.2 mg/L **DO saturation _______ %**

Field readings #1______ #2_____ #3_____ #4_____ #5 _____ **MEDIAN: _______ mg/L** Method Code _______ Remark ___ ___ Qualifier ____

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Figure 6.8–01.01 Example of a blank U.S. Geological Survey GW Form (version 9.1).

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