Standard Operating Procedure

Multiparameter Water Quality Sonde

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Author(s): Kyle Milke, TMDL, DEQ/WQPB

Approvals:

/s/: Michael W. Suplee 11/21/2024

Michael Suplee, PhD, Technical Review, Water Quality Standards and Modeling, DEQ/WQPB

/s/: Gabrielle Metzner 11/22/2024

Gabrielle Metzner, Technical Review, Monitoring and Assessment Section, DEQ/WQPB

/s/: Erin Louden 4/3/2025

Erin Louden, Quality Assurance Review, QA Officer, DEQ/WQPB

/s/: Andy Ulven 4/7/2025

Andy Ulven, Water Quality Planning Bureau Chief, DEQ/WQPB

Signatures on file

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Although the WQPB follows this SOP in most cases, there may be situations where an alternative methodology, procedure, or process is used to meet specific project objectives. In such cases, the project manager is responsible for documenting deviations from these procedures in the Quality Assurance Project Plans (QAPPs), Sampling and Analysis Plans (SAPs), and end of project summary reports.

Document Revision and Version History

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ACRONYMS

°C	degrees Celsius
µg/L	micrograms per liter
µs/cm	microsiemens per centimeter
chl-*a*	chlorophyll-*a*
Cl^-	chloride
cm^{-1}	1/cm
DEQ	Montana Department of Environmental Quality
DI water	deionized water
DO	dissolved oxygen
FNU	Formazin nephelometric units
ISE	Ion-Selective Electrode
L	liter
mg/L	milligram per liter
mL	milliliter
mm Hg	millimeters of mercury
MT-eWQX	Montana EQuIS Water Quality Exchange
mV	millivolt
NIST	National Institute of Standards and Technology
NTU	Nephelometric turbidity units
ODO	optical dissolved oxygen
ORP	oxidation reduction potential
PC	phycocyanin
PE	phycoerythrin
QA	quality assurance
QAPP	quality assurance project plan
QC	quality control
RFU	relative fluorescence units
SAP	sampling and analysis plan
SC	specific conductivity
SDS	safety data sheet
SOP	standard operating procedure
S.U.	Standard Units
SVC	site visit code
SVF	site visit form
TAL	total algae
USB	universal serial bus
V	volt
WQPB	Water Quality Planning Bureau

1.0 PURPOSE

This document describes the Montana Department of Environmental Quality (DEQ) Water Quality Planning Bureau (WQPB) Standard Operating Procedure (SOP) for maintaining and deploying multiparameter water quality sondes. This type of equipment collects continuous data for multiple parameters. The parameter list is determined by the types of sensors that are installed on the instrument. Depending on the sensor type, there are calibration and drift correcting procedures. This standard operating procedure covers some common parameter calibrations, sonde deployment considerations, field maintenance, data processing, and how to use certain YSI EXO™ Series sondes.

2.0 APPLICABILITY

Multiparameter water quality sondes are deployed by the WQPB to collect continuous data for the following parameters:

- Temperature
- Conductivity
- pH
- Oxidation Reduction Potential (ORP)
- Chlorophyll-a (chl-*a)*
- Phycocyanin (Blue-Green Algae)
- Turbidity
- Dissolved Oxygen (DO)
- Ion-Selective Electrodes (ISEs): Ammonium (NH_4^+), Nitrate (NO_3^-), and Chloride (Cl^-)

Sondes can be deployed in wadable streams, lakes, reservoirs, and within reaches of large non-wadable rivers. This equipment can be deployed in all seasons, but the probe end should not be allowed to be encased in ice or allowed to dry out, depending on which probes are installed (see **Table 2-1**).

Table 2-1. Sensor storage recommendations (YSI 2020b).

Sensor(s)	Storage[1,2]
Turbidity, total algae (TAL), chl-*a*, and Blue-Green Algae	Can be stored in **dry air** with shipping cap.
Conductivity/Temperature	Can be stored in **dry air or water-saturated air**. In the field, store sensor in water-saturated air.
DO	Moist or wet environment. If sensor is left in dry air longer than **8 hours**, it must be rehydrated.
pH/ORP	2 molar solution of pH 4 buffer (bottle it was shipped in). Do not store in Zobell solution, DI or distilled water. **Never** let sensor dry out.
ISE	Store in bottle it was shipped in with a small amount of tap water. **Never** let sensor dry out.

[1]Ideally, sensors will never be allowed to dry out.
[2]Refer to sensor manual for more detailed storage instructions.

The maximum length of time that a sonde can be deployed is dependent upon battery life and storage capacity. Multiple factors may affect the battery life and storage capacity: number of installed sensors, logging interval, and external temperature. Cold temperatures will drain batteries faster and more frequent logging shortens logging life (see **Table 6-1** below). However, DEQ experience shows that YSI EXO2s can, with longer logging intervals (e.g., every 3 hours), be deployed for four to five months over winter and successfully wipe and collect data throughout.

3.0 Method Summary

Any applicable calibration and checks for sensors must be done before a sonde can be used in the field. Pre-deployment benchmarks must be recorded for each parameter and will be compared to post-deployment benchmarks to verify data collection accuracy and to allow for correction of calibration drift when necessary. Some parameters, such as chl-*a,* require additional procedures to correct for drift. All sondes will be tested after calibration to ensure that all sensors are logging correctly and, if the instrument will be left for continuous deployment, that the sonde enters the appropriate sleep mode between logging intervals.

The methods used to deploy a sonde will depend upon the project's objectives and waterbody conditions. Periodic field cleanings and downloads may be required.

After the sondes are retrieved, the accuracy of the sensors will need to be checked with post deployment benchmarks and the data will need to be downloaded and checked for any errors or drift.

4.0 Definitions

Benchmark: A lab reading after calibration and taken again after a sonde has been deployed. It is used to calculate sensor accuracy and drift.

Deploy (or Deployment): The placing of the sonde in the water at a study site.

Deionized (DI) water: Deionized water, provided by a lab. Commercial grade distilled water can be used if DI water is unavailable.

Launch: Setting the interval, date, and time of data collection on the sonde, and then starting the instrument.

Quality assurance: An integrated system of management activities involving planning, implementation, assessment, reporting, and improvement to ensure that a process, item, or service is of the type and quality needed (EPA 2002).

Quality control: An overall system of technical activities that measures the performance of a process, item, or service against defined standards to verify that the performance meets the stated requirements (EPA 2002).

Readout (or Download): The process of transferring the data from the sonde to another device, a computer primarily.

Rinse Solution: A standard calibration solution that can be used only for rinsing the meter, usually immediately prior to calibrating a sensor. Bottles of this type of solution are marked "Rinse".

Sensor Module: A user replaceable portion of a sensor.

Sonde: A device that has more than one sensor that can be used for long term deployments, depth profiles, and instantaneous measurements.

5.0 HEALTH AND SAFETY WARNINGS

Field personnel should be aware of job hazards associated with the procedures contained in this SOP that could result in personal injury or loss of life. Driving, boating, wading, and tool use safety are especially pertinent to the procedures contained in this SOP. Personnel should be aware of unstable banks, loose substrate, and swift currents when wading and standing in running water. Some projects may require using boats to deploy the sondes. DEQ field personnel should review the Water Quality Division Job Hazard and Analysis form and the Waterborne Operations Procedure before collecting data (DEQ 2016). Always use caution when using calibration or cleaning solutions. Consult the appropriate Safety Data Sheets (SDS) for any solution prior to use.

6.0 CAUTIONS

Field personnel must be cautious when using equipment around water. Water may damage electronics if seals are damaged or left open. Do not allow any equipment to be washed downstream. Maintain appropriate equipment care and maintenance (e.g., batteries, sensor cleanings, firmware updates, O-ring or other seal replacement).

NOTE: Consult the user manual, equipment, and sensor specification tables for more detailed use restrictions before field use (YSI 2020b). See **Table 6-1** for basic sonde specifications.

Table 6-1. EXO™ Series sonde specifications.

			Temperature Rating (°C)	
Sonde	**Battery Life (Days)[1]**	**Depth Rating (m)**	**Operating**	**Storage**
EXO1	90	250	-5 to 50	-20 to 80
EXO2				
EXO2[s]				
EXO3	60			

[1]Battery life will depend on the type of sensors and measurement frequency.

6.1 CALIBRATION CAUTIONS

An accurate calibration is necessary for accurate data collection. The user should take steps to ensure that an accurate calibration is possible by following the rinsing procedure in **Section 10.2**.

Some calibration solutions are susceptible to evaporation or other degrading factors. If there is an expiration date, it is normally listed on the bottle. The date that the solution was first opened should be written on the bottle in permanent marker. The user should ensure that no solution has expired or been opened for too long. Check the manufacturer's recommended shelf and opened lifespan of the calibration solution. If a solution has expired it should be labeled as such and labeled "rinse". Rinse solutions may be used for probe storage purposes as well. **Table 6-2** shows some of the expiration dates for commonly used calibration solutions.

Table 6-2. Common calibration solution expiration dates (YSI 2019b).

YSI Solutions	Expiration Dates[1, 2]
Conductivity	Unopened - 18 months Opened - 1 month
pH	Unopened - 2 years Opened - 2 months
Turbidity	Unopened - 1 year Opened - 6 months
Zobell	Unmixed - 5 years Mixed - 6 months

[1]Expiration dates are clearly labeled on the bottle. Expiration times for unopened/unmixed solutions are from date of manufacture, not date of purchase.
[2]The manufacturer recommends these solutions should be used before the expiration date after being opened; expired solutions may still be used for rinsing or storage purposes. Expired solutions should be labeled as such and labeled "rinse".

The last part of the pre-deployment calibration is a test of unattended deployment for a 2-5 minute interval to ensure that the sonde is operating correctly, it is wiping, and the sensors are recording correctly. See **Section 10.2.11** for more information.

6.2 Bluetooth® vs. Cable connections

Some sondes can connect to handhelds or a computer through a Bluetooth® connection. Bluetooth® connections are useful for lab calibrations, sonde set up, launching, and they can be used to transfer data to and from the sonde. It is recommended to use a cabled or wired connection when transferring large amounts of information such as field files or firmware updates to avoid the possibility of data corruption. For the YSI EXO™ series, field cables are used to connect to the handhelds and a universal serial bus (USB) Signal Output Adapter is used to connect the sonde to a computer via a USB cable (YSI 2020b).

6.3 Battery and Field Temperatures

Most sondes can show estimated battery life at the start of a launch; battery voltage can typically be one of the sonde exports. At a certain voltage (for the YSI EXO™ 2 sonde, this is approximately 3.6 volts [V]) the sonde will stop logging. The rate of battery voltage decrease is related, but not limited to, the number of sensors on the sonde, the logging interval, and the temperature of the environment. The more sensors that are on the sonde, the shorter the interval, and/or a colder environment will be more draining on battery life.

It is best to install new batteries at the start of a field deployment (Section 2.2, YSI, 2020b). It is also best to replace the batteries in the field occasionally if the sonde is deployed for a few months, the logging interval is short (less than or equal to 15 minutes), or if the temperature has been cold.

6.4 MAINTENANCE UPKEEP

The user is responsible for regular maintenance of the sonde. This includes but is not limited to examining the sonde and sensors for damage and fouling and replacing external O-rings, sensor modules, and batteries as needed. Occasionally the sonde should be sent to the manufacturer for additional care. This may include seal replacements, pressure tests, and circuit board inspections. Manufacturer maintenance may be recommended every 1 to 2 years per sonde, and after a long deployment, or a deployment over the winter. See **Section 10.1** for more maintenance information.

6.5 DEPLOYMENT PRECAUTIONS

Project managers should choose deployment sites carefully when planning a project. Field personnel should choose appropriate locations at the site and methods for deployment. Deploy away from high traffic areas to avoid loss.

- Deploy some distance from bridges, if possible. Anglers are thorough in targeting fish habitat.
- Avoid fishing access sites. If unavoidable, avoid the put-in spots. These places are heavily used by anglers.
- Use stainless steel cable and salt resistant hardware. Avoid using aluminum and plain braided steel cables for deployment in highly conductive streams. These may dissolve or rust over time and the sonde may be lost.
- Avoid deploying sondes in a location that is being actively eroded.
- Avoid stranded pools, slack water, eddies, and backwater areas, unless the project is intended to target intermittent streams.
- Use the appropriate deployment method for the waterbody. Examples include sturgeon deployers (**Figure D-7**, **Appendix D**) in streams or an anchored line in a lake or reservoir (**Figure D-4**, **Appendix D**).
- If you need to flag the site, place the flag well away from the sonde and note the location on the Continuous Datalogger Deployment Form (**Section 11.3**). People investigate flags, and livestock and wildlife will often eat flagging.
- Do not deploy a sonde at a depth greater than what the sonde and the installed sensors are rated for (**Table 6-1**). **NOTE:** ISE sensors should not be used at depths greater than 55 feet (17 m). Always consult the sensor's user manual for manufacturer recommended maximum depth.

7.0 INTERFERENCES

This section describes components of the process that may interfere with the accuracy of the final results.

7.1 SENSOR FOULING AND DRIFT

Fouling is the accumulation of aquatic growth, silt, or anything that would interfere with a sensor's ability to collect accurate data. The amount of fouling that a sensor will accumulate depends on what type of waterbody and the location of the waterbody the sonde is deployed in. In many flowing Montana waterbodies detached, drifting filamentous algae and macrophytes are a major source of sonde smothering and sensor fouling. If available on the sonde, the wiping function helps decrease the impacts of this but may not eliminate effects of major smothering. Field personnel should take photos of the sensor faces and the sonde/deployment unit and make notes about their condition at the time of mid-deployment checks and retrieval. This information, along with a post deployment benchmark reading can be used to check the data's quality. See **Section 12.2.1** for more information on how to correct for drift.

7.2 Deployment Orientation

EXO™ Series sondes can be deployed vertically or horizontally. If deployed vertically, it is recommended that the sensors are face down toward the river or lakebed. If a project plan requires the sonde sensors to face the surface, additional cleaning may be required. If deployed horizontally, sondes should be deployed with the sensors facing downstream to avoid any potential damage from flowing debris; this is also the correct orientation when deploying a sonde using a sturgeon deployer. Bubbles are less likely to be caught on the sensor faces if deployed horizontally and in the downstream orientation.

8.0 Personnel Qualifications/Responsibilities

Any personnel who calibrates, launches, or downloads data from a sonde must understand the applicable instrument programs and handheld devices as well as Microsoft Excel.

Field personnel who deploy, check, or retrieve a sonde should have prior experience with that type of sonde. Any field personnel that do not have experience with the equipment should be accompanied by experienced field personnel for training, until the processes are understood.

Quality assurance (QA) processing of datalogger data must be done by a trained environmental resource professional familiar with the associated project. Quality assurance processing is described more in **Section 12.0**.

9.0 Equipment and Supplies

This section contains a general list of equipment and supplies associated with this procedure; additional items may be needed depending on project- and site-specific plans.

9.1 Calibration (General)

- ❑ Sonde
- ❑ Calibration cup/guard
- ❑ Calibration solutions (pH, conductivity, turbidity...etc.)
- ❑ Lab wipes (Kimwipes®)
- ❑ DI water
- ❑ Computer with appropriately installed programs
    - For YSI EXO Kor Software, download at https://www.ysi.com/kor-software
- ❑ Computer to sonde connection piece (if applicable)
- ❑ Sensors and installation tools
- ❑ Vacuum grease
- ❑ Bucket of room temperature water
- ❑ Aerator (for DO calibration method)
- ❑ Batteries

9.2 Stream/River Deployment

- ❑ Sonde
- ❑ Handheld
- ❑ Field cable
- ❑ Batteries
- ❑ Deployment platform
- ❑ Anchor system
- ❑ Camouflage system

9.3 Lake/Reservoir Deployment

- ❑ Sonde
- ❑ Handheld
- ❑ Field cable
- ❑ Batteries
- ❑ Line system
- ❑ Anchor system
- ❑ Buoy

9.4 Lake Profile

- ❑ Sonde
- ❑ Handheld
- ❑ Field cable
- ❑ Batteries
- ❑ Line system

10.0 Procedural Steps

All probes must be calibrated and tested before being used for data collection. Sondes need to be set up for deployment with adequate deployment settings depending on the project and adequate maintenance for preventing sonde failure/poor data quality. Each type of sonde make/model may have different methods for how to calibrate their sensors; however general calibration guidelines will be described in this SOP. See **Table 10-1** for a quick guide to sensor calibration and maintenance sections in the EXO™ user manual (YSI 2020b).

Table 10-1. EXO™ user manual sensor calibration and maintenance quick guide (YSI 2020b).

Sensor		**Calibration**		**Maintenance**	
		Section	**Page**	**Section**	**Page**
TAL, chl-*a*, and Blue-Green Algae		4.26	136-139	5.6	155
Turbidity		4.28	143-145		
Conductivity/Temperature	Non-wiped	4.6	86-87	5.7	156
	Wiped	4.8	89-90		
Depth and Level		4.10	92-93	5.5	154
DO		4.12	96-99	5.9 & 5.10	158-160
pH		4.21	122-125	5.12	162

Table 10-1. EXO™ user manual sensor calibration and maintenance quick guide (YSI 2020b).

Sensor	Calibration		Maintenance	
	Section	Page	Section	Page
ORP	4.22	126-127		
ISE	4.17	106-111	5.13	163
Sensor Module	N/A		5.14	164-165
Central Wiper			5.15	166-167
Field Cable			5.16	168
Connectors			5.17	169
Antifouling Equipment			5.18	170
Flow Cell			5.19	171

Most multiparameter sondes can either be used to collect instantaneous data or continuous data. This SOP will describe how a sonde may be used to collect depth profiles and be deployed in a variety of waterbody types.

10.1 SONDE MAINTENANCE

Sonde maintenance is the responsibility of all users. It may vary from one model to another, but some basic principles will be applicable to all sondes.

Firmware updates are occasionally put forward by the sonde manufacturer. It is good practice to check for and apply any updates before the equipment is used for the field season.

NOTE: Reference the appropriate manual for any specific user maintenance required for a particular sonde (YSI 2020b).

Check the sonde and sensors for any visible damage that will need to be replaced or fixed before setting up a sonde for deployment.

- Check if the sonde or sensor connections are damaged or fouled, if so repair/replace or clean before calibrating.
- Check that batteries are installed correctly, charged if they are rechargeable, and replace if they are showing any damage or corrosion; clean or repair any corrosion damage to the battery compartment. It is good practice to install new batteries prior to a long deployment.
- Check the cleaning wiper(s) (if applicable) and replace when the wiper shows degradation or splaying. Prior to calibration steps, run the EXO™2 wiper (**Table 10-1**) with the blue calibration cup removed and listen closely to the central wiper while it's completing a wipe cycle; it should produce a smooth, somewhat high-pitched sound. If grinding or grating sounds are heard, or if the unit is not properly completing its two rotations and parking correctly, replace it.
- Check all external O-rings for damage, cracks, and any grit; they should be smooth, clean, and slightly stretchable, clean any grit away with Kimwipes® and lightly lubricate the O-ring with the appropriate YSI grease or vacuum grease; if there is any damage or cracks in the O-ring it should be replaced (see Section 5.2 YSI, 2020b for further information on O-ring maintenance).

NOTE: Wipe off excess grease at the base of sensors as excess grease will have the opposite effect and will collect grit that can damage the sensors.

The WQPB tracks all calibrations and maintenance in binders for individual sondes. The manufacturer, model, and serial number should be written on the outside of the binder. All pre- and post-calibration sheets and any applicable notes or sheets to the maintenance and calibration of the sonde should be kept in the binder. Digital copies should be made and stored here:

G:\WQP\3_Monitoring_Assessment\3_Field_Resources\Equipment\EXO Sondes

Some of the EXO™ series sensors have user replaceable parts. For example, DO sensors have replaceable membrane caps and pH sensors have replaceable modules where the top portion is removed and replaced with a new component. Follow the provided instructions for sensor modular replacement (**Table 10-1**). The module replacement should only be done in an indoor, dry, and clean environment.

NOTE: If a sensor's module is replaced, the sensor may need to be reverted to the factory settings before calibration. If not, the sensor base may not be able to read the new module correctly. Refer to manufacturer's instructions.

NOTE: Take care not to cross thread the sensors when installing them on a sonde. This is particularly important when plastic ports and metal screw pieces are involved.

Make sure to check the manufacturer instructions for any sensor specific installation requirements. For example: The EXO™ series wipeable conductivity/temperature sensor has specific requirements about which ports it should be installed in, that an O-ring should be placed around the central wiper, and that all sensors should be surrounded by a lightly but firmly secured zip-tie when installed (YSI 2020b).

10.2 Sonde Sensor Calibration

NOTE: This section contains general sensor calibration procedures. It is recommended that users review the user manuals for specific calibration instructions for each specific sonde type and sensor (YSI 2020b).

NOTE: Some sensors require that the wiper is installed during calibration. The wiper assists with removing bubbles from the probe faces which may affect the calibration. As a good practice, ensure that the wiper is properly installed and functional before calibrating.

Most calibration processes require the sensors to be placed in a solution. To prevent contamination and dilution, the sensors should be prepared beforehand by cleaning and rinsing. The WQPB uses "rinse solution" as part of the rinsing cycle. "Rinse solution" is calibration solution that has previously been used for a calibration and is kept in a separate bottle marked "Rinse". Once the solution has been used to rinse the sensors it should be properly disposed of; do not place rinse solution back in the rinse container after using it to rinse.

Any calibration process that requires sensors to be placed in a solution requires rinsing to remove the previous solution from the sensors and to prepare the sensors for the next calibration solution.

1. Ensure that the calibration/storage cup is clean.
2. Rinse the sensors with DI water.
3. Rinse cup and sensors twice with the corresponding rinse calibration solution.

If doing a two-point calibration, repeat steps 2 and 3 for the second calibration solution.

NOTE: Never accept a questionable calibration. If there are warning messages – stop calibrating and determine why there is an error. See the appropriate manual or calibration guide for any troubleshooting.

The WQPB uses pre- and post-deployment calibration sheets to record all sonde calibration information. See **Section 11.0** and **Appendix A** for more information. These sheets can be modified based on the project needs and the sensors used. The original calibration sheets are attached to the site visit form (SVF) along with the Continuous Datalogger Form (**Appendix A**). Copies are made of the form and stored in individual sonde binders for additional record keeping. Additional maintenance notes can be recorded on additional paper in the sonde binder. Electronic versions should be stored on the G drive to ensure an electronic record. The electronic record is located here:

G:\WQP\3_Monitoring_Assessment\3_Field_Resources\Equipment\EXOSondes
Below is a comprehensive list of possible sensor calibrations. Refer to the project sampling and analysis plan (SAP) for the specific sensors required for the project.

NOTE: Two sensors of the same type may be installed on a sonde if data gathering for that parameter is particularly important.

1. Prepare for calibration
    a. Fill a 5-gallon bucket with water. Let the bucket come to room temperature. This will be used for a temperature check (**Section 10.2.1**).
    b. Chill any solutions needed (if applicable) (e.g., ISE calibration solution)
    c. Set up sondes and sensors
2. Check temperature readings
3. Calibrate specific conductivity (SC)
4. Calibrate pH
5. Calibrate ORP
6. Calibrate total algae (TAL) (includes chl-*a* and Blue-green-algae)
7. Calibrate turbidity
8. Calibrate DO
9. Calibrate ISE*
10. Setup sonde
11. Conduct unattended deployment test

***NOTE:** Due to their sensitivity, ISE sensors must not be on the sonde when calibrating conductivity or pH. Calibrate ISE sensors separately with a calibrated temperature/conductivity sensor and pH sensor.

After a sensor is calibrated, switch the sonde to live reading mode and record the output reading from either: (a) the solution that it was calibrated in or (b) another standard solution. The recorded value represents the sensor benchmark. The sensor will be placed into the same type of solution at the end of the deployment and the pre- and post-deployment readings will be used to determine if the sensor experienced any drift during deployment in the field. See **Section 12.2.1** for more information.

10.2.1 Temperature Accuracy Check

Temperature sensors are not user-calibrated, and most are integrated with the conductivity sensor. Many parameters are temperature dependent and temperature accuracy should be checked before continuing with the calibrations as it is a foundational field parameter that is necessary for other parameters to be reported accurately.

Using a water bath to check temperature readings is the preferred way to check for accuracy as it provides a stable medium for testing. A bucket of water should be filled and left to equilibrate with the room's temperature for at least four hours. Equilibrium is reached after the National Institute of Standards and Technology (NIST) approved thermometer readings are within ± 0.1 degrees Celsius (°C) for 10 minutes. The sonde's temperature reading should match the NIST thermometer reading; if it does, the other sensors will read accurately to within the reported accuracy of the sensor (see **Table 10-2** for sensor accuracies). If the sonde's temperature reading does not match the NIST thermometer reading, the probe may need to be replaced.

Table 10-2. YSI sensor accuracy.

Sensor		**EXO™ Series Accuracy (YSI 2020a)**
Temperature		± 0.2 °C
Conductivity	Non-Wiped	For 0-10,000 µS/cm: ± 0.5% of reading or 1 µS/cm (whichever is greater) For 10,000-20,000 µS/cm: ± 1% of reading
	Wiped	± 1% of reading or 2 µS/cm (whichever is greater)
pH		± 0.1 within ± 10 °C of calibration temperature ± 0.2 for all other temperatures
ORP		± 20 mV
TAL		Linearity: $r^2 \geq 0.999$ for Rhodamine WT across full range
Turbidity		For 0-999 FNU: 0.3 FNU or ± 3% of reading For 1,000-4,000 FNU: ± 5% of reading
Barometer (YSI 2020b)		± 1.5 mmHg from 0-50 °C
DO		For 0-200%: ± 1% of reading or 1% saturation (whichever is greater) For 200-500%: ± 5% of reading
ISE (YSI 2020b)	NH_4^+ & NO_3^-	± 10% of reading or ± 2 mg/L – N (whichever is greater)
	Cl^-	± 15% of reading or ± 5 mg/L – Cl (whichever is greater)

An ambient air temperature check can be used if a water check is unavailable (such as if in the field or if checking in the office). Leave the sonde and a NIST approved thermometer on a tabletop for at least 30 minutes in a stable temperature environment and compare the readings once equilibrium is reached.

NOTE: The ambient air temperature check cannot be used with sensors that require a hydrated environment for storage (such as pH sensors) as all sensors on the meter must be left in the same environment.

10.2.2 SC Calibration

Electrical conductivity is temperature dependent and must be reported in SC—that is, temperature corrected to 25 °C with the units of microsiemens per centimeter (µS/cm).

The EXO™ series sondes have two types of conductivity sensors. One is the standard sensor with two flow cells (Section 4.5 YSI 2020b), the other one is a wipeable sensor that allows for the EXO™ central brush to clean the electrodes (Section 4.7 YSI 2020b). Either can be used for instantaneous readings, but it is recommended to use the wipeable sensor for continuous deployments.

Specific conductivity is a one-point calibration. EXO™ sondes are calibrated with 1000 or 1413 µS/cm calibration solution. Either will provide acceptable calibration, however western MT waterbodies have lower conductivity and, if available, it is better to calibrate with the 1000 µS/cm calibration solution.

NOTE: Check your SAP for SC calibration solution concentration recommendation. You may need to use a particular calibration solution concentration depending on the study site's expected conductivity.

NOTE: Conductivity calibration solutions are not buffered and are affected by dilution and evaporation. Always ensure that the cap is tight (i.e., no evaporation occurred) and check the expiration date and the opened-on date before calibration. The manufacturer recommends these solutions should be used within 1 month of being opened (YSI 2019b); expired solutions may still be used for rinsing or storage purposes. It is important for the user to be aware that an expired calibration solution may possibly cause an inaccurate calibration. See **Table 6-2** for additional calibration solution expiration dates.

Make sure that the conductivity cells are clean before calibrating. A small test-tube style brush (provided in the sonde maintenance kit) should be swept through the flow cells and over the electrodes to remove any deposits that have developed on the electrodes, then rinse with DI water (YSI 2020b).

After calibration, the cell constant should be recorded on the calibration form. The cell constant will be in the range of a specific number determined by the type of sensor. If the value shifts from previous readings or from the given range, it is a sign that the conductivity sensor is drifting (YSI 2020b).

The ideal cell constants for the EXO™ series sensors are:

- Wipeable Conductivity Smart Sensor = 0.469 cm^{-1} ± 0.05 cm^{-1}
- Conductivity Smart Sensor (non-wipeable) = 5.1 cm^{-1} ± 10% (YSI 2020b)

If the sensor is not reading within the accuracy specifications for the benchmark or the cell constant is showing inconsistencies from previous calibration records:

1. Check the electrodes for damage or debris.
2. Check that the calibration solution is fresh.
3. Repeat the calibration.

If the sensor is damaged it should be replaced with a new sensor and the calibration must be repeated. If the problem persists, see the manual, or contact the manufacturer for trouble shooting.

10.2.3 pH Calibration

Measurement of pH is temperature dependent. Most pH sensors designed for sondes are non-refillable and require that the bulb be replaced every 12-24 months depending on model, storage, and use. The EXO™ series pH sensor has a replaceable top module portion of the sensor, so the whole sensor does not need to be replaced.

Calibration of pH is either a 2- or 3-point calibration of pH 4.00 Standard Units (S.U.), 7.00 S.U., or 10.00 S.U. solutions. If using a 2-point calibration the values are to bracket the sampling water's pH. The WQPB usually carries out 2-point calibrations using 7.00 S.U. and 10.00 S.U. solutions, which straddles the natural pH range of most state surface waters. The pH 7.00 S.U. solution must always be included. The sonde manual will dictate whether pH 7.00 S.U. solution is required to be the first calibration point, or if the order of the calibration solution does not matter (the latter is the most common case).

Before calibrating, make sure that the pH bulb is not fouled or damaged. If damaged, the sensor will need to be replaced. A fouled sensor will slow the response time and needs to be cleaned. The sensor typically should be removed from the sonde before cleaning. There are multiple ways to clean a pH sensor depending on the level of fouling, none include mechanically cleaning the glass bulb. Do not scrub or wipe the glass bulb (YSI 2020b). It is recommended to start with the gentler soap solution before trying the acid or bleach soaks, and testing for sensor reading in between the soaks.

NOTE: In some circumstances it may be necessary to gently swab the glass bulb with a moist Q-tip to remove debris (e.g., in the field during a sonde check if a wiper has failed). It is important to not apply too much pressure as the bulb may break. This should only be performed by staff who have experience with this cleaning method.

1. Soak for 10-15 minutes in a water and dishwashing soap solution, rinse with tap water, and test.
2. If step 1 does not correct the slow response, soak for 30-60 minutes in a one molar hydrochloric acid solution, then rinse with tap water and soak in tap water for 1 hour, stirring occasionally, rinse in tap water, and test.
3. If neither step 1 or step 2 correct the slow response, soak for 1 hour in a 1:1 solution of chlorine bleach and tap water, rinse with tap water and soak in tap water for one hour, stirring occasionally, rinse in tap water, and test.

If the sensor continues to have a slow response after trying all three cleaning steps, if it is damaged, or if it is past its lifespan it will need to be replaced before calibration.

NOTE: Check the user's manual for any cautions before attempting to clean the sensor (see **Table 10-1**).

After the calibration, record the temperature and what the millivolt (mV) reading was for each solution on the calibration form. Millivolt readings can help determine the state and lifespan of the pH sensor. The ranges for mV readings depends on the sensor manufacturer, however **Table 10-3** includes the general ranges. The difference between the pH 7.00 S.U. mV reading and either the pH 4.00 S.U. or pH 10.00 S.U. mV reading determines the delta slope. Ideally in situations where calibrations are done near 25 °C the delta slope is ≥ 165 mV. Over time the mV readings and the delta slope will drift negative, this indicates that the sensor is approaching the end of its lifespan and needs to be replaced (YSI 2020b).

Table 10-3. pH mV values and slopes (YSI 2015).

pH Buffer (S.U.)	Values (mV)
4.00	165 – 180
7.00	0 ± 50
10.00	-165 to -180

10.2.4 ORP Calibration

Oxidation reduction potential sensors are typically integrated into a pH sensor but require a separate calibration. Oxidation reduction potential results are temperature dependent and are reported in mV. A real time temperature reading of the calibration solution is needed to determine the calibration value. The calibration is 1-point. Different solutions can be used to calibrate ORP, but Zobell solution is recommended for YSI sensors (YSI 2019a). This calibration solution is temperature dependent, and the calibration value will have to be interpolated from **Table 10-4** once the temperature has stabilized. See **Appendix A** for a spreadsheet that has been created to assist in this interpolation.

Table 10-4. ORP temperature values (YSI 2019a).

Temperature (°C)	ORP (mV)	Temperature (°C)	ORP (mV)	Temperature (°C)	ORP (mV)
-5.0	270.0	15.0	244.0	35.0	218.0
0.0	263.5	20.0	237.5	40.0	211.0
5.0	257.0	25.0	231.0	45.0	205.0
10.0	250.0	30.0	224.5	50.0	198.5

NOTE: Make sure to rinse the sonde and sensors after the calibration and do not leave the sensors in the Zobell solution for a long time as this may degrade sonde materials (YSI 2019a). Follow rinse procedures in **Section 10.2**.

After the calibration, record the temperature and mV value that were used to calibrate the sensor, along with the benchmark reading.

10.2.5 Total Algae (Chl-*a* and Blue-green Algae) Calibration

Chlorophyll-*a* and blue-green algae (phycoerythrin [PE] or phycocyanin [PC]) sensors are optical. Take care to avoid damage to the sensor face. Clean the sensor face with the wiper and visually check for any bubbles on the sensor face before accepting any calibration point. Bubbles may interfere with the sensors ability to accurately read the solution.

The EXO™ TAL sensors are either set up to read chl-*a* and phycoerythrin (TAL-PE) or chl-*a* and phycocyanin (TAL-PC). Each sensor can report either parameter in micrograms per liter (µg/L) (estimate of pigment concentration) and in relative fluorescence units (RFU) (normalizes the sensor's output on a 0-100% scale). Relative fluorescence units are recommended as they allow for data to be compared from one sensor to the next, as well as monitoring fouling or degrading performance. They are calibrated separately and for each parameter (for example, the TAL-PC sensor would need to be individually calibrated in chl-*a* RFU, chl-*a* µg/L, PC RFU, and PC µg/L).

The calibration for these parameters can either be a 1- or 2-point calibration. The first calibration would be in 0 milligrams per liter (mg/L) or 0 RFU. If a second calibration point is required, it will be a diluted solution of Rhodamine WT and will need to be temperature compensated. An additional benchmark reading is to be taken in the Rhodamine WT solution. It is recommended to use a 2-point calibration for the EXO™ series TAL sensors. The type of pigment (chl-*a* vs PC vs PE) determines what strength of Rhodamine WT solution is needed for the calibration. See **Table 10-5**.

Rhodamine WT at a 2.5% solution strength is required. Prepare a stock solution by combining 5.0 milliliters (mL) of 2.5% Rhodamine WT and 995 mL of DI water for a final total solution volume of 1000 mL (this results in a 125 mg/L Rhodamine WT solution). Keep this stock solution in a refrigerator; it can be stored for up to two years. To prepare a solution to calibrate the chl-*a* and PC parameters, combine 5.0 mL of the 125 mg/L Rhodamine WT solution previously made and 995 mL of DI water for a final total solution volume of 1000 mL (resulting in 0.625 mg/L of Rhodamine WT). Use this within 24 hours of preparation and discard after use (YSI 2020b). Phycoerythrin calibration requires a different concentration, see the user manual for the correct mixture.

This calibration solution is temperature dependent, and the calibration value will have to be extrapolated from **Table 10-5** once the temperature has stabilized. See **Appendix A** for a spreadsheet that has been created to assist in this interpolation.

Table 10-5. Temperature-compensated standard solution values for EXO™ TAL sensors (YSI 2020b).

Solution Temperature (°C)	Chl-*a* 0.625 mg/L Rhodamine		PC 0.625 mg/L Rhodamine		PE 0.025 mg/L Rhodamine	
	Chl-*a* (RFU)	Chl-*a* (µg/L)	PC (RFU)	PC (µg/L)	PE (RFU)	PE (µg/L)
30	14.0	56.5	11.4	11.4	37.3	104.0
28	14.6	58.7	13.1	13.1	39.1	109.0
26	15.2	61.3	14.1	14.1	41.0	115.0
24	15.8	63.5	15.0	15.0	43.0	120.0
22	16.4	66.0	16.0	16.0	45.0	126.0
20	17.0	68.4	17.1	17.1	47.0	132.0
18	17.6	70.8	17.5	17.5	49.2	138.0
16	18.3	73.5	19.1	19.1	51.4	144.0
14	18.9	76.0	20.1	20.1	53.6	150.0
12	19.5	78.6	21.2	21.2	55.9	157.0
10	20.2	81.2	22.2	22.2	58.2	163.0
8	20.8	83.8	22.6	22.6	60.6	170.0

10.2.6 Turbidity Calibration

Turbidity sensors are optical. Take care to avoid damage to the sensor face. Clean the sensor face with the wiper and visually check for any bubbles on the sensor face before accepting any calibration point. Bubbles may interfere with the sensor's ability to accurately read the solution. Optical turbidity sensors will report in units of formazin nephelometric units (FNU). It's possible that other turbidity sensors or meters may report in nephelometric turbidity units (NTU). The difference between these two units is based on the kind of light source the sensor or meter uses, but the conversion rate between these two units is 1:1 (USGS 2019). Different types of turbidity sensors may report different values in the same solution due to the natural variations in the optical components and geometries (YSI 2020b).

A turbidity sensor calibration is either a 2- or 3-point calibration in a prepared formazin standard or a standard provided by the manufacturer (**Table 10-1**). DEQ uses a 2-point calibration with standards that were prepared by YSI. It is important to use the same type of standard throughout a calibration and field season (YSI 2020b).

The turbidity calibration is 2-point with a low reading and a high reading (value is dependent on the manufacturer). The benchmark solution should have a reading between the two calibration solutions. The EXO™ series Turbidity sensor uses 0 NTU and 124 NTU and then a 12.4 NTU benchmark.

NOTE: The same YSI turbidity solution may require slightly different calibration values be input to the sonde, depending on the type of sonde (e.g., EXO™ series vs. other YSI instruments). Check the bottle label before proceeding.

10.2.7 Barometer Calibration and Calculation

DO calibration requires true barometric pressure, uncorrected from sea level. Barometric pressure will either have to be determined from a local barometer or recorded from the sonde's handheld barometer. Therefore, it is important to ensure that the sonde's internal barometer is properly calibrated, as covered below.

To verify true barometric pressure, use the National Weather Service reports for **station pressure** at airports:

1. Visit (https://www.wrh.noaa.gov)
2. Search for the nearest city (example: Helena, MT)
3. Select "3 Day History" under "More Information" on the right.

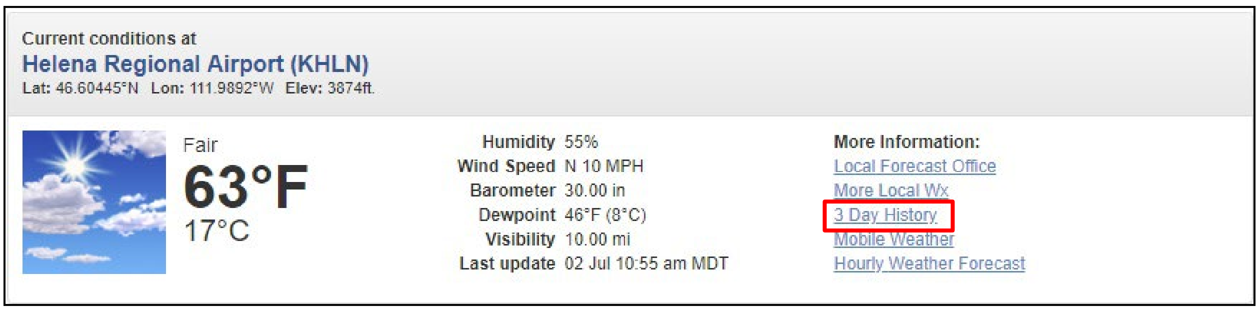


Figure 10-1. NOAA Helena Regional Airport front page.

The link will open a webpage with a table. One of the columns is titled "Station Pressure (inches)". Use the values near the top of the page closest in time to your calibration time. Values should usually be within an hour of the current time. Use this value when calibrating the instrument's barometer or computing DO saturation. Be aware of rapidly changing station barometric pressures, as this could affect your calibration accuracy.

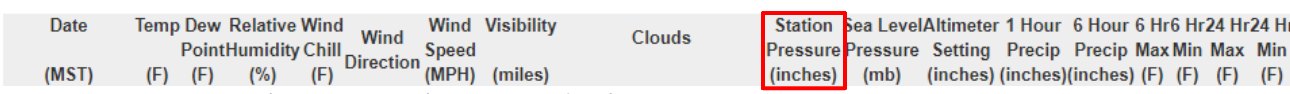


Figure 10-2. NOAA Helena Regional Airport 3-day history.

NOTE: The pressure in inches of mercury must be converted into millimeters of mercury (mm Hg) before calibrating the meter's barometer, as provided below in **Table 10-6**.

Table 10-6. Conversion from inches or millibar to mm Hg.

1 inch of Hg =	25.4 mm Hg
1 millibar of Hg =	0.750062 mm Hg

The pressure value (in mm Hg) should be used to calibrate the internal barometer of the YSI and can also be used as an independent measure of BP for DO calibration. If you are calibrating at DEQ's watershed (on Carter Drive near the airport), the elevation difference from the airport is very minor and you can directly use the airport's station pressure for calibration.

At other weather station locations, BP may only be reported as "Sea Level Pressure." If this is the case, the data will need to be *uncorrected* before calibrating the meter's barometer or calibrating DO. Use this equation to correct for the true barometric pressure (YSI 2020b):

True BP in mmHg = Corrected BP in mmHg – [2.5 * (Local Altitude in ft. above sea level/100)]

Where BP = barometric pressure, and Corrected BP = sea level pressure

NOTE: When using weather station data for weather station outside of Helena, be aware that your physical location may not be at the same elevation as the weather station you are accessing. This could make a big impact on your calibration. Best practice is to ensure, prior to leaving the watershed, that your instrument's internal barometer is properly calibrated and rely on it for local BP.

10.2.8 DO Calibration

Dissolved oxygen sensors are normally optical, but some are electrochemical and have a membrane covering the sensor face. Mostly what is used by DEQ on multiparameter sondes is optical dissolved oxygen probes (ODO). Clean the sensor face with the central wiper and visually check for any bubbles on the sensor face before accepting any calibration point. Bubbles may interfere with the sensor's ability to accurately read the solution.

Optical dissolved oxygen sensors include a user replaceable membrane cap that must remain in a humid environment to maintain accuracy (YSI 2020b). If the cap is left to dry out, it may still be usable if rehydrated (**Table 10-1**). The EXO™ series ODO sensor's cap has an approximate lifespan of 12 months (YSI 2020b).

The DO calibration is a 1-point calibration in an oxygen saturated environment (**Table 10-1**). This calibration can take place in many ways but for DEQ's EXO™ series sondes and associated ODO probes it is recommended to calibrate via a water-saturated air environment (humid air saturation). This is the most reliable calibration that is easily repeatable in a lab setting and out in the field. Ensure no water droplets are on the DO sensor or the thermistor. Place the dry ODO and temperature sensor in a calibration cup with approximately 1/8th inch of water and vent the sensors to the atmosphere by disengaging a few threads. Wait at least 15 minutes before calibrating to allow for the temperature and oxygen pressure to equilibrate (YSI 2020b). Depending on atmospheric temperature, calibration may take longer to build a humid environment and equilibrate.

There are at least two ways to calibrate for DO with either % saturation or mg/L, but the calibration should be done with % saturation. One calibration is needed to calibrate both DO readings.

After the calibrations, do not move the sonde or the probes and record a live reading in DO mg/L along with the temperature and the current barometric pressure on the calibration form. The instrument's DO (in mg/L) is compared to a table-calculated DO mg/L value to verify that the sensor is properly calibrated. The table-calculated mg/L DO values are computed by multiplying the interpolated solubility and % saturation from two tables (YSI 2019c). Copies of these tables can be found in **Appendix C**.

1. Locate a modified calibration table value in tenths of percent's e.g. 88.1%, 88.2%, etc.
2. Locate a modified solubility table value in tenths of °C.
3. The equation for computing the table value DO is:
    x = % saturation at a given atmospheric pressure/elevation (**Table C-2**, mm Hg), e.g. 0.865
    z = solubility of oxygen at a given temperature (**Table C-1**; use Chlorinity and Salinity = 0 column), e.g., at 20 °C DO solubility is 9.09 mg/L
    y= expected DO concentration in mg/L at that temp and pressure.

$$y = xz$$

Using these two tables, even in the field, you can quickly determine with a calculator if your sonde's calibrated DO value is correct for your location's elevation and current temperature.

Excel Spreadsheet DO X-Check: Dissolved oxygen % saturation can be found by converting barometric pressure into atmospheres (atm's) (also known as percent saturation). Then using the Excel spreadsheet DO_pressure_temp_correction.xls located here:

G:\WQP\7_QAProgram\3_SOPs\Multiparameter_WQ_Sonde\DOmgL-%sat

it can be converted to mg/L if the temperature is known. This spreadsheet is also extremely handy when needing to convert from % saturation to mg/L and back. When using the spreadsheet:

1. Determine the percent sat (which is also equal to atmospheres) from the regression equation in the figure in the spreadsheet, using the barometric pressure recorded the day the YSI was calibrated.
2. Enter the percent sat value from bullet 1 into cell C44 and enter the water temperature the instrument was recording into cell D44; the "DO table value" (correct DO in mg/L at that % saturation and temperature) is computed in cell G44.
3. Then, see what you recorded as the instrument's % saturation after it was calibrated, and put that value into cell C44 while leaving the value in D44 unchanged. The new concentration (mg DO/L) in G44 represents what the instrument would have read had you recorded it.

A spreadsheet has been created to assist in interpolating the solubility and % saturation values of the temperature and barometric pressure located here:

G:\WQP\7_QAProgram\3_SOPs\Multiparameter_WQ_Sonde\Appendice_Documents, "QA_Cal interpolation" spreadsheet, "DO Tables" Tab.

10.2.9 ISE Sensor Calibration

Ion-selective electrode sensors may be either: NH_4^+, NO_3^-, or Cl^-. They are depth sensitive (i.e., for use in less than 55 ft. of water) and should only be used in freshwater (YSI 2020b). It is best to calibrate ISEs separately from conductivity or pH sensors and to not include them in the conductivity and pH calibrations because ISEs are greatly affected by conductivity and pH solutions (being in those solutions decreases the response time and reduces data quality of the ISE sensors).

It is recommended to let the sensor soak in its high-calibration solution (4 to 6 hours) before calibrating (YSI 2020b). Due to the short lifespan (3 to 6 months) and frequent calibration needs, the sensors need to be replaced often. YSI EXO™ series uses a module replacement similar to the pH/ORP sensors for replacement (**Table 10-1**).

A 3-point calibration is recommended for all of these circumstances:

- When the module has been replaced
- When the sensor is new
- When the sensor will be deployed for 30 days
- When the temperature of the monitored substance cannot be anticipated

For most of WQPB's purposes a 3-point calibration is necessary. 1- and 2-point calibrations may be possible and are discussed in the user manual (**Table 10-1**).

A 3-point calibration includes a low point at ambient temperature, a high point at ambient temperature, and the same low point, but at a temperature that is at least 10 °C different than the first temperature (YSI 2020b). Before beginning the calibration, make sure that there is a sufficient amount of calibration solution and that it is the correct temperature.

NOTE: If the temperature of the third solution is less than 10 °C of the first solution, the YSI Kor Software will not let the user accept the third calibration value.

NOTE: ISE calibration solutions should not be frozen, leave solution to chill (if chilling the third solution) in a refrigerator overnight. If possible, chill a calibration cup and guard along with the solution to help the solution stay chilled after the sensors and the sonde are placed in the solution.

For NH_4^+ and NO_3^- the two solutions that the EXO™ series uses are 1 mg/L and 100 mg/L concentrations of the respective sensors. The Cl^- sensor uses 10 mg/L and 1,000 mg/L concentrations.

After calibration, record the raw mV values and delta slope on the calibration form along with the benchmark readings. The benchmark readings should be of both calibration solutions.

Table 10-7 shows "ball-park" values of what the mV and delta slope values should read. The Smart quality control (QC) score determined by the YSI Kor Software takes more than these values into account when determining if an ISE sensor passes QC.

Table 10-7. ISE raw mV ranges (YSI 2020b).

Calibration Solution	NH_4^+ (mg/L)		NO_3^- (mg/L)		Cl^- (mg/L)	
	1	100	1	100	10	1,000
Raw values (mV)	0 ± 20[1]	90 - 130[2]	200 ± 20[1]	90 – 130[3]	225 ± 20[1]	80 – 130[4]
Delta Slope (mV)	~ 90 - 130				~ 80 - 130	
mV /decade	45 - 65		-45 to -65		-40 to -65	

[1]New sensors only.
[2]>1 mg/L mV value.
[3]<1 mg/L mV value.
[4]<10 mg/L mV value.

If an ISE sensor has failed a calibration, it may be due to the following:

- Sensor needs to be reset to factory default before calibrating
- Module was not soaked in the sensor's high-calibration solution for 4 to 6 hours
- Module needs to be replaced

Recalibrate the sensor after correcting the issue.

10.2.10 Other Types of Sensors

For any other sensor types that are not mentioned by this SOP, see the appropriate manual or calibration guidance given by the manufacturer. These are some things to keep in mind when calibrating a sensor:

- What does the sensor measure – are there multiple readings that require multiple calibrations?
- What solutions to use?
- What is clean or in good condition?

- What secondary information is helpful to verify the data?
- What does a successful calibration look like?
- What to do when there is an unsuccessful calibration?

10.2.11 Unattended Deployment

Each sonde should be tested for an unattended deployment after calibrations are complete and before field use. This checks to make sure that all sensors are operating correctly, batteries are installed, and that the sonde is cycling through its awake and sleep cycle. Most sondes will go into a low power mode in between sampling intervals to conserve power.

NOTE: When carrying out benchtop launch tests, use the launching method corresponding to how the sonde will be launched in the field, if possible. Use the same computer or the same handheld. This makes sure that there are no communication problems between the devices.

To carry out a benchtop unattended deployment test, launch each sonde with at least a 3-minute logging interval so that the difference between the sleep and awake cycles are clear. If the sleep/awake cycle is not clear; increase the interval so that the sleep cycle will be longer. Most sondes will wake up before logging a reading to clean the sensors. Make sure that each sonde goes through this cycle.

Sondes can be placed in a bucket of water to record a few readings. Let the sonde record for at least 15 minutes. Stop the sonde and download the data and look at the file for any anomalies in the data.

NOTE: Make sure that the handheld or computer is disconnected from the sonde during the unattended deployment test. Some settings may allow for the handheld or computer to power the sonde.

10.2.12 Depth Sensor Calibration

Some sondes have integrated depth sensors and are primarily used for profiling a water column. Follow the instructions from the appropriate manual to calibrate the depth sensor (**Table 10-1**).

For the EXO™ series it is recommended to calibrate the depth sensor on site. The maximum depth that the sonde can measure at is recorded next to the serial number on the main body. Use a 1-point calibration exposed to air. The sonde should be kept still while calibrating. Wait for the readings to stabilize before accepting the calibration point. Depth offsets are an advanced setting that are described in the EXO™ User manual and may be used to determine the location of the probes or bottom of the guard (YSI 2020b).

10.3 Sonde Deployment

Once a sonde has been calibrated and checked, it is ready for field use. The sonde can either be deployed for continuous data collection, used as an instantaneous field meter, or to collect depth profiles.

Each type of sonde may have multiple ways to be launched (through a handheld device or a computer) but the information that is needed for launching should include:

- Date and time to start logging
- Logging interval
- Unique file name

The unique file name at a minimum should include the sonde serial number and a user input description/suffix to help identify the file after the sonde has been retrieved.

If a sonde is being used for in situ measurements such as a depth profile, launching may not be necessary.

Please see the appropriate user guide for the sonde for how to launch that sonde (Section 3.7 YSI 2020b).

10.3.1 Deployment Considerations

Most sonde deployments done by the WQPB orient the sonde in a horizontal direction. This creates some potential problems due to water flow and sunlight. When deploying, choose a spot that will allow for the sensors to remain hydrated throughout the whole deployment (DO, pH and ISE sensors require a humid environment and will need maintenance or replacement if they are allowed to go dry for any extended period). To protect the sensors faces from debris or sediment flowing downstream ensure that the sensor-end of the sonde is on the downstream end. EXO™ sondes are typically deployed vertically in lakes and reservoirs with the sensors facing the lake bottom; they are deployed parallel to water flow with the sensors facing downstream in streams and rivers.

When deploying in a lake or reservoir, the sonde will need to be connected to a line with buoys and anchors (**Appendix D**).

Always consult the user manual for any deployment restrictions such as clamping guidelines (Section 2.18 YSI 2020b).

10.3.2 Sonde Battery Lifespan

The set interval, number of probes, and advanced settings may affect the sonde's battery life. Keep these factors in mind when planning on how often to check/clean the sonde. The Kor Software dashboard is able to report the battery voltage of the EXO™ sonde, but not the estimated lifespan.

NOTE: The EXO™ sonde typically fails to collect data when the battery voltage reaches 3.6 V, and the max battery life for an EXO™2 sonde is 90 days if logging is set to a frequent interval, e.g., 15 min.

10.3.3 Field Checks/Cleanings

Depending on the waterbody and how long the scheduled deployment is, the sonde should be visited during the field season to check if there are any problems and to do any cleaning that may be necessary to ensure quality data collection. It is a good practice to take pictures of the sonde and sensors before cleaning to record any fouling that may negatively affect the data and serve as field observations regarding what may have been affecting the data negatively when looking at the final set of data. Always note when a sonde is removed from the sampling location on the Continuous Datalogger Form and the SVF (**Appendix A**). During these checks the sonde should be cleaned, and the probes should be inspected. Cleaning should be a general removal of any obstructions such as detached algae or sticks that are tangled in the deployment device or sonde. The sonde should be brushed off to remove any accumulation of organisms, muck, or algae. The probe housing should be scrubbed with a toothbrush removing any accumulation. The probe faces should not be cleaned with a toothbrush or touched. If needed, they can be gently cleaned with a Kim wipe or moist Q-tip and rinsed with water. Record any observations as these can be useful when looking at the data later (e.g., "large mat of dead detached algae smothering the sonde causing likely effects on DO"). If necessary, the sonde's batteries should be replaced, and if this is carried out the sonde will need to be relaunched. The project's SAP should indicate the frequency of when a sonde is to be checked and cleaned. As general guidance, a sonde should be checked at least every 10-14 days.

10.3.4 Retrieving Sondes

Always note when a sonde is removed from the sampling location on the Continuous Datalogger Form and the SVF (**Appendix A**). It is recommended to make notes about the condition of the sonde and the sensors as well as taking photos of the sensors. This will help when looking at the data that was collected. If required by the project's SAP, conduct any post deployment benchmark checks in the field before returning to the office. The sonde does not need to be paused as it is retrieved (the unit can be left in continuous data-collection mode) but it is necessary to record the time the sonde is removed from the water. This is important when reviewing the data.

10.4 Post Deployment

Once the sonde has been returned to the office, the data are to be downloaded and saved correctly; save the file in the appropriate project folder on the G drive using the naming convention [sonde]_[site name]_[year]. Post-deployment benchmarks are measured and then assessed to assist in checking the data for any drift from calibration. Additional readings must be collected in the lab to help account for any drift in the sensors. See **Section 12.0** for more information on how to QA/QC the data.

10.4.1 Post Deployment Benchmarks

Post deployment benchmarks are collected after data are downloaded and the sonde is returned to the watershed. The post deployment benchmarks are crucial for determining drift that happened when the sonde was deployed. Determining drift is an important part of the QA/QC process. The QA/QC process is described in further detail in **Section 12.2.1**.

10.4.2 Sonde Storage and Protection

After the sonde has been post-calibrated the sonde will need to be put into a storage setting or "winterized."

Since some sensors require a humid environment for short storage the system normally includes a cup to hold approximately a centimeter of water. The EXO™ series sondes have a plastic guard that protects the sensors when deployed and that slides into the calibration and storage cup. Each sonde has its own cup and guard system. It is recommended to write the serial number on the cup so that cups can be matched up with the same sonde.

NOTE: Two sets of an EXO™ cup and guard are set aside for calibration use. This is to help ensure that the calibration equipment is clean.

For short term storage (such as after calibration, but before field use) it is acceptable to store all sensors on the sonde in the cup with about a centimeter of water in the bottom to maintain a humid atmosphere.

For long-term storage (when not assigned to a project and post-field season) some sensors will need to be removed and placed in other solutions to maintain their accuracy; most sensors should be removed from the sonde and put into storage (**Table 2-1**). When disassembling a sonde and probes, care should be taken to thoroughly clean both the sonde and probes. Extra time should be taken to ensure the screw threads have been thoroughly cleaned. Both male and female ends of the screw should be wiped with Kim wipes and cotton swabs. This is crucial for future ease in assembly and disassembly.

11.0 DATA AND RECORDS MANAGEMENT

All hardcopy documentation of the data, such as completed SVFs and Continuous Data Logger Forms, are kept, and maintained by the WQPB. Data collected will be reviewed, verified, and stored based on the WQPB QA/QC procedures (**Section 12.0**) and the QAPP.

11.1 CALIBRATION FORMS

Pre- and post-field calibration forms are to be filled out by the calibrator. Original forms are to be kept with the corresponding deployment or retrieval Continuous Data Logger Form. Copies are to be stored in the appropriate sonde binder for maintenance record keeping. **Appendix A** has more information about the calibration forms.

11.2 RECORDING ON SVF

Whenever a sonde is deployed, it is recorded on the SVF (**Appendix A**). There is a section built into all SVFs that addresses dataloggers and the actions taken during the site visit (
Figure 11-1. Datalogger section of the SVF).

Data Loggers	Temperature ☐ YSI ☐ MiniDOT ☐ EC ☐ TruTrack ☐ AquaRod ☐ Weather Station ☐
	Deployed ☐ Cleaned/Checked ☐ Retrieved ☐

Figure 11-1. Datalogger section of the SVF.
Additionally, if a datalogger is being deployed or retrieved, a Continuous Datalogger Form will be attached to the SVF. This is indicated in the "Field Assessments" section of the SVF by writing the form name in the "Other:" section (**Figure 11-2**).

Field Assessments
Photos ☐ Aquatic Plant Visual Assessment ☐ SAM ☐
Aquatic Plant Tracking ☐ Rosgen ☐ NRCS ☐
EMAP ☐ Total Discharge ☐ Channel X-Section ☐
Wetland ☐ Bacteria ☐ Other:

Figure 11-2. Field assessment section of SVF.

Any comments about the datalogger condition, retrieval time, or additional field measurements that were collected are recorded in the "Site Visit Comments" section on the back of the SVF or on a separate corresponding form. If the field meter is required to be calibrated in the field for project purposes, there is also a section to record the last date of calibration for SC and DO (**Figure 11-3**).

Field Meter Calibration		
pH Meter:	Manufacturer & Model:	Date of Last Calibration:
	Comments:	
Multiparameter Meter:	Manufacturer & Model:	
	Date of SC Calibration:	DO calibrated at site visit ☐
	Comments:	

Figure 11-3. Field meter calibration record section of SVF.

11.3 CONTINUOUS DATALOGGER FORM

Field personnel are required to fill out a Continuous Data Logger Form (**Appendix A)** whenever a sonde is deployed. The form is connected to the SVF at the time of deployment with the same site visit code (SVC) and Project ID. The sampling medium, interval, sonde make/model, and serial number must be recorded. It is important to record the launch date and time (when sonde began logging) and the deployment date and time (when the sonde is in the water collecting field data). The latitude and longitude should be the location where the sonde was deployed, this location may be different than the site location indicated on the SVF. Field personnel are to describe any key information about the sonde's deployed location and draw a detailed map to assist in the retrieval. If flags were used to mark any camouflaged locations, they should be noted on the map.

A photocopy of the deployed Continuous Data Logger Form must be made to bring into the field at the time of retrieval. Additional information at the bottom of the form is to be filled out at that time, including the retrieval SVC date/time, comment, and file name if given. Field personnel are encouraged to elaborate about the retrieval condition on the SVF's comment section and take pictures of the datalogger at the time of deployment and retrieval.

11.4 PREPARING DATA FOR MT-EWQX UPLOAD

All data collected by or for DEQ must be stored in the Montana EQuIS Water Quality Exchange (MT-eWQX) database. Sonde data collected by the WQPB is uploaded as a "blob" file to MT-eWQX after being formatted correctly.

After the data has been QC checked, it is to be saved in the same format as the MT-eWQX Datalogger Template (**Appendix A**). The Excel file has four tabs:

1. Instructions – On how to use the file
2. Final – How the data appears after QC check has occurred. Includes site and deployment information, drift corrections, temperature accuracy results, and any flags.
3. Formatted raw data – Applicable for temperature and macro analysis (may be applicable to temperature data collected for temperature assessment).
4. Original raw data – How the data appears when it is read out from the datalogger, no flags.

Once completed, the sonde spreadsheet is named:

[Waterbody Name]_[Station ID]_[yymmdd]_(SVC)_[Suffix].xlsx

Suffixes describe the type of datalogger. For WQPB sondes the suffix is YSI. The file is then saved in the appropriate project folder and on the DEQ network at the location:

G:\WQP\6_DataMgmt\3_EQuIS\EQuIS_Staging\20xx_FS_MDEQ_WQ\20xx_Dataloggers\Pending\ [Project ID]

12.0 QA/QC

It is the responsibility of field personnel to record accurate field notes and information at the time of collection and to ensure that forms are properly filled out. Accurate descriptions of a sonde's condition (observations of fouling, failed wipers, etc.) on the field forms are invaluable later when sonde datasets are reviewed and QCed in the office.

All equipment users must be familiar with the equipment and be able to troubleshoot common problems in the field. Routine inspections and repairs (or notification of need for repair) are necessary to ensure quality of collected data. It is up to the user to be thorough with observations and quick with repairs or notifications.

12.1 In Field QC Methods

Equipment that is deployed in the field should be checked occasionally to ensure that the sonde is still functioning properly, and that the equipment is still in the correct orientation. It is also important to ensure that there has not been a large amount of fouling or debris caught up on the deployed equipment. The timing of these checks is dictated by the project SAP. General information on field checks and cleaning can be found in **Section 10.3.3**.

Measurements taken by a deployed sonde can be cross referenced against another properly calibrated sonde or instrument by taking an instantaneous measurement close by and recording the time that they were taken to compare later when the data are downloaded. In addition, with YSI EXO™ series sondes, the deployed sonde can be connected to a computer (or handheld device) via Bluetooth® or a cable to view the data live in the waterbody it is deployed in. This allows the sonde to be compared to another calibrated device deployed in real time at the site.

12.2 Calibrations, Benchmark Readings, Drift, Flagging Data

Sensor calibrations should have been completed prior to deployment by experienced staff. Most sensors do not need to be recalibrated more than once per field season, but specific sensors, such as the ISE sensors, require more frequent calibration.

Benchmark readings will have been collected after sensors were calibrated. These benchmarks are then compared to post-deployment readings using the same standard solutions, to determine if there was any sensor calibration drift. A certain amount of calibration drift is usually acceptable; acceptable levels of drift are addressed below.

12.2.1 Drift from Calibration

Once the sonde has been returned to the office, the data are downloaded and saved correctly, and post-deployment benchmarks are collected to assist in checking the data for any drift. Additional readings must be collected in the lab to help account for any drift in the sensors.

Determining drift is an important part of the QA/QC process. When calculating drift, the probes should be in a clean condition similar to how they were deployed but extra care should be taken so they are not too clean. Excess cleaning of the probes can affect drift calculations, making them unrepresentative of the overall drift during the deployment (USGS 2006). **A cleaning of the probe faces themselves should not take place until after the post deployment benchmarks have been collected**. A scrubbing with a toothbrush and flushing with running water of probe bodies and the bulkhead is satisfactory. The sonde should be gently rubbed down and cleaned, especially all the nooks and crannies of the probes. The probe housing near the probe face should be cleaned with care to avoid damaging the probe face. The probe face itself should be inspected carefully, noting any damage or obstructions.
This subsection provides acceptable levels of drift from calibration for some common water quality parameters, based mainly on USGS (2006) but also on many years of DEQ project QAPPs and SAPs involving deployed sondes. For each parameter, the equation for calculating calibration drift is shown below the acceptable drift criterion. Acceptable levels of drift span the "excellent" to "good" accuracy ranges in **Table 12-1** (reproduced from table 18 in USGS, 2006). Acceptable drift from calibration criteria not provided by USGS (2006), but used by DEQ, are in **Table 12-2**.

NOTE: Data that drift beyond the recommended drift criteria here, or as specified in a project QAPP, are to be flagged. Methods for inputting the flags into continuous datasets (usually in Excel) are detailed in **Section 12.3**.

DO: $\leq \pm 0.5 \frac{mg}{L}$ DO over deployment
[Table Value$_i$ – Instrument Value$_i$] – [Table Value$_f$ – Instrument Value$_f$]

pH: $\leq \pm$0.5 units over deployment
[Standard$_i$ – Instrument$_i$] – [Standard$_f$ – Instrument$_f$]

ORP: $\leq$ 10 units over deployment

SC: $\leq$ 10% change over deployment from initial calibration

Where i = initial and f = final.

Use the instrument measured value, not calibration value at initial condition; use the same equation as for turbidity (see below).

Turbidity: $\leq$ 10% change from initial calibration (using instrument values)

$\left(\frac{Instrument_i - Instrument_f}{Instrument_i}\right)$*100 = % Decrease $\left(\frac{Instrument_f - Instrument_i}{Instrument_i}\right)$*100 = % Increase

Chlorophyl-*a*: < 10% over deployment from initial calibration using Rhodamine dye.

Data which has drifted into the fair to poor categories over the course of a deployment should be flagged in a continuous dataset.

Table 12-1. Accuracy ratings of continuous water quality recordings (USGS 2006).

Measured Field Parameter	Rating of Accuracy (Based on combined fouling and calibration drift corrections)			
	Excellent	**Good**	**Fair**	**Poor**
Water Temperature (°C)	≤ ±0.2	> ±0.2 – 0.5	> ±0.5 – 0.8	> ±0.8
SC	≤ ±3%	> ±3 – 10%	> ±10 – 15%	> ±15%
DO	≤ ±0.3 mg/L or ≤ ±5%, whichever is greater	> ±0.3 – 0.5 mg/L or > ±5 – 10%, whichever is greater	> ±0.5 – 0.8 mg/L or > ±10 – 15%, whichever is greater	> ±0.8 mg/L or > ±15%, whichever is greater
pH (S.U.)	≤ ±0.2	> ±0.2 – 0.5	> ±0.5 – 0.8	> ±0.8
Turbidity	≤ ±0.5 turbidity units or ≤ ±5%, whichever is greater	> ±0.5 – 1.0 turbidity units or > ±5 – 10%, whichever is greater	> ±1.0 – 1.5 turbidity units or > ±10 – 15%, whichever is greater	> ±1.5 turbidity units or > ±15%, whichever is greater

Table 12-2. Calibration drift criteria for other parameters, as specified by DEQ.

Sensor	Readings	Acceptable Drift	Source of Drift Criterion
ORP	Zobell solution	> 10 units over the course of the deployment	DEQ
Chl-*a*	Diluted Rhodamine WT solution (**Section 10.2.5**)	≤ 10% change from initial calibration	
Blue-Green Algae			

12.2.2 STORET Flags

Data flags will be used to mark data which may be affected by biofouling or other interferences; flags distinguish affected data from data which may be used with high confidence (no flags). The QC outcome should be recorded within the first few lines of the "Notes" column of the MT-eWQX Data_Logger_Template Excel document (more on this in **Section 12.3**) (Suplee 2007):

- "R" flag (data rejected) will be used when the sonde is out of the water: such as the time of deployment, retrieval, and cleaning.
- "BD" flag (beyond allowable drift) will be used when the data fails to meet the drift criteria established for the project. See **Table 12-2** for general drift guidance. Data will be flagged back to the previous known point of calibration.
- "DX" flag (differs from cross-check) will be used if the data are substantially different from a secondary sonde or instrument taking a reading near the deployed sonde. Data are determined to be substantially different if the variation is greater than the allowable drift:

Allowable Drift = instrument accuracy * number of instruments + 0.1 units for spatial variation
Spatial variation is included to allow for any difference between the two sondes' deployment locations.

- "II" flag (instrument interference) will be used when (a) there is a sharp change in data values that is unexplainable, (b) there is sharp change after a cleaning event, (c) there are unexplainable changes in the magnitude of daily diel patterns of pH and DO, or (d) there is unexplainable scatter of individual data points inconsistent with a parameter's overall patterns.

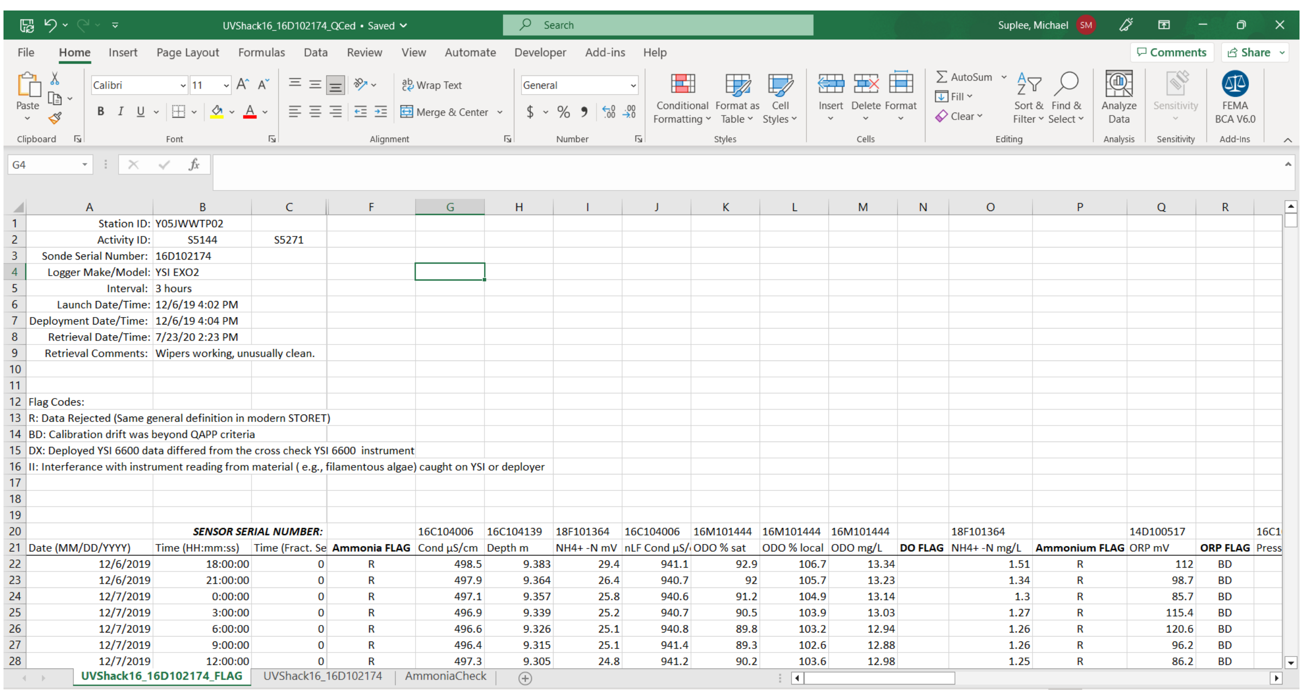
NOTE: An "R" flag may be used instead of II If you judge the data to be completely unusable due to some fairly severe instrument interference, such as a period of time when the sonde was completely smothered by drifting algae or plants.

12.3 Post-deployment Review of a Continuous Dataset: QC Methods

Post-deployment review of a continuous dataset for events/occurrences which may have affected the proper collection of data during deployment is an important part of the QC process. These events (e.g., episodic fouling of the sonde and deployer) can significantly impact the dataset and need to be identified to the degree possible. Impacted data are flagged accordingly, using the flagging criteria provided in **Section 12.2.2**. Step-by-step review instructions are provided here. The continuous data logger Excel is located on the network here:

G:\WQP\6_DataMgmt\3_EQuIS\EQuIS_Resources\MT-eWQX_Webpage\Documents\Step_1

Step 1: In the continuous Excel file, create a copy of the raw dataset on a new tab and add columns to accommodate the flags (**Figure 12-1**). Extra rows also need to be added at the top of the tab to accommodate the Header information and Flag Code definitions as shown in **Figure 12-1** (Suplee 2014). Required fields in column A of the Header Section are Station ID, Activity ID (at time of deployment, column B, and upon retrieval, column C), Sonde Serial Number, Logger Make/Model, Interval, Launch Date/Time, Deployment Date/Time, Retrieval Date/Time, Retrieval Comments, and, just a few rows below these, the flag codes and definitions. Corresponding data from your sonde for each field in the Header are recorded in column B of the Header, as shown in the figure.



	A	B	C
1	Station ID:	Y05JWWTP02	
2	Activity ID:	S5144	S5271
3	Sonde Serial Number:	16D102174	
4	Logger Make/Model:	YSI EXO2	
5	Interval:	3 hours	
6	Launch Date/Time:	12/6/19 4:02 PM	
7	Deployment Date/Time:	12/6/19 4:04 PM	
8	Retrieval Date/Time:	7/23/20 2:23 PM	
9	Retrieval Comments:	Wipers working, unusually clean.	
12	Flag Codes:		
13	R: Data Rejected (Same general definition in modern STORET)		
14	BD: Calibration drift was beyond QAPP criteria		
15	DX: Deployed YSI 6600 data differed from the cross check YSI 6600 instrument		
16	II: Interferance with instrument reading from material (e.g., filamentous algae) caught on YSI or deployer		

	A	B	C	F	G	H	I	J	K	L	M	N	O	P	Q	R	
20		**SENSOR SERIAL NUMBER:**			16C104006	16C104139	18F101364	16C104006	16M101444	16M101444	16M101444		18F101364		14D100517		16C1
21	Date (MM/DD/YYYY)	Time (HH:mm:ss)	Time (Fract. Se	**Ammonia FLAG**	Cond µS/cm	Depth m	NH4+ -N mV	nLF Cond µS/	ODO % sat	ODO % local	ODO mg/L	**DO FLAG**	NH4+ -N mg/L	**Ammonium FLAG**	ORP mV	**ORP FLAG**	Press
22	12/6/2019	18:00:00	0	R	498.5	9.383	29.4	941.1	92.9	106.7	13.34		1.51	R	112	BD	
23	12/6/2019	21:00:00	0	R	497.9	9.364	26.4	940.7	92	105.7	13.23		1.34	R	98.7	BD	
24	12/7/2019	0:00:00	0	R	497.1	9.357	25.8	940.6	91.2	104.9	13.14		1.3	R	85.7	BD	
25	12/7/2019	3:00:00	0	R	496.9	9.339	25.2	940.7	90.5	103.9	13.03		1.27	R	115.4	BD	
26	12/7/2019	6:00:00	0	R	496.6	9.326	25.1	940.8	89.8	103.2	12.94		1.26	R	120.6	BD	
27	12/7/2019	9:00:00	0	R	496.4	9.315	25.1	941.4	89.3	102.6	12.88		1.26	R	96.2	BD	
28	12/7/2019	12:00:00	0	R	497.3	9.305	24.8	941.2	90.2	103.6	12.98		1.25	R	86.2	BD	

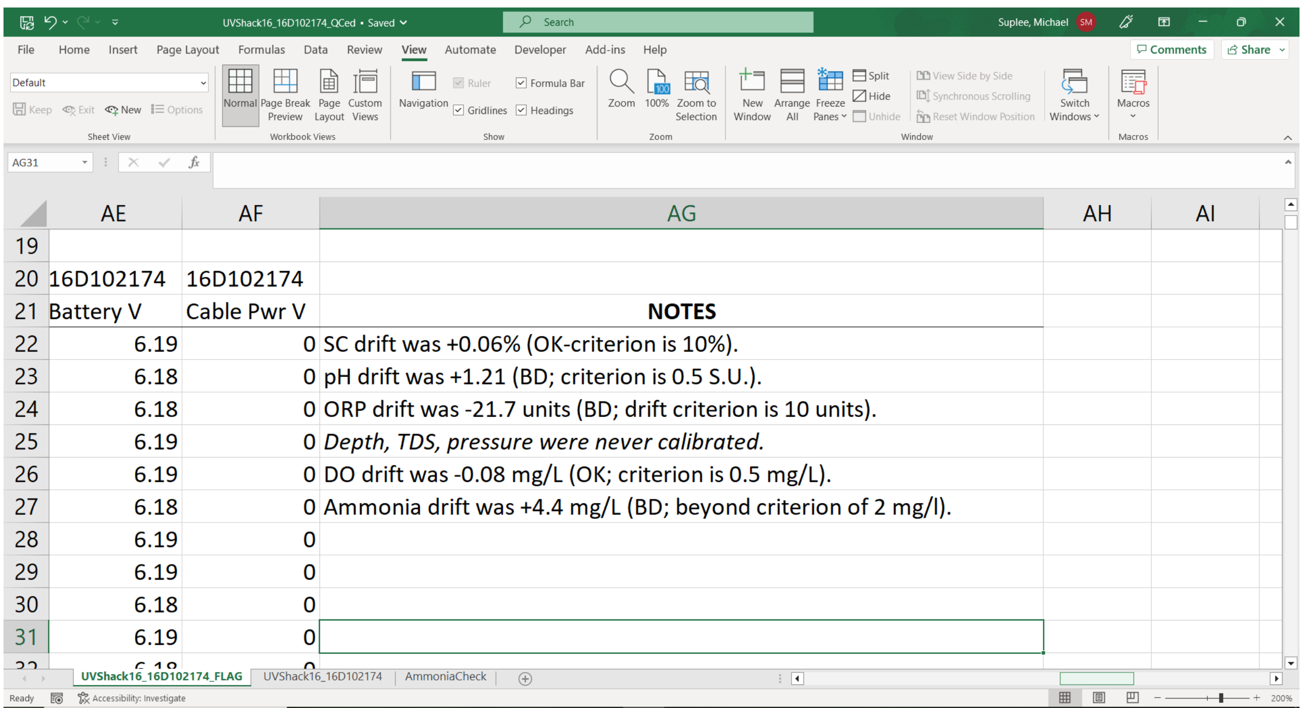
UVShack16_16D102174_FLAG | UVShack16_16D102174 | AmmoniaCheck

Figure 12-1. Example template for the tab used to incorporate key metadata, complete QC of the sonde data, and include data flags where necessary.

Most information necessary to carry out the dataset review is found in the SVFs and Continuous Data Logger Form. They indicate if the unit had any malfunctions during deployment or upon retrieval, if it was smothered by algae or plants, how it appeared during cleaning events, etc. Rely on this information to help you judge the dataset.

Step 2. Check deployment and retrieval date/time against the initial and final instrument readings. Flag "R" all instrument data outside the recorded deployment-to-retrieval period. This may also include cleaning events when the instrument was out of the water.

Create a "Notes" column to the right of and near the top of the dataset (**Figure 12-2**). Record in the first few cells under the "Notes" column your evaluations of the drift criteria (**per Section 12.2.1**) and by how much, e.g., "DO drift was 0.35 mg/L over the deployment (OK; criterion is ≤ 0.5 mg/L)." Include this information even for cases where no flags will be applied as the actual amount of drift and the drift criterion will help later when data are used for decision making.



	AE	AF	AG	AH	AI
19					
20	16D102174	16D102174			
21	Battery V	Cable Pwr V	**NOTES**		
22	6.19	0	SC drift was +0.06% (OK-criterion is 10%).		
23	6.18	0	pH drift was +1.21 (BD; criterion is 0.5 S.U.).		
24	6.18	0	ORP drift was -21.7 units (BD; drift criterion is 10 units).		
25	6.19	0	*Depth, TDS, pressure were never calibrated.*		
26	6.19	0	DO drift was -0.08 mg/L (OK; criterion is 0.5 mg/L).		
27	6.18	0	Ammonia drift was +4.4 mg/L (BD; beyond criterion of 2 mg/l).		
28	6.19	0			
29	6.19	0			
30	6.18	0			
31	6.19	0			

Figure 12-2. The "NOTES" column. The "Notes" column is placed to the right of the dataset and occupying several rows where important information about calibration drift and other QC review information is recorded.

Step 3. Create across-time plots of the principal data parameters (e.g., temperature, DO, pH, chl-*a*, and turbidity). Use these plots to evaluate sensor interferences and, in turn, flag the affected data "II", or even "R" (if you judge the data to be completely unusable), accordingly. The following describes commonly encountered situations in continuous datasets:

a. Sudden increases or decreases in sensor readings immediately after a cleaning event. Use the pattern of data before and after the cleaning to judge how far back before the cleaning event the data should be flagged.

b. Increasing diel oscillation patterns for DO and pH which are resolved after a cleaning event and the removal of snagged algae/plants on the sonde (**Figure 12-3**). Plotting temperature along with DO provides clues about the overall pattern of DO; water temperature drops usually equate to increased DO concentrations and often occur with flow increases (**Figure 12-3**).

c. Cases where a parameter, often DO and pH, drops to very low levels suddenly and then returns to "normal" just as quickly (**Figure 12-4**). This is probably associated with snagged drifting filamentous algae smothering the sonde which later detaches on its own after decaying or a change in flow, after which the sonde can read normally again. If a turbidity or chl-*a* sensor was included on the sonde, review the patterns these sensors manifest to help judge what occurred (**Figure 12-4**) (Suplee 2014).

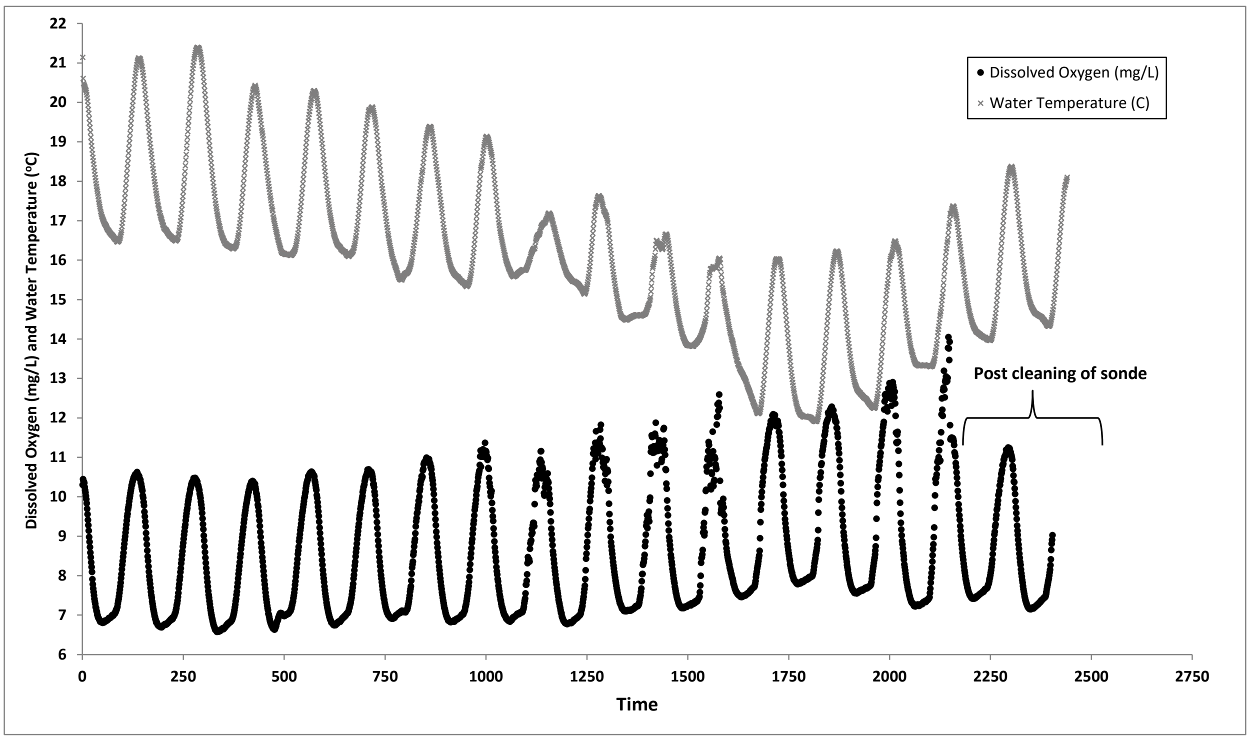


Figure 12-3. Example of increasing diel DO delta in a stream which returns to its initial magnitude after cleaning. DO data from about time step 1250 to time step 2100 (just prior to cleaning) should be flagged "II." Plotting water temperature assists with making judgements about DO; note that the daily DO concentration low increases as water temperature decreases, consistent with the temperature vs. DO-saturation relationship.

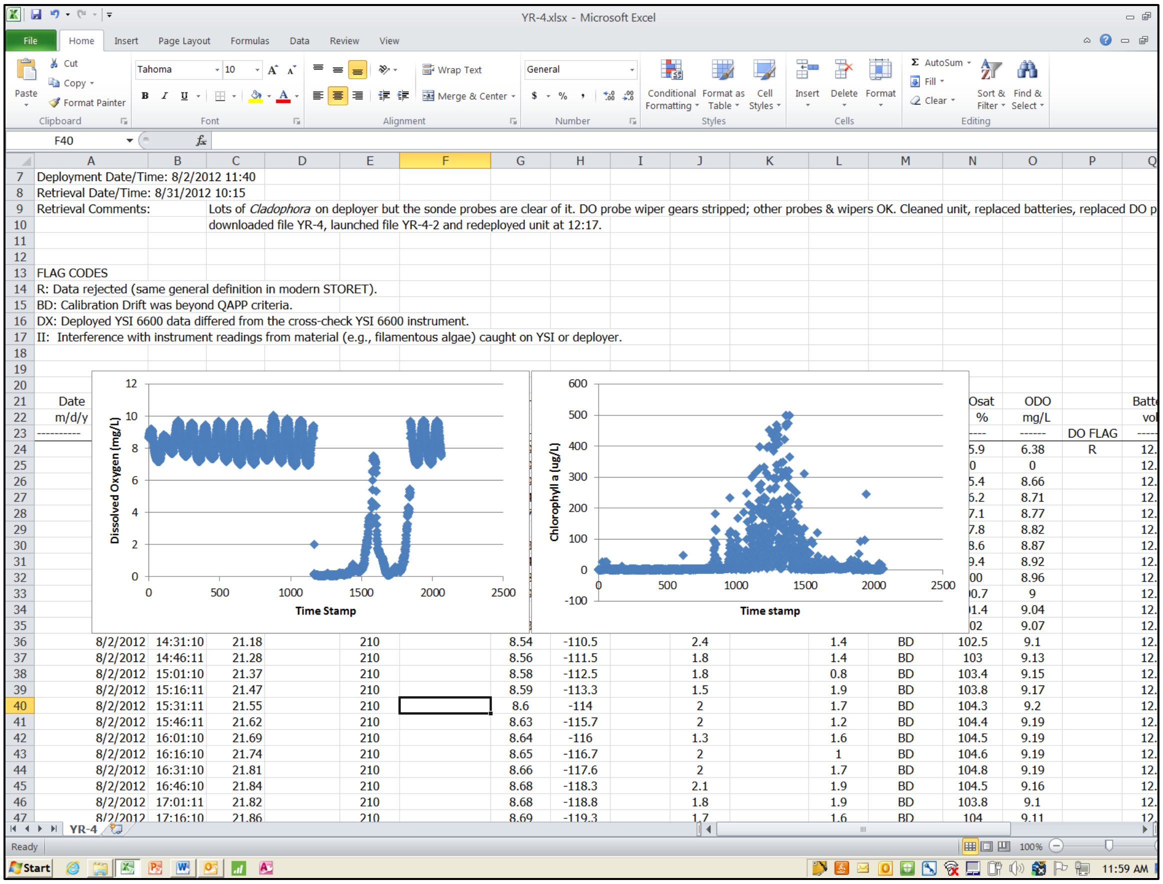


Figure 12-4. Example of DO measurement interference in a stream which appears and disappears during the deployment. In this example a chl-a sensor had been included and shows abnormally high chl-a values corresponding to the low-DO period; this is indicative of snagged drifting filamentous algae smothering the sonde. DO and chl-a data from approximately time steps 1100 to 1800 should be flagged "R."

Assessing continuous datasets requires careful attention to all of the field notes available and careful review of the patterns manifested by different sensors. Only a few of the more common situations have been covered here, you will likely encounter others. Use your best judgement to decide if the data you are seeing is real or not.

13.0 References

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Appendix A - FORMS

- MT-eWQX Data_Logger_Template
- Site Visit Form (Front and Back) (**NOTE**: DEQ modifies this form to meet project-specific needs)
- Pre-Deployment Calibration Form Example (Includes SC, pH, chl-*a,* turbidity, and DO)
- Post -Deployment Drift Check Form Example (Includes SC, pH, chl-*a,* turbidity, and DO)
- Continuous Data Logger Field Form
- QA_Cal Interpolation (used for ORP, DO, and TAL)

A Pre-Deployment Calibration Template and Post-Deployment Drift Check Template are located on the network:

G:\WQP\7_QAProgram\3_SOPs\Multiparameter_WQ_Sonde\Appendice_Documents

MT-eWQX Data_Logger_Template Spreadsheet
An Excel spreadsheet template is available for DEQ staff on the network here:

G:\WQP\6_DataMgmt\3_EQuIS\EQuIS_Staging\20xx_FS_MDEQ_WQ\20xx_Dataloggers

Place Site Visit Label Here

Site Visit Form

Project ID:____________________

Date: ______________ **Time:** ____________ **Personnel:** ____

Waterbody:____ Location: ______________________________________

Station ID: _________________ HUC: ______________ County: _________________ AUID: ________________

Latitude: __ __ . __ __ __ __ __ __ Longitude: __ __ __ . __ __ __ __ __ __ Elevation: __________ ft m

Field Duplicate to ☐ Field Blank ☐ Trip Blank ☐ Field Equipment Blank ☐

Samples Collected		**Sample ID**	**Sample Collection Information/Preservation**
Water	☐		GRAB EWI BACT
Analysis:			0.45µ Filtered | HNO_3 H_2SO_4 H_3PO_4 HCL | Ice Frozen
Analysis:			0.45µ Filtered | HNO_3 H_2SO_4 H_3PO_4 HCL | Ice Frozen
Analysis:			0.45µ Filtered | HNO_3 H_2SO_4 H_3PO_4 HCL | Ice Frozen
Analysis:			0.45µ Filtered | HNO_3 H_2SO_4 H_3PO_4 HCL | Ice Frozen
Analysis:			0.45µ Filtered | HNO_3 H_2SO_4 H_3PO_4 HCL | Ice Frozen
Analysis:			0.45µ Filtered | HNO_3 H_2SO_4 H_3PO_4 HCL | Ice Frozen
Analysis:			0.45µ Filtered | HNO_3 H_2SO_4 H_3PO_4 HCL | Ice Frozen
Analysis:			0.45µ Filtered | HNO_3 H_2SO_4 H_3PO_4 HCL | Ice Frozen
Sediment	☐		SED-1
Analysis:			Preserved: None Other:
Benthic Chl-a	☐		Sample Method: C=Core H=Hoop T=Template N=None
Composite at Lab ☐ AFDW ☐ Visual Est. <50 mg/m2 ☐			Sample Location: R=Right C=Center L=Left
Transect: A__-__ B__-__ C__-__ D__-__ E__-__			F__-__ G__-__ H__-__ I__-__ J__-__ K__-__
Phytoplankton Chl-a	☐		D1 Filtered:_________mL D2 Filtered:_________mL
Phytoplankton CNP	☐		CN Filtered:_________mL P Filtered:_________mL
Algae	☐		PERI-1-MOD PERI-1 OTHER:
Macroinvertebrates	☐		MAC-R-500 OTHER: | # of Jars:

Field Measurements	Time: am pm	**Field Assessments**
Water Temp: °C °F	Air Temp: °C °F	Photos ☐ Aquatic Plant Visual Assessment ☐ SAM ☐
Bar. Pressure: mm/Hg	SC: uS/cm	Aquatic Plant Tracking ☐ Rosgen ☐ NRCS ☐
pH: | DO: mg/L	Turbidity: NTU	EMAP ☐ Total Discharge ☐ Channel X-Section ☐
Turbidity: Clear ☐ Slight ☐ Turbid ☐ Opaque ☐		Wetland ☐ Bacteria ☐ Other:
Flow: ft3/sec (Dry Bed ☐ Stranded Pools ☐)		Only Transect F ☐ Total Site Length__________m
Meter ☐ Meter-Auto ☐ Float ☐ Gage ☐ Visual Est. ☐		Transect Length_______m Average Wetted Width______m

Data Loggers	
	Temperature ☐ YSI ☐ MiniDOT ☐ EC ☐ TruTrack ☐ AquaRod ☐ Weather Station ☐
	Deployed ☐ Cleaned/Checked ☐ Retrieved ☐

Chemistry Lab Information		
Lab Samples Submitted to:	Account #:	Term Contract Number:
Invoice Contact:		
Contact Name & Phone:		EDD ☒ Format: MT-eWQX Compatible
1) Relinquished By & Date/Time:	1) Shipped By: Hand ☐ FedEx/UPS ☐ USPS ☐	1) Received By & Date/Time:
2) Relinquished By & Date/Time:	2) Shipped By: Hand ☐ FedEx/UPS ☐ USPS ☐	2) Received By & Date/Time:

Lab Use Only - Delivery Temperature: Wet Ice_______°C Dry Ice_______°C

Rev. 3/6/2019

This is an example SVF and gives a general idea of the format. Project-specific SVFs are created to reflect specific documentation requirements and project IDs.

Place Site Visit Label Here

Site Visit Form Continued

Field Meter Calibration			
pH Meter:	Manufacturer & Model:		Date of Last Calibration:
	Comments:		
Multiparameter Meter:	Manufacturer & Model:		
	Date of SC Calibration:		DO calibrated at site visit ☐
	Comments:		

Site Visit Comments
Data Logger Notes:
Time data logger removed:
Time data logger returned:
☐ Data logger cleaned
☐ Data logger downloaded
☐ Data logger re-launched
Photos:
#
#
#
#
#
#

Pre-Deployment Calibration Form

Sonde Model: **Serial No.:** **Project ID:**

- ☐ Check sonde firmware, date, time, initialization procedures, etc. **Date:** ___________
- ☐ Check temperature reading **Sensor:** ___________ **NIST:** ___________ **Date:** ___________
- ☐ Complete unattended deployment after all calibrations **Date:** ___________

Parameter Sensor Serial Number	Date	Solution	Calibration Value	Calibration Temp	Benchmark Value + Temp	Initials
Specific Conductivity **SN:**						
pH **SN:**						
Chlorophyll-*a* **SN:**						
Turbidity **SN:**						
Dissolved Oxygen **SN:**						

NOTES:

Post-Deployment Drift Check Form

Sonde Model: **Serial No.:** **Project ID:**

☐ Retrieval: **Date/Time:** ________________ ☐ Termination: **Date/Time:** ________________

☐ Condition upon retrieval: ____

____

☐ Download? **File Name(s):** ____

Parameter, Sensor Serial Number	Date Calibrated	Benchmark Value	Drift Check Date	Drift Check Description	Drift Check Value & °C	Comments
Specific Conductivity, **SN:**						
pH, **SN:**						
Chlorophyll-*a*, **SN:**						
Turbidity, **SN:**						
Dissolved Oxygen **SN:**		Sonde: Table:			Sonde: Table:	Barom. Press.

NOTES:

Place Site Visit Label Here

Continuous Data Logger Field Form

(One Station per page)

Project ID:____________________

Date: ____

Waterbody: ____

Station ID: ____

YSI, Surveyor, AquaRod, or Mini DOT Data Logger	
Medium:	Water Air Other:________
Interval *(hh:mm)*:	
Logger Make/Model:	
Serial #:	
Launch Date/Time:	
Deployment Date:	
Deployment Time:	
Latitude *(dd.dddd)*:	
Longitude *(ddd.dddd)*:	
Deployment Location & Additional Information:	
Data Logger Deployment Map:	
Retrieval Site Visit Code:	
Retrieval Date:	
Retrieval Time:	
Retrieval Comment:	
Electronic File Name:	

Temperature or Electrical Conductivity Data Logger	
Medium:	Water Air Other:________
Interval *(hh:mm)*:	
Logger Make/Model:	
Serial #:	
Launch Date/Time:	
Deployment Date:	
Deployment Time:	
Latitude *(dd.dddd)*:	
Longitude *(ddd.dddd)*:	
Deployment Location & Additional Information:	
Data Logger Deployment Map:	
Retrieval Site Visit Code:	
Retrieval Date:	
Retrieval Time:	
Retrieval Comment:	
Electronic File Name:	

Weather Station Data Logger	
Medium:	Water Air Other:________
Interval *(hh:mm)*:	
Logger Make/Model:	
Serial #:	
Launch Date/Time:	
Deployment Date:	
Deployment Time:	
Latitude *(dd.dddd)*:	
Longitude *(ddd.dddd)*:	
Deployment Location & Additional Information:	
Data Logger Deployment Map:	
Retrieval Site Visit Code:	
Retrieval Date:	
Retrieval Time:	
Retrieval Comment:	
Electronic File Name:	

Rev. 4/16/2014

Appendix B - FIELD HELP SHEETS

These sheets are to help personnel to prepare equipment for the field and for use in the field.

NOTE: Users should reference the appropriate user manual whenever necessary.

EXO™ Field

Calibration Check List

- ❑ Sonde with calibrated sensors
- ❑ Handheld (Is it charged?)
- ❑ Field Cable to connect sonde to handheld
- ❑ Maintenance/Calibration Logbook
- ❑ 4 D sized batteries
- ❑ Kit
    - Battery wrench
    - Hex wrenches
    - Extra wiper brush
    - Sensor Remover tool, also activates the sonde
    - Vacuum grease
    - Extra O-rings

Sonde Light Status:

- 10s Red Blink = Asleep: A low power state between logging intervals
- 1s Red Blink = Awake: The sonde is connected to the handheld or logging data. The sonde will wake up about 15s before the scheduled logging time
- Solid Red = Awake with faults (Do not deploy)
- Blue Solid = Bluetooth® on but not connected
- Blue Blink = Bluetooth® on and connected

Downloading and Viewing Data on the Computer

Using Kor software and the USB Signal Output Adapter, connect the sonde to the computer.

1. Either “Start Download from the Device” on the home page, or go the “Instrument and Sensors” tab and select which files to download
    a. File names are structured by “FilePrefix_SN_Date_Time” with the date and time being of the launch date/time.
    b. It’s best to make a note of the sonde file before selecting the file from the recorded data window.
2. Import selected files
3. Go to “Recorded Data” Tab
4. Search: There are multiple search options available including “Recently Downloaded”
    a. Multiple files can be selected and viewed at once.
5. Export to CSV
6. Unfortunately, the CSV file name does not match the file name from the sonde. It reads: “KorEXO Measurement File Export – *Date Time*”, with the Date and Time being when it was exported.
7. Kor will state the data was exported successfully and the file will open.
8. Each sensor column will include the serial number of the sensor. The serial number above the battery and cable power will be the serial number of the sonde.

EXO™ Download

EXO™ series sonde download and data processing help sheet.

Files exported from KOR are a .csv file. These can be opened in excel to be imported into the MT-eWQX Datalogger Template. This is the “Original Raw Data”. Make a copy of this tab and save as “Final”. Add the appropriate site, deployment, and flagging information to sheet.

Additional columns will need to be added for Notes. Once exported to an Excel table name data tab as “Original Raw Data”. Make a copy of this tab and name it “Final”; all edits to the data will occur in the “Final” tab.

The first section of rows (1 through 10) lays out the sonde and deployment information. Starting at Row 12 the sonde and sensor information is recorded, including: Serial numbers, Firmware installed, and Corresponding data columns. The next section is the recorded data; each column is numbered indicating which sensor collected the data.

	A	B	C	D	E	F	G	H	I
1	KOR Export File								
2									
3	File Created:11/23/2016 1:17:54 PM								
4									
5	Sonde ID	Sonde 13G101254							
6	User ID	MAS-SFernandes							
7	Site	MUSSEL-mouth							
8	Template	deployment_14E102297_060716_191							
9	Averaging Mode	Default							
10	Time Zone	(UTC-07:00) Mountain Time (US & Canada)							
11									
12	Devices List:								
13	Name	SN	Firmware	Corresponding Data Column(s)					
14	Data Collection Device			1;2;3;4;5					
15	EXO2 Sonde	13G101254	1.0.18	6;7					
16	Turbidity	13G101277	3.0.0	8;9					
17	pH/ORP	14D101869	3.0.0	10;11;12;13					
18	Optical DO	16C103951	3.0.0	14;15					
19	Wiped CT	15L103702	3.0.5	16;17;18					
20	Conductivity/Temp	15L102456	3.0.5	19;20;21					
21	Wiper	13G100351	3.0.0						
22	Depth Non-Vented 0-100m	13G101124	3.0.0	22;23					
23									
24	1	2	3	4	5	6	7	8	9
25	Date (MM/DD/YYYY)	Time (HH:MM:SS)	Time (Fract. Sec)	Site Name	Fault Code	Battery V	Cable Pwr V	Turbidity FNU	TSS mg/L
26	6/7/2016	12:30:00	0	MUSSEL-mouth	0	6	0	1.13	0
27	6/7/2016	13:00:00	0	MUSSEL-mouth	0	5.9	0	50	0
28	6/7/2016	13:30:00	0	MUSSEL-mouth	0	5.9	0	51.49	0
29	6/7/2016	14:00:00	0	MUSSEL-mouth	0	5.9	0	50.43	0

Figure B-1. Example EXO™ data download.

Create a “Notes” column at the end of the data columns. Number of data columns will be determined by how many and what sensors were installed on the sonde. Look at the “Fault Code” column and record any other value than “0” in the “Notes” column. Delete “Fault Code” column. Remove the unused power column – for battery deployments: “Cable Pwer V”. Also remove any parameter column that was not collected or calibrated for (Example: TSS and ORP).

“Date” and “Time” columns will need to be combined into one (Format: M/D/Y Hr:Mn, where the hours are reported in 24-hour notation), and then the separate columns removed.

One way to do this to ensure data is not lost is to insert a column in front of the “Date” column and use excel to combine the columns

24		1	2	3	4
25		Date (MM/DD/YYYY)	Time (HH:MM:SS)	Time (Fract. Sec)	Site Name
26	=B26+C26	6/7/2016	12:30:00	0	MUSSEL-mouth
27	6/7/2016 13:00	6/7/2016	13:00:00	0	MUSSEL-mouth
28	6/7/2016 13:30	6/7/2016	13:30:00	0	MUSSEL-mouth
29	6/7/2016 14:00	6/7/2016	14:00:00	0	MUSSEL-mouth

Figure B-2. Combined "Date" and "Time" column.

If the "Date" and "Time" columns are deleted now, so is the data in the third column. Insert another column, ensure that the number format for the whole column is MM/DD/YYYY HH:MM, where hours are in 24-hour notation. This is found under the Category "Time" in the Format Cells window. Copy the combined column and paste "Values" into the new column.

Before deleting any more columns ensure that the data columns are thoroughly labeled to indicate their sensor. This may mostly affect Wiped Conductivity vs. Non-wiped Conductivity.

Delete columns for combined date and time, "Date", "Time", "Time (Fraction)", and "Site Name". Any information that is left can be removed at this time as well. Copy the site and data flag information into a spreadsheet and enter in the correct information (**Appendix A**).

Drift: Calculate drift by:

$$Drift = \frac{post\ benchmark - pre\ benchmark}{post\ benchmark}$$

Appendix C - SOLUBILITY AND PRESSURE/ALTITUDE TABLES

Excerpts from YSI, 2019c.

Table C-1. Solubility of oxygen (mg/L) in water exposed to water-saturated air at 760 mm Hg pressure.

Temp °C	Chlorinity: 0 Salinity: 0	5.0 ppt 9.0 ppt	10.0 ppt 18.1 ppt	15.0 ppt 27.1 ppt	20.0 ppt 36.1 ppt	25.0 ppt 45.2 ppt
0.0	14.62	13.73	12.89	12.10	11.36	10.66
1.0	14.22	13.36	12.55	11.78	11.07	10.39
2.0	13.83	13.00	12.22	11.48	10.79	10.14
3.0	13.46	12.66	11.91	11.20	10.53	9.90
4.0	13.11	12.45	11.61	10.92	10.27	9.66
5.0	12.77	12.02	11.32	10.66	10.03	9.44
6.0	12.45	11.73	11.05	10.40	9.80	9.23
7.0	12.14	11.44	10.78	10.16	9.58	9.02
8.0	11.84	11.17	10.53	9.93	9.36	8.83
9.0	11.56	10.91	10.29	9.71	9.16	8.64
10.0	11.29	10.66	10.06	9.49	8.96	8.45
11.0	11.03	10.41	9.84	9.29	8.77	8.28
12.0	10.78	10.18	9.62	9.09	8.59	8.11
13.0	10.54	9.96	9.42	8.90	8.41	7.95
14.0	10.31	9.75	9.22	8.72	8.24	7.79
15.0	10.08	9.54	9.03	8.54	8.08	7.64
16.0	9.87	9.34	8.84	8.37	7.92	7.50
17.0	9.67	9.15	8.67	8.21	7.77	7.36
18.0	9.47	8.97	8.50	8.05	7.62	7.22
19.0	9.28	8.79	8.33	7.90	7.48	7.09
20.0	9.09	8.62	8.17	7.75	7.35	6.96
21.0	8.92	8.46	8.02	7.61	7.21	6.84
22.0	8.74	8.30	7.87	7.47	7.09	6.72
23.0	8.58	8.14	7.73	7.34	6.96	6.61
24.0	8.42	7.99	7.59	7.21	6.84	6.50
25.0	8.26	7.85	7.46	7.08	6.72	6.39
26.0	8.11	7.71	7.33	6.96	6.62	6.28
27.0	7.97	7.58	7.20	6.85	6.51	6.18
28.0	7.83	7.44	7.08	6.73	6.40	6.09
29.0	7.69	7.32	6.96	6.62	6.30	5.99
30.0	7.56	7.19	6.85	6.51	6.20	5.90
31.0	7.43	7.07	6.73	6.41	6.10	5.81
32.0	7.31	6.96	6.62	6.31	6.01	5.72
33.0	7.18	6.84	6.52	6.21	5.91	5.63
34.0	7.07	6.73	6.42	6.11	5.28	5.55
35.0	6.95	6.62	6.31	6.02	5.73	5.46
36.0	6.84	3.52	6.22	5.93	5.65	5.38
37.0	6.73	6.42	6.12	5.84	5.56	5.31
38.0	6.62	6.32	6.03	5.75	5.48	5.23
39.0	6.52	6.22	5.98	5.66	5.40	5.15
40.0	6.41	6.12	5.84	5.58	5.32	5.08
41.0	6.31	6.03	5.75	5.49	5.24	5.01
42.0	6.21	5.93	5.67	5.41	5.17	4.93
43.0	6.12	5.84	5.58	5.33	5.09	4.86
44.0	6.02	5.75	5.50	5.25	5.02	4.79
45.0	5.93	5.67	5.41	5.17	4.94	4.72

Salinity = Measure of quantity of dissolved salts in water.
Chlorinity = Measure of chloride content, by mass, of water.
S(0/00) = 1.80655 x Chlorinity (0/00)

Table C-2. Calibration values for various atmospheric pressures and altitudes.

PRESSURE			ALTITUDE		CALIBRATION VALUE
Inches Hg	mm Hg	kPa	Feet	Meters	Percent Saturation
30.23	768	102.3	-276	-84	101
29.92	760	101.3	0	0	100
29.61	752	100.3	278	85	99
29.33	745	99.3	558	170	98
29.02	737	98.3	841	256	97
28.74	730	97.3	1126	343	96
28.43	722	96.3	1413	431	95
28.11	714	95.2	1703	519	94
27.83	707	94.2	1995	608	93
27.52	699	93.2	2290	698	92
27.24	692	92.2	2587	789	91
26.93	684	91.2	2887	880	90
26.61	676	90.2	3190	972	89
26.34	669	89.2	3496	1066	88
26.02	661	88.2	3804	1160	87
25.75	654	87.1	4115	1254	86
25.43	646	86.1	4430	1350	85
25.12	638	85.1	4747	1447	84
24.84	631	84.1	5067	1544	83
24.53	623	83.1	5391	1643	82
24.25	616	82.1	5717	1743	81
23.94	608	81.1	6047	1843	80
23.62	600	80.0	6381	1945	79
23.35	593	79.0	6717	2047	78
23.03	585	78.0	7058	2151	77
22.76	578	77.0	7401	2256	76
22.44	570	76.0	7749	2362	75
22.13	562	75.0	8100	2469	74
21.85	555	74.0	8455	2577	73
21.54	547	73.0	8815	2687	72
21.26	540	71.9	9178	2797	71
20.94	532	70.9	9545	2909	70
20.63	524	69.9	9917	3023	69
20.35	517	68.9	10293	3137	68
20.04	509	67.9	10673	3253	67
19.76	502	66.9	11058	3371	66

Appendix D - DEPLOYMENT PHOTOS

Figure D-1. Sonde attached to buoy line.
Lower YSI sonde attached to buoy line in a sensors-upward orientation.

Figure D-2. Sonde attached to buoy line close-up.
YSI EXO™2 sonde attached to polypropylene buoy line with multiple (4) zip ties and hose clamps. Smaller zip ties around poly rope prevents movement of attachment points on the line.

Figure D-4. Intermediate buoy.
Small Dow foam board buoy added to buoy line to help the lower sonde stay off the lake bed.

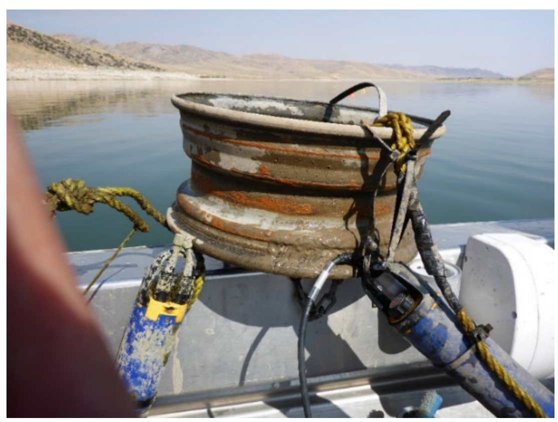

Figure D-3. Wheel anchor and sonde assembly.
Multiple attachment points with heavy duty zip ties.

Figure D-6. Post-deployment condition – calcium carbonate and algal growth.
Sondes in the euphotic zone of reservoirs tend to accumulate a lot of algal growth and calcium carbonate.

Figure D-5. Post-deployment condition – calcium carbonate.
Buoy with calcium carbonate crusts, upper sonde and brick intermediate line weight.

Figure D-8. Sonde and sturgeon.
YSI EXO™2 sonde and sturgeon fixture.

Figure D-7. Sonde with camouflage.
Camo burlap in place over the sonde, and sheet metal shroud in place over the sensor end of the sonde.

Figure D-9. Sonde river deployment. Periodic battery changes, sensor condition checks, and data download. Camo burlap is removed in this photo, revealing the blue case of the YSI EXO™2 sonde. Sheet metal shroud is in place over the sensors.

Figure D-10. Sonde river deployment. Sonde check and battery replacement. Two cinderblocks and cable hold the sturgeon and sonde in place.