

Standard Operating Procedure #6:

Water Quality Field Measurements

Version 1.0

In Monitoring Protocol for Wadeable Streams of the Great Lakes Network

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Revision History Log

The following table lists all edits and amendments to this document since the original publication date. Information entered in the log must be complete and concise. Users of this standard operating procedure will promptly notify the project manager and/or the Great Lakes Network (GLKN) data manager about recommended and required changes. The project manager must review and incorporate all changes, complete the revision history log, and change the date and version number on the title page and in the header of the document file. For complete instructions, please refer to Procedure for Revising the Protocol, SOP #16.

Previous Version #	Revision Date	Author (with title and affiliation)	Location in Document and Concise Description of Revision	Reason for Change	New Version #
Add rows as needed for each change or set of changes tied to an updated version number					

Acknowledgements

This standard operating procedure (SOP) was based on those by Magdalene et al. (2008a) and Axler et al. (2008) for monitoring water quality on large rivers (Magdalene et al. 2008b) and inland lakes (Elias et al. 2008).

6.0 Introduction

Field measurements should represent, as closely as possible, the natural condition of the surface water at the time of sampling. Experience with and knowledge of the sampling equipment is critical for collecting data of high quality. To ensure consistent, high-quality data, always:

- Make field measurements with properly calibrated and maintained instruments that have been allowed to equilibrate *in situ*.
- Maintain a permanent log book for each field instrument for recording calibrations and maintenance. Review the log books before leaving for the field. This book should also be used for recording results of pre-and post-calibration checks as well as housing copies of results from alternate measurement sensitivity (AMS) checks, if applicable.
- Test each instrument (meters and sensors) before leaving for the field. Verify that batteries are fully charged and bring spare batteries. Become familiar with new instruments and new measurement techniques before collecting data.
- Have backup instruments readily available and in good working condition, if possible.
- Follow quality assurance/quality control procedures in SOP #15. Such protocols are mandatory for every data collection effort, and include practicing good field procedures and implementing quality-control checks. Make field measurements in a manner that minimizes artifacts that can bias the result. Check field-measurement precision and accuracy (variability and bias).

6.0.1 Core Suite of Water Quality Variables

The core field variables are temperature, specific conductance, pH, water level, and dissolved oxygen, all of which are mandated by the National Park Service Water Resources Division (NPS-WRD). To this mandated suite, GLKN has added a measure of water clarity. Depth profiles of temperature, specific conductance, pH, and dissolved oxygen will be measured at each sampling station using a multiparameter instrument (multiprobe). Water clarity will be measured with a transparency tube. Flow can be a key parameter for physical conditions in wadeable streams and is needed to interpret concentration data. Flow conditions will be tracked using the network of U.S. Geological Survey (USGS) gauging stations, where available. It is recommended that some form of flow data be collected, if active gauging stations do not exist on a stream. The expected ranges and resolutions required of multiprobes are listed in Table 1, and the methods for taking field measurements are described in Section 6.4.

6.1 Equipment and Supplies

6.1.1 Instrument Specifications

Toward low bias and high precision of water quality data for this protocol, Table 1 lists typical field sensor performance specifications that should be expected from monitoring equipment for this protocol. Multiparameter sensor instruments (or multiprobes), while expensive, are convenient and commonly used in water quality monitoring. A multiprobe instrument should be selected based on the observable range for each variable. However, an additional investment in a back-up set of less expensive individual sensors will help ensure the development of a long-term data set, should the multiprobe not be working properly.

Table 1. Typical sensor performance specifications^a for field instruments (Penoyer 2003).

Sensor	Expected Range	Reporting Resolution ^b	Estimated Bias ^c
Temperature	-5°C to 45°C	0.01°C	±0.15°C
Specific Conductivity (SC25)	0 to 2000 µS/cm	1 µS/cm (range dependent)	±0.5% of reading + 1 µS/cm
pH	1 to 14 units	0.01 unit	±0.2 units
Dissolved Oxygen (Concentration)	0 to 50 mg/L	0.01 mg/L	0 to 20 mg/L ±0.2 mg/L; 20 to 50 mg/L ±0.6 mg/L
Dissolved Oxygen (% saturation)	0%–200%	0.1%	ca. ±2 %
Turbidity	---	---	---
Depth - Z (pressure sensor)	0→100 m	0.1 m	ca. 0.1 m

^a In the case of field probes, accuracy is typically a best-case maximum deviation from known correct values (typically based on comparisons with known NIST certified reference materials or standards).

True accuracy is a combination of high precision and low bias (see Irwin 2004 for more details).

^b Resolution/sensitivity is a data quality indicator related to detection limits but typically handled differently for field probes than for laboratory parameters. For more information, see Irwin (2004).

^c Estimated bias specifications reflect the uncertainty in measurement of the instrument and sensor in combination only, and not other factors that can affect accuracy, such as environmental variables or the ability of field personnel to calibrate and operate the instrument using proper protocols.

Instrument-specific estimations of the range of uncertainty for each variable must be calculated for use in the interpretation of data. Therefore documentation will be maintained regarding the ability of each multiprobe to meet the data quality objectives of this project; blank forms are included in SOP #15. The completed forms for each multiprobe will be maintained along with the calibration and maintenance logs for the multiprobe.

Details on estimating instrument sensitivity are also included in SOP #15. Because field equipment is likely to change during the course of this long-term monitoring project, QA/QC procedures must be followed on documenting cumulative bias (SOP #15).

6.1.2 Additional Equipment, Supplies, Forms, etc.

Refer to the checklist of supplies and equipment needed for field sampling (Table 2) prior to each sampling trip. Keep on hand all necessary forms, calibration logbooks, field logbooks, field data sheets, procedural manuals, and equipment instructional manuals.

Table 2. Checklist of field equipment and supplies required for monitoring water quality.

√	Equipment and Supplies
☐	Field notebook, pencils, and pen (waterproof ink)
☐	New field forms on waterproof paper
☐	Up-to-date field folders containing recent data sheets for field comparison (copies only; never take originals in the field)
☐	Multiparameter instrument (calibrated), calibration standards, check solutions, data logger
☐	Long and short cables for multiprobe instrument(s)
☐	Calibration logbook for each instrument
☐	All maintenance parts and calibration standards for field instruments
☐	Backup instruments in case of electronic failure of multiprobe (for example: YSI 85 [T-DO-SC25] or equivalent, YSI 200 [T-DO], Hannah Dist3 [SC25], armored NIST certified thermometer [°C], portable pH meter)
☐	Transparency tube
☐	Secchi disk and metered line (marked at 0.5 m intervals)
☐	Sounding weight(s)
☐	Water samplers: Integrating tube, Van Dorn type sampler
☐	Compositing jug and other bottles, including brown or amber bottles for chlorophyll-a
☐	Sonde with barometric pressure sensor, weather radio barometer, or other way to obtain barometric pressure
☐	Pocket calculator (waterproof, if possible)
☐	Extra batteries for all field equipment (multiparameter probe, calculator, GPS, etc.)
☐	Rain gear
☐	First aid kit
☐	Personal flotation device(s)
☐	Field trip itinerary
☐	Cellular phone and/or park radio
☐	Digital camera with extra flash cards and battery
☐	Map(s) of station location, preferably at different scales
☐	Global positioning system (GPS) with extra batteries
☐	Deionized or distilled water for field rinsing

Copy field data sheets on waterproof paper. See the attachments for blank data sheets. The instruction manuals for each instrument should be copied and the originals placed in a secure file and kept in the office. Specific sections of the manual that might be important to have in the field should

be copied onto waterproof paper and remain in the field kit. Include copies of a datalogger software manual.

6.2 Overview of Field Work

6.2.1 Sequence of Activities

1. Prepare sample bottles and labels in advance.
2. Review checklist of field gear.
3. Prepare new data sheets for each monitoring station, printed on waterproof paper. Separate data sheets are needed for a) mapping and measuring habitat features; b) habitat sampling along transects; c) station summary, including water quality; d) flow; e) macroinvertebrate collection; and f) periphyton collection.
4. Conduct daily calibration of appropriate meters and probes.
5. Inspect motorized vehicles at the beginning of every field day, including all safety and directional lights, oil, gasoline, and air pressure levels of tires.
6. Travel to monitoring site. Refer to description of monitoring station location, directions, and photos to verify correct location. Verify coordinates on GPS unit.
7. Measure water quality variables with a multiprobe and transparency with a transparency tube downstream of first transect per SOP #6; record measurements on data sheet.
8. Obtain mean stream width to calculate 40 X MSW to find sample reach length, as needed.
9. Moving from downstream to up, conduct physical habitat assessment instream and in the riparian area along transects, Map and measure habitat features as you go. Also as you move upstream, select three riffles or other appropriate habitats for collecting macroinvertebrate and periphyton samples (per SOPs #7 and #8).
10. Collect and preserve macroinvertebrate and periphyton samples, per SOPs #7 and #8, respectively.
11. Measure water quality variables with a multiprobe and transparency with a transparency tube upstream of last transect per SOP #6; record measurements on data sheet.
12. Measure flow along a cross section of the stream (per SOP #10) at an appropriate place within the sampling reach; record measurements on data sheet.
13. Download data from continuous logging devices (if deployed), replace batteries or logging devices if necessary, and re-deploy.
14. Record stage reading.

15. Verify that all data sheets are completely filled out, and initial them.
16. If sampling more than one monitoring station in a day, go back to step 6, ensuring that equipment has first been decontaminated for invasive species per SOP #5.
17. Return to office or park laboratory.
18. Clean and decontaminate sampling equipment (SOP #5) and perform calibration checks, as detailed in SOP #6.
19. Download field data and check against hard copy field data sheets as soon as feasible.
20. Enter all data into NPSTORET at the end of the season.
21. This SOP contains details on mapping and measuring habitat features and conducting physical habitat assessments instream and in the riparian area.

6.2.2 Record Field Information Upon Arrival at Monitoring Site

Consistent methods are important for long-term data quality. In actuality, the ideal conditions are not always met in the field or in the lab and changes in staff occur. Therefore, documentation of procedures, site conditions, laboratory analysis, and reasons for deviations of any kind is important. Personnel are encouraged to write down more than they feel may be necessary in the moment, as the future interpretation of their data will depend on the written record and not the memory of an individual. Waterproof field forms (copy “Station Summary Form” is available in the attachments) should be prepared ahead of time labeled with the project and station IDs. Sampling stations will be identified by park, waterbody name, and river mile according to GLKN guidance. Information on the sampling station and park will comply with NPSTORET requirements. Field sampling forms are used to record the physical and chemical water quality variables measured at the time of sample collection. In addition to recording the field variables, any other samples collected (e.g., biological samples) must be so indicated. Any planned samples that were not collected should also be indicated, along with the reason for not collecting the sample. Documentation should include calibration data for each instrument, field conditions at the time of sample collection, visual observations, and other information that might prove useful in interpreting these data in the future.

While at each monitoring site, the information recorded on field sampling forms should include:

- Date
- Time of arrival
- Names of field team members, with the person acting as crew leader listed first
- GPS coordinates, to verify location
- Current weather (air temperature and wind speed) and relevant notes about recent weather (storms or drought), including days since last significant precipitation
- Observations of water quality conditions (see below)

- Multiparameter meter (model/serial no.), calibration date, and field measurements of core suite variables; add dissolved oxygen calibration information if calibrating on-site
- Whether any samples were not collected, and reason
- Quality assurance/quality control procedures followed
- Water level measurement, if collected at a given site
- Qualitative assessment of flow conditions (e.g., low, average, high)
- Any other required metadata for NPSTORET data entry
- Any additional non-routine monitoring
- Time of departure

All entries should be made clearly. If an incorrect entry is made, a single heavy line should be drawn through the incorrect entry and the correction made. All corrections should be initialed and dated. The completed field forms will be copied into project binders and the originals maintained on file indefinitely in the GLKN office.

Upon arrival at the monitoring station, record visual observations of water quality conditions that will be useful in interpreting water quality data. To be consistent and to help orient others to the location of observations, the convention left bank/right bank is used. *Left bank* is defined as the bank to the left of the observer when facing upstream, and the *right bank* is to the right of the observer when facing upstream. Examples of conditions to record include but are not limited to:

- Water appearance — General observations on the water such as color, unusual amount of suspended matter, debris, or foam.
- Biological activity — Excessive macrophyte, phytoplankton, or periphyton growth; presence and types of fish, birds, and mussels.
- Unusual odors — Examples include hydrogen sulfide, mustiness, sewage, petroleum, chemicals, or chlorine.
- Watershed or in-stream activities — Activities or events that are impacting water quality, for example, bridge construction, shoreline mowing, or livestock watering upstream.

6.2.3 Preventing Contamination

Field technicians should be aware of and record potential sources of contamination at each field site. Decontaminate field sampling equipment according to SOP #5 for minimizing the risk of spreading invasive species. Clean field and laboratory equipment according to SOP #7 to avoid contamination of analytes to be measured.

6.2.4 Using Disposable Gloves

Wearing disposable gloves is strongly recommended when handling acid preservatives. Check manufacturer's chemical resistance information to be sure gloves are appropriate for compounds to

which they will be exposed. Common glove types include those made of vinyl, latex, and nitrile; nitrile is in standard use for USGS sampling work because of its resistance to most of the chemicals to which it typically will be exposed for the length of exposure (usually <15 minutes). Field personnel are cautioned that direct contact with materials such as latex or nitrile can cause severe allergic reactions in some individuals and should be monitored.

Physical properties to consider when selecting disposable gloves are glove length, slip protection, puncture resistance, heat and flame resistance, cold protection and comfort. These factors can vary between manufacturers. Gloves should be inspected visually for defects. Check for tears, punctures and other flaws that can prevent the glove from being an effective shield. After putting the gloves on, rinse them with water while gently rubbing hands together to remove any surface residue before handling sampling equipment.

6.2.5 Bottle Preparation – Types and Sizes of Bottles

For each monitoring station, select the bottles appropriate for each analyte and label them with Station ID, sample date, and analyte code according to the requirements of the contact analytical laboratory. Store pre-labeled bottles in a dry box or in separate bags for each station.

6.3 Taking Field Measurements

6.3.1 When and Where to Sample

Sampling will typically be conducted once annually per site in late spring/early summer or late summer/early fall, depending on degree day (see the protocol narrative, chapter 3, Field Methods, for details on schedule). GLKN will work with the parks to determine the appropriate sampling window each year. The timing and placement of sample collection are controlled by concerns for the physical safety of field personnel and the quality assurance of monitoring data.

- Sampling should be planned to allow all samples at a station to be completed on a single day. If all sampling cannot be finished on a single day, all data collections from a particular data type, macroinvertebrates, for example will be completed before leaving the site. This will ensure that the sample is not altered by unforeseen events such as a precipitation event.
- Do not collect samples from an ice-covered stream – it can be difficult and dangerous. Do not wade into the stream if the current velocity is too great. You must use your best judgment, but a good rule of thumb is if the product of the velocity and the flow depth is greater than 10 ft²/sec, do not wade into the stream. For example, water depth of 2 ft. and flow of >5 ft. /s may constitute unsafe conditions. Each stream and reach should be evaluated for safety on an individual basis. If working alone, or far away from other crew members it is advisable to wear a PFD.
- Conduct sampling during daylight hours. Plan the field day accordingly, and begin sampling the last station of the day well before dusk. However, as a precaution, pack flashlights or headlamps for each member of the field team. If a site must be left, sampling should be completed the next day. Plan ahead to fully complete select data collections in a single day (e.g. water quality at downstream and upstream sites, macroinvertebrates and periphyton collected from all sites) to avoid variance caused by unforeseen events such as precipitation.
- Stream water quality can vary in diurnal cycles. Try to sample each site at the same time of day as on previous visits, preferable between 10:00 A.M. and 2:00 P.M.
- Multiple streams sampled on the same day should be sampled in a way to minimize contamination. If there is reason to suspect that part of the resource is contaminated by regulatory parameters (chemical or bacteriological contaminants, such as salts, metals, herbicides, and fecal coliform) or invasive species, then conduct sampling from uncontaminated streams, or those of lowest concentrations first.
- Before making field measurements, properly-calibrated sensors must be allowed to equilibrate to the condition of the water being monitored. For details, see Section 6.3.2.
- All of the core suite water quality variables shall be measured *in situ* (Table 3). A vertical profile of all core suite variables, except clarity, should be measured simultaneously at the centroid of flow. The centroid of flow is the midpoint of streamflow, or the point on the

stream's cross-section perpendicular to flow that has equal volumes of flow to the right and to the left sides. Sampling from the centroid of flow assures that average water quality conditions are being sampled, and that water quality results are representative of average flow conditions. In small wadeable streams, such as those included in this protocol, the centroid can be estimated visually. The centroid of flow will be confirmed during site establishment (see SOP #4) and again any time there has been an obvious change in channel morphology. If there is no water flow in the stream, leaving isolated, stagnant pools in the stream bed, DO NOT take measurements or collect samples from a pool; water in the pools will not be representative of the water quality of flowing waters.

- After disturbances from wading have cleared, take measurements of the field variables upstream or to the side of where you are standing.
- When collecting stream water for any reason (e.g., to fill the transparency tube), make sure to open and close the sampling jug below the surface of the water in order to avoid surfactants and floating debris.

6.3.2 Stabilization of Sensor Probe Readings

Before making field measurements, properly-calibrated sensors must be allowed to equilibrate to the condition of the water being monitored. Sensors have equilibrated adequately when instrument readings have stabilized, that is, when the variability among measurements does not exceed an established criterion. The criteria for stabilized field readings were defined by O'Ney (2005) for a set of three or more sequential measurements (Table 3). Although the criteria used by the Greater Yellowstone Network (O'Ney 2005) differ from those used in the upper Midwest by the University of Minnesota Natural Resources Research Institute (WOW 2004), the differences are small in comparison to the true range of variability one might expect in the field and with aging instrument sensors. The natural variability inherent in surface water or ground water at the time of sampling generally falls within these stability criteria and reflects the accuracy that should be attainable with a calibrated instrument. In the case of field probes, accuracy is typically a best case maximum deviation from known correct values (typically based on comparisons with known NIST certified reference materials or standards). True accuracy is a combination of high precision and low bias (see Irwin [2004, 2006] for more details).

Dissolved oxygen typically requires the greatest amount of time to stabilize. For dissolved oxygen sensors that utilize a membrane, differences in polarographic sensor membrane thicknesses, age, and rates of oxygen consumption increase the variability of the equilibration time. The longest equilibration times will typically occur where dissolved oxygen exhibits a steep gradient (change in DO concentration >5 mg/L) or very low oxygen levels (anoxia; DO concentration <3 mg/L). Depending on the site characteristics and the specific oxygen sensor, 3 to 5 minutes may be required for complete equilibration. This time far exceeds what is needed for the other variables, which typically stabilize in less than 60 seconds. Observers should only note instrument DO readings after the stabilization criteria in Table 3 are met, and then record readings for all variables at once.

Table 3. Recommended instrument stabilization criteria for recording field measurements.

Standard Direct Field Measurement	Stabilization Criteria (O’Ney 2005)	Stabilization Criteria <i>In situ</i> Multisensors (WOW 2004)
Temperature:		
Thermistor Thermometer	$\pm 0.2^{\circ}\text{C}$	$\pm 0.2^{\circ}\text{C}$
Liquid-in-glass Thermometer	$\pm 0.5^{\circ}\text{C}$	(5%)
Specific Conductivity (SC25)		
When $\leq 100\ \mu\text{S}/\text{cm}$	$\pm 5\%$	$< 5\ \mu\text{S}/\text{cm}$
When $> 100\ \mu\text{S}/\text{cm}$	$\pm 3\%$	(10%)
pH: Meter displays to 0.01	± 0.1 unit	± 0.2 unit (10%)
Dissolved oxygen:		
Amperometric (same as polarigraphic) method	$\pm 0.3\ \text{mg}/\text{L}$ $\pm 2\%$	$\pm 0.5\ \text{mg}/\text{L}$ (10%)

6.3.3 Measurement Sequence

Acquiring high quality results requires the use of consistent measurement methods. Use the following sequence:

1. Go to the centroid of flow. Obtain measurements directly from the waterbody by immersing the multiprobe instrument, allowing it to equilibrate before measurements are recorded.
2. If the depth of the stream allows, measure at multiple depths in the vertical: take first reading at approx. 0.1 m depth after stabilization of the multiprobe. Lower the multiprobe and take stabilized readings every 0.5 m to near-bottom. In many cases, only a single depth may be feasible.
3. Quality Assurance (QA): Replicate at least one set of measurements at each site. The replicate should be taken immediately following the original reading. Values should agree within $\pm 10\%$ or the stabilization levels listed in Table 4, whichever is larger.
4. Use a 2–4 L jug to collect a water sample. Open and close the jug below the water’s surface to avoid surfactants and floating debris. Use sample water from the jug to fill the transparency tube and measure clarity. Ensure sample is well-mixed prior to filling the transparency tube.

Table 4. Ideal calibration frequency and acceptance criteria.

Parameter	USEPA Method	Minimum Calibration Frequency and QC Checks	Acceptance Criteria	Corrective Actions
Temperature	170.1	Annually, 2-point check with NIST thermometer	$\pm 1.0^{\circ}\text{C}$	Re-test with a different thermometer; repeat measurement.
Specific conductance (SC25)	120.1	Daily, prior to field mobilization; calibration check prior to each round of sampling; 10% of the readings taken each day must be duplicated or a minimum of 1 reading if fewer than 10 samples are read.	$\pm 5\%$	Re-test; check low battery indicator; use a different meter; use different standards; repeat measurement
pH	150.1	Daily, prior to field mobilization (two buffers should be selected that bracket the anticipated pH of the water body to be sampled)	± 0.05 pH unit	Re-test; check low battery indicator; use different standards; repeat measurement; don't move cords or cause friction/static
		Calibration check w/ third buffer prior to each round of sampling; check with low ionic strength buffer in addition, if conductivity is $< 50 \mu\text{S}/\text{cm}$	± 0.1 pH unit	
		10% of the readings taken each day must be duplicated or a minimum of 1 reading if fewer than 10 samples are read.	RPD 10%	
Dissolved oxygen	360.1	Daily, prior to field mobilization; check at the field site if elevation or barometric pressure changed since calibration	0.2 mg/L concentration or $\pm 10\%$ saturation	Re-enter altitude; re-test; check low battery indicator; check membrane for wrinkles, tears or air bubbles; replace membrane; use a different meter; repeat measurement; allow more time for stabilization
Depth	--	Daily, prior to field mobilization, check at the field site. Check annually against commercially purchased brass sash chain labeled every 0.5 m to ensure that it reads zero at the surface and varies < 0.3 m for depths < 10 m and no more than 2% for greater depths.	± 0.1 m	Retest, check low battery indicator; repeat measurement; use with accurately calibrated line
Transparency tube	--	Transparency tubes have a 100- or 120-cm scale; ensure tube is clean	± 1.0 cm for transparency tube	

6.3.4 Detailed Description and Troubleshooting Hints for Field Variables

Because temperature, DO, and other water quality variables are important determinants of biotic habitats, it is important that observers write down values on field forms and think about their ecological meaning, even if a data logger is recording the measurements. The hard copy also serves as backup in case there is an electronic failure.

6.3.4.1 Temperature

Temperature (T) is measured in units of degrees Celsius (°C), and recorded to the nearest degree or tenth of a degree as warranted by instrument.

1. If a cabled thermistor is not available, the high specific heat of water allows temperature measurements to be obtained by bringing deeper samples to the surface with a water sampler and immediately measuring temperature with a hand-held thermometer or thermistor.
2. The upper few centimeters of soft sediments are often several tenths of a degree warmer than the overlying water. The rise in temperature can be an indication that the probe is submersed into the sediments. If this happens, pull the instrument to the surface and clean it before re-taking measurements.

6.3.4.2 Specific Conductance

Specific conductance (SC) is the ability of water to conduct an electrical current for a unit length and unit cross-section at a certain temperature, measured in units of microsiemens per centimeter ($\mu\text{S}/\text{cm}$), and recorded to the nearest $\mu\text{S}/\text{cm}$. Commonly used in water quality monitoring, SC is a general measure of the number of ions dissolved in the water. It is important to be aware of the difference between conductivity (at the ambient temperature of the sensor) and SC (specific conductance temperature compensated to 25°C).

- Many instruments will display conductivity in addition to SC. In the event that an uncompensated sensor must be used (older instruments and most pocket conductivity meters are not temperature-compensated), the value of SC can be calculated from conductivity and temperature values. Contact the instrument vendor for the appropriate formula.
- A common physical problem in using a specific conductance probe (or meter) is entrapment of air in the conductivity probe chambers. Its presence is indicated by unstable specific conductance values fluctuating up to $\pm 100 \mu\text{S}/\text{cm}$. This artifact is much more prevalent in turbulent stream waters and can be minimized by slowly and carefully placing the probe into the water and when completely submerged, quickly move it through the water to release any air bubbles. An SC probe with an open flow design does not trap air.
- If specific conductance values fall outside the expected range, check the instrument calibration with a known standard in the field. For example, if the expected specific conductance is around 200 and the reading is 1500, use a known standard in the instrument storage cup to determine whether the instrument is reading correctly or is out of calibration.

6.3.4.3 Hydrogen Ion Activity (pH)

Commonly used in water quality monitoring, pH is a measure of the acidity of water. It is measured in standard pH units (SU) that range from 1 (acidic) to 14 (alkaline), and it is generally recorded to the nearest 0.1 pH unit.

- Low ionic strength waters with SC <50 $\mu\text{S}/\text{cm}$ can cause pH measurement stability problems with some probes. Probes will often calibrate fine in strong ionic strength buffers but will not read accurately in lower ionic strength surface waters. If you suspect this is the case, use low ionic strength buffers for calibration or use a sensor that is designed for low ionic strength waters.
- Because the pH scale is logarithmic, field values may have to be converted to hydrogen ion activity (i.e., concentration) values prior to conducting statistical summaries and analyses. Check for normalcy of data.
- To convert pH value to hydrogen-ion activity, use the equation: Hydrogen Activity = $10^{-\text{pH}}$.
- To convert the calculated hydrogen ion activity back to pH units, use the equation, $\text{pH} = -\log_{10}(\text{mean hydrogen activity})$.
- pH values that fall outside the expected range can be checked in the field with a known standard. For example, the expected pH is around 7.0 and the reading is 9.5. A known standard can be measured in the instrument storage cup to determine if the instrument is reading correctly or is out of calibration.

6.3.4.4 Dissolved Oxygen

Dissolved Oxygen (DO) concentration is reported as mg/L and/or percent saturation (% DO). Values measured by multiprobes are temperature compensated to 25°C.

- Be aware that if a water sample has a strong rotten egg smell (H_2S gas) it must have a DO of zero. This is a good way to check your meter. You can use the measured offset value to correct your higher DO values. Do not report negative DO values in the final database although it is important to report them on the field data sheet. Do the correction afterwards but note on the field sheet the depth at which you could smell sulfide gas.
- Equilibration time is critical; the steeper the DO gradient, the longer the equilibration time. It may take >5 minutes when DO drops abruptly to near zero.
- The DO probes with Clark cells actually consume oxygen as they work; measurements therefore require moving water using either a built-in stirrer (typical in multiparameter sondes and BOD probes) or swirling the instrument by hand during the measurement. New optical sensors do not consume oxygen and hence do not require moving water.

- If the electronic DO meter is not functioning properly, DO can be measured by Winkler titration (APHA 2005). A variety of field kits are convenient and cost effective, including LaMotte, Hach, and others.

6.3.4.6 Water Clarity

Measurement of water clarity is a qualitative evaluation of the transparency of water to light. It is based on the reflection of light from the surface of a miniature Secchi disk at the bottom of the transparency tube and is a function of the absorption characteristics both of the water and its dissolved and particulate matter. A transparency tube is commonly used to measure water clarity of streams. Note that a reading taken from one tube cannot be compared with a reading taken from another tube made by a different manufacturer if the dimensions are different.

Use the following steps to measure clarity with a transparency tube:

1. Begin with a 120 cm transparency tube.
2. The tube should be set on a light-colored background (a white towel works well), shaded by your body, and read without sunglasses.
3. Water should be dispensed from a jug that was used to collect a water sample at approximately elbow depth. Shake the jug well prior to filling the tube to ensure that any particles that may have settled are well-mixed. Allow air bubbles to dissipate before making the final measurement.
4. While slowly releasing water from the bottom of the tube via its valve, note and record the depth to the nearest 0.1 cm at which the mini-secchi first becomes visible. Continue releasing water until the white screw in the center of the mini-secchi becomes visible: record this reading. Take the average of the two readings.
5. Several attempts to read the clarity may be necessary because of overshooting the endpoint, so collect plenty of water for this analysis. A standard 120 cm × 4.5 cm outside diameter tube requires approximately 1.5 L to fill it, so dedicate at least 4 L of water for this measurement.
6. If the mini-secchi can be seen through a full tube of water, record the value as >120 cm. If it appears to be barely visible, this fact should be recorded to distinguish it from a measurement where it is clearly visible.
7. Replicate transparency tube readings at every site for quality assurance. Values should agree to ±10%.

Maintenance notes and other precautions

1. The rubber stopper (with attached secchi) can be dislodged easily. Tape the stopper with black vinyl electrical tape and carry an extra stopper-secchi.
2. Clean the transparency tube periodically with mild dish soap and a soft cloth.

3. Subsampling and settling issues are important, as particles settle quickly. A stopper for the top of the tube is useful to allow for agitation and resuspension during the measurement if rapid settling occurs.
4. Dissolved color due to organic matter (humic and fulvic acids, usually from bogs and conifer needles) can confound comparisons of transparency tube data between monitoring stations. Also, water bodies with similar concentrations of suspended sediments can have different transparency because smaller particles scatter more light.

6.4 Departure from Monitoring Site

Before leaving the monitoring site, all field forms and sample labels must be reviewed for legibility, accuracy, and completeness. Any changes in procedure due to field condition must be explained in the comments section. Make sure the information is complete on all forms. After reviewing each form, initial the upper right corner of each page of the form. Document any photos taken.

6.5 Field Methods Summary

- Test, calibrate, and check field equipment before going into the field.
- Allow sensors to equilibrate with ambient water. Always wait for the DO sensor to equilibrate prior to sampling, because it takes the longest to equilibrate.
- Manually record data on waterproof paper, even if the instrument has a data logger. Note any abnormalities or qualifications to the data.
- Always examine the data while in the field. If a measurement does not make sense hydrologically in comparison with previous data from that site, re-measure it immediately to help address the problem.

6.6 Quality Assurance/Quality Control (QA/QC)

QA/QC basically refers to all those things good investigators do to make sure their measurements are as accurate (the absolute true value) and precise (reproducible and consistent) as possible, and include good estimates of uncertainty. Specifically, QA/QC involves following established rules in the field and lab to assure everyone that the sample is representative of the site, free from outside contamination by the sample collector, and that it has been analyzed following standard QA/QC methods. QA measures are conducted prior to sampling, and include such things as training, calibrating probes and meters, documenting instrument sensitivity, and standardizing methods and procedures. QC measures occur afterwards, and determine whether the QA measures were successful. Typical QC procedures include conducting calibration checks, conducting equipment and field blanks, taking duplicate measurements. See SOP #15 for detailed QA/QC procedures.

6.6.1 Summary of QA/QC Field Procedures

QA/QC protocols are meant to ensure data collected are as representative of the natural environment as possible and are required in all data collection efforts as part of this monitoring protocol. A summary of important QA/QC procedures follows.

- Field staff must be trained by an expert hydrologist(s). Training will include classroom time as well as field and lab components. Details of the training are given in the Standard Operating Procedure #2: Training and Safety.
- Use calibrated instruments for all field measurements. Test and/or calibrate the instruments before leaving for the field. Each field instrument must have a permanent log book for recording calibrations and repairs.
- All manually recorded field measurement data will be collected on field forms; data that are automatically recorded will be captured electronically and the equipment used will be documented on field forms. Hard and electronic backup copies will be made as soon as possible after surveys.
- Complete records will be maintained for each uniquely identified sampling station and all supporting metadata will be recorded appropriately (field forms or electronically).
- Make field measurements in a manner that minimizes artifacts that can bias the result.
- Conduct duplicate measurements of field parameters at a rate of at least 10% or at least once at every site, whichever is greater.
- Check field-measurement precision and accuracy.

6.6.2 Corrective Responsive Action

The project manager, in consultation with experienced professionals, will be responsible for taking corrective responsive action if QA/QC procedures are not followed or in the case of an unexpected event. Responsive action is often needed in the event of missing data, errors on field sheets, changes due to field conditions, problematic analyses, and other events that do not fall within the standard operating procedures. Often a correction will be a decision on whether to delete data or re-measure a parameter that failed QC checks for precision or bias. A 'Memo-to-file' will be used to document any decisions or corrections that are made.

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Attachments

- Station Summary Form
- Eureka Manta Calibration Log
- Eureka Manta Maintenance Log
- YSI Multiprobe Calibration/Maintenance Log
- Alternate Measurement Sensitivity Worksheet

Note: left bank/right bank facing upstream

Field Observations - Indicate Estimated Abundance Throughout Site**0 = Absent/Not Observed, 1 = Rare (1-3 organisms), 2 = Common (3-9 organisms),****3 = Abundant (>10 organisms), 4 = Dominant (>50 organisms)**

Sponges	0	1	2	3	4	Crayfish	0	1	2	3	4
Hydrozoa	0	1	2	3	4	Snails	0	1	2	3	4
Bryozoans	0	1	2	3	4	Clams	0	1	2	3	4
Leaches	0	1	2	3	4	Filamentous algae	0	1	2	3	4
Fish	0	1	2	3	4	Periphyton	0	1	2	3	4
Macrophytes	0	1	2	3	4	Other _____	0	1	2	3	4

Description of photos taken (e.g., #1 - from downstream end of station looking upstream)

Eureka Manta Multiprobe Calibration**Personnel****Multiprobe Eureka Manta # MM09110775****Calibration
Date****Time****pH Reference
Electrolyte Changed
Date**

	Calibration Standard (True Value)	Pre Calibration Reading	Calibration Reading	Calibration Check	Pre- or Post- Field?
Cable Power					
Depth in air	0				
Baro. Pressure					
Temperature					
SpCond (µS/cm)	Air (0)				
	value _____				
SpCond (µS/cm)	Lot # _____				
	value _____				
SpCond (µS/cm)	Lot # _____				
	value _____				
SpCond (µS/cm)	Lot # _____				
pH	7.____				
	Lot # _____				
pH	10.____				
	Lot # _____				
pH	4.____				
	Lot # _____				
pH	_____				
	Lot # _____				
pH	_____				
	Lot # _____				
pH	_____				
	Lot # _____				
pH	millivolts at pH 7.0				
Baro Press.					
DO% Saturation					
DO (mg/L)					

Eureka Manta Maintenance log

Record maintenance performed, date, and person conducting maintenance

Date & Personnel	DO Probe	pH probe	EC25 probe	Temperature	Depth Sensor

YSI MULTIPROBE CALIBRATION/MAINTENANCE LOG					
PRE FIELD CALIBRATION Calibration _____ Initials: _____ Sonde ID: _____ Date: _____ Time: _____ Instrument: _____ Battery Voltage: _____					
Function	Temp. of Standard	Value of Standard	Initial Reading	Calibrated to	Comments
Specific conductance					
pH calibrated (~7)					
pH secondary standard (4 or 10)					
Dissolved oxygen					
DATA NEEDED FOR DISSOLVED OXYGEN CALIBRATION					
Altitude (A) = _____ feet above msl		Barometric pressure _____ inches			
Barometric Pressure (BP) Options		Barometric Pressure Formulas			
Barometer		Barometric pressure (inches) _____ x 25.4 = BP _____ mm			
From local source after correction (CBP)		BP _____ mm = CBP _____ mm - 2.5 (altitude ____/100)			
Estimated from altitude only		BP _____ mm = 760 mm - 2.5 (altitude ____/100)			
For older Hydrolabs: Table DO value _____ x ALTCORR _____ x BAROCORR _____ = DO standard _____					
POST FIELD CALIBRATION CHECK Post Calibration Initials: _____ Date: _____ Time: _____ Instrument: _____ Battery Voltage: _____ date of original calibration _____					
Function	Temp. of Standard	Value of Standard	Initial Reading	Calibrated to	Comments
Specific conductance					
pH 7					
pH secondary standard (4 or 10)					
Dissolved oxygen					
Check previous maintenance and use; do the following before calibration:					
Polish conductivity electrodes. Must be polished within the last two months or once every 15 field trips			Date:	Name/comments:	
Change pH reference probe solution. Must be renewed within last two months or once every 15 field trips.			Date:	Name/comments:	
Inspect DO membrane for nicks or bubbles. Must be changed within last six months or once every 15 field trips.			Date:	Name/comments:	
Change battery. Change once a year. Change internal batteries for newer generation products according to guidelines in product manual.			Date:	Name/comments:	

Alternative Measurement Sensitivity Worksheet

Alternative measurement sensitivity readings (check one) _____ Lab (AMS) _____ Field (AMS+)

Location _____

Performed by _____

Date _____

Began calibration log _____

Sensor	1	2	3	4	5	6	7
Temperature							
Specific conductance (SC)							
pH (sensor units)							
DO (Conc.)							
DO (% sat.)							
Depth – Z (pressure sensor)							

Calculations

For each parameter calculate the standard deviation of the 7 readings. If more than 7 readings are taken, use a t-table to find the appropriate value to multiply the standard deviation by.

Sensor	Standard deviation	AMS 3.708 x sd		
Temperature				
Specific conductance (SC)				
pH (sensor units)				
DO (Conc.)				
DO (% sat.)				
Depth – Z (pressure sensor)				

Alternate Measurement Sensitivity is a two-sided estimation based on the 99% confidence interval for sample size 7. Of interest is the size of the difference between two individual values that can be considered to actually be a true difference.