



Cover Sheet Standard Operating Procedure

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

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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: Depth, Dissolved Oxygen (DO), Temperature, Specific Conductance, Salinity, pH, Turbidity, Chlorophyll, and Colored Dissolved Organic Matter (CDOM). These data are valuable for a variety of purposes including but not limited to, characterizing baseline physicochemical stream conditions, describing seasonal and diel fluctuations, and documenting potential violations to water quality criteria. This SOP borrows heavily, sometimes verbatim, from manuals from the United States Geologic Survey (USGS; Wagner et al. 2006), Pennsylvania Department of Environmental Protection (Shull and Lookenbill 2013), Illinois Environmental Protection Agency (IL EPA 2015), U.S. Environmental Protection Agency (USEPA 2014), and the National Estuarine Research Reserve System (NERRS 2013 and 2015).

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, estuaries and marine waters to minimize the collection of inaccurate data and to ensure consistent operating procedures. 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. 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). Deviations from this SOP must be documented by each program, such as in their QAPP, Sampling and Analysis Plan (SAP) or Annual Project Plan (APP).

3.0 Definitions

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

3.2 Sensor Calibration Drift – Changes in the accuracy of a sensor 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 Conductivity – Measure of the ability of water to pass an electrical current. Most conductivity sensors can calculate other more typically reported parameters using algorithms based on the



measured conductivity and temperature, including specific conductance (the electrical conductance of 1 cm³ of solution at 25°C), salinity, and total dissolved solids.

3.5 DEA – Division of Environmental Assessment of DEP’s Bureau of Water Quality.

3.6 Edited Data – Data file where outlier or erroneous data points have been removed (e.g., data collected prior to deployment, when out of water, during vandalism/while damaged).

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

3.8 Field Meter (meter) – An independent meter used to collect instantaneous readings as a quality assurance check for the unattended monitoring device at deployment and retrieval and any other field visits during the deployment period, and for calibration corrections for loggers.

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 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.

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

3.12 Quality Assurance Project/Program Plan (QAPP) – Documentation of all aspects of a project, including project management, data generation and acquisition, assessment and oversight, and data validation and usability.

3.13 R - A software program for data manipulation, calculation, statistical computing and graphical display, containing an integrated collection of tools developed around an open-source programming language. R runs on a wide variety of computer platforms.

3.14 Raw Data – Data without any corrections or manipulation.

3.15 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 and name of staff involved.

3.16 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 $\mu\text{S}/\text{cm}$ or mS/cm , Salinity in PSS, and Total Dissolved Solids in mg/l).

3.17 Sonde – A type of unattended continuous monitoring device that can capture real-time values of multiple parameters and that can be deployed unattended to collect continuous monitoring data. Data can be stored internally or transmitted to a telemetric device for instantaneous display. A sonde is more sophisticated than a logger. Common manufacturers include YSI, Eureka, In-Situ, and Hydrolab.

3.18 Specific Conductance – Calculated parameter based on the measured conductivity, defined as the electrical conductance of 1 cm^3 of solution at 25°C . Electrical conductivity is typically reported as specific conductance, with units of $\mu\text{S}/\text{cm}$ or mS/cm .

3.19 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.

3.20 Water Resource Data Base (WRDB) – 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 Sampling and Analysis Plan (SAP) or Annual Project Plan (APP).

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 (Fig. 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 the QAPP.

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 Operation – Major considerations in carrying out continuous in-situ monitoring include: site selection (section 5.1.1), monitoring device selection (based on purpose of data collection and the type of deployment), monitoring device deployment configuration (section 5.1.2), and sensor selection (based on precision, accuracy, and calibration criteria).

5.1.1 Site Selection and Deployment – Site selection is guided by the purpose of monitoring and the data objectives and 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 selecting a location that best represents the waterbody being measured. Major factors include depth, horizontal and vertical variability, and flow patterns.

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. 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. Following a major streamflow event, streams subject to substantial bed movement can result in devices being lost or relocated out of water or to a point no longer representative of the flow. A site may be ideal for monitoring high flow but not satisfactory during low flows.



5.1.2 Monitoring Device Deployment Configuration – 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 monitoring device at the required depth taking care not to impede navigation, moorage, recreation, 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. Floats may be surface or sub-surface.

For **marine sites**, important hydrologic considerations for device placement include tidal range, velocity and direction, degree of exposure to surge, navigation channel location, and vessel wakes.

The deployment depth and habitat zone or type (e.g., intertidal, subtidal, riffle, pool, eddy) need to be appropriate for the primary purpose of the monitoring installation. The depth should be chosen to accommodate anticipated flow conditions. If the monitoring device is being placed in a deposition area such as on the bottom of a river or in marine waters subject to rapid tidal flow, 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 (Fig. 1, Appendix 2).

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, Figs. 1 and 2) is necessary. In some environments the shroud can protect the monitoring



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

equipment from colonization and fouling from organisms and algae. In other environments, such as small, slow-moving streams, the shroud may contribute to sedimentation around the monitoring equipment. 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 (do not attach to large woody debris, which can be mobilized at high flows). 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 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 (Fig. 2). 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.



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

5.1.3 Site Description and Documentation – At each site, metadata should be recorded to sufficiently characterize the specific deployment location, to aid with device retrieval and to document any factors that may impact the continuous data record. This information could include (as specified in the relevant QAPP):

- a. GPS coordinates (required for all sites)
- b. Photos up and downstream of deployment site, or of the adjacent shoreline
- c. Water depth at deployment location
- d. Habitat type (pool, riffle, run, intertidal, shallow marine, subtidal, etc.)
- e. Dominant substrate characteristics
- f. Dominant riparian or shoreline vegetation and cover
- g. Riparian or shoreline disturbances
- h. For stream and river systems, channel width (measured or estimated)
- i. For marine water, tide stage at deployment
- j. 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 for a given purpose. The common operational categories include (1) calibration, (2) deployment programming, (3) sensor inspection and calibration checks (field visits), (4) cleaning, (5) maintenance frequency, and (6) comprehensive record keeping (equipment logs).

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 service visit that are less than the calibration criteria (Table 1). Marine water conditions that are more rapidly changing may require adaptations to operating



procedures described in this document.

Before deployment, the device must be visually inspected for any abnormalities such as cracks and each sensor needs to be calibrated. Field visits are critical for longer-term deployments to verify that sensors are working accurately, upload recorded data, remove any sensor fouling, confirm calibrations, replace batteries as needed, and provide a reference point for subsequent data management. **A field visit should result in a calibrated, and fully powered and functional monitoring device.**

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.). Calibration order may be important as some sensors rely on accurate readings from other sensors, especially temperature. In general, start with temperature, then depth, conductivity (specific conductance/salinity), pH, DO and turbidity. Calibrate in the same order each time to minimize the potential for accidentally skipping calibration of an individual sensor. Make sure the calibration standards have not expired; obtain replacements if necessary.

Calibration checks on deployed continuous monitoring devices should be conducted before each extended deployment, routinely (at least every four weeks, especially for probes that are vulnerable to drift such as pH probes, or up to every six months for temperature loggers) throughout the field season, and at the end of each extended deployment. Field meters should also be checked routinely (at least every four weeks) throughout the field season. Each cleaned sensor should be checked with at least two standard solutions (if possible) that bracket the range of expected environmental

Table 1. Monitoring device calibration criteria.

Percentages are based on the difference between the measured value and the calibration standard. For example, when using 100 $\mu\text{S}/\text{cm}$ standard, the calibration criteria would be 5 $\mu\text{S}/\text{cm}$ rather than 3% (3 $\mu\text{S}/\text{cm}$). When using 1000 $\mu\text{S}/\text{cm}$ standard, the calibration criteria would be 3% (30 $\mu\text{S}/\text{cm}$) and not 5 $\mu\text{S}/\text{cm}$.

Measurement	Calibration criteria (variation outside the value shown requires recalibration)
Temperature	$\pm 0.2\text{ }^{\circ}\text{C}$
Specific conductance	$\pm 5\text{ }\mu\text{S}/\text{cm}$ or $\pm 3\%$ of the measured value, whichever is greater
Salinity	0.3 ppt/pss or $\pm 3\%$ of the measured value, whichever is greater
Dissolved oxygen	$\pm 0.3\text{ mg/L}$
pH	$\pm 0.2\text{ pH unit}$
Turbidity	$\pm 0.5\text{ turbidity unit}$ or $\pm 5\%$ of the measured value, whichever is greater
Chlorophyll	$\pm 0.3\text{ }\mu\text{g/L}$
Colored Dissolved Organic Matter (CDOM)	$\pm 5\text{ ppb}$



conditions, and ideally a third standard near the ambient environmental conditions, before any calibration adjustments are made. Field calibration is performed if the cleaned-sensor readings during the calibration check differ by more than the calibration criteria (Table 1). Loggers are often not able to be calibrated in the field, but a field meter is used to check performance and calculate calibration corrections after the data are downloaded.

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 both the sensor and the temperature sensor are submerged in the standard (e.g., the YSI conductivity probe has a port on the side which must be covered by the standard solution).

After calibrating, **if a sensor does not meet the calibration criteria (Table 1), recalibrate.** If the sensor is still outside the criteria following the second calibration, apply the troubleshooting steps in Table 2 and then recalibrate a third time. If these steps fail, replace the sensor or device with a spare calibrated unit.

Temperature: 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 water temperature readings from both the sensor and the calibrated thermistor simultaneously. If the temperature sensor fails calibration, then all data for all temperature-dependent parameters will be inaccurate and will need to be rejected. A single-point accuracy check should be conducted on temperature loggers pre- and post-deployment by placing them in a container of ice water in a refrigerator. The logger should stabilize at 0° C. Loggers are often not able to be calibrated in the field, but a field meter or NIST certified thermometer is used to check performance and calculate calibration corrections after the data are downloaded.

Depth: Water stage calibration procedures vary slightly with manufacturer. 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, accounting 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.



Table 2. Troubleshooting procedures for the most common issues encountered in the field. Adapted from USGS (Wagner et al. 2006).

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 $\pm 0.2^{\circ}\text{C}$	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



Table 2. Troubleshooting procedures, continued.

Symptom	Possible problem	Likely solution
Dissolved oxygen (continued)		
Sensor slow to stabilize	Gold cathode tarnished Fouled membrane Silver anode blackened	Buff with pencil eraser or recondition sensor Recondition sensor Replace sensor and soak fouled sensor in 3-percent ammonia for 24 hours.
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 Defective sensor	Replace optical membrane cap Replace sensor
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 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
Erratic readings	Passing clumps of suspended particulate matter	Interpret data based on background knowledge of waterbody characteristics
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



Table 2. Troubleshooting procedures, continued.

Symptom	Possible problem	Likely solution
Chlorophyll (continued)		
Readings do not change	Wiper parked on top of sensor port Fouled sensor port	Clean sensor Recalibrate sensor Replace wiper as necessary
Colored Dissolved Organic Matter (CDOM)		
Erratic readings	Detection of adjacent water masses with differing optical qualities	Interpret data based on background knowledge of waterbody characteristics

Conductivity (specific conductance/salinity): The selected standard solution should be higher than expected recorded values. In general, the standard solution should be greater than 1 mS/cm (e.g., 1,413 μ S/cm), due to the ease of contamination of solutions with lower concentrations (see Appendix 4 for standard solution concentrations). 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. Temperature affects conductivity buffer solutions (see Appendix 4). The conductivity sensor reading must be standardized to the temperature-corrected value if the monitor does not have automatic temperature correction. Loggers are often not able to be calibrated in the field, but a field meter is used to check performance and calculate calibration corrections after the data are downloaded.

pH: Check the globe for any bubbles before calibration. If there is a bubble, follow the manufacturer's recommendation (YSI suggests shaking downward, as you would with a liquid filled thermometer with a bubble; Eureka says leave the bubble). Some pH sensors have expiration dates (e.g., YSI pH sensors need to be rebuilt or replaced every two years, or every year in low conductivity water), while others can be rebuilt and have extended life (e.g., Eureka requires regular refilling of the reference electrode). Temperature affects pH buffer solutions (see Table 3 for examples). Verify the temperature-correction factor with the solution manufacturer before standardizing the pH sensor reading to the temperature-corrected value.

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

To bracket ambient pH, select at least two buffer solutions (7 and 4 or 10). The temperature sensor must be in the solution with the pH sensor. A 3-point calibration may be needed for



waterbodies with expected pH values on both sides of 7.00. pH calibration should start with 7, then 10 and end with 4, unless the manufacturer's instructions say otherwise. Check slope of pH readings to determine if the

sensor is operating properly. Manufacturers of pH electrodes often specify the slope value tolerances for an electrode in good conditions (see Table 4 for examples).

Table 4. Calibration slope for pH sensors		
Slope %	mV range	Action
<90%	53	Replace electrode
90-95	-53.3 and -56.2	Clean and recalibrate
95-102	-56.2 and -60.4	Accept calibration
102-105	-60.3 and -62.1	Clean and recalibrate
>105	62	Replace electrode

Dissolved Oxygen: The concentration of dissolved oxygen in water is influenced by many factors including ambient water temperature, atmospheric pressure, and conductivity (or salinity). See Appendix 3 or the [USGS DO Tables \(https://water.usgs.gov/water-resources/software/DOTABLES/\)](https://water.usgs.gov/water-resources/software/DOTABLES/) for solubility of oxygen in water at various temperatures and pressures. Most multiparameter sondes with calibrated conductivity sensors automatically apply a salinity correction to DO readings when needed.

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 verify the correct operation of the sensor in the local measurement environment.

If deploying in water with low DO levels (4 mg/l or less), it is recommended to calibrate to zero. Zero-DO calibrations can be done with Sodium Sulfite (Na_2SO_3) solution or baker's yeast. For the yeast method, dissolve 1 tablespoon of fast-rise yeast in 8 oz of warm water and let stabilize for ~15 minutes (see [In-Situ's Technical note](#) for more information). Subsequent calibration checks and minor recalibrations can consist of a 1-point check in 100% air saturated water or water saturated air and a local barometric pressure value. 100% air saturated water can be made by using an aerator in a tank or bucket of water for three hours prior to calibration or by shaking a bottle of DI water for one minute and letting it stabilize in the vented calibration cup for three minutes. Water saturated air can be made by wrapping a wet towel two times around the device, or by using the rubber logger cap containing a saturated sponge, and placing it in a plastic bag out of direct sunlight for 5-10 minutes. See Appendix 3 or the [USGS DO Tables](#) for solubility of oxygen in water at various temperatures and pressures.

Turbidity: 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 (4,000 NTU Formazin is recommended) can be diluted but caution is required to avoid introducing errors during the dilution process, and diluted standards are less stable in storage, lasting only 2-3 months. Turbidity-free water (distilled or deionized water, filtered through a ≤ 0.2 mm filter membrane if possible) should be used in the preparation of standard solutions, dilutions,



rinsing and for the zero NTU standard solution. Zero turbidity standard is especially vulnerable to contamination by silt or other sources. Confirm the turbidity of any diluted solutions and zero standard in the field support area (deionized water may range from 0.2-1.0 NTU).

Wash and dry the monitor with a soft cloth, 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 (YSI has a special tall calibration cup).

Two primary standard solutions covering the expected range must be used for calibration. The low end of the calibration range should always be zero. Depending on the expected range of values, typical calibration values might be 0, 100, and 1,000 NTU, or 0, 40 and 400 NTU.

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. For sensors that are factory calibrated (e.g., Turner C-Fluor), sensor accuracy checks can be completed using readings in air, deionized water and/or a rhodamine dye, or by using a calibration cube (solid “standard”) and determining consistency of readings over a series of deployments.

Colored Dissolved Organic Matter (CDOM): For sensors that are factory calibrated (e.g., Turner C-Fluor), sensor accuracy checks can be completed using readings in air, deionized water, or by using a calibration cube (solid “standard”) and determining consistency of readings over a series of deployments. User calibration is advisable when absolute data are desired for a particular application and when comparing data across sensors, or when collecting data in colored and/or turbid environments.

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 manufacturers 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 made 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 endpoint 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. Field meters should be placed as close to the monitor deployment's position as possible. Field meter readings provide a sense of the reasonableness of the monitor readings and an indication of potential electronic calibration drift and fouling errors, as well as a tool to document environmental changes that may occur while the monitor is being serviced. If field repair of a sensor or device is not possible, replace with a calibrated backup unit and repair the malfunctioning unit in the field support area or return it to the manufacturer for repair.

If sensor readings can be viewed in the field:

- 1) Record the stabilized field meter *in situ* readings and sample 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) Connect device, re-immerses, and record the initial stabilized, *in situ* sensor readings and the sample time.
- 4) Clean the sensors according to the manufacturer's specifications (section 5.2.4).
- 5) Re-immerses device and record the stabilized, *in situ* cleaned-sensor readings and the sample 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.



Turbidity note: 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.

- 6) Perform a calibration check of sensors by measuring concentrations of appropriate calibration standards (see section 5.2.1). The difference between the cleaned-sensor readings and the expected reading in calibration standard solution is the result of sensor calibration drift error.
- 7) Calibrate sensors, if necessary (see section 5.2.1 and Table 1)
- 8) Inspect any equipment that holds the device in position and make repairs as necessary.
- 9) Return the device to the aquatic environment and record the time of re-deployment.
The fouling and calibration drift error can be computed with consideration being given to any environmental changes (e.g., change in cloud cover, rain event; also see section 5.5 Data Handling).

If sensor readings 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)

- 1) Retrieve the deployed monitoring device and bring back to field support area. If deployment period continues, inspect any equipment that holds the device in position, make repairs as necessary, and deploy a replacement calibrated device.
- 2) Ideally within 24 hours of retrieval, submerge the field meter and the retrieved device in a clean, temperature-stabilized aerated water bath. Record stabilized parameter values and sample time.
- 3) Clean the retrieved device according to manufacturer's specifications (section 5.2.4)
- 4) Re-immerses device in water bath. Record stabilized parameter values and sample time. Conditions in the water bath should be steady-state, so 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.
- 5) Perform a calibration check of sensors by measuring concentrations of appropriate calibration standards (see section 5.2.1 and Table 1). The difference between the cleaned-sensor readings and the expected reading in calibration standard solution is the result of sensor calibration drift error.
- 6) Calibrate sensors, if necessary (see section 5.2.1), prior to next deployment.



If sensor readings cannot be viewed in the field: (e.g., due to lack of a field computer or logger capability). Note: Loggers that are not configured for submerged real-time measurement viewing still require accuracy checks with a calibrated field meter or NIST certified thermometer.

- 1) Record the stabilized field meter *in situ* readings and sample time as close to a recorded sampling interval as possible, in order to collect readings simultaneously with the deployed device.
- 2) Retrieve the deployed monitoring device. If deployment period continues, inspect any equipment that holds the device in position, make repairs as necessary, and deploy a replacement calibrated device.
 - a. If under rapidly changing conditions, ideally within 24 hours of retrieval, submerge the field meter and retrieved device in a clean, temperature-stabilized aerated water bath. Record the sample time.
- 3) Clean the sensors according to the manufacturer's specifications (section 5.2.4).
- 4) Re-immerses device (either *in situ* under steady-state conditions, or in the aerated water bath). At the next logging interval (e.g., 15 minutes from step 1), record sample time.
- 5) Perform a calibration check of sensors by placing device in appropriate calibration standards (see section 5.2.1 and Table 1), allowing sensor to stabilize, and recording time at next logging interval.
- 6) When able to connect device to device, download the data. Based on the time log, determine fouling (the observed difference between the initial sensor reading and the cleaned-sensor reading) and calibration (the difference between the cleaned-sensor readings and the expected reading in calibration standard solution) drift errors. Correct for fouling and calibration drift (e.g., using software assistants).
- 7) Calibrate sensors, if necessary (see section 5.2.1) prior to next deployment.

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.

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.

Text Box 1. Field cleaning supplies:

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



Conductivity (specific conductance/salinity): USGS recommends cleaning conductivity 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. Conductivity 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 (DO): 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. Follow manufacturer's guidelines for replacement of sensor caps and water seals (for probes with wipers). 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) and replaced as required.

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 can destabilize the probe *for an hour or more*. 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.

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° 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 (e.g., 15 or 20-minute intervals) and then plot averages (e.g., hourly).

Chlorophyll and Colored Dissolved Organic Matter (CDOM): Optical chlorophyll and CDOM 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 ideally should 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 and CDOM 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 couple of weeks to year-round. Maintenance frequency depends primarily on fouling rate of the sensors (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, chlorophyll and CDOM sensors. Wiper mechanisms on turbidity, optical DO, chlorophyll and CDOM sensors have substantially decreased fouling in certain aquatic and marine environments. Monitoring sites with nutrient-enriched waters, high sedimentation 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 (e.g., pH probes) must be recalibrated at least monthly. Temperature loggers should be maintained at least every six months.

5.2.6 Equipment Logs – An equipment logbook should be maintained for each field meter and water-quality monitoring device, and all pertinent information recorded. The equipment logbook should contain a complete record of all maintenance in the field, the field support area, or by the manufacturer or service company, throughout the life of the device. Information can be recorded initially on field forms or in field notebooks, but should be copied into the equipment logbook. Information important to log for record processing includes:

- a. Sensor repair or replacement and modifications to device software;
- b. Calibration dates, times, and temperatures;
- c. Calibration standard values, expiration dates, and lot numbers;



- d. Initial and post calibration data from each calibration event, including relevant barometric pressure;
- e. Field meter calibration values and results of post calibration standard checks;
- 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 calibration drift and obtain similar results. Clear notes simplify the record computation and final review processes.

5.3 Field Notes – 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 or specified in a relevant QAPP:

1. Waterbody name
2. Site name or code
3. Town
4. GPS coordinates
5. Date and time
6. Device manufacturer, model and serial number
7. Device data file name
8. Field meter manufacturer, model, and serial number
9. Start and end time of deployments and checks
10. Name(s) of staff
11. Field checks of device values & field meter values
12. Calibration checks, calibrations/recalibrations, and final readings
13. Comments on site conditions, sensor condition, and any other pertinent observations
14. Notes on sensor/monitoring device changes or replacements, and other comments that facilitate processing of the record

Suggested data:

15. Photos taken (camera ID, photo numbers and descriptions)
16. 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)
17. Battery voltage of device at departure
18. Battery replacement
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 or electronic forms, and equipment logbooks 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 each program's QAPP. 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 for drift and fouling; (5) data quality determination; (6) record computation; (7) final record review; and (8) data storage in EGAD or as directed by the QAPP.

5.5.1 Data retrieval – Raw data can be accessed and downloaded in the field, office, or field support area 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 QAPP.

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. Conduct a preliminary review for each parameter, using WRDB, R, or other data exploration tool, to view primary data tables, summary statistics (including minimum, maximum, mean, and standard deviation) and plots, looking for anomalies and discontinuities. 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 or data that were logged outside of the in-water deployment period. Regardless of how data are recorded and downloaded, the record should be processed and plotted immediately after the field 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 other parameters that are temperature-compensated (e.g., for YSI these



include salinity, specific conductivity, depth, DO, pH, turbidity, and chlorophyll) will be inaccurate. If the conductivity sensor fails, DO and depth data will also be inaccurate, especially in brackish or marine waters. 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 the QAPP on DEP's network drive.

Emphasis should be placed on the relation of variations among the water quality parameters (temperature, specific conductance or salinity, DO, pH, turbidity, chlorophyll and CDOM) 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. Data errors can be caused by numerous factors including 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. A few examples are discussed below, and see Appendix 5 for graphical examples of data errors.

5.5.2.1 Stop/Start and Out-of-Water Edits – Often monitoring devices are calibrated in the field support area 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 for all parameters, 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 (Appendix 5.3). Large particles, leaves, twigs, or other natural debris may interfere with the measurement of true turbidity by causing spikes in the data. Sometimes single spikes are real (e.g., due to a breached beaver dam, bank failure, industrial discharge), but the operator generally does not know whether to believe them or not, so single isolated spikes should be documented, noted as suspect, and often edited out of the data record.



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, which might cause spikes at repeating intervals, or by drifting detritus (see section 5.5.2.2 and Appendix 5.3). 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). Unexplained data anomalies should be documented and edited out of the data record. Verified discrete data from a calibrated field meter may be used to apply a drift correction in addition to any documented fouling and calibration drift correction (see section 5.5.3).

5.5.2.4 Out of Range Errors – Many sensors have an upper and lower range beyond which they are not considered reliable. Reject any data values above or below the detection range of the equipment. The only sensors that may appropriately display negative values are depth and temperature.

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 applied when the combined absolute values for fouling and calibration drift error exceed the minimum relevant criterion for water quality data corrections (Table 5). More stringent data correction criteria may be needed to meet the data quality objectives of the project. Methods for applying data corrections are described in detail below.

Table 5. Criteria for water quality data corrections.

Parameter	Data Correction Criteria (apply correction when total error ($E_T = E_F + E_D $) exceeds the value listed)
Temperature	$\pm 0.2^\circ\text{C}$
Specific Conductance	$\pm 5 \mu\text{S/cm}$ or 3%, whichever is greater
Salinity	$\pm 0.3 \text{ ppt/pss}$ or 3% of the measured value, whichever is greater
pH	± 0.2 units
Dissolved Oxygen	$\pm 0.3 \text{ mg/L}$
Turbidity	$\pm 0.5 \text{ NTU}$ or $\pm 5\%$, whichever is greater
Chlorophyll	$\pm 0.3 \mu\text{g/L}$
Colored Dissolved Organic Matter (CDOM)	$\pm 1.0 \text{ ppb}$



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 field visit 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 a certain environmental or hydrologic event, such as a rise in gage height (affecting turbidity, for example) or increase in temperature (affecting DO, for example), can be identified as a significant fouling event, that event may be used as the start or end of the correction period. See Appendix 5 for examples of data corrections.

For all corrections, save the original and corrected data separately and document the reason for the correction. Data should be stored per each program's QAPP on DEP's network drive.

5.5.3.1 Manual Error Corrections – Error quantification closely follows USGS (Wagner et al. 2006). Numerically defining error is a necessary precursor to performing data correction and grading. Total error (E_T) is equal to the sum of the absolute values of fouling error (E_F) and calibration drift error (E_D):

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

Highly reliable discrete data may be used to bracket the time series of data for which the error is being determined, thereby allowing computation of 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 equation (1) to read as:

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

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

Fouling error (E_F) may be determined from equations (3):

$$(3) \quad E_F = (\text{Sensor}_{AC} - \text{Sensor}_{BC}) - (\text{FM}_{AC} - \text{FM}_{BC})$$

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

In steady-state conditions, the field meter readings in equation (3) are not needed, as there will be no change during device servicing ($\text{FM}_{AC} - \text{FM}_{BC} = 0$).



Calibration drift error (E_D) may be determined from equation (4):

$$(4) \quad E_D = V_{STD} - V_{Sensor}$$

Where

V_{STD} = Value of the standard or buffer

V_{Sensor} = Value measured by the Sensor.

When the recorded range of values is large, a correction based on percentage error should be applied instead, to avoid a significant and unintended effect on the correct record. For example, if the ending specific conductance measured was 100 $\mu S/cm$ but the E_T was -50 $\mu S/cm$, this would be a 50% adjustment using the calculated error, but only 10% when using the percent. Percent error is recommended for all specific conductance records, as well as any parameters that have a large range of values (e.g., temperature, DO, or turbidity).

Percent fouling error ($\%E_F$) may be determined from equation (5):

$$(5) \quad \% E_F = 100 (E_F / \text{Sensor}_{BC})$$

Percent calibration drift error ($\%E_D$) may be determined from equation (6):

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

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, such as from an error in calibration or from fouling from dirt from a single storm event. An offset correction is made by adding or subtracting a constant correction factor to the data (see Appendix 5.1 for graphical example). This can be done manually or by a computer program such as WRDB or R.

5.5.3.3 Drift and Fouling Corrections – Drift and fouling corrections are made when the monitor data are judged to be faulty by an incremental correction factor. A drift correction is made when a sensor loses sensitivity during deployment, resulting in the final field measurement being different from the recalibrated value (the amount of drift). 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 and interfere with readings.

Drift and fouling corrections are 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. (see Appendix 5.2 for graphical example). This can be done manually or by a computer program such as WRDB or R.



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. The review package includes the water quality monitoring data record, field notes, equipment logs, calibration details, documentation of data edit and correction decisions, and the name of the staff involved. The review package will be stored in each program's folder structure on the network drive.

Ideally, it is recommended that the review package be examined annually for completeness and accuracy by a second individual, such as a senior colleague or project manager.

5.5.5 Secondary QA of Data (Final Review, Grading & Approval) – All data used in producing the final water quality record 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; it is recommended that 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 a 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 (Fig. 3). The accuracy of water quality monitoring records in EGAD is defined by data grades (Table 6). Any data graded less than 'Good' should not be used for regulatory or attainment decision making. Data grades are included in the review package and coded in EGAD in the validation qualifier field. Comments applicable to the entire deployment (e.g., data quality comments) may be added as a 'Sample Event Comment' in EGAD. Additional comments specific to a data subset (e.g., missing data explanation) may be added in 'Sample Comments'.

If the total error (E_T) exceeds the maximum allowable limits (Table 7), the data should not be used for any purpose. 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. Data that fall between these limits and the data grade 'Good' (Table 6) require best professional judgement to determine if the data are of sufficient quality for the intended use, such as for relative trend analysis or screening.



Figure 3. EGAD flow chart.

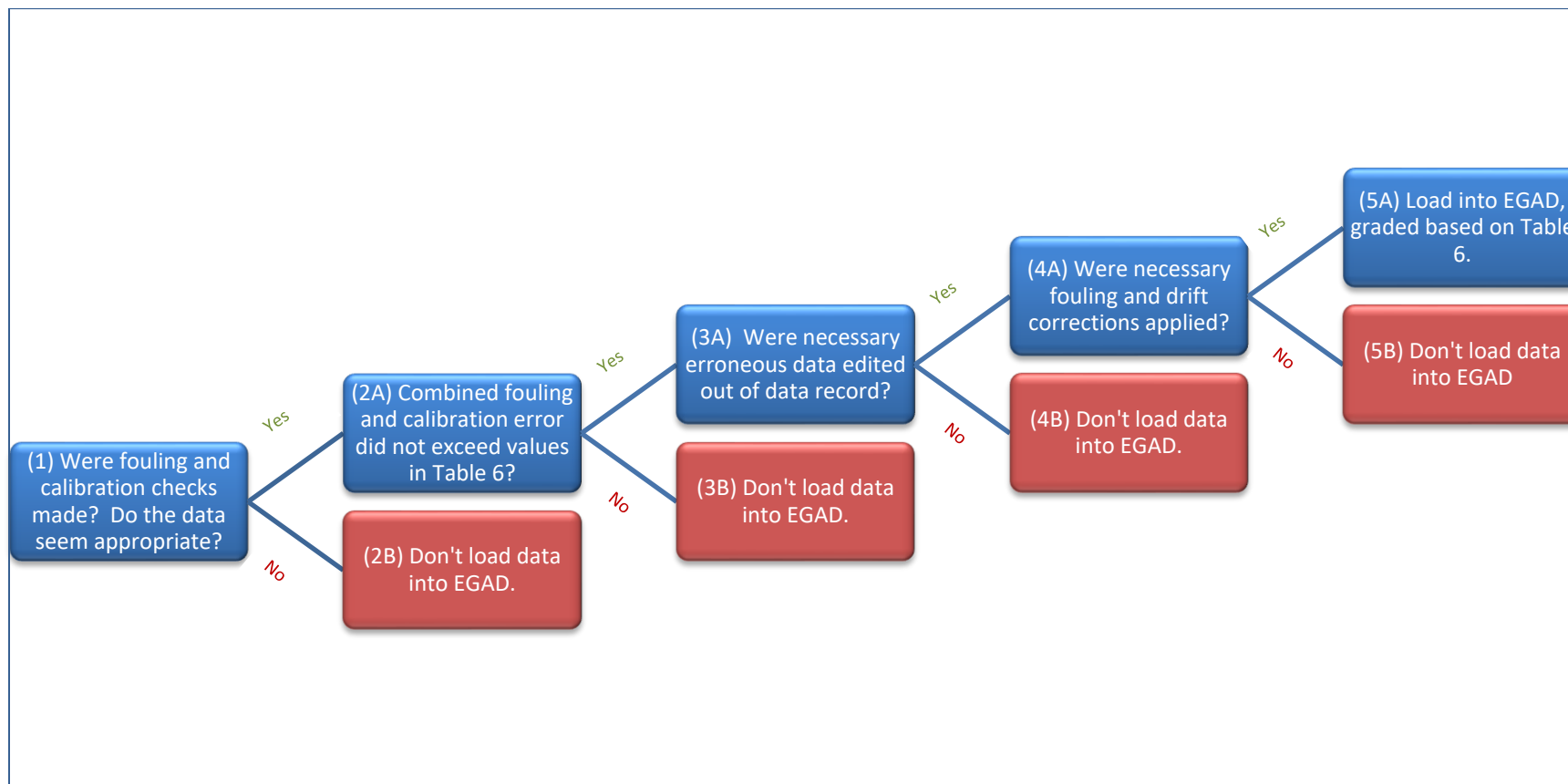




Table 6. Accuracy criteria for continuous water quality records (based on USGS (Wagner et al. 2006). Chlorophyll and Colored Dissolved Organic Matter (CDOM) values based on guidance from Turner sensors.

Measured field parameter	Ratings of accuracy (based on E_T , the 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
Water temperature	$\leq \pm 0.2^\circ\text{C}$	$> \pm 0.2 - 0.5^\circ\text{C}$	$> \pm 0.5 - 0.8^\circ\text{C}$	$> \pm 0.8^\circ\text{C}$
Specific conductance	$\leq \pm 3\%$	$> \pm 3 - 10\%$	$> \pm 10 - 15\%$	$> \pm 15\%$
Dissolved oxygen	$\leq \pm 0.3\text{ mg/L}$ or $\leq \pm 5\%$, whichever is greater	$> \pm 0.3 - 0.5\text{ mg/L}$ or $> \pm 5 - 10\%$, whichever is greater	$> \pm 0.5 - 0.8\text{ mg/L}$ or $> \pm 10 - 15\%$, whichever is greater	$> \pm 0.8\text{ mg/L}$ or $> \pm 15\%$, whichever is greater
pH	$\leq \pm 0.2$ units	$> \pm 0.2 - 0.4$ units	$> \pm 0.4 - 0.6$ units	$> \pm 0.6 - 0.8$ units
Turbidity	$\leq \pm 0.6$ turbidity units or $\leq \pm 5\%$, whichever is greater	$> \pm 0.6 - 2.0$ turbidity units or $> \pm 5 - 10\%$, whichever is greater	$> \pm 2.0 - 3.0$ turbidity units or $> \pm 10 - 15\%$, whichever is greater	$> \pm 3.0$ turbidity units or $> \pm 15\%$, whichever is greater
Chlorophyll	$\leq \pm 0.3\text{ }\mu\text{g/L}$	$> \pm 0.3 - 1.0\text{ }\mu\text{g/L}$	$> \pm 1.0 - 1.5\text{ }\mu\text{g/L}$	$> \pm 1.5\text{ }\mu\text{g/L}$
Colored Dissolved Organic Matter	$\leq \pm 1.5\text{ ppb}$	$> \pm 1.5 - 3.0\text{ ppb}$	$> \pm 3.0 - 4.5\text{ ppb}$	$> \pm 4.5\text{ ppb}$

Table 7. Maximum allowable limits for overall sensor drift (E_T). If total error (E_T) exceeds these limits, the data should not be used for any purpose. Data that fall between these minimum standards and data grade 'Good' in Table 6 require professional judgement to determine if the data are of sufficient quality for the intended use, such as for relative trend analysis or screening.

Field Parameter	Maximum Allowable Limits for E_T
Temperature	$\pm 2.0^\circ\text{C}$
Specific Conductance/Salinity	$\pm 15\%$
pH	± 0.8 units
Dissolved Oxygen	$\pm 2.0\text{ mg/L}$ or $\pm 20\%$, whichever is greater
Turbidity	$\pm 3.0\text{ NTU}$ or $\pm 30\%$, whichever is greater
Chlorophyll	$\pm 1.5\text{ }\mu\text{g/L}$
Colored Dissolved Organic Matter (CDOM)	$\pm 5.0\text{ ppb}$

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, review package, equipment logs, etc.) be archived within the program's folder structure on a DEP network drive (NOT your personal C:\ drive or OneDrive). Original paper copies of project files are to be archived in an organized manner per the 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 to 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 each program's QAPP.

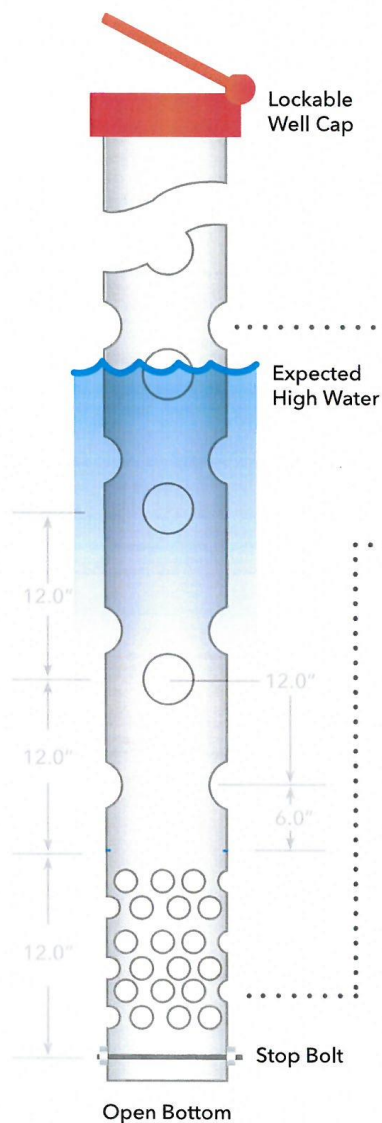


Appendix 1. References

- Exowater. 2014. Exo Long Term Monitoring Guide. YSI. EXOwater.com URL:
<https://www.ysi.com/File%20Library/Documents/Guides/Long-Term-Deployment-Tube-Guide.pdf>.
- Illinois Environmental Protection Agency (IL EPA). 2015. Standard Operating Procedure for Continuous Monitoring of Water Quality Illinois Environmental Protection Agency Bureau of Water Document Control Number 202.
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- U.S. Geological Service (USGS). 2023. Dissolved Oxygen Solubility Tables. Accessed 1/10/2023. URL: <https://water.usgs.gov/water-resources/software/DOTABLES/>.
- Wagner, R.J., Boulger, R.W., Jr., Oblinger, C.J. and Smith, B. A. 2006. Guidelines and standard procedures for continuous water-quality monitors-station operation, record computation, and data reporting. U.S. Geological Survey Techniques and Methods 1-D3, 51 p. + 8 attachments. URL: <https://pubs.usgs.gov/tm/2006/tm1D3/>.

Appendix 2. EXO Long Term Monitoring Guide.

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

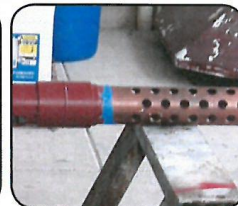
Vent or tube flushing hole pattern:
2.5" internal diameter.

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°.

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



Mounted to Pier

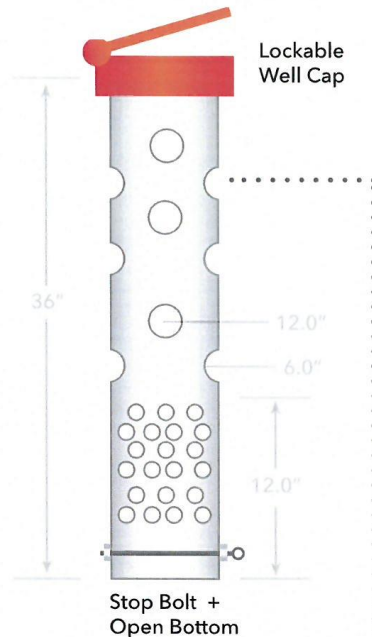


Copper Design

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

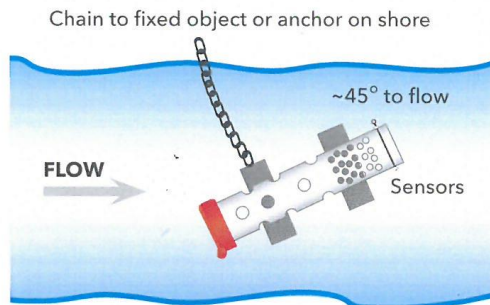
exo™ Long Term Monitoring Guide Horizontal Tube Deployments



Shows exposed sensors.
No debris deployments only.

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



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 Techniques and Methods, book 9, chap. A6.2 Dissolved Oxygen (USGS 2020), or use the USGS DO Tables (<https://water.usgs.gov/water-resources/software/DOTABLES/>)

Table 6.2-2. Solubility of oxygen in freshwater at various temperatures and pressures.

[Solubility shown in milligrams per liter, values are based on equations published by Benson and Krause (1980, 1984); Temp. (°C), temperature in degrees Celsius; solubility values for atmospheric pressures from 600 to 695 millimeters of mercury are after the values for 0-40 °C]

Temp. (deg C)	Atmospheric pressure, in millimeters of mercury																			
	700	705	710	715	720	725	730	735	740	745	750	755	760	765	770	775	780	785	790	795
0.0	13.46	13.56	13.65	13.75	13.85	13.94	14.04	14.14	14.23	14.33	14.43	14.52	14.62	14.72	14.81	14.91	15.01	15.10	15.20	15.30
0.5	13.27	13.37	13.46	13.56	13.65	13.75	13.84	13.94	14.03	14.13	14.23	14.32	14.42	14.51	14.61	14.70	14.80	14.89	14.99	15.08
1.0	13.09	13.18	13.28	13.37	13.46	13.56	13.65	13.75	13.84	13.93	14.03	14.12	14.22	14.31	14.40	14.50	14.59	14.69	14.78	14.87
1.5	12.91	13.00	13.09	13.19	13.28	13.37	13.46	13.56	13.65	13.74	13.84	13.93	14.02	14.11	14.21	14.30	14.39	14.48	14.58	14.67
2.0	12.73	12.82	12.91	13.01	13.10	13.19	13.28	13.37	13.46	13.56	13.65	13.74	13.83	13.92	14.01	14.10	14.20	14.29	14.38	14.47
2.5	12.56	12.65	12.74	12.83	12.92	13.01	13.10	13.19	13.28	13.37	13.46	13.55	13.64	13.73	13.82	13.91	14.00	14.10	14.19	14.28
3.0	12.39	12.48	12.57	12.66	12.75	12.84	12.93	13.02	13.10	13.19	13.28	13.37	13.46	13.55	13.64	13.73	13.82	13.91	14.00	14.09
3.5	12.23	12.31	12.40	12.49	12.58	12.67	12.75	12.84	12.93	13.02	13.11	13.19	13.28	13.37	13.46	13.55	13.63	13.72	13.81	13.90
4.0	12.07	12.15	12.24	12.33	12.41	12.50	12.59	12.67	12.76	12.85	12.93	13.02	13.11	13.20	13.28	13.37	13.46	13.54	13.63	13.72
4.5	11.91	11.99	12.08	12.17	12.25	12.34	12.42	12.51	12.59	12.68	12.77	12.85	12.94	13.02	13.11	13.20	13.28	13.37	13.45	13.54
5.0	11.75	11.84	11.92	12.01	12.09	12.18	12.26	12.35	12.43	12.52	12.60	12.69	12.77	12.86	12.94	13.03	13.11	13.19	13.28	13.36
5.5	11.60	11.69	11.77	11.86	11.94	12.02	12.11	12.19	12.27	12.36	12.44	12.52	12.61	12.69	12.78	12.86	12.94	13.03	13.11	13.19
6.0	11.46	11.54	11.62	11.70	11.79	11.87	11.95	12.04	12.12	12.20	12.28	12.37	12.45	12.53	12.61	12.70	12.78	12.86	12.94	13.03
6.5	11.31	11.39	11.48	11.56	11.64	11.72	11.80	11.88	11.97	12.05	12.13	12.21	12.29	12.37	12.46	12.54	12.62	12.70	12.78	12.86
7.0	11.17	11.25	11.33	11.41	11.49	11.58	11.66	11.74	11.82	11.90	11.98	12.06	12.14	12.22	12.30	12.38	12.46	12.54	12.62	12.70
7.5	11.03	11.11	11.19	11.27	11.35	11.43	11.51	11.59	11.67	11.75	11.83	11.91	11.99	12.07	12.15	12.23	12.31	12.39	12.47	12.55
8.0	10.90	10.98	11.06	11.14	11.21	11.29	11.37	11.45	11.53	11.61	11.69	11.76	11.84	11.92	12.00	12.08	12.16	12.24	12.32	12.39
8.5	10.77	10.84	10.92	11.00	11.08	11.16	11.23	11.31	11.39	11.47	11.54	11.62	11.70	11.78	11.86	11.93	12.01	12.09	12.17	12.24
9.0	10.64	10.71	10.79	10.87	10.94	11.02	11.10	11.18	11.25	11.33	11.41	11.48	11.56	11.64	11.71	11.79	11.87	11.94	12.02	12.10
9.5	10.51	10.59	10.66	10.74	10.81	10.89	10.97	11.04	11.12	11.19	11.27	11.35	11.42	11.50	11.57	11.65	11.73	11.80	11.88	11.95
10.0	10.39	10.46	10.54	10.61	10.69	10.76	10.84	10.91	10.99	11.06	11.14	11.21	11.29	11.36	11.44	11.51	11.59	11.66	11.74	11.81
10.5	10.26	10.34	10.41	10.49	10.56	10.64	10.71	10.78	10.86	10.93	11.01	11.08	11.16	11.23	11.30	11.38	11.45	11.53	11.60	11.68
11.0	10.15	10.22	10.29	10.37	10.44	10.51	10.59	10.66	10.73	10.81	10.88	10.95	11.03	11.10	11.17	11.25	11.32	11.39	11.47	11.54
11.5	10.03	10.10	10.17	10.25	10.32	10.39	10.47	10.54	10.61	10.68	10.76	10.83	10.90	10.97	11.05	11.12	11.19	11.26	11.34	11.41
12.0	9.91	9.99	10.06	10.13	10.20	10.27	10.35	10.42	10.49	10.56	10.63	10.71	10.78	10.85	10.92	10.99	11.06	11.14	11.21	11.28
12.5	9.80	9.87	9.94	10.02	10.09	10.16	10.23	10.30	10.37	10.44	10.51	10.58	10.66	10.73	10.80	10.87	10.94	11.01	11.08	11.15
13.0	9.69	9.76	9.83	9.90	9.97	10.04	10.11	10.19	10.26	10.33	10.40	10.47	10.54	10.61	10.68	10.75	10.82	10.89	10.96	11.03
13.5	9.59	9.65	9.72	9.79	9.86	9.93	10.00	10.07	10.14	10.21	10.28	10.35	10.42	10.49	10.56	10.63	10.70	10.77	10.84	10.91
14.0	9.48	9.55	9.62	9.69	9.76	9.82	9.89	9.96	10.03	10.10	10.17	10.24	10.31	10.37	10.44	10.51	10.58	10.65	10.72	10.79
14.5	9.38	9.44	9.51	9.58	9.65	9.72	9.78	9.85	9.92	9.99	10.06	10.13	10.19	10.26	10.33	10.40	10.47	10.53	10.60	10.67

Table 6.2-2. Solubility of oxygen in freshwater at various temperatures and pressures.—Continued

[Solubility shown in milligrams per liter; values are based on equations published by Benson and Krause (1980, 1984); Temp. (°C), temperature in degrees Celsius; solubility values for atmospheric pressures from 600 to 695 millimeters of mercury are after the values for (0-40 °C)]

Temp. (deg C)	Atmospheric pressure, in millimeters of mercury																			
	700	705	710	715	720	725	730	735	740	745	750	755	760	765	770	775	780	785	790	795
15.0	9.27	9.34	9.41	9.48	9.54	9.61	9.68	9.75	9.81	9.88	9.95	10.02	10.08	10.15	10.22	10.29	10.35	10.42	10.49	10.56
15.5	9.18	9.24	9.31	9.38	9.44	9.51	9.58	9.64	9.71	9.78	9.84	9.91	9.98	10.04	10.11	10.18	10.24	10.31	10.38	10.44
16.0	9.08	9.14	9.21	9.28	9.34	9.41	9.47	9.54	9.61	9.67	9.74	9.80	9.87	9.94	10.00	10.07	10.13	10.20	10.27	10.33
16.5	8.98	9.05	9.11	9.18	9.24	9.31	9.37	9.44	9.50	9.57	9.64	9.70	9.77	9.83	9.90	9.96	10.03	10.09	10.16	10.22
17.0	8.89	8.95	9.02	9.08	9.15	9.21	9.28	9.34	9.41	9.47	9.54	9.60	9.66	9.73	9.79	9.86	9.92	9.99	10.05	10.12
17.5	8.80	8.86	8.92	8.99	9.05	9.12	9.18	9.24	9.31	9.37	9.44	9.50	9.57	9.63	9.69	9.76	9.82	9.89	9.95	10.01
18.0	8.70	8.77	8.83	8.90	8.96	9.02	9.09	9.15	9.21	9.28	9.34	9.40	9.47	9.53	9.59	9.66	9.72	9.78	9.85	9.91
18.5	8.62	8.68	8.74	8.80	8.87	8.93	8.99	9.06	9.12	9.18	9.24	9.31	9.37	9.43	9.50	9.56	9.62	9.69	9.75	9.81
19.0	8.53	8.59	8.65	8.72	8.78	8.84	8.90	8.96	9.03	9.09	9.15	9.21	9.28	9.34	9.40	9.46	9.53	9.59	9.65	9.71
19.5	8.44	8.50	8.57	8.63	8.69	8.75	8.81	8.87	8.94	9.00	9.06	9.12	9.18	9.25	9.31	9.37	9.43	9.49	9.55	9.62
20.0	8.36	8.42	8.48	8.54	8.60	8.66	8.73	8.79	8.85	8.91	8.97	9.03	9.09	9.15	9.21	9.28	9.34	9.40	9.46	9.52
20.5	8.28	8.34	8.40	8.46	8.52	8.58	8.64	8.70	8.76	8.82	8.88	8.94	9.00	9.06	9.12	9.18	9.25	9.31	9.37	9.43
21.0	8.19	8.25	8.31	8.37	8.43	8.49	8.55	8.61	8.67	8.73	8.79	8.85	8.92	8.98	9.04	9.10	9.16	9.22	9.28	9.34
21.5	8.11	8.17	8.23	8.29	8.35	8.41	8.47	8.53	8.59	8.65	8.71	8.77	8.83	8.89	8.95	9.01	9.07	9.13	9.19	9.25
22.0	8.04	8.09	8.15	8.21	8.27	8.33	8.39	8.45	8.51	8.57	8.63	8.68	8.74	8.80	8.86	8.92	8.98	9.04	9.10	9.16
22.5	7.96	8.02	8.08	8.13	8.19	8.25	8.31	8.37	8.43	8.48	8.54	8.60	8.66	8.72	8.78	8.84	8.89	8.95	9.01	9.07
23.0	7.88	7.94	8.00	8.06	8.11	8.17	8.23	8.29	8.35	8.40	8.46	8.52	8.58	8.64	8.69	8.75	8.81	8.87	8.93	8.98
23.5	7.81	7.86	7.92	7.98	8.04	8.09	8.15	8.21	8.27	8.33	8.38	8.44	8.50	8.56	8.61	8.67	8.73	8.79	8.84	8.90
24.0	7.73	7.79	7.85	7.90	7.96	8.02	8.08	8.13	8.19	8.25	8.30	8.36	8.42	8.48	8.53	8.59	8.65	8.70	8.76	8.82
24.5	7.66	7.72	7.77	7.83	7.89	7.94	8.00	8.06	8.11	8.17	8.23	8.28	8.34	8.40	8.45	8.51	8.57	8.62	8.68	8.74
25.0	7.59	7.65	7.70	7.76	7.81	7.87	7.93	7.98	8.04	8.10	8.15	8.21	8.26	8.32	8.38	8.43	8.49	8.54	8.60	8.66
25.5	7.52	7.58	7.63	7.69	7.74	7.80	7.85	7.91	7.97	8.02	8.08	8.13	8.19	8.24	8.30	8.35	8.41	8.47	8.52	8.58
26.0	7.45	7.51	7.56	7.62	7.67	7.73	7.78	7.84	7.89	7.95	8.00	8.06	8.11	8.17	8.22	8.28	8.33	8.39	8.44	8.50
26.5	7.38	7.44	7.49	7.55	7.60	7.66	7.71	7.77	7.82	7.88	7.93	7.99	8.04	8.10	8.15	8.20	8.26	8.31	8.37	8.42
27.0	7.32	7.37	7.43	7.48	7.53	7.59	7.64	7.70	7.75	7.81	7.86	7.91	7.97	8.02	8.08	8.13	8.19	8.24	8.29	8.35
27.5	7.25	7.30	7.36	7.41	7.47	7.52	7.57	7.63	7.68	7.74	7.79	7.84	7.90	7.95	8.01	8.06	8.11	8.17	8.22	8.27
28.0	7.19	7.24	7.29	7.35	7.40	7.45	7.51	7.56	7.61	7.67	7.72	7.77	7.83	7.88	7.93	7.99	8.04	8.10	8.15	8.20
28.5	7.12	7.18	7.23	7.28	7.33	7.39	7.44	7.49	7.55	7.60	7.65	7.71	7.76	7.81	7.87	7.92	7.97	8.02	8.08	8.13
29.0	7.06	7.11	7.16	7.22	7.27	7.32	7.38	7.43	7.48	7.53	7.59	7.64	7.69	7.74	7.80	7.85	7.90	7.95	8.01	8.06
29.5	7.00	7.05	7.10	7.15	7.21	7.26	7.31	7.36	7.42	7.47	7.52	7.57	7.62	7.68	7.73	7.78	7.83	7.89	7.94	7.99

Table 6.2-2. Solubility of oxygen in freshwater at various temperatures and pressures.—Continued

[Solubility shown in milligrams per liter; values are based on equations published by Benson and Krause (1980, 1984); Temp. (°C), temperature in degrees Celsius; solubility values for atmospheric pressures from 600 to 695 millimeters of mercury are after the values for 0-40 °C]

Temp. (deg C)	Atmospheric pressure, in millimeters of mercury																			
	700	705	710	715	720	725	730	735	740	745	750	755	760	765	770	775	780	785	790	795
30.0	6.94	6.99	7.04	7.09	7.14	7.20	7.25	7.30	7.35	7.40	7.46	7.51	7.56	7.61	7.66	7.71	7.77	7.82	7.87	7.92
30.5	6.88	6.93	6.98	7.03	7.08	7.13	7.19	7.24	7.29	7.34	7.39	7.44	7.49	7.55	7.60	7.65	7.70	7.75	7.80	7.85
31.0	6.82	6.87	6.92	6.97	7.02	7.07	7.12	7.17	7.23	7.28	7.33	7.38	7.43	7.48	7.53	7.58	7.63	7.69	7.74	7.79
31.5	6.76	6.81	6.86	6.91	6.96	7.01	7.06	7.11	7.16	7.21	7.27	7.32	7.37	7.42	7.47	7.52	7.57	7.62	7.67	7.72
32.0	6.70	6.75	6.80	6.85	6.90	6.95	7.00	7.05	7.10	7.15	7.20	7.25	7.30	7.36	7.41	7.46	7.51	7.56	7.61	7.66
32.5	6.64	6.69	6.74	6.79	6.84	6.89	6.94	6.99	7.04	7.09	7.14	7.19	7.24	7.29	7.34	7.39	7.44	7.49	7.54	7.59
33.0	6.59	6.64	6.69	6.74	6.79	6.84	6.89	6.93	6.98	7.03	7.08	7.13	7.18	7.23	7.28	7.33	7.38	7.43	7.48	7.53
33.5	6.53	6.58	6.63	6.68	6.73	6.78	6.83	6.88	6.93	6.98	7.02	7.07	7.12	7.17	7.22	7.27	7.32	7.37	7.42	7.47
34.0	6.48	6.53	6.57	6.62	6.67	6.72	6.77	6.82	6.87	6.92	6.97	7.02	7.06	7.11	7.16	7.21	7.26	7.31	7.36	7.41
34.5	6.42	6.47	6.52	6.57	6.62	6.67	6.71	6.76	6.81	6.86	6.91	6.96	7.01	7.06	7.10	7.15	7.20	7.25	7.30	7.35
35.0	6.37	6.42	6.47	6.51	6.56	6.61	6.66	6.71	6.76	6.80	6.85	6.90	6.95	7.00	7.05	7.09	7.14	7.19	7.24	7.29
35.5	6.32	6.36	6.41	6.46	6.51	6.56	6.60	6.65	6.70	6.75	6.80	6.84	6.89	6.94	6.99	7.04	7.08	7.13	7.18	7.23
36.0	6.26	6.31	6.36	6.41	6.45	6.50	6.55	6.60	6.65	6.69	6.74	6.79	6.84	6.88	6.93	6.98	7.03	7.08	7.12	7.17
36.5	6.21	6.26	6.31	6.35	6.40	6.45	6.50	6.54	6.59	6.64	6.69	6.73	6.78	6.83	6.88	6.92	6.97	7.02	7.07	7.11
37.0	6.16	6.21	6.26	6.30	6.35	6.40	6.44	6.49	6.54	6.59	6.63	6.68	6.73	6.77	6.82	6.87	6.92	6.96	7.01	7.06
37.5	6.11	6.16	6.20	6.25	6.30	6.35	6.39	6.44	6.49	6.53	6.58	6.63	6.67	6.72	6.77	6.81	6.86	6.91	6.95	7.00
38.0	6.06	6.11	6.15	6.20	6.25	6.29	6.34	6.39	6.43	6.48	6.53	6.57	6.62	6.67	6.71	6.76	6.81	6.85	6.90	6.95
38.5	6.01	6.06	6.10	6.15	6.20	6.24	6.29	6.34	6.38	6.43	6.47	6.52	6.57	6.61	6.66	6.71	6.75	6.80	6.84	6.89
39.0	5.96	6.01	6.05	6.10	6.15	6.19	6.24	6.29	6.33	6.38	6.42	6.47	6.52	6.56	6.61	6.65	6.70	6.75	6.79	6.84
39.5	5.91	5.96	6.01	6.05	6.10	6.14	6.19	6.23	6.28	6.33	6.37	6.42	6.46	6.51	6.56	6.60	6.65	6.69	6.74	6.78
40.0	5.87	5.91	5.96	6.00	6.05	6.09	6.14	6.19	6.23	6.28	6.32	6.37	6.41	6.46	6.50	6.55	6.59	6.64	6.69	6.73

Table 6.2-2. Solubility of oxygen in freshwater at various temperatures and pressures.—Continued

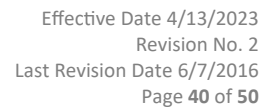
[Solubility shown in milligrams per liter; values are based on equations published by Benson and Krause (1980, 1984); Temp. (°C), temperature in degrees Celsius]

Temp. (deg C)	Atmospheric pressure, in millimeters of mercury																			
	600	605	610	615	620	625	630	635	640	645	650	655	660	665	670	675	680	685	690	695
0.0	11.53	11.62	11.72	11.82	11.91	12.01	12.11	12.20	12.30	12.40	12.49	12.59	12.69	12.78	12.88	12.98	13.07	13.17	13.27	13.36
0.5	11.36	11.46	11.56	11.65	11.75	11.84	11.94	12.03	12.13	12.22	12.32	12.41	12.51	12.60	12.70	12.80	12.89	12.99	13.08	13.18
1.0	11.21	11.30	11.39	11.49	11.58	11.68	11.77	11.86	11.96	12.05	12.15	12.24	12.34	12.43	12.52	12.62	12.71	12.81	12.90	12.99
1.5	11.05	11.14	11.24	11.33	11.42	11.52	11.61	11.70	11.79	11.89	11.98	12.07	12.17	12.26	12.35	12.44	12.54	12.63	12.72	12.81
2.0	10.90	10.99	11.08	11.18	11.27	11.36	11.45	11.54	11.63	11.72	11.82	11.91	12.00	12.09	12.18	12.27	12.37	12.46	12.55	12.64
2.5	10.75	10.84	10.93	11.02	11.11	11.20	11.29	11.39	11.48	11.57	11.66	11.75	11.84	11.93	12.02	12.11	12.20	12.29	12.38	12.47
3.0	10.61	10.70	10.79	10.88	10.96	11.05	11.14	11.23	11.32	11.41	11.50	11.59	11.68	11.77	11.86	11.95	12.03	12.12	12.21	12.30
3.5	10.47	10.55	10.64	10.73	10.82	10.91	10.99	11.08	11.17	11.26	11.35	11.43	11.52	11.61	11.70	11.79	11.87	11.96	12.05	12.14
4.0	10.33	10.42	10.50	10.59	10.68	10.76	10.85	10.94	11.02	11.11	11.20	11.28	11.37	11.46	11.54	11.63	11.72	11.81	11.89	11.98
4.5	10.19	10.28	10.36	10.45	10.54	10.62	10.71	10.79	10.88	10.97	11.05	11.14	11.22	11.31	11.39	11.48	11.57	11.65	11.74	11.82
5.0	10.06	10.15	10.23	10.32	10.40	10.48	10.57	10.65	10.74	10.82	10.91	10.99	11.08	11.16	11.25	11.33	11.42	11.50	11.59	11.67
5.5	9.93	10.02	10.10	10.18	10.27	10.35	10.43	10.52	10.60	10.68	10.77	10.85	10.94	11.02	11.10	11.19	11.27	11.35	11.44	11.52
6.0	9.80	9.89	9.97	10.05	10.14	10.22	10.30	10.38	10.47	10.55	10.63	10.71	10.80	10.88	10.96	11.04	11.13	11.21	11.29	11.37
6.5	9.68	9.76	9.84	9.93	10.01	10.09	10.17	10.25	10.33	10.42	10.50	10.58	10.66	10.74	10.82	10.91	10.99	11.07	11.15	11.23
7.0	9.56	9.64	9.72	9.80	9.88	9.96	10.04	10.12	10.20	10.29	10.37	10.45	10.53	10.61	10.69	10.77	10.85	10.93	11.01	11.09
7.5	9.44	9.52	9.60	9.68	9.76	9.84	9.92	10.00	10.08	10.16	10.24	10.32	10.40	10.48	10.56	10.64	10.72	10.80	10.87	10.95
8.0	9.33	9.40	9.48	9.56	9.64	9.72	9.80	9.88	9.95	10.03	10.11	10.19	10.27	10.35	10.43	10.51	10.58	10.66	10.74	10.82
8.5	9.21	9.29	9.37	9.44	9.52	9.60	9.68	9.76	9.83	9.91	9.99	10.07	10.14	10.22	10.30	10.38	10.46	10.53	10.61	10.69
9.0	9.10	9.18	9.25	9.33	9.41	9.48	9.56	9.64	9.71	9.79	9.87	9.95	10.02	10.10	10.18	10.25	10.33	10.41	10.48	10.56
9.5	8.99	9.07	9.14	9.22	9.29	9.37	9.45	9.52	9.60	9.67	9.75	9.83	9.90	9.98	10.05	10.13	10.21	10.28	10.36	10.43
10.0	8.88	8.96	9.03	9.11	9.18	9.26	9.33	9.41	9.49	9.56	9.64	9.71	9.79	9.86	9.94	10.01	10.09	10.16	10.24	10.31
10.5	8.78	8.85	8.93	9.00	9.08	9.15	9.23	9.30	9.37	9.45	9.52	9.60	9.67	9.75	9.82	9.89	9.97	10.04	10.12	10.19
11.0	8.68	8.75	8.82	8.90	8.97	9.04	9.12	9.19	9.26	9.34	9.41	9.48	9.56	9.63	9.71	9.78	9.85	9.93	10.00	10.07
11.5	8.58	8.65	8.72	8.79	8.87	8.94	9.01	9.08	9.16	9.23	9.30	9.38	9.45	9.52	9.59	9.67	9.74	9.81	9.88	9.96
12.0	8.48	8.55	8.62	8.69	8.77	8.84	8.91	8.98	9.05	9.12	9.20	9.27	9.34	9.41	9.48	9.56	9.63	9.70	9.77	9.84
12.5	8.38	8.45	8.52	8.59	8.67	8.74	8.81	8.88	8.95	9.02	9.09	9.16	9.23	9.31	9.38	9.45	9.52	9.59	9.66	9.73
13.0	8.29	8.36	8.43	8.50	8.57	8.64	8.71	8.78	8.85	8.92	8.99	9.06	9.13	9.20	9.27	9.34	9.41	9.48	9.55	9.62
13.5	8.19	8.26	8.33	8.40	8.47	8.54	8.61	8.68	8.75	8.82	8.89	8.96	9.03	9.10	9.17	9.24	9.31	9.38	9.45	9.52
14.0	8.10	8.17	8.24	8.31	8.38	8.45	8.52	8.58	8.65	8.72	8.79	8.86	8.93	9.00	9.07	9.14	9.20	9.27	9.34	9.41
14.5	8.01	8.08	8.15	8.22	8.29	8.35	8.42	8.49	8.56	8.63	8.69	8.76	8.83	8.90	8.97	9.04	9.10	9.17	9.24	9.31
15.0	7.93	7.99	8.06	8.13	8.20	8.26	8.33	8.40	8.47	8.53	8.60	8.67	8.74	8.80	8.87	8.94	9.00	9.07	9.14	9.21

Table 6.2-2. Solubility of oxygen in freshwater at various temperatures and pressures.—Continued

[Solubility shown in milligrams per liter; values are based on equations published by Benson and Krause (1980, 1984); Temp. (°C), temperature in degrees Celsius]

Temp. (deg C)	Atmospheric pressure, in millimeters of mercury																			
	600	605	610	615	620	625	630	635	640	645	650	655	660	665	670	675	680	685	690	695
15.5	7.84	7.91	7.97	8.04	8.11	8.17	8.24	8.31	8.37	8.44	8.51	8.57	8.64	8.71	8.77	8.84	8.91	8.97	9.04	9.11
16.0	7.76	7.82	7.89	7.95	8.02	8.09	8.15	8.22	8.28	8.35	8.42	8.48	8.55	8.61	8.68	8.75	8.81	8.88	8.95	9.01
16.5	7.67	7.74	7.80	7.87	7.93	8.00	8.07	8.13	8.20	8.26	8.33	8.39	8.46	8.52	8.59	8.65	8.72	8.79	8.85	8.92
17.0	7.59	7.66	7.72	7.79	7.85	7.92	7.98	8.05	8.11	8.17	8.24	8.30	8.37	8.43	8.50	8.56	8.63	8.69	8.76	8.82
17.5	7.51	7.58	7.64	7.70	7.77	7.83	7.90	7.96	8.03	8.09	8.15	8.22	8.28	8.35	8.41	8.47	8.54	8.60	8.67	8.73
18.0	7.43	7.50	7.56	7.62	7.69	7.75	7.81	7.88	7.94	8.01	8.07	8.13	8.20	8.26	8.32	8.39	8.45	8.51	8.58	8.64
18.5	7.36	7.42	7.48	7.55	7.61	7.67	7.73	7.80	7.86	7.92	7.99	8.05	8.11	8.18	8.24	8.30	8.36	8.43	8.49	8.55
19.0	7.28	7.34	7.41	7.47	7.53	7.59	7.66	7.72	7.78	7.84	7.90	7.97	8.03	8.09	8.15	8.22	8.28	8.34	8.40	8.47
19.5	7.21	7.27	7.33	7.39	7.45	7.52	7.58	7.64	7.70	7.76	7.82	7.89	7.95	8.01	8.07	8.13	8.20	8.26	8.32	8.38
20.0	7.13	7.20	7.26	7.32	7.38	7.44	7.50	7.56	7.62	7.68	7.75	7.81	7.87	7.93	7.99	8.05	8.11	8.17	8.24	8.30
20.5	7.06	7.12	7.18	7.24	7.31	7.37	7.43	7.49	7.55	7.61	7.67	7.73	7.79	7.85	7.91	7.97	8.03	8.09	8.15	8.21
21.0	6.99	7.05	7.11	7.17	7.23	7.29	7.35	7.41	7.47	7.53	7.59	7.65	7.71	7.77	7.83	7.89	7.95	8.01	8.07	8.13
21.5	6.92	6.98	7.04	7.10	7.16	7.22	7.28	7.34	7.40	7.46	7.52	7.58	7.64	7.70	7.76	7.82	7.88	7.94	7.99	8.05
22.0	6.85	6.91	6.97	7.03	7.09	7.15	7.21	7.27	7.33	7.39	7.45	7.50	7.56	7.62	7.68	7.74	7.80	7.86	7.92	7.98
22.5	6.79	6.85	6.90	6.96	7.02	7.08	7.14	7.20	7.26	7.31	7.37	7.43	7.49	7.55	7.61	7.67	7.72	7.78	7.84	7.90
23.0	6.72	6.78	6.84	6.90	6.95	7.01	7.07	7.13	7.19	7.24	7.30	7.36	7.42	7.48	7.53	7.59	7.65	7.71	7.77	7.82
23.5	6.66	6.71	6.77	6.83	6.89	6.94	7.00	7.06	7.12	7.17	7.23	7.29	7.35	7.40	7.46	7.52	7.58	7.63	7.69	7.75
24.0	6.59	6.65	6.71	6.76	6.82	6.88	6.94	6.99	7.05	7.11	7.16	7.22	7.28	7.33	7.39	7.45	7.51	7.56	7.62	7.68
24.5	6.53	6.59	6.64	6.70	6.76	6.81	6.87	6.93	6.98	7.04	7.10	7.15	7.21	7.27	7.32	7.38	7.44	7.49	7.55	7.61
25.0	6.47	6.52	6.58	6.64	6.69	6.75	6.81	6.86	6.92	6.97	7.03	7.09	7.14	7.20	7.25	7.31	7.37	7.42	7.48	7.53
25.5	6.41	6.46	6.52	6.57	6.63	6.69	6.74	6.80	6.85	6.91	6.96	7.02	7.08	7.13	7.19	7.24	7.30	7.35	7.41	7.46
26.0	6.35	6.40	6.46	6.51	6.57	6.62	6.68	6.73	6.79	6.84	6.90	6.95	7.01	7.07	7.12	7.18	7.23	7.29	7.34	7.40
26.5	6.29	6.34	6.40	6.45	6.51	6.56	6.62	6.67	6.73	6.78	6.84	6.89	6.95	7.00	7.06	7.11	7.16	7.22	7.27	7.33
27.0	6.23	6.28	6.34	6.39	6.45	6.50	6.56	6.61	6.67	6.72	6.77	6.83	6.88	6.94	6.99	7.05	7.10	7.15	7.21	7.26
27.5	6.17	6.23	6.28	6.33	6.39	6.44	6.50	6.55	6.60	6.66	6.71	6.77	6.82	6.87	6.93	6.98	7.04	7.09	7.14	7.20
28.0	6.12	6.17	6.22	6.28	6.33	6.38	6.44	6.49	6.54	6.60	6.65	6.70	6.76	6.81	6.87	6.92	6.97	7.03	7.08	7.13
28.5	6.06	6.11	6.17	6.22	6.27	6.33	6.38	6.43	6.49	6.54	6.59	6.64	6.70	6.75	6.80	6.86	6.91	6.96	7.02	7.07
29.0	6.01	6.06	6.11	6.16	6.22	6.27	6.32	6.37	6.43	6.48	6.53	6.59	6.64	6.69	6.74	6.80	6.85	6.90	6.95	7.01
29.5	5.95	6.00	6.06	6.11	6.16	6.21	6.27	6.32	6.37	6.42	6.47	6.53	6.58	6.63	6.68	6.74	6.79	6.84	6.89	6.95
30.0	5.90	5.95	6.00	6.05	6.11	6.16	6.21	6.26	6.31	6.37	6.42	6.47	6.52	6.57	6.63	6.68	6.73	6.78	6.83	6.88
30.5	5.85	5.90	5.95	6.00	6.05	6.10	6.16	6.21	6.26	6.31	6.36	6.41	6.46	6.52	6.57	6.62	6.67	6.72	6.77	6.82



[Solubility shown in milligrams per liter; values are based on equations published by Benson and Krause (1980, 1984); Temp ($^{\circ}\text{C}$), temperature in degrees Celsius]

Temp. (deg C)	Atmospheric pressure, in millimeters of mercury																			
	600	605	610	615	620	625	630	635	640	645	650	655	660	665	670	675	680	685	690	695
31.0	5.79	5.85	5.90	5.95	6.00	6.05	6.10	6.15	6.20	6.25	6.31	6.36	6.41	6.46	6.51	6.56	6.61	6.66	6.71	6.77
31.5	5.74	5.79	5.84	5.90	5.95	6.00	6.05	6.10	6.15	6.20	6.25	6.30	6.35	6.40	6.45	6.50	6.55	6.61	6.66	6.71
32.0	5.69	5.74	5.79	5.84	5.89	5.94	5.99	6.04	6.10	6.15	6.20	6.25	6.30	6.35	6.40	6.45	6.50	6.55	6.60	6.65
32.5	5.64	5.69	5.74	5.79	5.84	5.89	5.94	5.99	6.04	6.09	6.14	6.19	6.24	6.29	6.34	6.39	6.44	6.49	6.54	6.59
33.0	5.59	5.64	5.69	5.74	5.79	5.84	5.89	5.94	5.99	6.04	6.09	6.14	6.19	6.24	6.29	6.34	6.39	6.44	6.49	6.54
33.5	5.54	5.59	5.64	5.69	5.74	5.79	5.84	5.89	5.94	5.99	6.04	6.09	6.14	6.19	6.24	6.28	6.33	6.38	6.43	6.48
34.0	5.50	5.54	5.59	5.64	5.69	5.74	5.79	5.84	5.89	5.94	5.99	6.04	6.08	6.13	6.18	6.23	6.28	6.33	6.38	6.43
34.5	5.45	5.50	5.55	5.59	5.64	5.69	5.74	5.79	5.84	5.89	5.94	5.98	6.03	6.08	6.13	6.18	6.23	6.28	6.32	6.37
35.0	5.40	5.45	5.50	5.55	5.59	5.64	5.69	5.74	5.79	5.84	5.88	5.93	5.98	6.03	6.08	6.13	6.18	6.22	6.27	6.32
35.5	5.35	5.40	5.45	5.50	5.55	5.59	5.64	5.69	5.74	5.79	5.84	5.88	5.93	5.98	6.03	6.08	6.12	6.17	6.22	6.27
36.0	5.31	5.36	5.40	5.45	5.50	5.55	5.60	5.64	5.69	5.74	5.79	5.83	5.88	5.93	5.98	6.02	6.07	6.12	6.17	6.22
36.5	5.26	5.31	5.36	5.41	5.45	5.50	5.55	5.60	5.64	5.69	5.74	5.78	5.83	5.88	5.93	5.97	6.02	6.07	6.12	6.16
37.0	5.22	5.27	5.31	5.36	5.41	5.45	5.50	5.55	5.60	5.64	5.69	5.74	5.78	5.83	5.88	5.93	5.97	6.02	6.07	6.11
37.5	5.17	5.22	5.27	5.31	5.36	5.41	5.45	5.50	5.55	5.60	5.64	5.69	5.74	5.78	5.83	5.88	5.92	5.97	6.02	6.06
38.0	5.13	5.18	5.22	5.27	5.32	5.36	5.41	5.46	5.50	5.55	5.60	5.64	5.69	5.73	5.78	5.83	5.87	5.92	5.97	6.01
38.5	5.09	5.13	5.18	5.22	5.27	5.32	5.36	5.41	5.46	5.50	5.55	5.59	5.64	5.69	5.73	5.78	5.83	5.87	5.92	5.97
39.0	5.04	5.09	5.13	5.18	5.23	5.27	5.32	5.36	5.41	5.46	5.50	5.55	5.59	5.64	5.69	5.73	5.78	5.82	5.87	5.92
39.5	5.00	5.05	5.09	5.14	5.18	5.23	5.27	5.32	5.37	5.41	5.46	5.50	5.55	5.59	5.64	5.69	5.73	5.78	5.82	5.87
40.0	4.96	5.00	5.05	5.09	5.14	5.18	5.23	5.28	5.32	5.37	5.41	5.46	5.50	5.55	5.59	5.64	5.69	5.73	5.78	5.82

Table 6.2-4. Salinity correction factors for dissolved oxygen in water (based on specific conductance).

[Factors are dimensionless; values are based on equations published by Benson and Krause (1984); Temp. (°C), temperature in degrees Celsius]

Temp. (deg C)	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius														
	0	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000	13,000	14,000
0.0	1.0000	0.9961	0.9922	0.9882	0.9843	0.9804	0.9764	0.9724	0.9684	0.9644	0.9604	0.9564	0.9524	0.9483	0.9443
1.0	1.0000	0.9961	0.9923	0.9884	0.9845	0.9805	0.9766	0.9727	0.9687	0.9648	0.9608	0.9568	0.9528	0.9488	0.9448
2.0	1.0000	0.9962	0.9923	0.9885	0.9846	0.9807	0.9768	0.9729	0.9690	0.9651	0.9611	0.9572	0.9532	0.9493	0.9453
3.0	1.0000	0.9962	0.9924	0.9886	0.9847	0.9809	0.9770	0.9732	0.9693	0.9654	0.9615	0.9576	0.9536	0.9497	0.9458
4.0	1.0000	0.9962	0.9925	0.9887	0.9849	0.9811	0.9772	0.9734	0.9696	0.9657	0.9618	0.9579	0.9541	0.9502	0.9462
5.0	1.0000	0.9963	0.9925	0.9888	0.9850	0.9812	0.9774	0.9736	0.9698	0.9660	0.9622	0.9583	0.9545	0.9506	0.9467
6.0	1.0000	0.9963	0.9926	0.9889	0.9851	0.9814	0.9776	0.9739	0.9701	0.9663	0.9625	0.9587	0.9549	0.9510	0.9472
7.0	1.0000	0.9963	0.9927	0.9890	0.9853	0.9816	0.9778	0.9741	0.9703	0.9666	0.9628	0.9590	0.9552	0.9514	0.9476
8.0	1.0000	0.9964	0.9927	0.9891	0.9854	0.9817	0.9780	0.9743	0.9706	0.9669	0.9631	0.9594	0.9556	0.9519	0.9481
9.0	1.0000	0.9964	0.9928	0.9892	0.9855	0.9819	0.9782	0.9745	0.9708	0.9672	0.9634	0.9597	0.9560	0.9523	0.9485
10.0	1.0000	0.9964	0.9928	0.9893	0.9856	0.9820	0.9784	0.9747	0.9711	0.9674	0.9637	0.9601	0.9564	0.9527	0.9489
11.0	1.0000	0.9965	0.9929	0.9893	0.9858	0.9822	0.9786	0.9750	0.9713	0.9677	0.9640	0.9604	0.9567	0.9530	0.9494
12.0	1.0000	0.9965	0.9930	0.9894	0.9859	0.9823	0.9787	0.9752	0.9716	0.9680	0.9643	0.9607	0.9571	0.9534	0.9498
13.0	1.0000	0.9965	0.9930	0.9895	0.9860	0.9825	0.9789	0.9754	0.9718	0.9682	0.9646	0.9610	0.9574	0.9538	0.9502
14.0	1.0000	0.9965	0.9931	0.9896	0.9861	0.9826	0.9791	0.9756	0.9720	0.9685	0.9649	0.9613	0.9578	0.9542	0.9506
15.0	1.0000	0.9966	0.9931	0.9897	0.9862	0.9827	0.9793	0.9758	0.9723	0.9687	0.9652	0.9617	0.9581	0.9545	0.9510
16.0	1.0000	0.9966	0.9932	0.9898	0.9863	0.9829	0.9794	0.9760	0.9725	0.9690	0.9655	0.9620	0.9584	0.9549	0.9513
17.0	1.0000	0.9966	0.9932	0.9898	0.9864	0.9830	0.9796	0.9761	0.9727	0.9692	0.9657	0.9622	0.9587	0.9552	0.9517
18.0	1.0000	0.9967	0.9933	0.9899	0.9865	0.9831	0.9797	0.9763	0.9729	0.9695	0.9660	0.9625	0.9591	0.9556	0.9521
19.0	1.0000	0.9967	0.9933	0.9900	0.9866	0.9833	0.9799	0.9765	0.9731	0.9697	0.9663	0.9628	0.9594	0.9559	0.9524
20.0	1.0000	0.9967	0.9934	0.9901	0.9867	0.9834	0.9800	0.9767	0.9733	0.9699	0.9665	0.9631	0.9597	0.9562	0.9528
21.0	1.0000	0.9967	0.9934	0.9902	0.9868	0.9835	0.9802	0.9769	0.9735	0.9701	0.9668	0.9634	0.9600	0.9566	0.9531
22.0	1.0000	0.9968	0.9935	0.9902	0.9869	0.9836	0.9803	0.9770	0.9737	0.9704	0.9670	0.9636	0.9603	0.9569	0.9535
23.0	1.0000	0.9968	0.9935	0.9903	0.9870	0.9838	0.9805	0.9772	0.9739	0.9706	0.9672	0.9639	0.9605	0.9572	0.9538
24.0	1.0000	0.9968	0.9936	0.9904	0.9871	0.9839	0.9806	0.9774	0.9741	0.9708	0.9675	0.9642	0.9608	0.9575	0.9541
25.0	1.0000	0.9968	0.9936	0.9904	0.9872	0.9840	0.9808	0.9775	0.9743	0.9710	0.9677	0.9644	0.9611	0.9578	0.9545
26.0	1.0000	0.9968	0.9937	0.9905	0.9873	0.9841	0.9809	0.9777	0.9744	0.9712	0.9679	0.9647	0.9614	0.9581	0.9548
27.0	1.0000	0.9969	0.9937	0.9906	0.9874	0.9842	0.9810	0.9778	0.9746	0.9714	0.9681	0.9649	0.9616	0.9584	0.9551
28.0	1.0000	0.9969	0.9938	0.9906	0.9875	0.9843	0.9812	0.9780	0.9748	0.9716	0.9684	0.9651	0.9619	0.9586	0.9554
29.0	1.0000	0.9969	0.9938	0.9907	0.9876	0.9844	0.9813	0.9781	0.9750	0.9718	0.9686	0.9654	0.9621	0.9589	0.9557

Table 6.2-4. Salinity correction factors for dissolved oxygen in water (based on specific conductance).—Continued
[Factors are dimensionless; values are based on equations published by Benson and Krause (1984); Temp. (°C), temperature in degrees Celsius]

Temp. (deg C)	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius														
	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	26,000	27,000	28,000	29,000
0.0	0.9402	0.9361	0.9321	0.9280	0.9239	0.9198	0.9157	0.9116	0.9074	0.9033	0.8992	0.8950	0.8909	0.8867	0.8826
1.0	0.9408	0.9367	0.9327	0.9286	0.9246	0.9205	0.9164	0.9124	0.9083	0.9042	0.9001	0.8960	0.8918	0.8877	0.8836
2.0	0.9413	0.9373	0.9333	0.9293	0.9252	0.9212	0.9172	0.9131	0.9091	0.9050	0.9009	0.8969	0.8928	0.8887	0.8846
3.0	0.9418	0.9378	0.9339	0.9299	0.9259	0.9219	0.9179	0.9139	0.9099	0.9058	0.9018	0.8978	0.8937	0.8897	0.8856
4.0	0.9423	0.9384	0.9345	0.9305	0.9266	0.9226	0.9186	0.9146	0.9107	0.9067	0.9027	0.8986	0.8946	0.8906	0.8866
5.0	0.9428	0.9389	0.9350	0.9311	0.9272	0.9233	0.9193	0.9154	0.9114	0.9075	0.9035	0.8995	0.8955	0.8915	0.8875
6.0	0.9433	0.9395	0.9356	0.9317	0.9278	0.9239	0.9200	0.9161	0.9122	0.9082	0.9043	0.9004	0.8964	0.8924	0.8885
7.0	0.9438	0.9400	0.9361	0.9323	0.9284	0.9246	0.9207	0.9168	0.9129	0.9090	0.9051	0.9012	0.8973	0.8933	0.8894
8.0	0.9443	0.9405	0.9367	0.9329	0.9290	0.9252	0.9213	0.9175	0.9136	0.9098	0.9059	0.9020	0.8981	0.8942	0.8903
9.0	0.9447	0.9410	0.9372	0.9334	0.9296	0.9258	0.9220	0.9182	0.9143	0.9105	0.9067	0.9028	0.8989	0.8951	0.8912
10.0	0.9452	0.9415	0.9377	0.9340	0.9302	0.9264	0.9226	0.9188	0.9150	0.9112	0.9074	0.9036	0.8998	0.8959	0.8921
11.0	0.9457	0.9419	0.9382	0.9345	0.9308	0.9270	0.9233	0.9195	0.9157	0.9119	0.9082	0.9044	0.9006	0.8968	0.8929
12.0	0.9461	0.9424	0.9387	0.9350	0.9313	0.9276	0.9239	0.9201	0.9164	0.9126	0.9089	0.9051	0.9014	0.8976	0.8938
13.0	0.9465	0.9429	0.9392	0.9355	0.9319	0.9282	0.9245	0.9208	0.9171	0.9133	0.9096	0.9059	0.9021	0.8984	0.8946
14.0	0.9470	0.9433	0.9397	0.9361	0.9324	0.9287	0.9251	0.9214	0.9177	0.9140	0.9103	0.9066	0.9029	0.8992	0.8954
15.0	0.9474	0.9438	0.9402	0.9366	0.9329	0.9293	0.9257	0.9220	0.9183	0.9147	0.9110	0.9073	0.9036	0.8999	0.8962
16.0	0.9478	0.9442	0.9406	0.9370	0.9334	0.9298	0.9262	0.9226	0.9190	0.9153	0.9117	0.9080	0.9044	0.9007	0.8970
17.0	0.9482	0.9446	0.9411	0.9375	0.9340	0.9304	0.9268	0.9232	0.9196	0.9160	0.9123	0.9087	0.9051	0.9014	0.8978
18.0	0.9486	0.9451	0.9415	0.9380	0.9345	0.9309	0.9273	0.9238	0.9202	0.9166	0.9130	0.9094	0.9058	0.9022	0.8985
19.0	0.9490	0.9455	0.9420	0.9385	0.9349	0.9314	0.9279	0.9243	0.9208	0.9172	0.9136	0.9101	0.9065	0.9029	0.8993
20.0	0.9493	0.9459	0.9424	0.9389	0.9354	0.9319	0.9284	0.9249	0.9214	0.9178	0.9143	0.9107	0.9071	0.9036	0.9000
21.0	0.9497	0.9463	0.9428	0.9394	0.9359	0.9324	0.9289	0.9254	0.9219	0.9184	0.9149	0.9114	0.9078	0.9043	0.9007
22.0	0.9501	0.9467	0.9432	0.9398	0.9363	0.9329	0.9294	0.9260	0.9225	0.9190	0.9155	0.9120	0.9085	0.9049	0.9014
23.0	0.9504	0.9470	0.9436	0.9402	0.9368	0.9334	0.9299	0.9265	0.9230	0.9196	0.9161	0.9126	0.9091	0.9056	0.9021
24.0	0.9508	0.9474	0.9440	0.9406	0.9372	0.9338	0.9304	0.9270	0.9236	0.9201	0.9167	0.9132	0.9097	0.9063	0.9028
25.0	0.9511	0.9478	0.9444	0.9411	0.9377	0.9343	0.9309	0.9275	0.9241	0.9207	0.9172	0.9138	0.9104	0.9069	0.9034
26.0	0.9515	0.9481	0.9448	0.9415	0.9381	0.9347	0.9314	0.9280	0.9246	0.9212	0.9178	0.9144	0.9110	0.9075	0.9041
27.0	0.9518	0.9485	0.9452	0.9419	0.9385	0.9352	0.9318	0.9285	0.9251	0.9217	0.9183	0.9149	0.9115	0.9081	0.9047
28.0	0.9521	0.9488	0.9455	0.9422	0.9389	0.9356	0.9323	0.9289	0.9256	0.9222	0.9189	0.9155	0.9121	0.9087	0.9053
29.0	0.9524	0.9492	0.9459	0.9426	0.9393	0.9360	0.9327	0.9294	0.9261	0.9228	0.9194	0.9161	0.9127	0.9093	0.9060

Table 62-4. Salinity correction factors for dissolved oxygen in water (based on specific conductance).—Continued

[Factors are dimensionless; values are based on equations published by Benson and Krause (1984); Temp. (°C), temperature in degrees Celsius]

Temp. (deg C)	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius																			
	30,000	31,000	32,000	33,000	34,000	35,000	36,000	37,000	38,000	39,000	40,000	41,000	42,000	43,000	44,000					
0.0	0.8784	0.8742	0.8701	0.8659	0.8617	0.8575	0.8533	0.8491	0.8449	0.8407	0.8365	0.8323	0.8281	0.8239	0.8197					
1.0	0.8795	0.8753	0.8712	0.8670	0.8629	0.8587	0.8546	0.8504	0.8462	0.8421	0.8379	0.8337	0.8296	0.8254	0.8212					
2.0	0.8805	0.8764	0.8723	0.8682	0.8641	0.8599	0.8558	0.8517	0.8476	0.8434	0.8393	0.8351	0.8310	0.8268	0.8227					
3.0	0.8815	0.8775	0.8734	0.8693	0.8652	0.8611	0.8570	0.8529	0.8488	0.8447	0.8406	0.8365	0.8324	0.8283	0.8242					
4.0	0.8825	0.8785	0.8745	0.8704	0.8664	0.8623	0.8582	0.8542	0.8501	0.8460	0.8419	0.8379	0.8338	0.8297	0.8256					
5.0	0.8835	0.8795	0.8755	0.8715	0.8675	0.8635	0.8594	0.8554	0.8513	0.8473	0.8433	0.8392	0.8351	0.8311	0.8270					
6.0	0.8845	0.8805	0.8766	0.8726	0.8686	0.8646	0.8606	0.8566	0.8526	0.8485	0.8445	0.8405	0.8365	0.8325	0.8284					
7.0	0.8855	0.8815	0.8776	0.8736	0.8697	0.8657	0.8617	0.8577	0.8538	0.8498	0.8458	0.8418	0.8378	0.8338	0.8298					
8.0	0.8864	0.8825	0.8786	0.8746	0.8707	0.8668	0.8628	0.8589	0.8549	0.8510	0.8470	0.8431	0.8391	0.8351	0.8311					
9.0	0.8873	0.8834	0.8796	0.8757	0.8718	0.8678	0.8639	0.8600	0.8561	0.8522	0.8482	0.8443	0.8404	0.8364	0.8325					
10.0	0.8882	0.8844	0.8805	0.8766	0.8728	0.8689	0.8650	0.8611	0.8572	0.8533	0.8494	0.8455	0.8416	0.8377	0.8338					
11.0	0.8891	0.8853	0.8815	0.8776	0.8738	0.8699	0.8661	0.8622	0.8583	0.8545	0.8506	0.8467	0.8428	0.8389	0.8351					
12.0	0.8900	0.8862	0.8824	0.8786	0.8748	0.8709	0.8671	0.8633	0.8594	0.8556	0.8517	0.8479	0.8440	0.8402	0.8363					
13.0	0.8908	0.8871	0.8833	0.8795	0.8757	0.8719	0.8681	0.8643	0.8605	0.8567	0.8529	0.8490	0.8452	0.8414	0.8375					
14.0	0.8917	0.8879	0.8842	0.8804	0.8767	0.8729	0.8691	0.8654	0.8616	0.8578	0.8540	0.8502	0.8464	0.8426	0.8388					
15.0	0.8925	0.8888	0.8851	0.8813	0.8776	0.8739	0.8701	0.8664	0.8626	0.8588	0.8551	0.8513	0.8475	0.8437	0.8400					
16.0	0.8933	0.8896	0.8859	0.8822	0.8785	0.8748	0.8711	0.8674	0.8636	0.8599	0.8561	0.8524	0.8486	0.8449	0.8411					
17.0	0.8941	0.8905	0.8868	0.8831	0.8794	0.8757	0.8720	0.8683	0.8646	0.8609	0.8572	0.8535	0.8497	0.8460	0.8423					
18.0	0.8949	0.8913	0.8876	0.8840	0.8803	0.8766	0.8730	0.8693	0.8656	0.8619	0.8582	0.8545	0.8508	0.8471	0.8434					
19.0	0.8957	0.8921	0.8884	0.8848	0.8812	0.8775	0.8739	0.8702	0.8666	0.8629	0.8592	0.8556	0.8519	0.8482	0.8445					
20.0	0.8964	0.8928	0.8892	0.8856	0.8820	0.8784	0.8748	0.8711	0.8675	0.8639	0.8602	0.8566	0.8529	0.8493	0.8456					
21.0	0.8972	0.8936	0.8900	0.8864	0.8828	0.8793	0.8757	0.8720	0.8684	0.8648	0.8612	0.8576	0.8539	0.8503	0.8467					
22.0	0.8979	0.8943	0.8908	0.8872	0.8837	0.8801	0.8765	0.8729	0.8693	0.8658	0.8622	0.8585	0.8549	0.8513	0.8477					
23.0	0.8986	0.8951	0.8915	0.8880	0.8845	0.8809	0.8774	0.8738	0.8702	0.8667	0.8631	0.8595	0.8559	0.8523	0.8487					
24.0	0.8993	0.8958	0.8923	0.8888	0.8853	0.8817	0.8782	0.8747	0.8711	0.8676	0.8640	0.8605	0.8569	0.8533	0.8497					
25.0	0.9000	0.8965	0.8930	0.8895	0.8860	0.8825	0.8790	0.8755	0.8720	0.8685	0.8649	0.8614	0.8578	0.8543	0.8507					
26.0	0.9006	0.8972	0.8937	0.8903	0.8868	0.8833	0.8798	0.8763	0.8728	0.8693	0.8658	0.8623	0.8588	0.8552	0.8517					
27.0	0.9013	0.8979	0.8944	0.8910	0.8875	0.8841	0.8806	0.8771	0.8736	0.8702	0.8667	0.8632	0.8597	0.8562	0.8527					
28.0	0.9019	0.8985	0.8951	0.8917	0.8883	0.8848	0.8814	0.8779	0.8745	0.8710	0.8675	0.8641	0.8606	0.8571	0.8536					
29.0	0.9026	0.8992	0.8958	0.8924	0.8890	0.8856	0.8821	0.8787	0.8753	0.8718	0.8684	0.8649	0.8615	0.8580	0.8545					

Table 6.2-4. Salinity correction factors for dissolved oxygen in water (based on specific conductance).—Continued

[Factors are dimensionless; values are based on equations published by Benson and Krause (1984); Temp. (°C), temperature in degrees Celsius]

Temp. (deg C)	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius																		
	45,000	46,000	47,000	48,000	49,000	50,000	51,000	52,000	53,000	54,000	55,000	56,000	57,000	58,000	59,000				
0.0	0.8155	0.8112	0.8070	0.8028	0.7986	0.7944	0.7901	0.7859	0.7817	0.7775	0.7733	0.7691	0.7648	0.7606	0.7564				
1.0	0.8170	0.8128	0.8086	0.8045	0.8003	0.7961	0.7919	0.7877	0.7835	0.7793	0.7751	0.7709	0.7668	0.7626	0.7584				
2.0	0.8185	0.8144	0.8102	0.8061	0.8019	0.7978	0.7936	0.7894	0.7853	0.7811	0.7770	0.7728	0.7686	0.7645	0.7603				
3.0	0.8200	0.8159	0.8118	0.8077	0.8035	0.7994	0.7953	0.7911	0.7870	0.7829	0.7788	0.7746	0.7705	0.7664	0.7623				
4.0	0.8215	0.8174	0.8133	0.8092	0.8051	0.8010	0.7969	0.7928	0.7887	0.7846	0.7805	0.7764	0.7723	0.7682	0.7641				
5.0	0.8230	0.8189	0.8148	0.8108	0.8067	0.8026	0.7986	0.7945	0.7904	0.7863	0.7823	0.7782	0.7741	0.7700	0.7660				
6.0	0.8244	0.8204	0.8163	0.8123	0.8082	0.8042	0.8002	0.7961	0.7921	0.7880	0.7840	0.7799	0.7759	0.7718	0.7678				
7.0	0.8258	0.8218	0.8178	0.8138	0.8098	0.8057	0.8017	0.7977	0.7937	0.7897	0.7857	0.7816	0.7776	0.7736	0.7696				
8.0	0.8272	0.8232	0.8192	0.8152	0.8112	0.8073	0.8033	0.7993	0.7953	0.7913	0.7873	0.7833	0.7793	0.7753	0.7713				
9.0	0.8285	0.8246	0.8206	0.8167	0.8127	0.8088	0.8048	0.8008	0.7969	0.7929	0.7889	0.7850	0.7810	0.7770	0.7731				
10.0	0.8299	0.8259	0.8220	0.8181	0.8141	0.8102	0.8063	0.8023	0.7984	0.7945	0.7905	0.7866	0.7826	0.7787	0.7748				
11.0	0.8312	0.8273	0.8234	0.8195	0.8156	0.8117	0.8077	0.8038	0.7999	0.7960	0.7921	0.7882	0.7843	0.7804	0.7764				
12.0	0.8324	0.8286	0.8247	0.8208	0.8170	0.8131	0.8092	0.8053	0.8014	0.7975	0.7936	0.7898	0.7859	0.7820	0.7781				
13.0	0.8337	0.8299	0.8260	0.8222	0.8183	0.8145	0.8106	0.8067	0.8029	0.7990	0.7952	0.7913	0.7874	0.7836	0.7797				
14.0	0.8349	0.8311	0.8273	0.8235	0.8197	0.8158	0.8120	0.8082	0.8043	0.8005	0.7966	0.7928	0.7890	0.7851	0.7813				
15.0	0.8362	0.8324	0.8286	0.8248	0.8210	0.8172	0.8134	0.8095	0.8057	0.8019	0.7981	0.7943	0.7905	0.7867	0.7828				
16.0	0.8374	0.8336	0.8298	0.8260	0.8223	0.8185	0.8147	0.8109	0.8071	0.8033	0.7995	0.7958	0.7920	0.7882	0.7844				
17.0	0.8385	0.8348	0.8310	0.8273	0.8235	0.8198	0.8160	0.8123	0.8085	0.8047	0.8010	0.7972	0.7934	0.7896	0.7859				
18.0	0.8397	0.8360	0.8322	0.8285	0.8248	0.8210	0.8173	0.8136	0.8098	0.8061	0.8023	0.7986	0.7948	0.7911	0.7873				
19.0	0.8408	0.8371	0.8334	0.8297	0.8260	0.8223	0.8186	0.8149	0.8112	0.8074	0.8037	0.8000	0.7963	0.7925	0.7888				
20.0	0.8419	0.8383	0.8346	0.8309	0.8272	0.8235	0.8198	0.8161	0.8124	0.8087	0.8050	0.8013	0.7976	0.7939	0.7902				
21.0	0.8430	0.8394	0.8357	0.8321	0.8284	0.8247	0.8211	0.8174	0.8137	0.8100	0.8064	0.8027	0.7990	0.7953	0.7916				
22.0	0.8441	0.8405	0.8368	0.8332	0.8296	0.8259	0.8223	0.8186	0.8150	0.8113	0.8076	0.8040	0.8003	0.7967	0.7930				
23.0	0.8451	0.8415	0.8379	0.8343	0.8307	0.8271	0.8234	0.8198	0.8162	0.8126	0.8089	0.8053	0.8016	0.7980	0.7943				
24.0	0.8462	0.8426	0.8390	0.8354	0.8318	0.8282	0.8246	0.8210	0.8174	0.8138	0.8102	0.8065	0.8029	0.7993	0.7957				
25.0	0.8472	0.8436	0.8400	0.8365	0.8329	0.8293	0.8257	0.8222	0.8186	0.8150	0.8114	0.8078	0.8042	0.8006	0.7970				
26.0	0.8482	0.8446	0.8411	0.8375	0.8340	0.8304	0.8269	0.8233	0.8197	0.8162	0.8126	0.8090	0.8054	0.8018	0.7983				
27.0	0.8491	0.8456	0.8421	0.8386	0.8350	0.8315	0.8280	0.8244	0.8209	0.8173	0.8138	0.8102	0.8066	0.8031	0.7995				
28.0	0.8501	0.8466	0.8431	0.8396	0.8361	0.8326	0.8290	0.8255	0.8220	0.8184	0.8149	0.8114	0.8078	0.8043	0.8007				
29.0	0.8510	0.8476	0.8441	0.8406	0.8371	0.8336	0.8301	0.8266	0.8231	0.8196	0.8160	0.8125	0.8090	0.8055	0.8019				

Table 62-4. Salinity correction factors for dissolved oxygen in water (based on specific conductance).—Continued

[Factors are dimensionless; values are based on equations published by Benson and Krause (1984); Temp. (°C), temperature in degrees Celsius]

Temp. (deg C)	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius														
	0	1,000	2,000	3,000	4,000	5,000	6,000	7,000	8,000	9,000	10,000	11,000	12,000	13,000	14,000
30.0	1.0000	0.9969	0.9939	0.9908	0.9877	0.9845	0.9814	0.9783	0.9751	0.9720	0.9688	0.9656	0.9624	0.9592	0.9560
31.0	1.0000	0.9970	0.9939	0.9908	0.9877	0.9846	0.9815	0.9784	0.9753	0.9721	0.9690	0.9658	0.9626	0.9595	0.9563
32.0	1.0000	0.9970	0.9939	0.9909	0.9878	0.9847	0.9817	0.9785	0.9754	0.9723	0.9692	0.9660	0.9629	0.9597	0.9565
33.0	1.0000	0.9970	0.9940	0.9909	0.9879	0.9848	0.9818	0.9787	0.9756	0.9725	0.9694	0.9662	0.9631	0.9600	0.9568
34.0	1.0000	0.9970	0.9940	0.9910	0.9880	0.9849	0.9819	0.9788	0.9757	0.9727	0.9696	0.9665	0.9633	0.9602	0.9571
35.0	1.0000	0.9970	0.9940	0.9911	0.9880	0.9850	0.9820	0.9790	0.9759	0.9728	0.9698	0.9667	0.9636	0.9605	0.9573

Temp. (deg C)	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius														
	15,000	16,000	17,000	18,000	19,000	20,000	21,000	22,000	23,000	24,000	25,000	26,000	27,000	28,000	29,000
30.0	1.0000	0.9969	0.9939	0.9908	0.9877	0.9845	0.9814	0.9783	0.9751	0.9720	0.9688	0.9656	0.9624	0.9592	0.9560
31.0	1.0000	0.9970	0.9939	0.9908	0.9877	0.9846	0.9815	0.9784	0.9753	0.9721	0.9690	0.9658	0.9626	0.9595	0.9563
32.0	1.0000	0.9970	0.9939	0.9909	0.9878	0.9847	0.9817	0.9785	0.9754	0.9723	0.9692	0.9660	0.9629	0.9597	0.9565
33.0	1.0000	0.9970	0.9940	0.9909	0.9879	0.9848	0.9818	0.9787	0.9756	0.9725	0.9694	0.9662	0.9631	0.9600	0.9568
34.0	1.0000	0.9970	0.9940	0.9910	0.9880	0.9849	0.9819	0.9788	0.9757	0.9727	0.9696	0.9665	0.9633	0.9602	0.9571
35.0	1.0000	0.9970	0.9940	0.9911	0.9880	0.9850	0.9820	0.9790	0.9759	0.9728	0.9698	0.9667	0.9636	0.9605	0.9573

Temp. (deg C)	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius														
	30,000	31,000	32,000	33,000	34,000	35,000	36,000	37,000	38,000	39,000	40,000	41,000	42,000	43,000	44,000
30.0	0.9032	0.8998	0.8964	0.8931	0.8897	0.8863	0.8829	0.8795	0.8760	0.8726	0.8692	0.8658	0.8623	0.8589	0.8554
31.0	0.9038	0.9005	0.8971	0.8937	0.8904	0.8870	0.8836	0.8802	0.8768	0.8734	0.8700	0.8666	0.8632	0.8597	0.8563
32.0	0.9044	0.9011	0.8977	0.8944	0.8910	0.8877	0.8843	0.8809	0.8776	0.8742	0.8708	0.8674	0.8640	0.8606	0.8572
33.0	0.9050	0.9017	0.8984	0.8950	0.8917	0.8884	0.8850	0.8817	0.8783	0.8749	0.8716	0.8682	0.8648	0.8614	0.8580
34.0	0.9056	0.9023	0.8990	0.8957	0.8923	0.8890	0.8857	0.8824	0.8790	0.8757	0.8723	0.8690	0.8656	0.8622	0.8588
35.0	0.9061	0.9028	0.8996	0.8963	0.8930	0.8897	0.8864	0.8830	0.8797	0.8764	0.8731	0.8697	0.8664	0.8630	0.8597



Table 6.2-4. Salinity correction factors for dissolved oxygen in water (based on specific conductance).—Continued
[Factors are dimensionless; values are based on equations published by Benson and Krause (1984); Temp. (°C), temperature in degrees Celsius]

Temp. (deg C)	Specific conductance, in microsiemens per centimeter at 25 degrees Celsius														
	45,000	46,000	47,000	48,000	49,000	50,000	51,000	52,000	53,000	54,000	55,000	56,000	57,000	58,000	59,000
30.0	0.8520	0.8485	0.8450	0.8416	0.8381	0.8346	0.8311	0.8276	0.8241	0.8207	0.8172	0.8137	0.8102	0.8066	0.8031
31.0	0.8529	0.8494	0.8460	0.8425	0.8391	0.8356	0.8321	0.8287	0.8252	0.8217	0.8182	0.8148	0.8113	0.8078	0.8043
32.0	0.8537	0.8503	0.8469	0.8435	0.8400	0.8366	0.8331	0.8297	0.8262	0.8228	0.8193	0.8159	0.8124	0.8089	0.8054
33.0	0.8546	0.8512	0.8478	0.8444	0.8410	0.8375	0.8341	0.8307	0.8272	0.8238	0.8204	0.8169	0.8135	0.8100	0.8066
34.0	0.8555	0.8521	0.8487	0.8453	0.8419	0.8385	0.8351	0.8317	0.8282	0.8248	0.8214	0.8180	0.8145	0.8111	0.8077
35.0	0.8563	0.8529	0.8496	0.8462	0.8428	0.8394	0.8360	0.8326	0.8292	0.8258	0.8224	0.8190	0.8156	0.8122	0.8087



Appendix 4. Conductivity References.

Table 4.1. 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)

Table 4.2. Conductivity test solutions

1 Normal KCl is 74.7gms dissolved in distilled water and then made up to 1 L

0.1 Normal KCl is 7.47 gms KCl dissolved in distilled water and then made up to 1 L 0.02 Normal KCl

is 1.494 gms KCl dissolved in distilled water and then made up to 1 L

0.01 Normal KCl is .747 gms KCl dissolved in distilled water and then made up to 1 L

Conductivity values of Potassium Chloride								
Temp	1N KCl		0.1N KCl		0.02N KCl		0.01N KCl	
°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

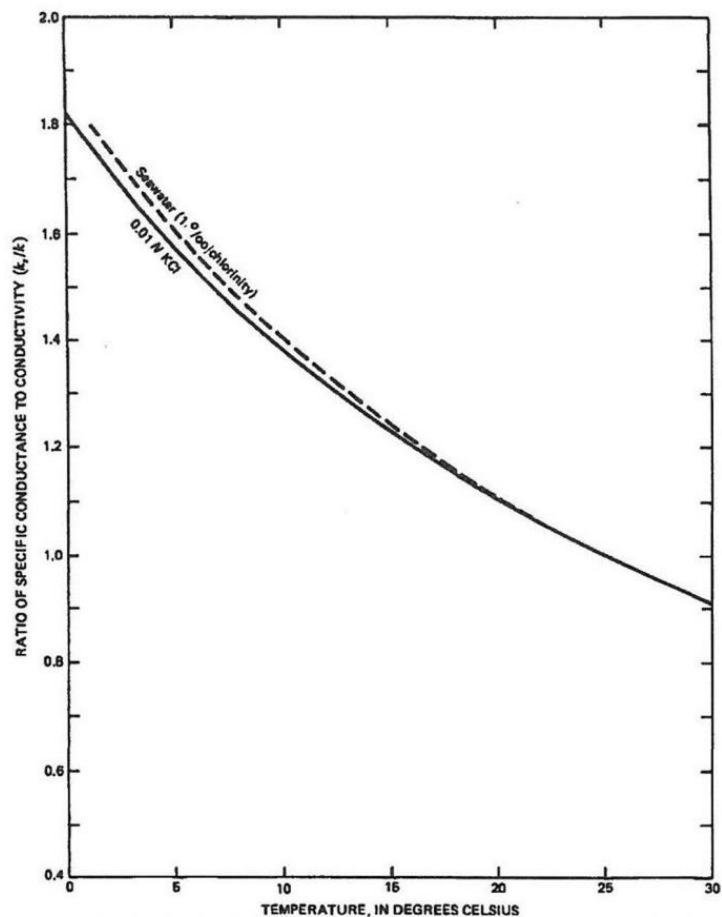


Figure 4.1. Values of the ratio of specific conductance to conductivity for 0.01N KCl solution and 1 per mill chlorinity seawater (USGS).



Appendix 5. Examples of data errors.

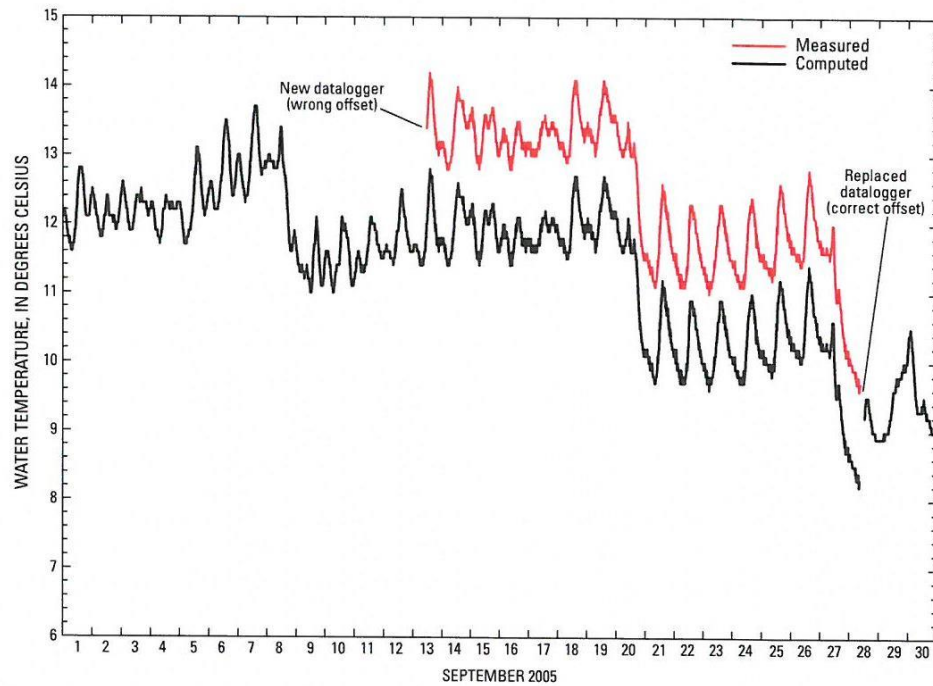


Figure 5.1. Example of an offset correction, from USGS (Figure 9, Wagner et al. 2006).

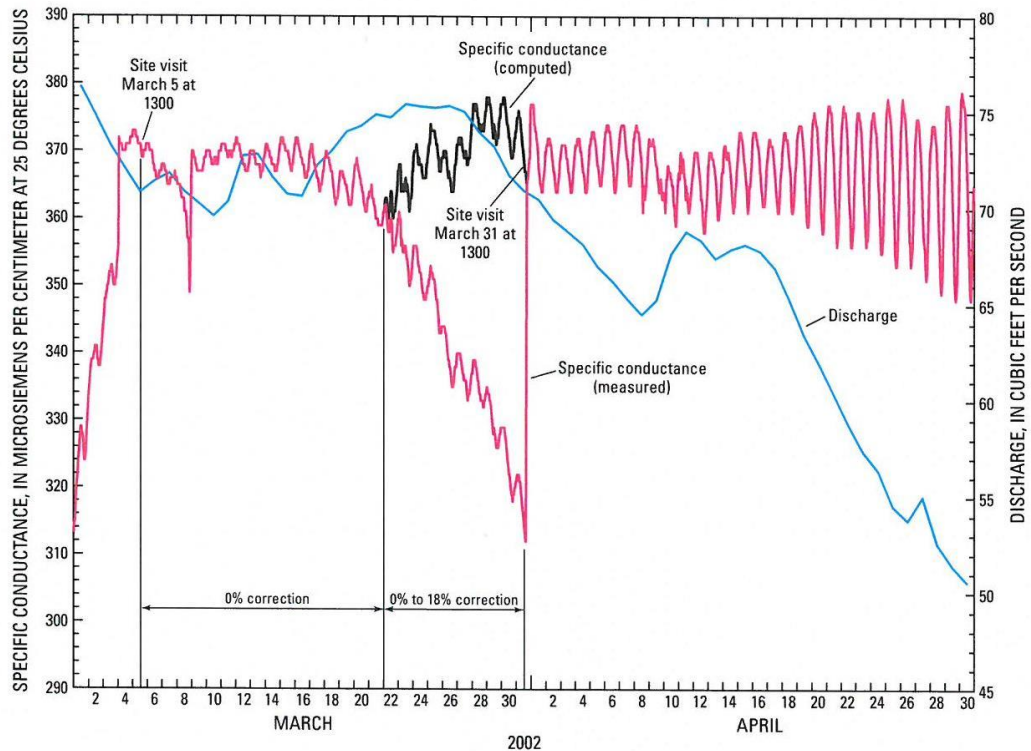


Figure 5.2. Example of a fouling correction, from USGS (Figure 8, Wagner et al. 2006).

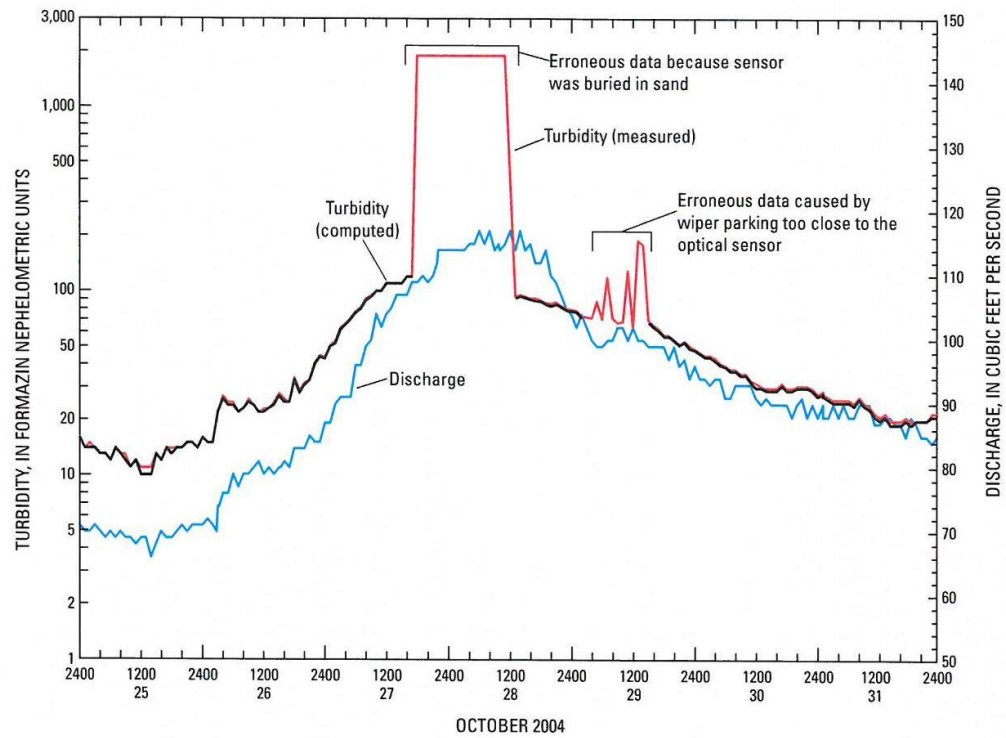


Figure 5.3. Example of turbidity spikes, from USGS (Figure 7, Wagner et al. 2006).