Cover Sheet Standard Operating Procedure

Operation Title: Continuous Monitoring Water Quality Standard Operating Procedures.

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Maine Department of Environmental Protection
Division of Environmental Assessment
Continuous Monitoring of Water Quality
Standard Operating Procedures

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Table of Contents

1.0 Applicability

This Standard Operating Procedure (SOP) is applicable to all unattended continuous monitoring data collection and analysis procedures that will be conducted by staff in the Maine Department of Environmental Protection's (DEP's) Division of Environmental Assessment (DEA) for assessing water quality. Typical data parameters may include: Dissolved Oxygen (DO), Temperature, Specific Conductance, Salinity, pH, Turbidity, Chlorophyll and Depth. DEP utilizes these types of data to make management decisions and this SOP is intended to ensure data accuracy. This SOP borrows heavily, sometimes verbatim, from United States Geologic Survey (USGS) Techniques and Methods 1-D3, Pennsylvania Department of Environmental Protection's Continuous Instream Monitoring Protocol December 2011, Illinois EPA Standard Operating Procedure for Continuous Monitoring of Water Quality document #202, U.S. Environmental Protection Agencies (EPA) Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams, and the National Estuarine Research Reserve's System-Wide Monitoring Program (SWMP) and Centralized Data Management Office (CDMO) Data Management Manual (Appendix 1).

2.0 Purpose

The purpose of this SOP is to provide standard methods for collecting, processing and analyzing data from unattended continuous water quality monitoring devices (e.g., sondes and loggers) for rivers, streams, lakes, wetlands and marine waters. This SOP does not replace any existing DEA SOPs relating to the collection and processing of continuous data (e.g. the Biological Monitoring Programs' *Protocols for Measuring Continuous Water Temperature Using an Onset Data Logger*, DEPLW0700A-2014). This SOP augments sonde/logger manufacturer manuals which should be followed in all instances as related to the proper use and care of monitoring devices, as well as the collection and management of data.

3.0 Definitions

3.1 Calibration - Set of procedures established by the manufacturer of a particular monitoring device to ensure device accuracy, a critical quality assurance step in device preparation prior to use.

3.2 Sensor Calibration Drift - Refers to changes in the accuracy of sensor/device during the deployment period, specifically the difference between the cleaned-sensor reading in standard solutions and the expected reading as compared to pre-deployment readings obtained in the same manner.

3.3 Corrected Data - Data file that has been adjusted for fouling and calibration errors.

3.4 DEA - Division of Environmental Assessment of DEP's Bureau of Water Quality.

3.5 ECOWatch –Manufacturer's (YSI) data analysis and programing software for YSI sondes

3.6 Edited Data - Data file where outlier or erroneous data points have been removed (e.g. prior to deployment, out of water, vandalism).

3.7 EGAD – DEP's Environmental and Geographic Analysis Database.

3.8 Field Meter (meter) - An independent meter that is carried into the field for the day and used to collect instantaneous readings as a quality assurance check for the unattended monitoring device.

3.9 Fouling - Surface contamination of sensors that results in inaccurate measurement attributable to chemical, physical, or biological factors such as chemical contamination, excessive physical abrasion, inundation by sediment, or excessive growth of algae or bacteria. The difference between the pre-cleaning sensor reading and the cleaned-sensor reading is the sensor error caused by fouling.

3.10 HoboWare – Manufacturer's (Onset) software used for launching, reading out, and plotting data from HOBO loggers and wireless HOBO data nodes. Includes Hobo Assistant program to manage data corrections.

3.11 Logger – A type of unattended continuous monitoring device that is limited to one or two parameters (e.g. temperature and DO). Loggers are less sophisticated than sondes and are not capable of displaying real-time values. Common manufactures include Onset and Omega.

3.12 Project Manager - The project manager is a DEA employee who plans and supervises the project and has the highest decision-making authority.

3.13 Raw Data - Data without any corrections or manipulation.

3.14 Review Package - Includes water quality monitoring data record, site information location, monitoring devices, site characteristics, calibration details, information regarding corrections, remarks, surveys, auxiliary information and date & name of staff involved.

3.15 Sensor - The part of the unattended continuous monitoring device that detects and responds with a measurement of some parameter from the physical environment. Examples include temperature, DO, pH, conductivity, chlorophyll, salinity and turbidity. A sensor is a basic device, like a thermistor or a pH electrode. Some sensors can read one or more parameters in one or more units (e.g. some conductivity sensors can measure Specific Conductance in µS/cm or mS/cm, Salinity in PSS, and Total Dissolved Solids in mg/l)

3.16 Sonde- A type of unattended continuous monitoring device that can capture real-time values and that can be deployed unattended to collect continuous monitoring data. Sondes can capture real-time values and store these internally or transmit them to a telemetric device for instantaneous display. A sonde is more sophisticated than a logger. Common manufacturers include YSI, Eureka and Hydrolab.

3.17 Streamline-ENV – Software program that acts as monitoring device manager, which provides a graphical environment and database to streamline setup, configuration and management of YSI sondes, handheld devices and GPS sensors. Also provides data analysis tools.

3.18 Unattended Continuous Monitoring Device (device) - A device that has electronic sensors or probes and self-contained recording systems that measure and store water quality data collected at pre-defined time intervals. Typically these instruments have multiple sensors or probes within a cylindrical housing. These include sondes and loggers.

3.19 Water Resource Data Base (WRDB) - Is a general-purpose software program for addressing a variety of water quality data management challenges including graphing, producing tables, and calculating summary statistics including maxima, minima and means. WRDB is a Microsoft Windows application utilizing the .Net Framework.

4.0 Responsibilities

4.1 SOP Use - It is the responsibility of project managers to ensure that this SOP is followed when collecting and analyzing water quality data with a continuous monitoring device for all applicable programs. Deviations from this SOP must be included in annual SAPs.

4.2 Data Validation - The project manager has the responsibility of validating data, rejecting data, and making any adjustments to data.

4.3 Data Archiving - The project manager has the responsibility of ensuring approved data (Figure 4) are archived in EGAD within a timely manner according to quality-assurance plan policies. Data unsuitable for EGAD must also be archived in a timely manner according to project quality assurance plan.

4.4 Training - It is the responsibility of the project manager to ensure that the individual(s) using the monitoring devices are familiar with and follow this SOP.

4.5 Tracking of Monitoring Device Use - It is the responsibility of the individual(s) launching, deploying, or retrieving a monitoring device to note these activities on the relevant tracking form(s) and/or field sheet; this is especially important if a monitoring device is to be deployed and retrieved by different program staff. It is the responsibility of the project manager to ensure tracking forms and/or field sheets are completed appropriately.

5.0 Guidelines & Procedures

5.1 Monitoring Site - Major considerations in carrying out continuous in-situ monitoring include: site selection, monitoring device selection, sensor configuration, and sensor selection. Sensor and site selection are guided by the purpose of monitoring and the data objectives.

5.1.1 Site Selection and Deployment - Site selection must be detailed in the specific project Sampling and Analysis Plan (SAP) or Annual Project Plan (APP).

Balancing the numerous considerations for placement of a continuous water quality monitoring system can be difficult. The most important site consideration is placing the monitoring device in a location that best represents the waterbody being measured. Depth, horizontal and vertical variability and flow patterns are major factors for site selection.

Some environments may present unique challenges for optimal site location. Lateral mixing in large rivers often is not complete for tens of miles downstream from a tributary or outfall. Turbulent water flow may aid in mixing, but turbulence can create problems in monitoring parameters such as DO or turbidity. A location near the shore may be more representative of local runoff or be affected by point-source discharges upstream, whereas a location in the channel center or offshore may be more representative of areas farther upstream in the drainage basin. Therefore, to ensure data representativeness relative to the larger waterbody, monitoring device site selection should account for degree of vertical stratification affecting physical, chemical and biological characteristics, and sediment type. Site selection also is dependent on fouling potential, ease of access, navigation, and susceptibility to vandalism. The rationale behind site selections should be documented appropriately.

During storm and flood events, deployed devices may be vulnerable to damage from tree debris and other floating hazards; access to deploy/retrieve devices may be more difficult and/or unsafe. Special attention should be paid to potential conflicts with vessel navigation, mooring, and fishing activities in working and/or industrial waterways.

For a medium to small stream with alternating pools and riffles, the best flow and mixing occurs in the riffle portion of the stream; however, if flooding changes the locations of shoals upstream of the monitoring site, the measurement point may no longer represent the overall water quality characteristics of the waterbody. Stream flow restrictions such as undersized culverts will also impact monitoring site during high flows. Streams subject to substantial bed movement can result in devices being lost, relocated out of water or to a point no longer representative of the flow following a major streamflow event. A site may be ideal for monitoring high flow but not satisfactory during low flows.

In deeper channels, impoundments and/or embayments, a specific depth of deployment may be required. This often requires the use of buoys or a frame to position the monitor at the required depth taking care not to impede navigation or expose the device to air during the deployment period.

Lake or pond monitoring locations may be in tributary streams, the lake outlet, or anywhere in the open water. The considerations listed above also apply in lakes, with special regard to navigation, wave and wake action, fishing activities and safety. Any monitoring devices deployed in open-water situations (e.g., a floating device or devices near the deep hole) should be well marked with floats to aid in device recovery and avoid accidental damage from other boaters.

For **marine sites**, important hydrologic considerations for device placement include tidal range, velocity, and direction, degree of exposure to surge, and vessel wakes. The deployment depth and habitat type (e.g., riffle, pool, eddy) also need to be appropriate for the primary purpose of the monitoring installation. The depth can be chosen to accommodate anticipated flow conditions.

Figure 1. Algae and other fouling materials adhering to shroud and monitor. To protect monitors and reduce the need for abrasive cleaning, a shroud can be used to cover all or parts of the monitor.

If the monitoring device is being placed on the bottom of the river in a depositional area, or in marine waters subject to rapid tidal flow and turbidity is to be measured, the device should be propped-up or attached to an object (e.g. cinder block) in order to prevent the sensors from being covered with bed-load sediment, or in the case of turbidity, influenced by bed-load movement (Appendix 2).

Figure 2. Marine example showing sonde in protective shroud attached to a frame and concrete anchor for bottom deployments (left), with focus (right) on sensor end.

Depending on manufacturers' recommendations, solar exposure, regulatory purposes, and susceptibility to damage and fouling, the project manager should decide if a shroud (e.g. PVC pipe,Fig. 1) is necessary. In some environments the shroud can protect the monitoring equipment from colonization and fouling from organisms and algae. A shroud can also protect the equipment from damage due to moving debris. The monitoring device and shroud (if used) must be attached by cable or chain to a solid object on shore or under water to reduce the chances of losing the device during a storm event or due to vandalism. Plastic netting can be wrapped over the shroud or sensor guard to keep debris and organisms from getting in front of optical sensors. The netting can be held in place with rubber bands.

Marine deployment scenarios (Fig. 2) can include anchors with subsurface and surface buoys, vertical posts with device attachment hardware, and/or rigid frames that simultaneously suspend the device above the benthic surface at a fixed height and protect the device from damage. Fouling will occur inevitably during longer deployments and to a greater degree at sites with less flow. Remedies to fouling include anti-fouling paint or tape, and/or frequent field checks to clean sensors and sensor cages.

5.1.2 Site Description and Documentation - At each site the following data should be collected and recorded on a data sheet:

a. GPS coordinates
b. Photos up and downstream of deployment site, or of the adjacent shoreline
c. Water depth where monitor deployed
d. For stream or river systems type of flow habitat; in lake and marine environments the zone (intertidal/shallow, subtidal ..).
e. Dominant substrate characteristics
f. Dominant riparian or shoreline vegetation
g. Riparian or shoreline disturbances
h. For stream and river systems, width & depth (measured or estimated)
i. For marine water, tide stage at deployment
j. Date and time
k. If applicable, means of securing monitoring device

5.2 Monitor Operation & Maintenance - The goal for continuous in-situ monitoring is to obtain the most accurate and complete record possible. The common operational categories include maintenance frequency, field visits, troubleshooting, and comprehensive record keeping.

This in-situ monitoring protocol details the operating procedure designed for well-mixed, stable, and relatively slowly changing systems. Slowly changing is defined as changes in field measurements during the time it takes to conduct maintenance that are less than the calibration criteria (see Table 1, Monitoring Device Calibration Criteria). Marine water conditions that are more rapidly changing may require adaptations to operating procedures described in this document.

5.2.1 Calibration - Proper device calibration is the most essential component of continuous monitor use to ensure accurate data. Each type of probe has a unique calibration procedure and different expiration dates. ***Monitoring device calibrations should be conducted in accordance with specifications provided by the manufacturer*.** Devices must be calibrated at the start of every field season. Devices with optical DO caps need to be checked for expiration date and replaced if needed (Note: The Onset DO sensor caps have a 6-month deployment life. The caps expire 7 months after initialization to allow some time before and after the deployment.) Subsequent calibration checks should be conducted routinely (at least every four weeks) throughout the field season. Conduct calibration checks (and necessary adjustments) before and after each extended deployment, and record the calibration data. Calibration order is important. Start with temperature, then DO, depth, conductivity (specific conductance/salinity), pH and turbidity. Also make sure the calibration standards have not expired; obtain replacements if necessary. Other general guidelines follow.

When using standard solutions for calibration, begin with the cup and sensor rinse procedure. Always start with the more dilute or neutral solutions before proceeding to more concentrated solutions. Put standard solution in the cup, place cup over sensor(s) to rinse; discard the solution and repeat the process three times before putting in the final standard for calibration. Make sure the sensor is submerged in the standard (e.g. the YSI conductivity probe has a port on the side which must be covered by the standard solution). Also, YSI has a special cup with extra depth for calibrating their turbidity probe, which ensures that the sensor does not detect the bottom of the cup and give a false reading.

Table 1. Monitoring device calibration criteria.

[±, plus or minus value shown; °C, degree Celsius; µS/cm, microsiemens per centimeter at 25 °C; ppt or pss, parts per thousand or practical salinity scale; %, percent; mg/L, milligram per liter; pH unit, standard pH unit; turbidity unit is dependent on the type of meter used; µg/L, micrograms per liter]

Measurement	**Calibration criteria** (variation outside the value shown requires recalibration)
Temperature	0.2 ºC
Specific conductance	5 µS/cm or ±3 % of the measured value, whichever is greater
Salinity	0.3 ppt/pss or ±3 % of the measured value, whichever is greater
Dissolved oxygen	0.3 mg/L
pH	0.2 pH unit
Turbidity	0.5 turbidity unit or ± 5% of the measured value, whichever is greater
Chlorophyll	0.3 µg/L

<u>Temperature</u>: Manufacturers generally make no provisions for field calibration of water temperature sensors. Because so many of the parameters vary with temperature (pH, specific conductance, DO), it is important to ensure the temperature probe reads accurately. Place the water temperature sensor and the calibrated field thermistor or National Institute of Standards and Technology (NIST) certified thermometer adjacent to each other, preferably in moving water. Sufficient time for temperature equilibration must elapse before a reading is made. Record the two water temperature sensor readings

instantaneously. If the monitoring water temperature sensor fails to agree within ±0.2 °C, troubleshooting steps must be taken (Table 2); if troubleshooting fails, the sensor must be replaced. The faulty sensor or sonde should be returned to the manufacturer for proper calibration, repair, or replacement. Temperature loggers are generally checked before the beginning of the field season by placing them in a container of ice water in a refrigerator. The logger should stabilize at 0º C. Like sondes, they are not calibrated in the field, but the performance is checked with a field meter or NIST certified thermometer.

Table 2. Troubleshooting procedures for the most common issues encountered in the field. Table adapted from USGS Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting. Techniques & Methods 1-D3.

Symptom	Possible problem	Likely solution
Water temperature		
Thermistor does not read accurately	Dirty sensor	Clean sensor
Erratic monitoring device readings	Poor connections at monitoring device or sensor	Tighten connections
Sensor slow to stabilize	Dirty sensor	Clean sensor
Readings off scale	Failure in electronics	Replace sensor or monitoring device
Monitoring device thermistor and field meter are off by more than ± 0.2°C	Failure of electronics	Confirm with NIST certified thermometer. Replace sensor or monitoring device
Specific electrical conductance, salinity		
Will not calibrate	Standard solutions may be old or contaminated Electrodes dirty Air trapped around sensor Weak batteries	Use fresh standard solutions Clean with soap solution Thrust sensors up and down and tap gently to expel air Replace batteries.
Erratic readings	Loose or defective connections	Tighten or replace connections
Sensor requires frequent calibration	Broken cables	Replace cables Replace monitoring device
Dissolved oxygen		
Meter drift or excessive time for sensor to stabilize	Temperature compensator has not equilibrated with temperature of stream Fouled sensor Stirrer or pulse mechanism not working properly	Wait for temperature equilibration Clean or recondition Check for obstructions or replace.
Erratic sensor readings	Bad connection at monitoring device or sensor Fouled sensor	Tighten connections Clean or recondition

Symptom	Possible problem	Likely solution
Sensor slow to stabilize	Gold cathode tarnished Fouled membrane Silver anode blackened	Buff with pencil eraser or recondition sensor Recondition sensor and replace membrane Replace sensor and soak fouled sensor in 3-percent
Sensor will not zero	Zero-DO solution contains oxygen Zero-DO solution is old	Add additional sodium sulfite to zero-DO solution Mix a fresh solution
Sensor will not calibrate	Membrane damaged Electrolyte diluted	Replace membrane Replace membrane and electrolyte
pH		
Meter will not calibrate	Buffers may be contaminated Faulty sensor	Replace buffers Replace sensor
Slow response time	Dirty sensor bulb Water is cold or of low ionic strength	Clean sensor Be patient
Erratic readings	Loose or defective connections Defective sensor	Tighten connections Replace sensor
Turbidity		
Unusually high or erratic readings	Entrained air bubbles on the optical sensor Damaged sensor Dirty sensor Water in connections	Follow manufacturer's directions Replace sensor Clean, following manufacturer's directions Dry connector and reinstall following manufactures directions
Chlorophyll		
Erratic readings	Passing clumps of fluorescing algae Passing water masses with differing Colored Dissolved Organic Matter (CDOM) concentrations	Clean or recondition Interpret data based on background knowledge of waterbody characteristics
Readings do not change	Wiper parked on top of sensor port Fouled sensor port	Clean sensor Recalibrate sensor Replace wiper as necessary

<u>Dissolved Oxygen</u>: The concentration of dissolved oxygen in water is influenced by many factors including ambient temperature, atmospheric pressure, and ion activity. Instrument systems for the membrane (amperometric) or the luminescent-sensor methods must be properly calibrated and tested before each field trip and cleaned in the field after each use.

Atmospheric pressure, the temperature of the water or water vapor, and the conductivity (or salinity) of the water must be known to determine the theoretical amount of oxygen that can be dissolved in water. See Appendix 3 for solubility of oxygen in water at various temperatures and pressures.

Luminescent/optical-based DO sensors are calibrated by the manufacturer, and calibration may not be required for up to a year. Regardless of the manufacturer's claims, the user must <u>verify</u> the correct operation of the sensor in the local measurement environment. USGS advises users to make frequent calibration checks and to recalibrate as frequently as required to meet the specific data-quality objectives. Recalibration should not be necessary if calibration checks show the sensor to be in agreement with the calibration criteria (Table 1).

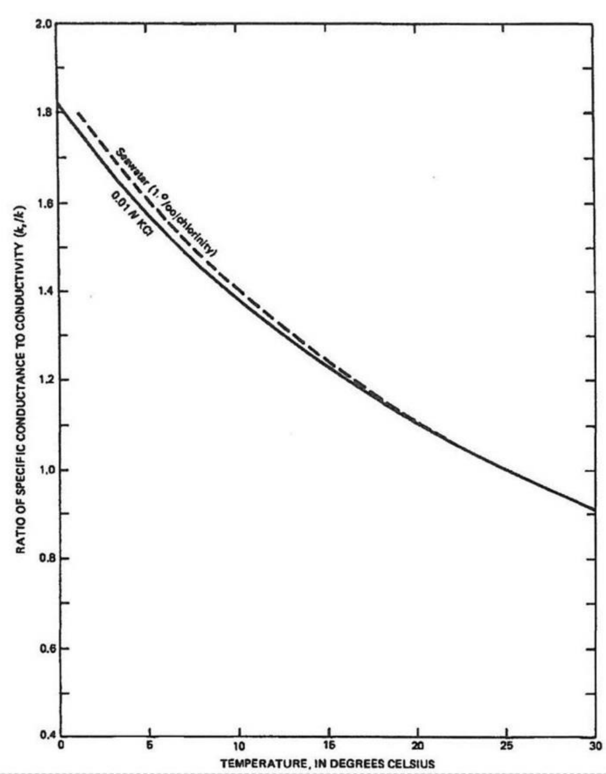


Figure 3. Values of the ratio of specific conductance to conductivity for 0.01 N KCl solution and 1 per mill chlorinity seawater. From USGS Water Supply Paper 2311.

Consult the manufacturer's guidelines for initial field season calibration. If deploying in water with low DO levels (4mg/l or less), it is recommended to calibrate to zero, but manufacturer's guidelines should be followed. Subsequent calibration checks and minor recalibrations can consist of a 1-point check in 100% air saturated water and a local barometric pressure value. 100% air saturated water can be made by using an aerator in a tank or bucket of water. The aerator should be allowed to oxygenate for approximately three hours prior to performing calculations. Use a table of expected DO concentrations for 100% saturation at different temperatures and barometric pressure to make sure DO concentration reading is correct (Appendix 3).

Membrane DO Sensors can be challenging to calibrate in the field because replacement of the Teflon® membrane may be required frequently, and the replaced membrane must be allowed to "relax" in water. Relaxation time depends on the manufacturer and whether replacement involves using the O-ring or membrane-cap method. Conditioning of membranes with O-rings, for example, generally ranges from a minimum of 2 hours up to 6 hours. For greater stability during calibration, allow the new membrane to condition overnight before calibration and use. Membranes in caps are prestretched and require less conditioning (Rounds, 2013). One solution to this problem is to carry into the field clean and serviced spare DO sensors, stored in water (or moist, saturated air). The replacement DO sensors then can be calibrated in the field, thus avoiding an interruption in the data record and a return site visit.

Specific conductance/salinity : The manufacturer's calibration procedures should be followed. YSI for example recommends against calibration in the field. For monitoring equipment calibration in the field, sensors should be checked with at least one standard solution of known concentration before any adjustments are made (Appendix 4 Conductivity). The selected standard solution should be higher than expected recorded values. In general, the standard solution for conductivity and salinity calibrations should be greater than 1 mS/cm (such as the 1413 uS/cm solution). In addition, the zero response of the dry sensor in air should be checked and recorded to ensure linearity of sensor response at low values. If the sensor-cleaning process fails to bring a specific conductance/salinity sensor within the calibration criteria (see Table 1), the sensor must be recalibrated. A temperature correction may be necessary if the monitor does not have automatic temperature correction.

Table 3. Effects of Temperature on pH calibration standard solutions

Temp °C	pH 4.01	pH 7.00	pH 10.00
0	4.00	7.14	10.30
5	4.00	7.10	10.23
10	4.00	7.07	10.17
15	4.00	7.04	10.11
20	4.00	7.02	10.05
25	4.01	7.00	10.00
30	4.01	6.99	9.96

Temperature affects conductivity buffer solutions. Examples of common conductivity buffer solution variances with temperature are given in Appendix 4. The conductivity sensor reading must be standardized to the temperature-corrected values.

pH: Prior to redeployment or calibration of the pH sensor, the sensor should be checked for calibration drift in two buffer solutions (4, 7, and/or 10) that bracket the expected ambient pH of the study site. This should be done for both the sensor and the field meter. (Note: a

3-point calibration may be needed for some waterbodies with expected pH values on both sides of 7.00. A 3-point calibration should be done for most marine, estuary and tidal environments.) pH calibration should start with 7, then 10 and end with 4, unless the manufacturer's instructions say otherwise. Expiration dates for the buffer solutions must be checked. After checking for drift, clean the sensor by rinsing in water. Do not touch the glass bulb as you can transfer static electricity to the probe, which can destabilize the probe for an hour or more. Check the globe for any bubbles before calibration. If there is a bubble try shaking it out (shake downward, as you would with a liquid filled thermometer with a bubble). After cleaning, use two buffer solutions to check for a fouling effect. If the pH sensor readings exceed the calibration criteria (Table 1), the monitoring sensor must be calibrated as described by the manufacturer's instructions.

Temperature effects on pH buffer solutions vary with individual solutions, and the temperature-correction factor must be verified with the manufacturer. Examples of common pH buffer solution variances with temperature are given in Table 3. The pH sensor reading must be standardized to the temperature-corrected pH value.

Some pH sensors have expiration dates, while others can be rebuilt and have extended life. In general YSI, pH sensors need to be rebuilt or replaced every other year, Eureka only requires regular refilling of the reference electrode. Calculate or check slope to determine if the sensor is operating properly (see manufacturer's manual).

<u>Turbidity</u>: Turbidity standard solutions with various ranges are available commercially, and most sensor manufacturers recommend either formazin-based or SDVB-polymer standards for calibrating turbidity sensors. Formazin-based standard solutions can be diluted by using a dilution formula; caution is required to avoid introducing errors during the dilution process. It is recommended to use a 4,000 NTU Formazin standard solution for dilutions, as more concentrated solutions are more stable in storage. Diluted standards are generally good for only 2-3 months. Turbidity-free water (distilled water) should be used in the preparation of standard solutions, dilutions, rinsing and for the zero NTU standard solution. A zero turbidity standard is especially vulnerable to contamination by silt or other sources. Wash <u>and dry</u> the monitor, and then rinse again, prior to zero calibration. A dry rag will be better at removing dirt from the unit than rinses alone. Care should be taken to make sure wipers are clean, which may require cleaning them separately.

Checking or calibrating the turbidity sensor must occur in an environment in which stable readings can be obtained. Such an environment minimizes movement of the standard solutions, and effects from wind and direct sunlight as much as possible. Care should be taken to avoid interference from the bottom of the calibration vessel. Follow the manufacturer's recommendations for calibration.

A three-point calibration process is recommended, covering the expected range of values, although some monitoring devices may be limited to calibration with only one or two standards. If device calibration allows only a two-step process, two primary standard solutions covering the expected range must be used for calibration and a third midpoint standard solution is used to check for linearity. Similarly, if the device calibration requires only turbidity-free water and one standard solution, another midpoint standard solution must be used to check for linearity. For the low value, always use distilled water for a 0 NTU reading. Typical calibration values might be 0, 100, and 1,000 NTU. Another range might be 0, 40 and 400 NTU, depending on the expected range of values. Many sensors have an upper range beyond which they are not considered reliable. Make a note of this and reject any data values above the detection range of your equipment. If the sensor readings exceed the calibration criteria (the greater of 5 percent or 0.5 turbidity units) during the inspection process, the sensor must be calibrated.

Depth: Water stage calibration procedures vary slightly with manufacturer; it is recommended to follow manufacturer's guidelines. When calibrating water stage for deployment it is important to calibrate at the monitoring location. Most non-vented sensors will calibrate to a depth of zero in the air. This accounts for the elevation and atmospheric pressure at the monitoring site. Since there is no change in elevation during deployment and most pressure transducers automatically compensate for water temperature, the only corrections needed are changes in barometric pressure.

Chlorophyll: For the YSI 6025 chlorophyll sensor, a one-point calibration utilizing deionized water should be performed before each use. However, the only true calibration method is to submerge the sensor in a phytoplankton suspension of known chlorophyll content based on lab extraction and analysis. Additionally, chlorophyll reading accuracy may be improved by calibration approximation using a dye (ex. rhodamine) suspension. If used, dye "calibration" may be useful as a check on sensor drift, but is not recommended as a regular step in the pre- and post-deployment process. As above, always follow manufacturer recommendations for sensor calibration.

5.2.2 Deployment Programing – Ensure the monitoring device has been programmed for the correct date, time and sampling interval. Confirm there is sufficient battery life for the anticipated deployment period. (Note that some manufactures specify brand or type of battery; if not, choose high-quality batteries to avoid battery failure during deployment.) Choosing a sampling interval is a balancing act. If long intervals are used there is the possibility of missing the maximum and minimum daily values because they might occur only briefly within a day. When measuring turbidity, long intervals can also result in under-reported short intense storm events. If too short an interval is used, too much memory could be used, requiring more site visits and/or data management/storage issues. In rapidly changing environments like estuaries, interval periods need to take into account tide stage. Short-duration deployments that require high resolution should use 10 to 30 minute intervals, while 30 or 60 minute intervals may be sufficient for longer deployments. Some parameters such as turbidity and chlorophyll are naturally highly variable and often benefit from high-frequency monitoring and then plotting mean values (often hourly means). Check that the monitoring device has been programmed to initiate readings at the desired time. Some monitors allow for a delayed start. Record the thought process for interval choice so that adjustments can be during future deployments based on results.

5.2.3 Sensor Inspection and Calibration Check - The goals of sensor inspection are to verify that a sensor is working properly, to provide an end-point for the interval of water-quality record since the last maintenance visit, and to provide a beginning point for the next interval of water-quality record. This information is the basis for data corrections made during the record-processing stage. Complete and thorough documentation of the sensor inspection is required. Field meters, for as many of the parameters being recorded by the deployed monitoring device, should be used as a quick QA check and to verify parameter stability during the process. If <u>sensor readings can be viewed in the field</u>, this is accomplished by following these steps:

1) Record the field meter readings (before cleaning) along with the time.
2) Remove monitoring device from the water and inspect sensors for signs of chemical precipitates, stains, siltation, or biological growths that may cause fouling. Take a photograph of the sensors (with and without guard, if applicable) to be stored in the data file.
3) Record the initial sensor readings in situ along with the time.
4) Clean the sensors according to the manufacturer's specifications.
5) Immerse the device and record the in situ cleaned-sensor readings along with the time. If the conditions are steady-state, the field meter readings should not change substantially during the time that the monitoring sensors are cleaned. The observed difference between the initial sensor reading and the cleaned-sensor reading is attributable to fouling (chemical precipitates, stains, siltation, or biological growths).
6) Perform a calibration check of sensors by measuring concentrations of appropriate calibration standards. Record the readings and the time; recalibrate sensors if readings are outside the range of acceptable differences (see Table 1 Calibration Criteria); the difference between the cleaned-sensor readings in calibration standard solutions and the expected reading in these solutions is the result of sensor calibration drift error. Inspect any equipment that holds the device in position and make repairs as necessary. Return the device to the aquatic environment and record the time of re-deployment. A set of initial readings is taken as the start of the new record. Except for temperature sensors, the field meter readings are not used directly in record computation; the field meter is used as a tool to document environmental changes that may occur while the monitor is being serviced or as a quick QA check (see field meter definition). If the environmental conditions do not fluctuate or are only slowly changing while the monitor

is being serviced , the fouling and calibration drift error can be computed with consideration being given to these environmental changes(e.g. change in cloud cover, rain event; also see section 5.5 Data Handling).

If sensor readings cannot be viewed in the field due to lack of a field computer, or are taken under rapidly changing conditions (e.g. in lakes, estuaries and marine conditions where a steep salinity or DO vertical gradient can result in large changes in these parameters over very short vertical distances in minutes) calculation of fouling or calibration error is accomplished by following these steps:

1) Take field meter readings prior to removal of the monitoring device for as many parameters as possible. Retrieve the deployed device and bring back to lab.
2) Submerse previously deployed device in clean temperature-stabilized aerated water bath. Once device readings have stabilize, record parameter values.
3) Clean the device according to manufacturer's specifications and place back in the water bath. Once device readings have stabilized, record parameter values.
4) Remove from water bath and calibrate.
5) Return to temperature-stabilized aerated water bath. Once device readings have stabilized, record parameter values.
6) Re-deploy device and record time. It is recommended that an independent field meter reading be taken at time of deployment.

Note that the initial sensor reading becomes the end-point of the data record since the last servicing, and the field meter reading provides a sense of the reasonableness of the monitor readings and an indication of potential electronic calibration drift and fouling errors.

If the calibrated sensor cannot be recalibrated or does not agree with a reliable field meter (Table 1), the faulty sensor must be repaired or replaced after verifying that the readings of the field meter are not in error (see section 5.2.7 Troubleshooting Procedures). The alternative is to replace the monitoring sonde or sensor with a calibrated backup unit and repair the malfunctioning monitor in the laboratory or return it to the manufacturer for repair. Note that for some YSI sondes, if the temperature sensor fails, then all data for all temperature-dependent parameters will be inaccurate and will need to be rejected.

Due to the inherently variable nature of turbidity, in-situ measurements before and after cleaning the sensor may not provide an accurate measure of fouling. A more accurate determination of fouling of turbidity sensors can be made by making pre-cleaning measurements in a bucket of clean tap or distilled water. Fouling error is then determined by comparing turbidity measurements in the bucket before and after cleaning the sensor, taking into consideration any changes in turbidity in the bucket using measurements obtained using a field meter.

Onset Hobo loggers only: The Onset loggers are not configured for submerged real-time measurements. Therefore the use of an independent field meter is needed to calibrate and process the data following deployment. To improve calculation of fouling and calibration error for loggers using Hoboware's Assistant, it is recommended that the loggers be placed in-situ upon site arrival to start equilibration to the environment.

5.2.4 Cleaning - During the cleaning process, the electrical connectors must be kept clean and dry. Water in the connector pins can cause erratic readings. For this reason, a container of compressed air can be useful. **Always review and follow the manufacturer's recommended cleaning procedures.** Refer to Text Box 1 for a list of recommended field cleaning supplies. Keep a maintenance log for each unit.

Text Box 1. Field cleaning supplies:

- Distilled water
- Soft bristle brush
- Canned air
- Alcohol
- Lint free rag
- Bucket
- Detergent

Temperature: Most commercially available temperature sensors can be cleaned with a detergent solution and a soft-bristle brush. Film on the sensor that resists removal usually can be removed by soaking the sensor in a detergent and water solution, but the manufacturer's recommended cleaning procedures must be followed carefully for multi-parameter sensor systems to avoid accidental damage to other sensors.

Specific conductance/salinity: USGS recommends cleaning specific conductance/salinity sensors thoroughly with distilled water before and after making a measurement. Oily residue or other chemical residues (salts) can be removed by using a detergent solution or a solvent. Specific conductance/salinity sensors can soak in detergent solution for many hours without damage, but solvents or diluted hydrochloric acid solution (5 percent) should only be in contact with the sensor for a few minutes. The manufacturer's recommendations must be checked before using acid solution or solvents on sensors. Carbon and stainless-steel sensors can be cleaned with a soft brush, but platinum-coated sensors must never be cleaned with a brush. To clean the recessed YSI conductivity sensors, which can be colonized by caddisflies or other invertebrates, use the manufacturer's brush.

Dissolved oxygen n (DO): For membrane sensors, use a soft-bristle brush to remove silt from the outside of the sensor, wipe the membrane with a damp, lint-free cotton swab (available at electronics stores), and rinse with distilled water. The sensor usually is covered with a permeable membrane and filled with an electrolyte (e.g. potassium chloride) solution. These membranes are fouled easily and typically need to be replaced every 2 to 4 weeks. When the membrane is replaced, the potassium chloride solution must be rinsed out of the sensor with distilled water followed by several rinses with electrolyte solution before the sensor is refilled. The membrane must be replaced with care so that the surface of the membrane is not damaged or contaminated with grease, and no bubbles are trapped beneath the membrane. The surface of the membrane should be smooth, and the membrane should be secured tightly with the retaining mechanism. Some manufactures require that the sensor be stored in water for a minimum of 2 to 4 hours, preferably longer, to relax the membrane before installation and calibration. The need to relax the membrane requires either replacing the DO sensor membrane with a pre-relaxed membrane and recalibrating the sensor, or replacing the membrane and revisiting the site for calibration later. Membrane style DO probes are vulnerable to drift and should be checked for drift after each deployment. The retaining ring must be replaced annually or more frequently to prevent loss of electrolytes. Replacing the retaining ring when membranes are changed ensures a tight seal.

Optical DO sensors are cleaned with a soft bristle brush and rinsed with distilled water. If the optical DO sensor is equipped with a wiper, ensure the motor is operating properly and is parking in the correct position. Optical probes with wipers generally must have water seals replaced every other year. Also ensure that the wiping mechanism (pad or brush) is in good condition and clean. For Hobo loggers the sensor cap should be checked (manufactured expiration date plus cap life is 7 months from installation).

pH: The pH electrode must be kept clean in order to produce accurate pH values. The body of the electrode should be thoroughly rinsed with distilled water before and after use. In general, this is the only routine cleaning needed for pH electrodes; however, in cases of extreme fouling or contamination, the manufacturer's cleaning instructions must be followed. Do not touch the glass electrode with your fingers, rag or Q-tip. Static charge can be transferred to the probe which will produce calibration errors. Be careful as the glass part of the probe is thin fritted glass and is extremely fragile. Some pH probes have a short life span, generally only 1-2 years. For YSI sensors, the first two numbers of the serial number are the year of manufacture. Also pay attention to the slope during calibration and discard probes that do not have an adequate slope (between 95-102% (-56,2 & -60,4 mV) => Go ahead and accept the calibration; between 90-95% (-53,3 & -56,2 mV) => clean the electrode and then re-calibrate observing new slope; between 102-105% (-60,3 & -62,1 mV) => clean the electrode and then re-calibrate observing the new slope, < 90% (53 mV) or > 105% (62 mV) => change the electrode as it is no longer usable.) Manufacturers of pH electrodes often specify the slope value tolerances for an electrode in good conditions. . pH probes must be checked for drift after long deployments.

Turbidity: Optical turbidity sensors are extremely susceptible to fouling; thus, frequent maintenance trips may be necessary. Fouling is common in benthic environments high in fine sediment, algae accumulation, or other biological or chemical debris. Algae can accumulate on the wiper pad preventing complete removal of debris from the optical lens, resulting in erratic data. If the turbidity sensor is not equipped with a mechanical cleaning device that removes solids or a shutter that prevents accumulation on the lens before readings are recorded, reliable data collection is very difficult. Sensors should be inspected for damage, ensuring that the optical surfaces of the probe are in good condition. The wiper pad or other cleaning device should be inspected for wear and cleaned or replaced if necessary. The wiper should also be checked to make sure it parks in the correct location (normally 180^{0} from the optical surface). Do not force the wiper into the correct position, as this can damage the mechanism. Before placing the turbidity sensor in standards, the optic lens should be carefully cleaned with alcohol by using a soft cloth to prevent scratching (or as recommended by the manufacturer), rinsed three times with turbidity-free water, and carefully dried. If the readings are unusually high or erratic during the sensor inspection, entrained air bubbles may be present on the optic lens and must be removed. Optical probes with wipers generally must have water seals replaced every other year. Due to the inherent variability in turbidity readings, it is often a good idea to take high frequency readings (say at 15 or 20-minute intervals) and then plot averages (such as the hourly average).

Chlorophyll: Optical chlorophyll sensors are particularly susceptible to fouling in the absence of an active wiper, so proper function of the wiper is critical to collection of accurate data. During deployment, the wiper should ideally be run prior to collection of each data value, or realistically every few hours if data collection intervals are more frequent. In locations where heavy fouling is anticipated, the wiper should be set to rotate at least once per activation to ensure effective cleaning. Otherwise, chlorophyll sensors should be treated in the same manner as described above for optical DO and turbidity sensors.

5.2.5 Maintenance Frequency – Monitoring devices are typically placed at a site anywhere from a few weeks to 7 months. Maintenance frequency depends primarily on fouling rate of the sensors, which varies by sensor type, environmental conditions, weather events, battery life and season. The performance of water temperature, specific conductance/salinity, and water stage sensors tends to be less affected by fouling than DO, pH, turbidity and chlorophyll sensors. Wiper mechanisms on turbidity, optical DO and chlorophyll sensors have substantially decreased fouling in certain aquatic and marine environments. Monitoring sites with nutrient-enriched waters and moderate to high temperatures may require more frequent maintenance. Monitoring disruptions as a result of equipment malfunction, sedimentation, electrical disruption, debris, ice, or vandalism also may require additional site visits. Probes that are vulnerable to drift (membrane style DO probes and pH probes) must be recalibrated at least monthly.

5.2.6 Equipment Logs - An equipment logbook must be maintained for each field meter and water-quality monitoring device, and all pertinent information regarding the device and field meter must be recorded. Details of device calibration—both field and laboratory calibrations—are one of the most important pieces of recorded information. Calibration information can be recorded initially on field forms or in field notebooks, but the information then must be copied into the equipment logbook. Repair or replacement of monitoring devices, sensors, membranes, or modification to the device software must be recorded in the equipment logbook. The equipment logbook must contain a complete record of all maintenance in the field, the laboratory, or by the manufacturer or service company, throughout the life of the device. Calibration information important to log for record processing includes:

a. Sensor repair or replacement;
b. Calibration dates, times, and temperatures;
c. Calibration standard values, expiration dates, and lot numbers;
d. Initial and final monitor-calibration data including relevant barometric pressure;
e. Field meter calibration values and results of post calibration standard checks; and
f. Name of staff that performed work on the monitoring device.

The goal is to have sufficient information for another individual to be able to independently compute the record and obtain similar results. Clear notes simplify the record computation and final review processes.

5.2.7 Troubleshooting - When a field parameter cannot be calibrated with standard solutions, it must be determined if the problem is with the sensor or the monitoring device and the necessary corrections must be made to ensure that the device is operational. Some of the more common problems that are encountered in the field when servicing monitoring devices are listed in Table 2.

5.3 Field Notes - Logs and field notes are essential for accurate and efficient record processing. The goal is to have enough information so that anyone can independently process the collected data and obtain similar results.

Field note requirements for in-situ monitoring devices are included below:

1. Waterbody name
2. Site name or code
3. Town
4. GPS coordinates
5. Photos taken (camera ID, photo numbers and descriptions)
6. Device manufacturer, model and serial number
7. Device data file name
8. Field meter manufacturer, model and serial number
9. Data file storage (where was data saved after downloading from device)
10. Start and end time of deployments and checks
11. Name(s) of staff
12. Field checks of device values & field meter values
13. Calibration checks, calibrations/recalibrations, and final readings
14. Comments on site conditions, sensor condition, and any other pertinent observations

15. Battery voltage of device at departure
16. Battery replacement
17. Notes on sensor/monitoring device changes or replacements, and other comments that facilitate processing of the record

Suggested data:

18. Site characteristics: water level/tide stage, current direction and velocity, habitat type, dominant strata, canopy cover, riparian vegetation & disturbance, channel width & depth (estimated or measured), and/or adjacent land use observations (as appropriate)
19. Lot numbers and expiration dates of standard solutions
20. Measured flow or gage-height data
21. Sketch of location of monitoring device in-situ to facilitate locating it on return trip
22. County or river drainage

5.4 Record Storage and Retention - It is the responsibility of the project manager to ensure that all field sheets and equipment log books are stored as directed in each program's QAPP.

5.5 Data Handling - The processing of water-quality monitoring records must be completed in a timely manner according to quality assurance plan policies. Complete and accurate field notes reduce the amount of time required to process the data and are an essential part of the process. Corrections to data must not be made unless the cause(s) of error(s) can be validated or an explanation has been found in the field notes. If corrections are made, the correction, the name of the individual responsible for the change and the date of the change should be indicated on the relevant field notes.

Data processing includes eight procedures: (1) raw data retrieval; (2) initial raw data evaluation; (3) data editing (outlier & erroneous data removed); (4) data corrections, including offset, drift & fouling; (5) data quality determination based on Tables 4, 5 & 6; (6) record computation; (7) final record review; and (8) data storage in EGAD or as directed by QAPP.

5.5.1 Data retrieval – Raw data can be accessed and downloaded in the field, office or lab to either a handheld device or directly to a computer. Once downloaded, the raw data file should be saved to a location on the network server, which is backed-up nightly, ensuring data are not lost. Data files should follow established naming conventions per quality assurance plan.

5.5.2 Initial Data Evaluation & Editing - The initial raw data evaluation is conducted to verify the accurate transfer of raw field data (monitoring device readings) from the monitoring device to the computer and to identify and evaluate erroneous data. A variety of formats are available for storing raw field data, depending on the recording equipment and the means of downloading data from the equipment. Once data are stored they should be viewed using WRDB or Streamline-ENV to view primary data tables, summary statistics (including minimum, maximum, mean and standard deviation) and plots for preliminary review of each parameter. Sensors, recorders, transmitters, receivers, relays or unforeseen events can all produce erroneous data. Therefore, data that are automatically downloaded, decoded, and reported should be reviewed to remove/edit obvious erroneous data. Regardless of how data are recorded and downloaded, the record should be processed and plotted immediately after the service visit to confirm the accurate transfer of data and to detect device or sensor error. It is important to note that if the temperature sensor fails, all parameter data that depends on temperature-compensated values collected after failure will be inaccurate. Also, depth, temperature, and turbidity are the only sensors that may appropriately display negative values. Missing data (for example because of monitoring device problems) should be documented. Raw data files should not be overwritten with edited data; edited data files should be saved under a new name following an established naming convention per quality assurance plan.

Emphasis should be placed on the relation of variations among the water quality parameters (temperature, specific conductance or salinity, DO, pH, turbidity and chlorophyll) and variations in discharge or tide stage; other event-related changes are equally important and can be factored into the relation to past historical measurements, field experience, and first-hand on-site observation. Variables that can cause data errors include changes in air temperature, periods of sustained cloud cover or sunlight, chemical spills, increased photosynthesis (influenced by a variety of factors), increased wind conditions, monitoring device location relative to eddies, combined sewer overflows, beaver dam removal, forest fires in the watershed, road construction, and ice formation. Examples of data errors can be found in Attachment 4.

Large particles, leaves, twigs, or other natural debris may interfere with the measurement of true turbidity by causing spikes in the data. The faulty parking of the wiper can also lead to spurious readings. Edited data should be stored per a program's Data Management SOP on DEP's network drive.

5.5.2.1 Stop/Start and Out-of-Water Edits: Often monitoring devices are calibrated in the lab and then deployed in bodies of water, and the sample interval is such that some values are recorded while the monitor is out of water. Also, sometimes large storms can transport monitors from the water and deposit them on shore. These out-of-water values need to be documented and removed, which is why it is important to record time of deployment, removal from water, etc. A device that is out of the water should see a specific conductance reading that is zero and the air temperature is generally much higher than water temperature causing a discontinuity in the data; if a depth gauge is included, it should read zero out of water.

5.5.2.2 Low and High Values not Associated with Events: Turbidity sensors are vulnerable to low-level contamination of the zero-calibration solution that causes real zero events in-situ to read low negative values (generally -5 to -8 NTU). Spikes in turbidity (high values, often over 1,000 NTU), especially isolated spikes (single data points) and spikes not associated with hydrological events, are suspect. These may be associated with jammed or improperly docked wipers. Unlike other optical probes, turbidity probes can fail (be temporarily jammed by detritus) and then fully recover later. Sometimes single spikes are real (e.g., due to a breached beaver dam, bank failure, industrial discharge, etc.), but the operator generally does not know whether to believe them or not, so single isolated spikes should be noted as suspect. Generally, they should be edited out.

5.5.2.3 Undocumented Errors: Some causes for odd-looking data are unknown but can be inferred. For instance, unexplained spikes in turbidity data can be caused by improper parking of the wiper. These errors might be expected to occur at repeating intervals. Isolated turbidity spikes that are not associated with storm events may be simply drifting detritus or animals getting in front of the sensor. Such spikes can be edited out of the data as long as the reason is documented. Vandalism can also cause undocumented errors, which often appear as instantaneous changes in parameter values (e.g. spike in temperature, specific conductance value of zero). These values should be edited out.

5.5.3 Data Corrections - Data correction allows recorded data to be adjusted for sensor calibration drift, sensor fouling, and sensor errors that occurred during the interval between servicing visits due to environmental factors or mechanical interference. A data correction should be done when the combined absolute values for fouling and calibration drift error exceed the relevant criterion for water quality data corrections (Table).

The following data correction criteria (Table 4) are minimum requirements for data corrections. More stringent data correction criteria may be needed to meet the data quality objectives of the project. The data correction procedure is the same whether the monitoring device is serviced using the standard protocol under steady-state or rapidly changing environmental conditions. However, if environmental conditions change slowly (without fluctuating) during servicing, the procedure for determining data corrections for sensor fouling varies slightly to account for the change in environmental conditions. Methods for applying data corrections are described in detail below.

All data corrections have a starting date/time and an ending date/time that delineate the data correction interval. A data correction interval typically begins and ends on two servicing dates. Calibration drift is assumed to occur at a constant rate throughout the correction period. Sensor fouling commonly begins as soon as the device is deployed in the aquatic or marine environment; however, if certain environmental or hydrologic events, such as a rise in gage height (affecting turbidity, for example) or increase in temperature (affecting DO, for example), can be identified as significant fouling events, the event may be used as the start or end a correction point. Examples of data corrections can be found in Appendix 5.

5.5.3.1 Manual Error Corrections: Quantifying error is done, in part, in accordance with the 2006 USGS Techniques and Methods 1-D3 manual (TM1D3) *Guidelines and Standard Procedures for Continuous Water Quality Monitors: Site Operation, Record Computation, and Data Reporting*. Numerically defining error is necessary, as a precursor, to performing data correction and grading. Numerically, total error (E_T), as defined by the USGS, is equal to the sum of the absolute values of fouling error (E_F) and calibration drift error (E_D). This numeric computation is shown in equation (1) below.

(1) $$E_T = |E_F| + |E_D|$$

When highly reliable discrete data are available, they may be used to bracket the time series of data for which error is being determined, thereby allowing the scientist to also compute an undocumented error. This undocumented error (E_{UD}), is equal to the difference between data corrected for fouling and calibration drift and the discrete data. If undocumented error is present, the total error may be determined by modifying USGS equation (1) to read as:

(2) $$E_T = |E_F| + |E_D| \; |E_{UD}|$$

Total error, as shown in equation (2) may then be applied in data grading.

Fouling error (E_F) and percent fouling error ($\%E_F$) may be determined from equations (3) and (4), as shown below.

(3) $$E_F = (Sensor_{AC} – Sensor_{BC}) – (FM_{AC} – FM_{BC})$$

(4) $$\% E_F = 100 (E_F / Sensor_{BC})$$

Where

$Sensor_{AC}$ = Sensor measurement after cleaning
$Sensor_{BC}$ = Sensor measurement before cleaning
FM_{AC} = field meter measurement after cleaning
FM_{BC} = field meter measurement before cleaning.

Calibration drift error (E_D) and percent calibration drift error ($\%E_D$) may be determined from equations (5) and (6), as shown below.

(5) $$E_D = V_{STD} - V_{Sensor}$$

(6) $$\%E_D = 100\,[(V_{STD} - V_{Sensor}) / V_{Sensor}]$$

Where

V_{STD} = Value of the standard or buffer

V_{Sensor} = Value measured by the Sensor.

Table 4. Criteria for water-quality data corrections $E_T = |E_F| + |E_D|$ (adapted from USGS).

Field Parameter	**Data Correction Criteria** (apply correction when the sum of the absolute values for fouling and calibration exceeds the value listed)
Temperature	± 0.2°C
Specific Conductance	± 5 µS/cm or 3%, whichever is greater
Salinity	± 0.3 ppt/pss or 3% of the measured value, whichever is greater
pH	± 0.2 units
Dissolved Oxygen	± 0.3 mg/L
Turbidity	± 0.5 NTU or ± 5%, whichever is greater
Chlorophyll	± 0.3 µg/L

5.5.3.2 Offset Corrections: An offset correction is made when the monitor data are judged to be faulty by a constant correction factor. This correction is made by adding or subtracting a constant correction factor to the data. This can be done manually or by a computer program such as Aquarius or Streamline-ENV. The original and corrected data should be kept separately and the reason for the correction must be documented. Data should be stored per a program's Data Management SOP on DEP's network drive.

5.5.3.3 Drift and Fouling Corrections: A drift correction is made when a sensor can be documented to have lost sensitivity during deployment, resulting in the final field measurement being different from the recalibrated value (the amount of drift). This drift is prorated over the deployment interval (e.g., a given amount of change per sample interval). Time zero receives no correction, interval one gets one increment added or subtracted, interval two gets two increments, etc. The corrected and original data are kept separately and the reason for the correction is documented. Membrane-style DO sensors and pH sensors are vulnerable to drift as the probe ages (loses electrolyte).

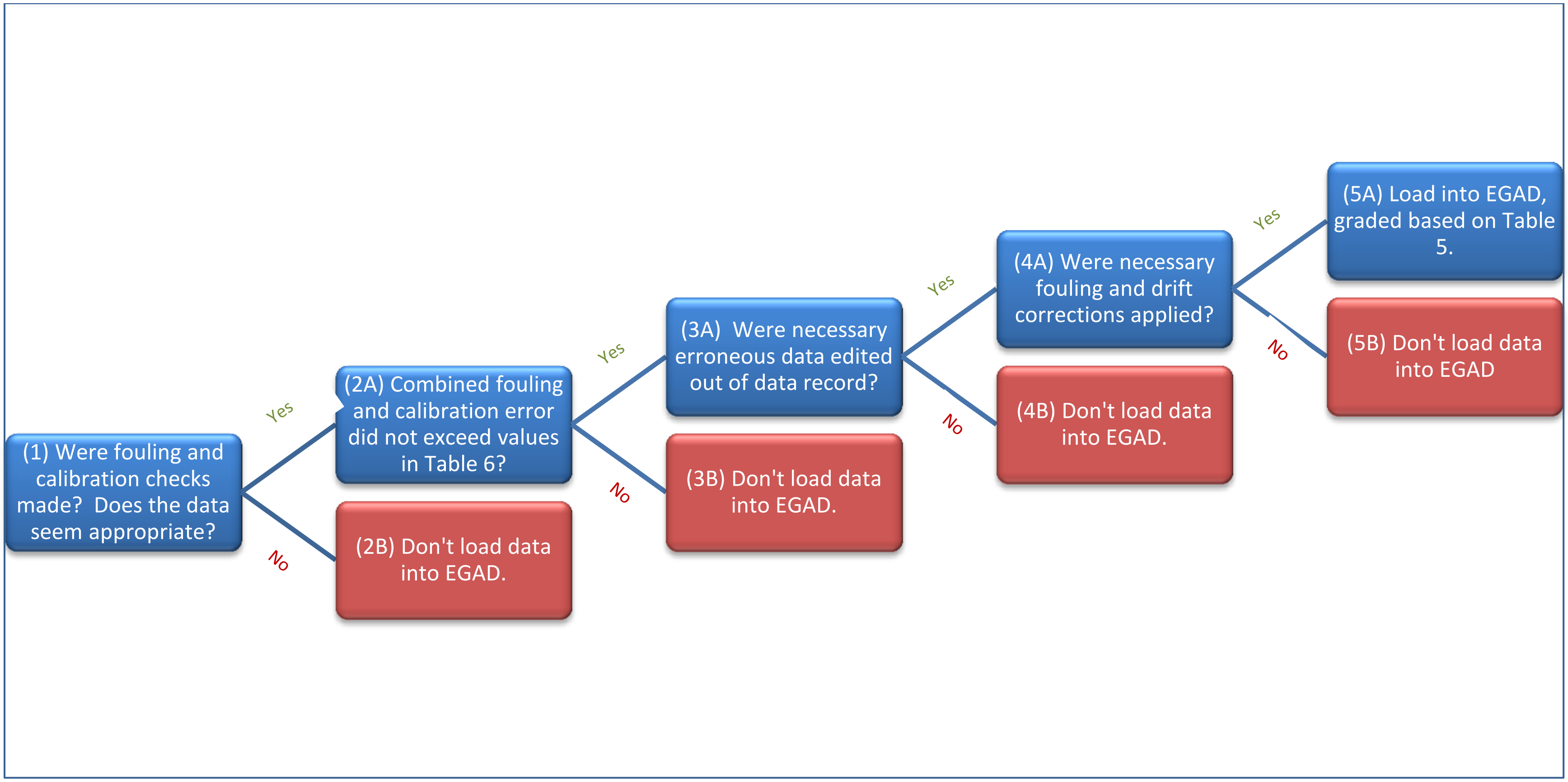
Fouling corrections are made when growth of algae or bacteria, settlement of dirt, or other types of films build up on the sensor, often incrementally (day- by-day), and interfere with readings. Fouling corrections are made similar to how calibration drift corrections are made. The correction factors are added or subtracted in a manner that compensates for the accumulated error in the sensor, in increments that make sense for the suspected cause. Algal and bacterial growth is generally assumed to have taken place gradually, e.g. day-by-day. Dirt accumulations on a probe in a river that is always muddy might also require day-by-day corrections. Fouling from dirt from a single storm event might be corrected for by a single correction to all values after the event (a special case of the offset correction).

5.5.4 Review Package and Level of Review: Typically, the same individual who services the monitoring device is responsible for the monitoring record, the water quality site analysis that describes annual operation of the site (e.g. deployment periods, calibrations, problems, significant weather events), necessary changes in the site description, and preparation of the review package which contains the auxiliary information to aid in the review of the record. When different staff handle different parts of this process, it is important to record which staff performed which steps and when.

In addition, the review package includes information regarding any data edits or corrections made to the data record. The review package will be stored in each program's folder structure on the network drive.

At a minimum, the review package should be examined annually for completeness and accuracy by a second individual, such as a senior colleague or project manager. The data editing and correction decisions must be documented in the review package. The completed record review package is then inspected by a water quality specialist or designated reviewer for completeness and accuracy.

Figure 4. EGAD flow chart.



5.5.5 Secondary QA of Data (Final Review, Grading & Approval): All data used in producing the final water quality record to be loaded into EGAD must be checked thoroughly for completeness and accuracy before being loaded into EGAD. The project manager responsible for computing the water quality record conducts the primary review; a second experienced DEP staffer conducts a second review for completeness and accuracy. All field data must be verified for accuracy of transcription from field sheets; all data edits and corrections must also be verified to assure that the corrections are accurate; all dates and numbers in the site review package must be checked for accuracy. Final inspection and review of the water quality record should be made by the program manager or designated reviewer.

Final data review requires reanalyzing the data record, verifying data corrections, and making any needed final corrections. When the review is completed, the data are evaluated for inclusion in EGAD (Figure 3). Systematic adoption of a standardized final data evaluation process, including rating criteria (Table) and maximum allowable limits for reporting data (Table) are vital in finalizing monitoring records. If the combined corrected values deviate by more than the maximum allowable limits (Table 6) the corrected data should not be loaded into EGAD. The maximum allowable limits are established at approximately 6–10 times the calibration criteria for all standard continuous-monitoring data collection activities. These limits and rating criteria are adapted from the USGS and will be considered minimum standards.

The accuracy of water-quality monitoring records in EGAD is defined by the rating of the record (Table 5), and this criteria is included in the review package and coded in EGAD in the validation qualifier field. Comments applicable to the entire deployment, such as data quality comments, may be added as a ‘Sample Event Comment’. Additional comments specific to a data subset (e.g, missing data explanation) may be noted in the EGAD field Sample_Comments..

Table 5. Accuracy criteria for continuous water quality records (based on USGS except for salinity and chlorophyll sections).

[≤, less than or equal to; ±, plus or minus value shown; °C, degree Celsius; ppt/pss, parts per thousand/practical salinity scale; >, greater than; %, percent; mg/L, milligram per liter; pH unit, standard pH unit; µg/L, micrograms per liter]

Measured field parameter	**Ratings of accuracy** (based on combined fouling and calibration drift corrections applied to the record)			
	Excellent/ Load to EGAD	**Good/Load to EGAD**	**Fair** Don't load in EGAD	**Poor** Don't load in EGAD
Water temperature	≤ ± 0.2 °C	> ± 0.2 – 0.5 °C	> ± 0.5 – 0.8 °C	> ± 0.8 °C
Specific conductance	≤ ± 3%	> ± 3 – 10%	> ± 10 – 15%	> ± 15 %
Salinity	≤ ± 0.3 ppt/pss or ≤ ± 3%, whichever is greater	> ± 0.3 – 1 ppt/pss or > ± 3 – 10%, whichever is greater		
Dissolved oxygen	≤ ± 0.3 mg/L or ≤ ± 5%, whichever is greater	> ± 0.3 – 0.5 mg/L or > ± 5 – 10%, whichever is greater	> ± 0.5 – 0.8 mg/L or > ± 10 – 15%, whichever is greater	> ± 0.8 mg/L or > ± 15%, whichever is greater
pH	≤ ± 0.2 units	> ± 0.2 – 0.4 units	> ± 0.4 – 0.6 units	> ±0.6 0.8 units
Turbidity	≤ ± 0.5 turbidity units or ≤ ± 5%, whichever is greater	> ± 0.5 – 1.0 turbidity units or > ± 5 – 10%, whichever is greater	> ± 1.0 – 1.5 turbidity units or > ± 10 – 15%, whichever is greater	> ± 1.5 turbidity units or > ± 15%, whichever is greater
Chlorophyll	≤ ± 0.3 µg/L	> ± 0.3 – 1.0 µg/L	> ± 1.0 – 1.5 µg/L	> ± 1.5 µg/L

Table 6. Maximum Allowable Limits for overall sensor drift. If recorded values differ from the corrected values by more than the maximum allowable limit (the fouling and drift are considered too large), the corrected data are not stored in EGAD. USGS has a maximum allowable limits established at 6-10 times the calibration criteria. The values in Table 6 are considered minimum standards; professional judgement is still needed.

Field Parameter	Maximum Allowable Limits
Temperature	± 2.0°C
Specific Conductance/Salinity	± 15%
pH	± 0.8 units
Dissolved Oxygen	± 2.0 mg/L or ± 20%, whichever is greater
Turbidity	± 3.0 NTU or ± 30%, whichever is greater
Chlorophyll	± 1.5 µg/L

5.5.6 Archiving Records: Once the data have been reviewed, graded, and approved by the program manager, the data must be archived. The corrected electronic data must be loaded to EGAD in a timely fashion. It is the responsibility of each program manager to ensure that all other electronic or scanned project files (including the original raw data set, edited data, field notes, calibration information, equipment logs, etc.) be archived within the program's folder structure on DEP's network H:\ drive (NOT THE O:\ drive!). Original paper copies of project files are to be archived in an organized manner per project QAPP.

To load the corrected, electronic data to EGAD, the data must be formatted as either a sonde pre-EDD or a full EDD. See the EGAD Data Manager for assistance. Data must be loaded into EGAD prior to the next field season and in time for consideration for the next Integrated Report. Original data should be archived on a network server as specified in the unit or program's SOP.

Appendix 1. References

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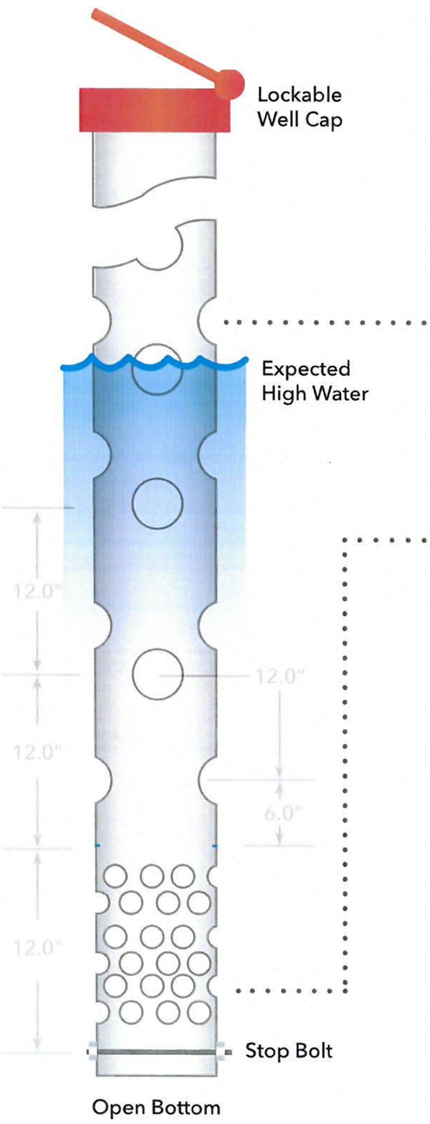
Appendix 2

EXO Long Term Monitoring Guide
Vertical Tube Deployments



MATERIALS

- SCH 40 or SCH 80 - 4" PVC Pipe
- 1/2" SS Bolt, 6" Long
- 1/2" Flat Washers, Lock and Nut
- 4" Lockable Well Cap, Plastic or Aluminum
- 5200 Marine Sealant (for bonding pipe to cap)

INSTRUCTIONS

<u>Vent or tube flushing hole pattern</u>:
2.5" internal diameter.

Start one set 6" from end or top of sensor holes. Drill two holes at 0° and 180°. Start second set of two holes at 12" from sensor holes, drill at 90° and 270°.

<u>Sensor area hole pattern</u>:
1.0" internal diameter, 1.5" on center from 1.0" above stop pin.


Mounted to Pier


Copper Design

NOTES

- Clean and degrease pipe prior to modifications
- In marine and other fouling sites paint inside and out with anti-fouling paint
- Clean pipe at least twice a year

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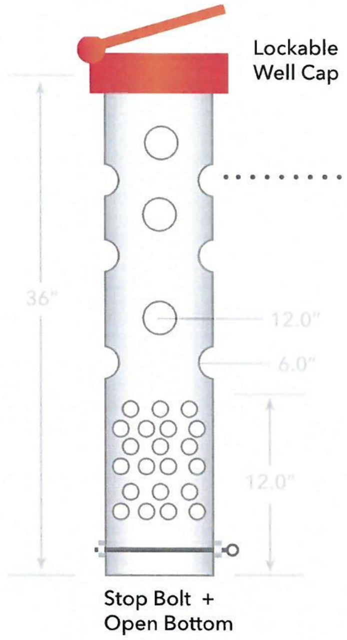
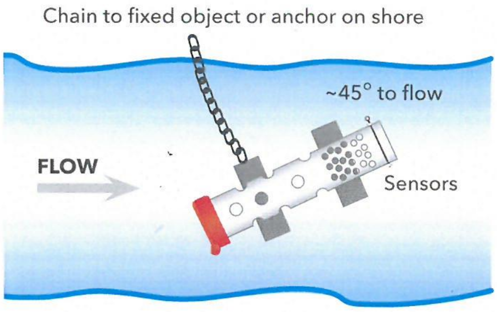
exo Long Term Monitoring Guide
Horizontal Tube Deployments



MATERIALS

- SCH 40 or SCH 80 - 4" PVC Pipe, 36" Long
- 1/2" SS Bolt or Eye Bolt, 6" Long
- 1/2" Flat Washers, Lock and Nut
- 4" Lockable Well Cap, Plastic or Aluminum
- 5200 Marine Sealant (for bonding pipe to cap)
- Two heavy weighted slabs to support pipe



Shows exposed sensors.
No debris deployments only.

INSTRUCTIONS

Vent or tube flushing hole pattern:
2.5" internal diameter.

Drill one set of two, starting 6" from sensor holes at 0° and 180°. Drill second set of two 12" holes upwards at 90° and 270°.

Sensor area hole pattern:
1.0" internal diameter, 1.5" on centers 12" area from 1" above stop bolt.

NOTES

- PVC pipe must be firmly secured to its base or mount to prevent loss in high flows
- Mount and pipe should be treated with anti-fouling paint if in fouling environment
- Secure submerged parts to shore with chain or SS wire rope to a fixed object
- Never clamp sonde directly to mount

Appendix 3. Solubility of oxygen in water. Taken from USGS Field Manual 6.2 Dissolved Oxygen, Version 2.0 (5/2006).

Table 6.2–6. Solubility of oxygen in water at various temperatures and pressures

[From R.F. Weiss (1970). Temp °C, temperature in degrees Celsius; atmospheric pressures from 695 to 600 millimeters mercury begin after 40°C]

Temp	Atmospheric pressure, in millimeters of mercury																			
°C	795	790	785	780	775	770	765	760	755	750	745	740	735	730	725	720	715	710	705	700
0.0	15.3	15.2	15.1	15.0	14.9	14.8	14.7	14.6	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4
0.5	15.1	15.0	14.9	14.8	14.7	14.6	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2
1.0	14.8	14.7	14.7	14.6	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2	13.2	13.1
1.5	14.6	14.5	14.5	14.4	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.2	13.2	13.1	13.0	12.9
2.0	14.4	14.3	14.3	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7
2.5	14.2	14.2	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5
3.0	14.1	14.0	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.5	12.4
3.5	13.9	13.8	13.7	13.6	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.6	12.5	12.4	12.3	12.2
4.0	13.7	13.6	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.6	12.6	12.5	12.4	12.3	12.2	12.1	12.0
4.5	13.5	13.4	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.1	12.0	11.9
5.0	13.3	13.3	13.2	13.1	13.0	12.9	12.8	12.7	12.7	12.6	12.5	12.4	12.3	12.2	12.2	12.1	12.0	11.9	11.8	11.7
5.5	13.2	13.1	13.0	12.9	12.8	12.7	12.7	12.6	12.5	12.4	12.3	12.2	12.2	12.1	12.0	11.9	11.8	11.7	11.7	11.6
6.0	13.0	12.9	12.8	12.8	12.7	12.6	12.5	12.4	12.3	12.3	12.2	12.1	12.0	11.9	11.8	11.8	11.7	11.6	11.5	11.4
6.5	12.8	12.8	12.7	12.6	12.5	12.4	12.3	12.3	12.2	12.1	12.0	11.9	11.9	11.8	11.7	11.6	11.5	11.5	11.4	11.3
7.0	12.7	12.6	12.5	12.4	12.4	12.3	12.2	12.1	12.0	12.0	11.9	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.2	11.1
7.5	12.5	12.4	12.4	12.3	12.2	12.1	12.0	12.0	11.9	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.3	11.2	11.1	11.0
8.0	12.4	12.3	12.2	12.1	12.1	12.0	11.9	11.8	11.7	11.7	11.6	11.5	11.4	11.3	11.3	11.2	11.1	11.0	11.0	10.9
8.5	12.2	12.1	12.1	12.0	11.9	11.8	11.8	11.7	11.6	11.5	11.4	11.4	11.3	11.2	11.1	11.1	11.0	10.9	10.8	10.7
9.0	12.1	12.0	11.9	11.8	11.8	11.7	11.6	11.5	11.5	11.4	11.3	11.2	11.2	11.1	11.0	10.9	10.8	10.8	10.7	10.6
9.5	11.9	11.9	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.2	11.2	11.1	11.0	10.9	10.9	10.8	10.7	10.6	10.6	10.5
10.0	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.3	11.2	11.1	11.0	11.0	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.4
10.5	11.7	11.6	11.5	11.4	11.4	11.3	11.2	11.1	11.1	11.0	10.9	10.8	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.2
11.0	11.5	11.4	11.4	11.3	11.2	11.2	11.1	11.0	10.9	10.9	10.8	10.7	10.6	10.6	10.5	10.4	10.3	10.3	10.2	10.1
11.5	11.4	11.3	11.2	11.2	11.1	11.0	11.0	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.4	10.3	10.2	10.2	10.1	10.0
12.0	11.3	11.2	11.1	11.0	11.0	10.9	10.8	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.3	10.2	10.1	10.0	10.0	9.9
12.5	11.1	11.1	11.0	10.9	10.8	10.8	10.7	10.6	10.6	10.5	10.4	10.4	10.3	10.2	10.1	10.1	10.0	9.9	9.9	9.8
13.0	11.0	10.9	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.4	10.3	10.2	10.2	10.1	10.0	10.0	9.9	9.8	9.7	9.7
13.5	10.9	10.8	10.7	10.7	10.6	10.5	10.5	10.4	10.3	10.3	10.2	10.1	10.1	10.0	9.9	9.8	9.8	9.7	9.6	9.6
14.0	10.8	10.7	10.6	10.6	10.5	10.4	10.4	10.3	10.2	10.1	10.1	10.0	9.9	9.9	9.8	9.7	9.7	9.6	9.5	9.5
14.5	10.6	10.6	10.5	10.4	10.4	10.3	10.2	10.2	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.4	9.4

Table 6.2–6. Solubility of oxygen in water at various temperatures and pressures—Continued

Temp °C	Atmospheric pressure, in millimeters of mercury 795	790	785	780	775	770	765	760	755	750	745	740	735	730	725	720	715	710	705	700
15.0	10.5	10.5	10.4	10.3	10.3	10.2	10.1	10.1	10.0	9.9	9.9	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3
15.5	10.4	10.4	10.3	10.2	10.2	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.2	9.2
16.0	10.3	10.2	10.2	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.1	9.1
16.5	10.2	10.1	10.1	10.0	9.9	9.9	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.4	9.3	9.2	9.2	9.1	9.0	9.0
17.0	10.1	10.0	10.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9	8.9
17.5	10.0	9.9	9.9	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.8	8.8
18.0	9.9	9.8	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.7	8.7
18.5	9.8	9.7	9.7	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.7	8.6
19.0	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.8	8.7	8.6	8.6	8.5
19.5	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.5	8.5	8.4
20.0	9.5	9.4	9.4	9.3	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.3
20.5	9.4	9.3	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3
21.0	9.3	9.2	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3	8.2	8.2
21.5	9.2	9.2	9.1	9.0	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3	8.2	8.1	8.1
22.0	9.1	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.1	8.0
22.5	9.0	9.0	8.9	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9
23.0	9.0	8.9	8.8	8.8	8.7	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3	8.2	8.1	8.1	8.0	8.0	7.9	7.9
23.5	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.8	7.8
24.0	8.8	8.7	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7
24.5	8.7	8.7	8.6	8.5	8.5	8.4	8.4	8.3	8.3	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6
25.0	8.6	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.6
25.5	8.5	8.5	8.4	8.4	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5
26.0	8.5	8.4	8.4	8.3	8.3	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.5	7.4
26.5	8.4	8.3	8.3	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4
27.0	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.3	7.3
27.5	8.2	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2
28.0	8.2	8.1	8.1	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2
28.5	8.1	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.1	7.1
29.0	8.0	8.0	7.9	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0
29.5	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0

Table 6.2–6. Solubility of oxygen in water at various temperatures and pressures—Continued

Temp	Atmospheric pressure, in millimeters of mercury																			
°C	795	790	785	780	775	770	765	760	755	750	745	740	735	730	725	720	715	710	705	700
30.0	7.9	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9
30.5	7.8	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9
31.0	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8
31.5	7.7	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7
32.0	7.6	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7
32.5	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6
33.0	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6
33.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5
34.0	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.5	6.5
34.5	7.3	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.5	6.4
35.0	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3
35.5	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3
36.0	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2
36.5	7.1	7.0	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2
37.0	7.0	7.0	6.9	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1
37.5	7.0	6.9	6.9	6.8	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1
38.0	6.9	6.9	6.8	6.8	6.7	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0
38.5	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0
39.0	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	6.0
39.5	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	6.0	5.9
40.0	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.9

Table 6.2–6. Solubility of oxygen in water at various temperatures and pressures—Continued

Temp °C	Atmospheric pressure, in millimeters of mercury																			
	695	690	685	680	675	670	665	660	655	650	645	640	635	630	625	620	615	610	605	600
0.0	13.3	13.2	13.1	13.0	12.9	12.8	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5
0.5	13.1	13.1	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3
1.0	13.0	12.9	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.6	11.5	11.4	11.3	11.2
1.5	12.8	12.7	12.6	12.5	12.4	12.3	12.2	12.1	12.0	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0
2.0	12.6	12.5	12.4	12.3	12.2	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.1	11.0	10.9
2.5	12.4	12.4	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.4	11.3	11.2	11.1	11.0	10.9	10.8	10.7
3.0	12.3	12.2	12.1	12.0	11.9	11.8	11.7	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.9	10.8	10.7	10.6
3.5	12.1	12.0	11.9	11.8	11.8	11.7	11.6	11.5	11.4	11.3	11.2	11.1	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.4
4.0	12.0	11.9	11.8	11.7	11.6	11.5	11.4	11.3	11.3	11.2	11.1	11.0	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.3
4.5	11.8	11.7	11.6	11.5	11.5	11.4	11.3	11.2	11.1	11.0	10.9	10.9	10.8	10.7	10.6	10.5	10.4	10.3	10.3	10.2
5.0	11.6	11.6	11.5	11.4	11.3	11.2	11.1	11.1	11.0	10.9	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.2	10.1	10.0
5.5	11.5	11.4	11.3	11.2	11.2	11.1	11.0	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.3	10.2	10.2	10.1	10.0	9.9
6.0	11.4	11.3	11.2	11.1	11.0	10.9	10.9	10.8	10.7	10.6	10.5	10.4	10.4	10.3	10.2	10.1	10.0	9.9	9.9	9.8
6.5	11.2	11.1	11.0	11.0	10.9	10.8	10.7	10.6	10.6	10.5	10.4	10.3	10.2	10.1	10.1	10.0	9.9	9.8	9.7	9.7
7.0	11.1	11.0	10.9	10.8	10.7	10.7	10.6	10.5	10.4	10.3	10.3	10.2	10.1	10.0	9.9	9.9	9.8	9.7	9.6	9.5
7.5	10.9	10.9	10.8	10.7	10.6	10.5	10.5	10.4	10.3	10.2	10.1	10.1	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.4
8.0	10.8	10.7	10.6	10.6	10.5	10.4	10.3	10.2	10.2	10.1	10.0	9.9	9.9	9.8	9.7	9.6	9.5	9.5	9.4	9.3
8.5	10.7	10.6	10.5	10.4	10.4	10.3	10.2	10.1	10.0	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.4	9.3	9.3	9.2
9.0	10.5	10.5	10.4	10.3	10.2	10.2	10.1	10.0	9.9	9.8	9.8	9.7	9.6	9.5	9.5	9.4	9.3	9.2	9.2	9.1
9.5	10.4	10.3	10.3	10.2	10.1	10.0	10.0	9.9	9.8	9.7	9.7	9.6	9.5	9.4	9.4	9.3	9.2	9.1	9.0	9.0
10.0	10.3	10.2	10.1	10.1	10.0	9.9	9.8	9.8	9.7	9.6	9.5	9.5	9.4	9.3	9.2	9.2	9.1	9.0	8.9	8.9
10.5	10.2	10.1	10.0	9.9	9.9	9.8	9.7	9.7	9.6	9.5	9.4	9.4	9.3	9.2	9.1	9.1	9.0	8.9	8.8	8.8
11.0	10.1	10.0	9.9	9.8	9.8	9.7	9.6	9.5	9.5	9.4	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.8	8.7	8.7
11.5	9.9	9.9	9.8	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.2	9.1	9.1	9.0	8.9	8.8	8.8	8.7	8.6	8.6
12.0	9.8	9.8	9.7	9.6	9.5	9.5	9.4	9.3	9.2	9.2	9.1	9.0	9.0	8.9	8.8	8.7	8.7	8.6	8.5	8.5
12.5	9.7	9.6	9.6	9.5	9.4	9.4	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.7	8.6	8.6	8.5	8.4	8.4
13.0	9.6	9.5	9.5	9.4	9.3	9.3	9.2	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.6	8.5	8.5	8.4	8.3	8.3
13.5	9.5	9.4	9.4	9.3	9.2	9.1	9.1	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.3	8.2	8.2
14.0	9.4	9.3	9.3	9.2	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.2	8.2	8.1
14.5	9.3	9.2	9.2	9.1	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.1	8.1	8.0

Table 6.2–6. Solubility of oxygen in water at various temperatures and pressures—Continued

Temp °C	Atmospheric pressure, in millimeters of mercury 695	690	685	680	675	670	665	660	655	650	645	640	635	630	625	620	615	610	605	600
15.0	9.2	9.1	9.1	9.0	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.0	8.0	7.9
15.5	9.1	9.0	9.0	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.8
16.0	9.0	8.9	8.9	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.1	8.1	8.0	7.9	7.9	7.8	7.7
16.5	8.9	8.8	8.8	8.7	8.6	8.6	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7
17.0	8.8	8.7	8.7	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.6	7.6
17.5	8.7	8.6	8.6	8.5	8.5	8.4	8.3	8.3	8.2	8.1	8.1	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.5
18.0	8.6	8.6	8.5	8.4	8.4	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.5	7.5	7.4
18.5	8.5	8.5	8.4	8.3	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.5	7.5	7.4	7.3
19.0	8.4	8.4	8.3	8.3	8.2	8.1	8.1	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.3
19.5	8.4	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.2	7.2
20.0	8.3	8.2	8.2	8.1	8.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.5	7.5	7.4	7.4	7.3	7.2	7.2	7.1
20.5	8.2	8.1	8.1	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.0
21.0	8.1	8.1	8.0	7.9	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.0	7.0
21.5	8.0	8.0	7.9	7.9	7.8	7.7	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.3	7.2	7.1	7.1	7.0	7.0	6.9
22.0	8.0	7.9	7.8	7.8	7.7	7.7	7.6	7.5	7.5	7.4	7.4	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.8
22.5	7.9	7.8	7.8	7.7	7.6	7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	6.9	6.9	6.8	6.8
23.0	7.8	7.7	7.7	7.6	7.6	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7
23.5	7.7	7.7	7.6	7.6	7.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.0	7.0	6.9	6.9	6.8	6.7	6.7	6.6
24.0	7.7	7.6	7.5	7.5	7.4	7.4	7.3	7.3	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.7	6.7	6.6	6.6
24.5	7.6	7.5	7.5	7.4	7.4	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5
25.0	7.5	7.5	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.4
25.5	7.4	7.4	7.3	7.3	7.2	7.2	7.1	7.1	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.4	6.4
26.0	7.4	7.3	7.3	7.2	7.2	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.5	6.5	6.4	6.4	6.3
26.5	7.3	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3
27.0	7.2	7.2	7.1	7.1	7.0	7.0	6.9	6.9	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2
27.5	7.2	7.1	7.1	7.0	7.0	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2
28.0	7.1	7.1	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.1	6.1
28.5	7.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.2	6.2	6.1	6.1	6.0
29.0	7.0	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.2	6.2	6.1	6.1	6.0	6.0
29.5	6.9	6.9	6.8	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9

Table 6.2–6. Solubility of oxygen in water at various temperatures and pressures—Continued

Temp °C	Atmospheric pressure, in millimeters of mercury 695	690	685	680	675	670	665	660	655	650	645	640	635	630	625	620	615	610	605	600
30.0	6.9	6.8	6.8	6.7	6.7	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9
30.5	6.8	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8
31.0	6.7	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8
31.5	6.7	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7
32.0	6.6	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7
32.5	6.6	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6
33.0	6.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6
33.5	6.5	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5
34.0	6.4	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5
34.5	6.4	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4
35.0	6.3	6.3	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4
35.5	6.2	6.2	6.2	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3
36.0	6.2	6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3
36.5	6.1	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.2
37.0	6.1	6.1	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.3	5.2
37.5	6.0	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.3	5.2	5.2
38.0	6.0	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.3	5.3	5.3	5.2	5.2	5.1
38.5	6.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.2	5.2	5.1	5.1
39.0	5.9	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.2	5.2	5.1	5.1	5.0
39.5	5.9	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.2	5.2	5.1	5.1	5.0	5.0
40.0	5.8	5.8	5.7	5.7	5.6	5.6	5.5	5.5	5.4	5.4	5.4	5.3	5.3	5.2	5.2	5.1	5.1	5.0	5.0	5.0

Table 6.2–7. Salinity correction factors for dissolved oxygen in water (based on conductivity)

[From R.F. Weiss (1970). Temp °C, temperature in degrees Celsius; salinity correction factors at 30 to 35 degrees Celsius are shown at the end of this table]

Temp	Conductivity, in microsiemens per centimeter at 25 degrees Celsius																
°C	0	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	16000
0.0	1.000	0.996	0.992	0.989	0.985	0.981	0.977	0.973	0.969	0.965	0.961	0.957	0.953	0.950	0.946	0.942	0.938
1.0	1.000	0.996	0.992	0.989	0.985	0.981	0.977	0.973	0.969	0.965	0.962	0.958	0.954	0.950	0.946	0.942	0.938
2.0	1.000	0.996	0.992	0.989	0.985	0.981	0.977	0.973	0.970	0.966	0.962	0.958	0.954	0.950	0.946	0.942	0.938
3.0	1.000	0.996	0.993	0.989	0.985	0.981	0.977	0.974	0.970	0.966	0.962	0.958	0.954	0.951	0.947	0.943	0.939
4.0	1.000	0.996	0.993	0.989	0.985	0.981	0.978	0.974	0.970	0.966	0.962	0.959	0.955	0.951	0.947	0.943	0.939
5.0	1.000	0.996	0.993	0.989	0.985	0.981	0.978	0.974	0.970	0.966	0.963	0.959	0.955	0.951	0.947	0.944	0.940
6.0	1.000	0.996	0.993	0.989	0.985	0.982	0.978	0.974	0.970	0.967	0.963	0.959	0.955	0.952	0.948	0.944	0.940
7.0	1.000	0.996	0.993	0.989	0.985	0.982	0.978	0.974	0.971	0.967	0.963	0.959	0.956	0.952	0.948	0.944	0.941
8.0	1.000	0.996	0.993	0.989	0.986	0.982	0.978	0.975	0.971	0.967	0.963	0.960	0.956	0.952	0.949	0.945	0.941
9.0	1.000	0.996	0.993	0.989	0.986	0.982	0.978	0.975	0.971	0.967	0.964	0.960	0.956	0.953	0.949	0.945	0.941
10.0	1.000	0.996	0.993	0.989	0.986	0.982	0.979	0.975	0.971	0.968	0.964	0.960	0.957	0.953	0.949	0.946	0.942
11.0	1.000	0.996	0.993	0.989	0.986	0.982	0.979	0.975	0.971	0.968	0.964	0.961	0.957	0.953	0.950	0.946	0.942
12.0	1.000	0.997	0.993	0.989	0.986	0.982	0.979	0.975	0.972	0.968	0.965	0.961	0.957	0.954	0.950	0.946	0.943
13.0	1.000	0.997	0.993	0.990	0.986	0.983	0.979	0.975	0.972	0.968	0.965	0.961	0.958	0.954	0.950	0.947	0.943
14.0	1.000	0.997	0.993	0.990	0.986	0.983	0.979	0.976	0.972	0.969	0.965	0.961	0.958	0.954	0.951	0.947	0.943
15.0	1.000	0.997	0.993	0.990	0.986	0.983	0.979	0.976	0.972	0.969	0.965	0.962	0.958	0.955	0.951	0.947	0.944
16.0	1.000	0.997	0.993	0.990	0.986	0.983	0.979	0.976	0.972	0.969	0.966	0.962	0.958	0.955	0.951	0.948	0.944
17.0	1.000	0.997	0.993	0.990	0.986	0.983	0.980	0.976	0.973	0.969	0.966	0.962	0.959	0.955	0.952	0.948	0.945
18.0	1.000	0.997	0.993	0.990	0.987	0.983	0.980	0.976	0.973	0.969	0.966	0.963	0.959	0.956	0.952	0.949	0.945
19.0	1.000	0.997	0.993	0.990	0.987	0.983	0.980	0.976	0.973	0.970	0.966	0.963	0.959	0.956	0.952	0.949	0.945
20.0	1.000	0.997	0.993	0.990	0.987	0.983	0.980	0.977	0.973	0.970	0.966	0.963	0.960	0.956	0.953	0.949	0.946
21.0	1.000	0.997	0.993	0.990	0.987	0.984	0.980	0.977	0.973	0.970	0.967	0.963	0.960	0.957	0.953	0.950	0.946
22.0	1.000	0.997	0.993	0.990	0.987	0.984	0.980	0.977	0.974	0.970	0.967	0.964	0.960	0.957	0.953	0.950	0.947
23.0	1.000	0.997	0.994	0.990	0.987	0.984	0.980	0.977	0.974	0.971	0.967	0.964	0.960	0.957	0.954	0.950	0.947
24.0	1.000	0.997	0.994	0.990	0.987	0.984	0.981	0.977	0.974	0.971	0.967	0.964	0.961	0.957	0.954	0.951	0.947
25.0	1.000	0.997	0.994	0.990	0.987	0.984	0.981	0.977	0.974	0.971	0.968	0.964	0.961	0.958	0.954	0.951	0.948
26.0	1.000	0.997	0.994	0.990	0.987	0.984	0.981	0.978	0.974	0.971	0.968	0.965	0.961	0.958	0.955	0.951	0.948
27.0	1.000	0.997	0.994	0.991	0.987	0.984	0.981	0.978	0.975	0.971	0.968	0.965	0.962	0.958	0.955	0.952	0.948
28.0	1.000	0.997	0.994	0.991	0.987	0.984	0.981	0.978	0.975	0.972	0.968	0.965	0.962	0.959	0.955	0.952	0.949
29.0	1.000	0.997	0.994	0.991	0.988	0.984	0.981	0.978	0.975	0.972	0.969	0.965	0.962	0.959	0.956	0.952	0.949

Table 6.2–7. Salinity correction factors for dissolved oxygen in water (based on conductivity)—Continued

Temp °C	Conductivity, in microsiemens per centimeter at 25 degrees Celsius 17000	18000	19000	20000	21000	22000	23000	24000	25000	26000	27000	28000	29000	30000	31000	32000	33000
0.0	0.934	0.930	0.926	0.922	0.918	0.914	0.910	0.905	0.901	0.897	0.893	0.889	0.885	0.881	0.877	0.873	0.869
1.0	0.934	0.930	0.926	0.922	0.918	0.914	0.910	0.906	0.902	0.898	0.894	0.890	0.886	0.882	0.878	0.874	0.870
2.0	0.935	0.931	0.927	0.923	0.919	0.915	0.911	0.907	0.903	0.899	0.895	0.891	0.887	0.883	0.879	0.875	0.871
3.0	0.935	0.931	0.927	0.923	0.919	0.915	0.911	0.907	0.903	0.899	0.895	0.891	0.887	0.883	0.879	0.875	0.871
4.0	0.935	0.932	0.928	0.924	0.920	0.916	0.912	0.908	0.904	0.900	0.896	0.892	0.888	0.884	0.880	0.876	0.872
5.0	0.936	0.932	0.928	0.924	0.920	0.917	0.913	0.909	0.905	0.901	0.897	0.893	0.889	0.885	0.881	0.877	0.873
6.0	0.936	0.933	0.929	0.925	0.921	0.917	0.913	0.909	0.905	0.902	0.898	0.894	0.890	0.886	0.882	0.878	0.874
7.0	0.937	0.933	0.929	0.925	0.922	0.918	0.914	0.910	0.906	0.902	0.898	0.894	0.891	0.887	0.883	0.879	0.875
8.0	0.937	0.933	0.930	0.926	0.922	0.918	0.914	0.911	0.907	0.903	0.899	0.895	0.891	0.887	0.884	0.880	0.876
9.0	0.938	0.934	0.930	0.926	0.923	0.919	0.915	0.911	0.907	0.904	0.900	0.896	0.892	0.888	0.884	0.880	0.877
10.0	0.938	0.934	0.931	0.927	0.923	0.919	0.916	0.912	0.908	0.904	0.900	0.897	0.893	0.889	0.885	0.881	0.877
11.0	0.939	0.935	0.931	0.927	0.924	0.920	0.916	0.912	0.909	0.905	0.901	0.897	0.894	0.890	0.886	0.882	0.878
12.0	0.939	0.935	0.932	0.928	0.924	0.920	0.917	0.913	0.909	0.906	0.902	0.898	0.894	0.890	0.887	0.883	0.879
13.0	0.939	0.936	0.932	0.928	0.925	0.921	0.917	0.914	0.910	0.906	0.902	0.899	0.895	0.891	0.887	0.884	0.880
14.0	0.940	0.936	0.933	0.929	0.925	0.922	0.918	0.914	0.911	0.907	0.903	0.899	0.896	0.892	0.888	0.884	0.881
15.0	0.940	0.937	0.933	0.929	0.926	0.922	0.918	0.915	0.911	0.907	0.904	0.900	0.896	0.893	0.889	0.885	0.882
16.0	0.941	0.937	0.934	0.930	0.926	0.923	0.919	0.915	0.912	0.908	0.904	0.901	0.897	0.893	0.890	0.886	0.882
17.0	0.941	0.938	0.934	0.930	0.927	0.923	0.920	0.916	0.912	0.909	0.905	0.901	0.898	0.894	0.891	0.887	0.883
18.0	0.942	0.938	0.934	0.931	0.927	0.924	0.920	0.917	0.913	0.909	0.906	0.902	0.899	0.895	0.891	0.888	0.884
19.0	0.942	0.938	0.935	0.931	0.928	0.924	0.921	0.917	0.914	0.910	0.906	0.903	0.899	0.896	0.892	0.888	0.885
20.0	0.942	0.939	0.935	0.932	0.928	0.925	0.921	0.918	0.914	0.911	0.907	0.903	0.900	0.896	0.893	0.889	0.886
21.0	0.943	0.939	0.936	0.932	0.929	0.925	0.922	0.918	0.915	0.911	0.908	0.904	0.901	0.897	0.893	0.890	0.886
22.0	0.943	0.940	0.936	0.933	0.929	0.926	0.922	0.919	0.915	0.912	0.908	0.905	0.901	0.898	0.894	0.891	0.887
23.0	0.944	0.940	0.937	0.933	0.930	0.926	0.923	0.919	0.916	0.912	0.909	0.905	0.902	0.898	0.895	0.891	0.888
24.0	0.944	0.941	0.937	0.934	0.930	0.927	0.923	0.920	0.917	0.913	0.910	0.906	0.903	0.899	0.896	0.892	0.889
25.0	0.944	0.941	0.938	0.934	0.931	0.927	0.924	0.921	0.917	0.914	0.910	0.907	0.903	0.900	0.896	0.893	0.889
26.0	0.945	0.941	0.938	0.935	0.931	0.928	0.925	0.921	0.918	0.914	0.911	0.907	0.904	0.901	0.897	0.894	0.890
27.0	0.945	0.942	0.938	0.935	0.932	0.928	0.925	0.922	0.918	0.915	0.911	0.908	0.905	0.901	0.898	0.894	0.891
28.0	0.946	0.942	0.939	0.936	0.932	0.929	0.926	0.922	0.919	0.915	0.912	0.909	0.905	0.902	0.898	0.895	0.892
29.0	0.946	0.943	0.939	0.936	0.933	0.929	0.926	0.923	0.919	0.916	0.913	0.909	0.906	0.903	0.899	0.896	0.892

Table 6.2–7. Salinity correction factors for dissolved oxygen in water (based on conductivity)—Continued

Temp °C	Conductivity, in microsiemens per centimeter at 25 degrees Celsius																
	34000	35000	36000	37000	38000	39000	40000	41000	42000	43000	44000	45000	46000	47000	48000	49000	50000
0.0	0.865	0.861	0.856	0.852	0.848	0.844	0.840	0.836	0.832	0.828	0.823	0.819	0.815	0.811	0.807	0.803	0.799
1.0	0.866	0.862	0.857	0.853	0.849	0.845	0.841	0.837	0.833	0.829	0.825	0.821	0.816	0.812	0.808	0.804	0.800
2.0	0.867	0.862	0.858	0.854	0.850	0.846	0.842	0.838	0.834	0.830	0.826	0.822	0.818	0.814	0.809	0.805	0.801
3.0	0.867	0.863	0.859	0.855	0.851	0.847	0.843	0.839	0.835	0.831	0.827	0.823	0.819	0.815	0.811	0.807	0.803
4.0	0.868	0.864	0.860	0.856	0.852	0.848	0.844	0.840	0.836	0.832	0.828	0.824	0.820	0.816	0.812	0.808	0.804
5.0	0.869	0.865	0.861	0.857	0.853	0.849	0.845	0.841	0.837	0.833	0.829	0.825	0.821	0.817	0.813	0.809	0.805
6.0	0.870	0.866	0.862	0.858	0.854	0.850	0.846	0.842	0.838	0.834	0.830	0.826	0.822	0.818	0.814	0.810	0.806
7.0	0.871	0.867	0.863	0.859	0.855	0.851	0.847	0.843	0.839	0.835	0.831	0.828	0.824	0.820	0.816	0.812	0.808
8.0	0.872	0.868	0.864	0.860	0.856	0.852	0.848	0.844	0.840	0.837	0.833	0.829	0.825	0.821	0.817	0.813	0.809
9.0	0.873	0.869	0.865	0.861	0.857	0.853	0.849	0.845	0.842	0.838	0.834	0.830	0.826	0.822	0.818	0.814	0.810
10.0	0.874	0.870	0.866	0.862	0.858	0.854	0.850	0.846	0.843	0.839	0.835	0.831	0.827	0.823	0.819	0.815	0.811
11.0	0.874	0.871	0.867	0.863	0.859	0.855	0.851	0.848	0.844	0.840	0.836	0.832	0.828	0.824	0.820	0.817	0.813
12.0	0.875	0.871	0.868	0.864	0.860	0.856	0.852	0.849	0.845	0.841	0.837	0.833	0.829	0.825	0.822	0.818	0.814
13.0	0.876	0.872	0.869	0.865	0.861	0.857	0.853	0.850	0.846	0.842	0.838	0.834	0.830	0.827	0.823	0.819	0.815
14.0	0.877	0.873	0.869	0.866	0.862	0.858	0.854	0.851	0.847	0.843	0.839	0.835	0.832	0.828	0.824	0.820	0.816
15.0	0.878	0.874	0.870	0.867	0.863	0.859	0.855	0.852	0.848	0.844	0.840	0.836	0.833	0.829	0.825	0.821	0.817
16.0	0.879	0.875	0.871	0.867	0.864	0.860	0.856	0.853	0.849	0.845	0.841	0.838	0.834	0.830	0.826	0.822	0.819
17.0	0.879	0.876	0.872	0.868	0.865	0.861	0.857	0.854	0.850	0.846	0.842	0.839	0.835	0.831	0.827	0.824	0.820
18.0	0.880	0.877	0.873	0.869	0.866	0.862	0.858	0.855	0.851	0.847	0.843	0.840	0.836	0.832	0.829	0.825	0.821
19.0	0.881	0.877	0.874	0.870	0.867	0.863	0.859	0.855	0.852	0.848	0.844	0.841	0.837	0.833	0.830	0.826	0.822
20.0	0.882	0.878	0.875	0.871	0.867	0.864	0.860	0.856	0.853	0.849	0.845	0.842	0.838	0.834	0.831	0.827	0.823
21.0	0.883	0.879	0.876	0.872	0.868	0.865	0.861	0.857	0.854	0.850	0.846	0.843	0.839	0.836	0.832	0.828	0.825
22.0	0.884	0.880	0.876	0.873	0.869	0.866	0.862	0.858	0.855	0.851	0.848	0.844	0.840	0.837	0.833	0.829	0.826
23.0	0.884	0.881	0.877	0.874	0.870	0.866	0.863	0.859	0.856	0.852	0.849	0.845	0.841	0.838	0.834	0.830	0.827
24.0	0.885	0.882	0.878	0.874	0.871	0.867	0.864	0.860	0.857	0.853	0.850	0.846	0.842	0.839	0.835	0.832	0.828
25.0	0.886	0.882	0.879	0.875	0.872	0.868	0.865	0.861	0.858	0.854	0.851	0.847	0.843	0.840	0.836	0.833	0.829
26.0	0.887	0.883	0.880	0.876	0.873	0.869	0.866	0.862	0.859	0.855	0.852	0.848	0.844	0.841	0.837	0.834	0.830
27.0	0.887	0.884	0.880	0.877	0.874	0.870	0.867	0.863	0.860	0.856	0.853	0.849	0.845	0.842	0.838	0.835	0.831
28.0	0.888	0.885	0.881	0.878	0.874	0.871	0.867	0.864	0.860	0.857	0.853	0.850	0.846	0.843	0.839	0.836	0.832
29.0	0.889	0.886	0.882	0.879	0.875	0.872	0.868	0.865	0.861	0.858	0.854	0.851	0.848	0.844	0.841	0.837	0.834

Table 6.2–7. Salinity correction factors for dissolved oxygen in water (based on conductivity)—Continued

Temp °C	Conductivity, in microsiemens per centimeter at 25 degrees Celsius 51000	52000	53000	54000	55000	56000	57000	58000	59000	60000	61000	62000	63000	64000	65000	66000	67000
0.0	0.795	0.790	0.786	0.782	0.778	0.774	0.770	0.766	0.761	0.757	0.753	0.749	0.745	0.741	0.737	0.732	0.728
1.0	0.796	0.792	0.788	0.783	0.779	0.775	0.771	0.767	0.763	0.759	0.755	0.751	0.746	0.742	0.738	0.734	0.730
2.0	0.797	0.793	0.789	0.785	0.781	0.777	0.773	0.768	0.764	0.760	0.756	0.752	0.748	0.744	0.740	0.736	0.732
3.0	0.798	0.794	0.790	0.786	0.782	0.778	0.774	0.770	0.766	0.762	0.758	0.754	0.750	0.746	0.741	0.737	0.733
4.0	0.800	0.796	0.792	0.788	0.784	0.780	0.775	0.771	0.767	0.763	0.759	0.755	0.751	0.747	0.743	0.739	0.735
5.0	0.801	0.797	0.793	0.789	0.785	0.781	0.777	0.773	0.769	0.765	0.761	0.757	0.753	0.749	0.745	0.741	0.737
6.0	0.802	0.798	0.794	0.790	0.786	0.782	0.778	0.774	0.770	0.766	0.762	0.758	0.754	0.750	0.746	0.742	0.738
7.0	0.804	0.800	0.796	0.792	0.788	0.784	0.780	0.776	0.772	0.768	0.764	0.760	0.756	0.752	0.748	0.744	0.740
8.0	0.805	0.801	0.797	0.793	0.789	0.785	0.781	0.777	0.773	0.769	0.765	0.761	0.757	0.753	0.749	0.745	0.742
9.0	0.806	0.802	0.798	0.794	0.790	0.787	0.783	0.779	0.775	0.771	0.767	0.763	0.759	0.755	0.751	0.747	0.743
10.0	0.807	0.804	0.800	0.796	0.792	0.788	0.784	0.780	0.776	0.772	0.768	0.764	0.760	0.757	0.753	0.749	0.745
11.0	0.809	0.805	0.801	0.797	0.793	0.789	0.785	0.781	0.778	0.774	0.770	0.766	0.762	0.758	0.754	0.750	0.746
12.0	0.810	0.806	0.802	0.798	0.794	0.791	0.787	0.783	0.779	0.775	0.771	0.767	0.763	0.760	0.756	0.752	0.748
13.0	0.811	0.807	0.804	0.800	0.796	0.792	0.788	0.784	0.780	0.777	0.773	0.769	0.765	0.761	0.757	0.753	0.750
14.0	0.812	0.809	0.805	0.801	0.797	0.793	0.789	0.786	0.782	0.778	0.774	0.770	0.766	0.763	0.759	0.755	0.751
15.0	0.814	0.810	0.806	0.802	0.798	0.795	0.791	0.787	0.783	0.779	0.776	0.772	0.768	0.764	0.760	0.756	0.753
16.0	0.815	0.811	0.807	0.804	0.800	0.796	0.792	0.788	0.785	0.781	0.777	0.773	0.769	0.766	0.762	0.758	0.754
17.0	0.816	0.812	0.809	0.805	0.801	0.797	0.794	0.790	0.786	0.782	0.778	0.775	0.771	0.767	0.763	0.760	0.756
18.0	0.817	0.814	0.810	0.806	0.802	0.799	0.795	0.791	0.787	0.784	0.780	0.776	0.772	0.769	0.765	0.761	0.757
19.0	0.819	0.815	0.811	0.807	0.804	0.800	0.796	0.792	0.789	0.785	0.781	0.777	0.774	0.770	0.766	0.763	0.759
20.0	0.820	0.816	0.812	0.809	0.805	0.801	0.797	0.794	0.790	0.786	0.783	0.779	0.775	0.771	0.768	0.764	0.760
21.0	0.821	0.817	0.814	0.810	0.806	0.802	0.799	0.795	0.791	0.788	0.784	0.780	0.777	0.773	0.769	0.766	0.762
22.0	0.822	0.818	0.815	0.811	0.807	0.804	0.800	0.796	0.793	0.789	0.785	0.782	0.778	0.774	0.771	0.767	0.763
23.0	0.823	0.820	0.816	0.812	0.809	0.805	0.801	0.798	0.794	0.790	0.787	0.783	0.779	0.776	0.772	0.768	0.765
24.0	0.824	0.821	0.817	0.814	0.810	0.806	0.803	0.799	0.795	0.792	0.788	0.785	0.781	0.777	0.774	0.770	0.766
25.0	0.826	0.822	0.818	0.815	0.811	0.808	0.804	0.800	0.797	0.793	0.789	0.786	0.782	0.779	0.775	0.771	0.768
26.0	0.827	0.823	0.820	0.816	0.812	0.809	0.805	0.802	0.798	0.794	0.791	0.787	0.784	0.780	0.776	0.773	0.769
27.0	0.828	0.824	0.821	0.817	0.814	0.810	0.806	0.803	0.799	0.796	0.792	0.789	0.785	0.781	0.778	0.774	0.771
28.0	0.829	0.825	0.822	0.818	0.815	0.811	0.808	0.804	0.801	0.797	0.794	0.790	0.786	0.783	0.779	0.776	0.772
29.0	0.830	0.827	0.823	0.820	0.816	0.812	0.809	0.805	0.802	0.798	0.795	0.791	0.788	0.784	0.781	0.777	0.774

Table 6.2–7. Salinity correction factors for dissolved oxygen in water (based on conductivity)—Continued

Temp °C	Conductivity, in microsiemens per centimeter at 25 degrees Celsius																
	0	1000	2000	3000	4000	5000	6000	7000	8000	9000	10000	11000	12000	13000	14000	15000	16000
30.0	1.000	0.997	0.994	0.991	0.988	0.985	0.981	0.978	0.975	0.972	0.969	0.966	0.962	0.959	0.956	0.953	0.950
31.0	1.000	0.997	0.994	0.991	0.988	0.985	0.982	0.978	0.975	0.972	0.969	0.966	0.963	0.959	0.956	0.953	0.950
32.0	1.000	0.997	0.994	0.991	0.988	0.985	0.982	0.979	0.975	0.972	0.969	0.966	0.963	0.960	0.957	0.953	0.950
33.0	1.000	0.997	0.994	0.991	0.988	0.985	0.982	0.979	0.976	0.973	0.969	0.966	0.963	0.960	0.957	0.954	0.951
34.0	1.000	0.997	0.994	0.991	0.988	0.985	0.982	0.979	0.976	0.973	0.970	0.967	0.963	0.960	0.957	0.954	0.951
35.0	1.000	0.997	0.994	0.991	0.988	0.985	0.982	0.979	0.976	0.973	0.970	0.967	0.964	0.961	0.957	0.954	0.951

Temp °C	Conductivity, in microsiemens per centimeter at 25 degrees Celsius																
	17000	18000	19000	20000	21000	22000	23000	24000	25000	26000	27000	28000	29000	30000	31000	32000	33000
30.0	0.946	0.943	0.940	0.936	0.933	0.930	0.927	0.923	0.920	0.917	0.913	0.910	0.907	0.903	0.900	0.896	0.893
31.0	0.947	0.943	0.940	0.937	0.934	0.930	0.927	0.924	0.920	0.917	0.914	0.911	0.907	0.904	0.901	0.897	0.894
32.0	0.947	0.944	0.941	0.937	0.934	0.931	0.928	0.924	0.921	0.918	0.914	0.911	0.908	0.905	0.901	0.898	0.895
33.0	0.947	0.944	0.941	0.938	0.935	0.931	0.928	0.925	0.922	0.918	0.915	0.912	0.908	0.905	0.902	0.899	0.895
34.0	0.948	0.945	0.941	0.938	0.935	0.932	0.929	0.925	0.922	0.919	0.916	0.912	0.909	0.906	0.903	0.899	0.896
35.0	0.948	0.945	0.942	0.939	0.935	0.932	0.929	0.926	0.923	0.919	0.916	0.913	0.910	0.906	0.903	0.900	0.897

Temp °C	Conductivity, in microsiemens per centimeter at 25 degrees Celsius																
	34000	35000	36000	37000	38000	39000	40000	41000	42000	43000	44000	45000	46000	47000	48000	49000	50000
30.0	0.890	0.886	0.883	0.879	0.876	0.873	0.869	0.866	0.862	0.859	0.855	0.852	0.849	0.845	0.842	0.838	0.835
31.0	0.890	0.887	0.884	0.880	0.877	0.873	0.870	0.867	0.863	0.860	0.856	0.853	0.850	0.846	0.843	0.839	0.836
32.0	0.891	0.888	0.884	0.881	0.878	0.874	0.871	0.868	0.864	0.861	0.857	0.854	0.851	0.847	0.844	0.840	0.837
33.0	0.892	0.889	0.885	0.882	0.879	0.875	0.872	0.868	0.865	0.862	0.858	0.855	0.851	0.848	0.845	0.841	0.838
34.0	0.893	0.889	0.886	0.883	0.879	0.876	0.873	0.869	0.866	0.863	0.859	0.856	0.852	0.849	0.846	0.842	0.839
35.0	0.893	0.890	0.887	0.883	0.880	0.877	0.874	0.870	0.867	0.863	0.860	0.857	0.853	0.850	0.847	0.843	0.840

Temp °C	Conductivity, in microsiemens per centimeter at 25 degrees Celsius																
	51000	52000	53000	54000	55000	56000	57000	58000	59000	60000	61000	62000	63000	64000	65000	66000	67000
30.0	0.831	0.828	0.824	0.821	0.817	0.814	0.810	0.807	0.803	0.800	0.796	0.793	0.789	0.786	0.782	0.779	0.775
31.0	0.832	0.829	0.825	0.822	0.818	0.815	0.811	0.808	0.804	0.801	0.797	0.794	0.790	0.787	0.783	0.780	0.776
32.0	0.833	0.830	0.826	0.823	0.820	0.816	0.813	0.809	0.806	0.802	0.799	0.795	0.792	0.788	0.785	0.781	0.778
33.0	0.834	0.831	0.828	0.824	0.821	0.817	0.814	0.810	0.807	0.803	0.800	0.797	0.793	0.790	0.786	0.783	0.779
34.0	0.836	0.832	0.829	0.825	0.822	0.818	0.815	0.812	0.808	0.805	0.801	0.798	0.794	0.791	0.788	0.784	0.781
35.0	0.837	0.833	0.830	0.826	0.823	0.820	0.816	0.813	0.809	0.806	0.803	0.799	0.796	0.792	0.789	0.785	0.782

Appendix 4 Conductivity

Cell resistance for calibration and simulation

Cell K Factor	mS/cm (milliSiemens/cm)	uS/cm (microSiemens/cm)	uS/m (microSiemens/m)	Substitute Resistance
K=1	1	1,000	100,000	1,00052 (1k52)
K=1	0.1	100	10,000	10,00052 (10k52)
K=1	0.01	10	1,000	100,00052 (100k52)
K=0.1	1	1,000	100,000	10052
K=0.1	0.1	100	10,000	1,00052 (1k52)
K=0.1	0.01	10	1,000	10,00052 (10k52)
K=0.1	0.01	1	100	100,00052 (100k52)
K=0.1	0.001	0.1	10	1,000,00052 (1MS1)

Conductivity test solutions

1 Normal KCI is 74.7gms dissolved in distilled water and then made up to 1 L
0.1 Normal KCI is 7.47 gms KCI dissolved in distilled water and then made up to 1 L
0.02 Normal KCI is 1.494 gms KCI dissolved in distilled water and then made up to 1 L
0.01 Normal KCI is .747 gms KCI dissolved in distilled water and then made up to 1 L

Conductivity values of Potassium Chloride

Temp	1N KCI		0.1N KCI		0.02N KCI		0.01N KCI	
°C	mS/cm	uS/cm	mS/cm	uS/cm	mS/cm	uS/cm	mS/cm	uS/cm
0	65.41	65,410	7.15	7,150	1.53	1,530	.776	776
5	74.14	74,140	8.22	8,220	1.74	1,740	.896	896
10	88.19	88,190	9.33	9,330	1.99	1,990	1.02	1,020
15	92.52	92,520	10.48	10,480	2.24	2,240	1.147	1,147
16	94.41	94,410	10.72	10,720	2.29	2,290	1.173	1,173
17	96.31	96,310	10.95	10,950	2.35	2,350	1.199	1,199
18	98.22	98,220	11.19	11,190	2.40	2,400	1.225	1,225
19	100.14	100,140	11.43	11,430	2.45	2,450	1.251	1,251
20	102.07	102,070	11.67	11,670	2.50	2,500	1.278	1,278
21	104.00	104,000	11.91	11,910	2.55	2,550	1.305	1,305
22	105.94	105,940	12.15	12,150	2.60	2,600	1.332	1,332
23	107.89	107,890	12.39	12,390	2.66	2,660	1.359	1,359
24	109.84	109,840	12.64	12,640	2.71	2,710	1.386	1,386
25	111.80	111,800	12.88	12,880	2.76	2,760	1.413	1,413
26	113.77	113,770	13.13	13,130	2.819	2,819	1.437	1,437
27	115.74	115,740	13.37	13,370	2.873	2,873	1.462	1,462
28	117.74	117,740	13.62	13,620	2.927	2,927	1.488	1,488
29	119.78	119,780	13.81	13,810	2.981	2,981	1.513	1,513
30	121.85	121,850	14.12	14,120	3.036	3,036	1.540	1,540

Appendix 5. Examples of data errors taken from USGS Continuous Monitoring Techniques Manual 1-D3

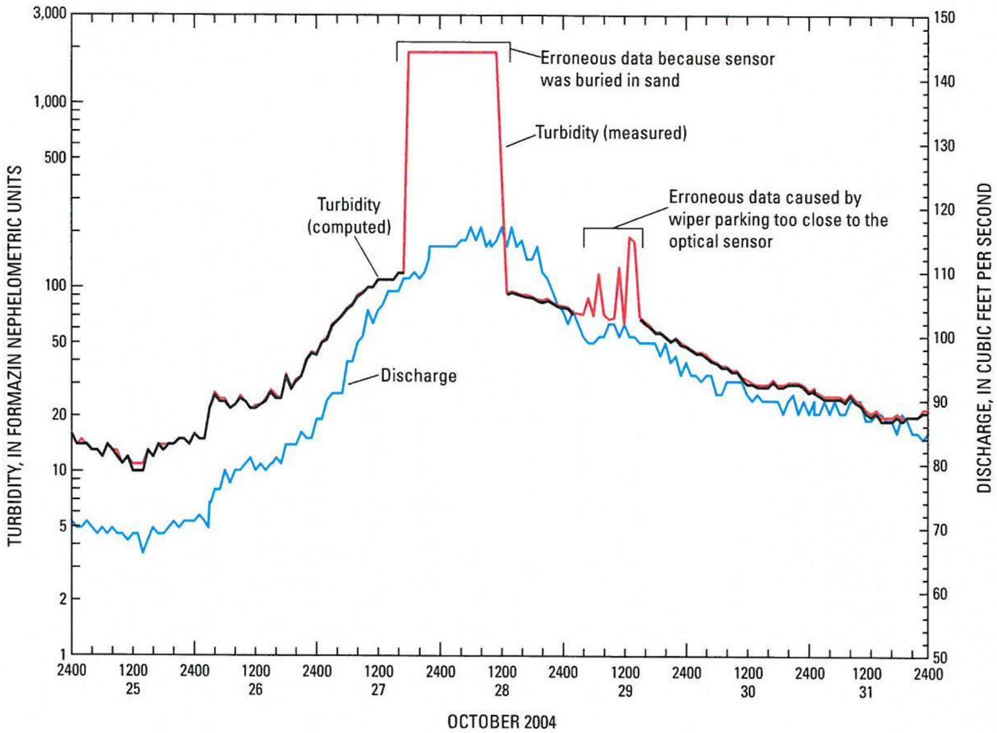


Figure 7. Turbidity values at the North Fork Ninnescah River above Cheney Reservoir, Kansas, October 2004.

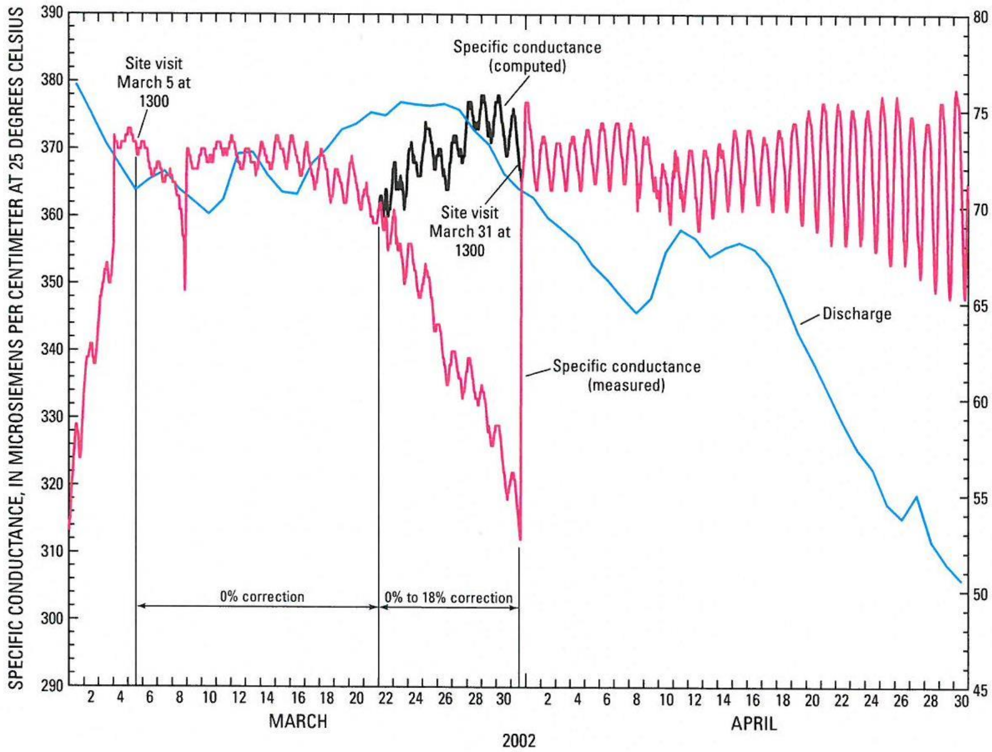


Figure 8. Example of fouling of specific conductance sensor.

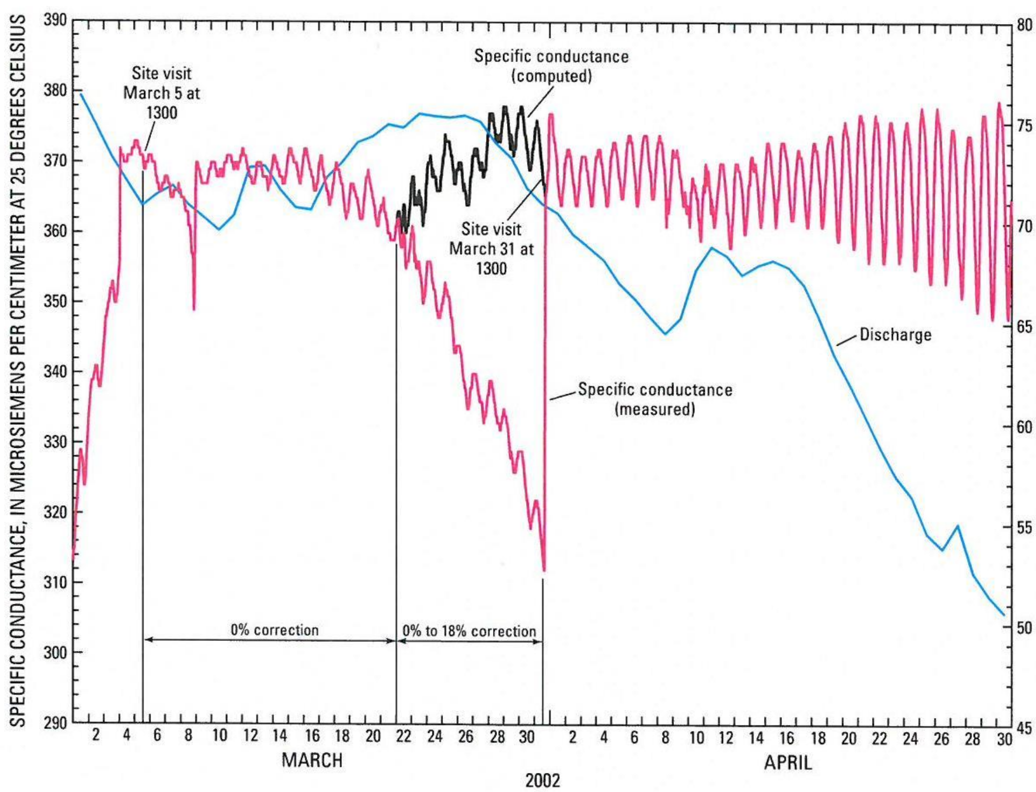


Figure 8. Example of fouling of specific conductance sensor.

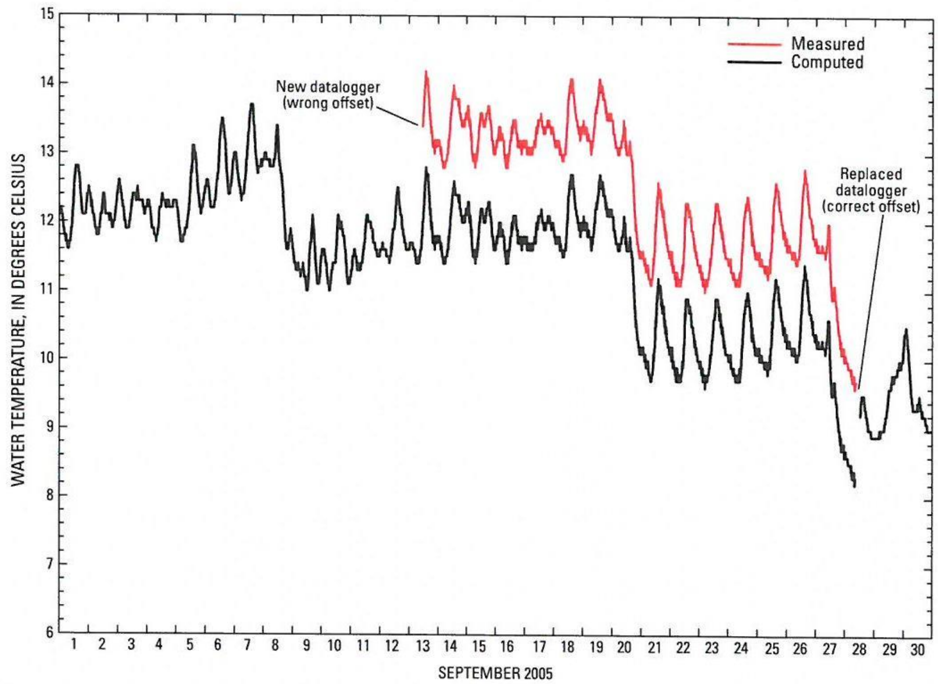


Figure 9. Example of a constant data correction of –1.4 degrees Celsius applied in September 2005 to correct for programming error that produced an incorrect offset at South Fork Tolt River (12148000) near Carnation, Washington.