

STANDARD OPERATING PROCEDURE (SOP)	
Title: Analysis of <i>In Situ</i> Dissolved Oxygen, Specific Conductance, pH, Water Temperature, and Sample Depth in Ambient Surface Water Using Yellow Springs Instrument EXO Multi-probes	
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1.0 PURPOSE

This document describes sampling, analytical, and quality control (QC) procedures for *in situ* continuous monitoring of Dissolved Oxygen (DO), Specific Conductance (SC), pH, water temperature, and sample depth in ambient surface water using Yellow Springs Instruments (YSI) EXO multi-probes.

2.0 SCOPE AND APPLICABILITY

- 2.1 These procedures are intended for use in the Texas Commission on Environmental Quality (TCEQ) Continuous Water Quality Monitoring Network (CWQMN). These procedures do not apply to CWQMN United States Geological Survey (USGS) - operated stations.
- 2.2 Multi-probe sensor fouling, and electronic drift QC measurements results are used to validate Leading Environmental Analysis and Display System (LEADS) data records collected over deployment periods. Results are compared against project-specific Data Quality objectives (DQOs). The TCEQ does not use sensor fouling and electronic drift measurement results to apply corrections to data records.
- 2.3 Project data are not validated for Environmental Monitoring and Response System stations.
- 2.4 Conductivity measurements are temperature corrected to 25.0 degrees Celsius (°C) and are reported as SC.
- 2.5 Total Dissolved Solids (TDS) in milligrams/liter (mg/L) can be estimated and reported by multiplying SC in micro Siemens/centimeter ($\mu\text{S}/\text{cm}$) by TCEQ's state-wide average correction factor of 0.65.
- 2.6 Multi-probe sample depth measurements can be used for water quality data interpretations.

- 2.7 Data generated by this procedure can be used for a variety of purposes. See CWQMN QAPP Section A5 for data uses.
- 2.8 The stated ranges of the sensors are listed in Table 1.

Table 1

Parameter	Ranges
DO	0 – 50 mg/L
SC, Standard CT Sensor	0 - 200,000 μ S/cm
SC, Wiped CT Sensor	0 - 100,000 μ S/cm
pH	0 - 14 pH Units
Water Temperature	-5° to 50°C
Sample Depth	Depth Sensor Dependent

CT = Combination temperature and conductivity sensor

3.0 METHOD SUMMARY

- 3.1 Multi-probes are deployed at various locations around the state via deployment structures. Discrete *in situ* DO, SC, pH, and temperature measurements are collected every 15-minutes by a data logger and data are transmitted every 15-minutes to TCEQ’s LEADS in Austin Texas.
- 3.2 EXO multi-probe sensors have three different averaging and filtering capabilities used for monitoring. For continuous water quality monitoring applications, the **Factory Default** for data averaging is used. The Factory Default allows for a rolling 40 seconds of averaging and filtering.
- 3.3 To date, YSI has three models of EXO multi-probes, EXO1, EXO2, and EXO3. The EXO2 and EXO3 multi-probes can be equipped with a central wiper to brush optical DO, pH, and SC sensors prior to each water quality measurement. The EXO1 multi-probe does not have sensor brushing capabilities. Optical sensors are the most susceptible to the various forms of fouling. As a result, EXO1 multi-probe use in the CWQMN is generally limited to collecting SC, pH, temperature, and, sample depth data.
- 3.4 DO concentrations are measured by optical luminescence sensors. The optical DO sensor emits a blue light on a membrane containing luminescent dye. Blue light causes the dye to luminesce and is measured by a photodiode. The duration of dye luminesce is inversely proportional to the amount of oxygen present. During a portion of the measurement sequence, the dye is irradiated with red light and this measurement is used as a reference. The optical DO sensor does not consume oxygen and has no flow dependence.
- 3.5 The conductivity sensor is a flow cell with four-electrodes. The sensor automatically auto-ranges between three ranges and all four electrodes are used in each range. Conductivity/specific resistance is measured through an approximately 5.5 centimeter⁻¹ cell.

- 3.6 Salinity affects the solubility of oxygen in water. The EXO multi-probes correct DO concentrations for this effect if the conductivity sensor is active and properly calibrated.
- 3.7 The pH sensor utilizes a glass sensing electrode with a combined double junction half-cell silver chloride reference electrode. The reference electrode provides a constant electrode potential and makes an electrical circuit with the sensing electrode. The sensing electrode contains a glass bulb of a fixed concentration of potassium chloride solution in contact with the reference electrode. Sodium ions are exchanged for hydrogen ions and a potential develops across the sensing membrane; the resulting membrane potential varies with pH. The reference electrode quantitatively compares the changes of the sensing membrane.
- 3.8 Water temperature is measured by a resistance thermistor.
- 3.9 Sample depth is measured by a non-vented pressure transducer. The transducer measures the pressure of the water column plus changes to atmospheric pressure after calibration.

4.0 LIMITATIONS

- 4.1 Multi-probe deployment structures can be susceptible to damage due to high water events. Data loss can occur because of damage to deployment structures. Replacement can be expensive and require significant resources.
- 4.2 See Section 7.3 for multi-probe deployment and sampling.
- 4.3 Over deployment periods, the interface between measurement sensors and the environment can become fouled by a variety of organisms, sedimentation, and hard scale fouling. Sensor fouling can compromise data quality. In some water bodies (or due to seasonal or event driven changes in water quality), sensor fouling can occur rapidly, decreasing deployment periods. EXO multi-probes can be equipped with various anti-fouling measures to increase deployment periods. The station operator will need to determine deployment durations based on fouling measurements in conjunction with employed anti-fouling measures.
- 4.4 QC measurements for this procedure include the measurement of multi-probe sensor and deployment tube fouling using USGS – based measurement procedures. Fouling measurements are estimates of environmental effects on sensor performance. These QC measurements are made at the end of multi-probe deployment periods. Stream scouring events can clean sensor interfaces and deployment tubes prior to performing the procedure, this can result in the fouling measurement not being representative of the entire deployment period.

- 4.5 Depending on the water body, multi-probe and deployment tube sedimentation fouling events can cause multi-probes and deployment tubes to become plugged with sediment and isolated from the water body. For these events, all collected data are invalidated back to the last station service visit.
- 4.6 Fouling measurement procedures are intended for use in situations when water quality conditions are not rapidly changing or fluctuating. When the procedures are performed, a lack of water flow across deployment tube/sensors can cause fluctuations and impact water quality due to the dislodgment of biological material and/or sediment (creating a debris cloud) because of deployment tube cleaning activities.
- 4.7 On-site fouling measurement procedures compare the responses of non-cleaned and cleaned sensors in the water body. The effectiveness of sensor cleaning activities is not assessed quantitatively in this procedure.
- 4.8 TDS concentrations in mg/l at some CWQMN stations are estimated by using TCEQ's statewide average 0.65 SC conversion factor ($0.65 \times \text{SC} = \text{TDS mg/l}$). TDS conversion factors vary depending on the soluble components of the water body. Empirically derived station-specific TDS conversion factors have not been developed.
- 4.9 Single-point calibrations are used to calibrate DO and SC sensors.
- 4.10 Calibration verification sample (CVS) checks are single-point checks for DO and SC sensors. Multi-point checks would provide more information about data quality.
- 4.11 Errors in DO, SC, and pH measurements can result from inaccurate temperature measurements. The SC temperature coefficient of most waters is only approximately the same as that of standard potassium chloride (KCl) solution; the more the temperature of measurement deviates from 25.0 °C, the greater the uncertainty in applying the temperature correction.
- 4.12 The glass pH electrode is relatively free from interference from color, turbidity, colloidal matter, oxidants, reductants, or high salinity, except for sodium error at $\text{pH} > 10$.
- 4.13 The depth sensor is non-vented. The software uses the atmospheric pressure at the time of calibration; changes in atmospheric pressure between calibrations will be measured as changes in depth.
- 4.14 Sample depth measurements are not assessed for accuracy.

5.0 SAFETY

This procedure includes processes that can be hazardous. Therefore, before attempting this process, operators should review the *TCEQ Chemical Hygiene Plan* for proper equipment and procedures necessary for the safe completion of this procedure. Operators must also read and be familiar with the Material Safety Data Sheets for the various chemicals that can be used in this procedure. Lab coats, safety glasses with side shields and/or splash goggles and chemical resistant gloves should be worn when handling chemicals.

6.0 EQUIPMENT AND REAGENTS

6.1 Equipment

- EXO multi-probes
- EXO Handheld (v2) or Electronic Device with KorEXO PC software
- EXO Calibration cable
- EXO2 and EXO3 Central Wiper Assembly
- EXO2 and EXO3 Replaceable central wiper brushes
- EXO Wiped combination conductivity/temperature (CT) sensor
- EXO Standard combination conductivity/temperature (CT) sensor
- EXO Optical DO sensor
- EXO guarded pH sensor
- EXO unguarded pH sensor
- EXO Calibration cup
- EXO plastic or brass anti-fouling sensor guards
- Calibration Worksheets
- Instrument logbook
- C-spray anti-fouling nanopolymer (optional)
- Ring stand and clamp
- Vessel large enough to immerse multi-probe sensors completely in water
- PC with internet access
- Multi-probe deployment structure

6.2 Cleaning equipment/supplies for measuring sensor fouling

- Chimney brush and extensions – Round Pro-Sweep Heavy-Duty (poly)
- All-purpose cleaner in spray bottle
- Water and white vinegar solution (hard fouling)
- Five-gallon bucket
- Kimwipes
- EXO conductivity sensor cleaning brush (for standard conductivity sensors)
- Large soft-bristle brush
- Small soft-bristle brush

- Cotton swabs
- Paper towels

6.3 Standards and Reagents (All reagents/chemicals must be analytical reagent grade).

- Conductivity and pH buffer calibration solution standards traceable to National Institute of Standards and Technology (NIST)
- When calibrating the pH sensor in neutral to basic water bodies, use buffer solutions with approximate pH values of 7.00 and 10.0 pH units. When calibrating for use in neutral to acidic water bodies, use approximate pH buffers of 4.00 and 7.00 pH.
- Control Company Model 400 or equivalent thermistor certified or traceable to NIST. *Requires re-certification every two-years. Change battery once a year.*
- Air-saturated water DO standards (optional) – five-gallon bucket and bubbler/aquarium pump
- De-ionized (DI) or distilled water

7.0 PROCEDURE

Before the multi-probe is deployed, the sensors are cleaned and calibrated. The multi-probe is deployed, and every business day the station's water quality parameters are monitored remotely by the station operator and the assigned data validator to evaluate operational status of the station. At the end of the deployment period, multiprobe sensor fouling and analytical drift is measured.

7.1 Station Service and DO, SC, pH, and Depth, Sensor Calibration

- 7.1.1 The station is serviced, and multi-probe sensors are calibrated at a minimum of once every month. More frequent service intervals may be needed depending on sensor fouling rates for a given water body, time of year, and employed anti-fouling measures. Station operators will need to determine appropriate deployment periods relative to the project's DQO's.
- 7.1.2 During routine station visits, the station operator brings a newly calibrated multi-probe to the station and exchanges the currently deployed multi-probe with the newly calibrated multi-probe. Prior to the exchange, sensor fouling QC measurements are made on-site. The multi-probe is taken back to a temperature-controlled environment where Calibration Verification Samples are (CVS) analyzed to determine the amount of analytical drift that has occurred over the deployment period.
- 7.1.3 Prior to any station service event that disrupts multi-probe data collection, the station's SUTRON data logger must be placed in "P" code (Preventative maintenance code) from "K" code (ambient sampling mode). Placing the station into P code prevents any erroneous data

collected during station service events from being reported in LEADS as ambient data. When station service is complete, the station is returned to K code and an operator log is entered. See CWQMN QAPP Appendix E for SUTRON data logger instructions and Appendix F for operator log content instructions.

(https://www.tceq.texas.gov/waterquality/monitoring/swqm_realtime.html).

7.2 Station Monitoring

Station operators should remotely monitor water quality measurements and station communications every business day to ensure the station is operational.

7.2.1 Every business day, the station operator and the assigned data validator (or designees) monitors via the web (TCEQ daily report, see link below) and screens water quality measurements, sample depth measurements, and station communications for anomalies. If problems are identified, a station visit may be needed to correct any problems.

(<https://www.tceq.texas.gov/cgi-bin/compliance/monops/dailywater.pl>)

7.2.2 Sample depth and conductivity measurements can be used as an indicator to whether the multi-probe sensors are submerged in the water body. When conductivity sensors are not submerged, readings will be close to zero $\mu\text{S}/\text{cm}$.

7.3 Multi-probe Deployment and Sampling

TCEQ Surface Water Quality Procedures Manual, Volume 1, prescribes collecting multi-probe data at a location that is representative of the water body in the centroid of flow and within the mixed surface layer at 0.3 meters of depth. In general, (non-tidal streams) flowing waters remain mixed and unstratified.

Station multi-probes are typically deployed at a fixed position in the water column using a poly vinyl chloride (PVC) deployment tubes that is attached to support structures. Depending on the monitoring location, it may not be possible to locate deployment tubes in or near the centroid of flow.

Deployment tubes are typically positioned to collect data during low water levels. As a result, data can be collected at depths greater than 0.3 meters during higher water levels.

7.3.1 For stream stations, it is recommended that multi-probe vertical profile data be collected periodically to assess potential thermal stratification and the representativeness of data collected by the station.

- 7.3.2 When buoys or other floatation devices are used to deploy multi-probes at stations with variable water levels, the multi-probes must collect data at approximately 0.3 meters during periods of no stream flow.
 - 7.3.3 PVC deployment tubes must include at least 48 evenly spaced 1-inch diameter holes per linear foot for at least the lower two feet of the deployment tube to allow water to flow across the sensors.
 - 7.3.4 For EXO2 and EXO3 multi-probes, the central wiping brush assembly must be programmed to wipe sensor interfaces prior to routine measurements. See User Manual Rev. H, p. 83, for wiped CT sensor installation for EXO 2 and 3 multi-probes.
 - 7.3.5 EXO multi-probe sensors have data averaging and filtering capabilities. For continuous water quality monitoring applications, the **Factory Default** setting is used. The Factory Default is a rolling 40 seconds of averaging and filtering. To check this setting, using the Handheld (v2) connect to the multi-probe and push the **Deploy** button, then select “Sonde Setting” and Under “Averaging” ensure it is set to [**Default**], if not change the setting.
- 7.4 Fouling Measurements, CVS, Temperature, and Barometer QC Checks. At the time of multi-probe exchanges/service, sensor fouling is measured. The multi-probe is taken to a temperature-controlled environment and CVSs are analyzed to determine the amount of analytical drift that has occurred over the deployment period.
- 7.4.1 SC, DO, pH, and temperature sensor fouling are measured on site. These QC samples are analyzed at a minimum of once every month (or more frequently). For further details, see Sections 9.2 and 9.3.
 - 7.4.2 SC, DO, and pH analytical drift is measured using standards. For further details, see Section 9.4.
 - 7.4.3 The multi-probe’s temperature sensor must be checked after each deployment. For further details, see Section 9.5.
 - 7.4.4 If barometric pressure for DO calibrations is determined using the barometer in the Handheld or barometers in other devices, the accuracy of the barometer must be checked once a month. For further details, see Section 9.6.
 - 7.4.5 After every routine service event, the operator must enter calibration drift, fouling, and temperature sensor QC measurement results into Post Deployment Excel Worksheets (PDW). These excel sheets calculates QC measurement results and compares them against the project’s quality

objectives. After the service event, the station operator emails the PDWs to their TCEQ data validator.

7.5 Optical DO Membrane Replacement

Optical DO membranes must be replaced every twelve months. The date the membrane is installed on the DO sensor is considered the starting date for the twelve-month replacement frequency.

The DO membrane has a black coating to limit ambient light interfering with the measurement. Sensor brushing in abrasive environments can remove coatings over deployments periods. If more than 25% of the coating is removed, the membrane must be replaced.

7.6 SC, pH, DO, and Depth Sensor Calibration

Sensor calibrations are performed (within a day) prior to each deployment period. Calibration information is recorded on the EXO Multi-probe Calibration Worksheet (Appendix B).

General Calibration Procedures

- Multi-probe sensor calibration commands for this SOP are described using the EXO Handheld v2. The EXO Handheld v2 or PC KorEXO PC software may be used to calibrate multi-probe sensors.
- Sensors must be cleaned before calibration and analyzing CVSs.
- The multi-probe must equilibrate at room temperature for at least two hours (as close to 25 °C as possible) prior to calibrating or analyzing CVSs when using water saturated air DO standards. A two-hour equilibration period is not needed when using air saturated water standards.
- When analyzing standards using the calibration cup, the sensors can either be pointed up or down; the sensors must be completely immersed in calibration solutions and the calibration cup must not be screwed on tight enough to prevent the cup being vented to atmospheric pressure.
- To lessen the likely hood of pH buffer solution carryover to SC calibration standards. SC sensors are calibrated before pH sensors are calibrated. DO sensors can be calibrated at any point in the calibration process.
- The EXO's sensor guard is used to attach the calibration cup to the multi-probe. The calibration cup fits over the sensor guard and the guard comes in direct contact with conductivity and pH calibration standards. Ideally a station will have three sensor guards. The extra sensor guard is kept in the laboratory and is only used for calibrations. If an extra sensor guard is not available, sensor guards must be thoroughly cleaned before they are used in multi-probe calibrations or analyzing CVSs.
- New or cleaned EXO Central Wiper brushes must be installed prior to each DO calibration and deployment period.

- For EXO2 and EXO3 inspect the wear condition of the Central Wipers brush. If the brush becomes to worn/splayed, the wiper can stall during wiping sequences. Brush wear can vary between 2-12 months. See EXO User Manual, Rev. H, (page 148) for more details.
- Water-saturated air or air-saturated water standards can be used for DO calibrations.
- Anti-fouling C-spray nanopolymer can be applied to the conductivity sensor bodies and interfaces prior to calibration. Applying C-spray is optional. C-spray is also applied to pH and optical DO sensor bodies. **Do not apply C-spray to pH or optical sensor interfaces.**
- Before the conductivity sensor is calibrated, the sensor's zero reading must be checked in ambient air. SC measurements must be $\leq 3 \mu\text{S}/\text{cm}$.
- The KCl conductivity standard value must 1000 $\mu\text{S}/\text{cm}$ or greater.
- Conductivity and pH standards must be within expiration date.
- All sensors must be rinsed twice with DI water before and between the introduction of KCl standards or buffers.
- The EXO Central Wiper Assembly brushes must be removed prior to water-saturated air DO calibrations and CVSs.
- To limit carry over, the Central Wiper brushes must be removed for SC and pH calibrations.
- Temperature and DO sensor interfaces must be dried before water-saturated air calibrations.
- For air-saturated water calibrations and CVSs the Central Wiper is not removed so any air bubbles on the sensor interface will be removed.
- Barometric pressure measurements for determining DO calibration standards can be obtained from the Handheld (v2) and other devices with barometers if they are checked against National Weather Service (NWS) barometric pressure measurements once a month.
- Calibration standards must be allowed time to equilibrate to room temperature before calibration(s) or initial readings.
- A ring-stand and clamp can be used to secure the multi-probe body.
- All sensors must be immersed in calibration solutions.
- For calibrations, the Hand Held has an indicator that alerts the user when reading have stabilized. Calibrations will not be allowed to occur before reading have stabilized to EXO stabilization criteria.

SC, pH and DO Calibration Acceptance Criteria

The EXO has both numeric and color codes (Green, Yellow, and Red) for accepting or rejecting calibrations. After calibration, color codes can be obtained by pushing the **Calibrate button** and selecting Smart QC. Only calibrations with Green or Yellow QC are accepted. If a red QC score is indicated, the calibration is rejected, and corrective action is performed before continuing.

Calibration Color Codes

- ✔ Indicates successful calibration.
- ✘ Indicates a poor or unsuccessful Calibration. Numeric criteria have been exceeded. A calibration error message will also occur.
- ⚠ Indicates a successful calibration that is nearing the edge of acceptable limits.

Note: When a pH sensor receives a yellow score, it is likely the pH reference solution (KCl & AgCl) has degraded and if the sensor is used for a routine extended deployment it is possible further degradation will cause the sensor to fail the post deployment CVS criterion resulting in pH data being invalidated for the deployment period.

Numeric Calibration Criteria

If outside these ranges, the QC color scores should indicate red. Numeric scores are obtained in the *View Cal Records* screen after calibration.

Standard CT sensor Cell Constants are within the numeric criteria of 5.1 ± 0.51

Wiped CT sensor Cell Constants are within the numeric criteria of 0.469 ± 0.05

DO gains are within the numeric criteria of 0.75 – 1.50

pH mV / Slope indicates a successful calibration

7.6.1 C-Spray Anti- Fouling Sensor Application (optional)

Prior to sensor calibration, C-spray nanopolymer can be applied to all sensor bodies and conductivity sensor interface. Do not apply C-spray to pH or optical sensor interfaces. **Note:** do not allow DO and pH sensor interfaces to dry out when applying and allowing C-spray to dry. Plastic sensor caps containing water can be used to keep the sensors moist.

7.6.1.1 Ensure sensor bodies and conductivity sensors interfaces are clean and dry. Apply C-spray and allow to air dry. Apply a second coat of C-spray and allow to air dry. Proceed with calibrations.

7.6.2 Single-Point SC Calibration

Calibration of the conductivity sensor consists of a single-point calibration with a KCl solution. The KCl conductivity standard value must be 1000

$\mu\text{S}/\text{cm}$ or greater. Station operators should choose a KCl calibration standard value that is just above the normal expected conductivity of the water body. Prior to calibration, the sensor's zero response must be checked in ambient air. During the calibration, the EXO multi-probe will measure the temperature of the standard and automatically calculate the SC of the standard.

- 7.6.2.1 Ensure sensor body and sensor interface are clean and dry. In ambient air, SC measurements must be $\leq 3 \mu\text{S}/\text{cm}$. If measurements are greater than $3 \mu\text{S}/\text{cm}$, the sensor must be replaced prior to calibration or deployment. **Note:** If the sensor fails this check indoors, take multi-probe outside away from all potential electrical interferences and redo the check. If still failing ground sensor (place multi-probe on ground). If the value is greater than $3 \mu\text{S}/\text{cm}$, the sensor cannot be used to collect data.
- 7.6.2.2 Rinse a clean calibration cup, sensor guard and sensors twice with DI water and then twice with conductivity standard.
- 7.6.2.3 Fill the calibration cup with conductivity standard. Pour standard in slowly to minimize air bubbles. Place the sensors into the conductivity standard and make sure the combination conductivity/temperature sensors are completely immersed.
- 7.6.2.4 Gently tap calibration cup and/or rotate the multi-probe to dislodge any air bubbles from the cell. Allow at least 60 seconds for temperature sensor equilibration before proceeding.
- 7.6.2.5 From the **Dashboard** screen. Push the **Calibration Button** on the v2 Handheld, then select **Conductivity** from the list of parameters. In the next screen select **Calibrate**. In the next screen select **Sp. Conductance**. In the Calibrate Sp. Cond. screen next screen select **Calibration Value []** and enter the value of the conductivity standard in $\mu\text{S}/\text{cm}$ and select **enter**.
- 7.6.2.6 Observe the actual SC measurement readings for stability (for calibrations, the hand-held has an indicator to alert the user when readings have stabilized), then, select **Accept Calibration**. If the calibration was successful a "Calibration successful" will be displayed in the message area. If a calibration is unsuccessful a calibration error message will be displayed.
- 7.6.2.7 A *View Cal Records* screen will appear. Record the following information in the EXO Calibration Worksheet (Appendix B).

- Cal Value

- Pre-Cal Value
- Temperature
- Cal Cell Constant

Push the **Esc** button to return to the **Dashboard** screen and record the SC value (Post-Cal Value) in the Calibration Worksheet's (Appendix B).

7.6.2.8 Obtain the QC color score for the calibration by pushing the **Calibration Button**. Then select **Smart QC** and record the QC color score into the calibration worksheet (Appendix B).

7.6.2.9 The Cal Cell Constant must be between the following limits for the calibration to be considered valid. Record the numeric result into the calibration worksheet (Appendix B).

CT, 5.1 ± 0.51

Wiped CT, 0.469 ± 0.05

If outside these range the sensors cannot be used to collect data.

7.6.3 Two-point pH Calibration

For the CWQMN a two-point calibration (pH 4.00 and 7.00 or pH 7.00 and 10.00) is required. Choose pH buffers that bracket the expected pH range of the water body. Calibration points can be in any order.

7.6.3.1 Rinse a clean calibration cup, sensor guard and sensors twice with DI water and then twice with pH buffer 7.00.

7.6.3.2 Fill the calibration cup with pH 7.00 buffer. Pour standard in slowly to minimize air bubbles. Place the sensors into the pH buffer and make sure the sensor is completely immersed.

7.6.3.3 Allow at least 60 seconds for sensor equilibration before proceeding.

7.6.3.4 From the **Dashboard** screen. Push the **Calibration Button** on the v2 Handheld, then select **pH** from the list of parameters. In the next screen select **Calibrate**. In the Calibrate pH screen next screen select **Calibration Value []** and enter the value of the pH buffer standard (7.00) in and select **enter**.

7.6.3.5 Observe the actual pH 7.00 measurement readings for stability (for calibrations, the hand-held has an indicator to alert the user when readings have stabilized). Record actual pH reading (pre-

calibration) and temperature reading in the EXO Calibration Worksheet (Appendix B) and then select **Accept Calibration**. “Ready for cal point 2” will be displayed in the message area.

- 7.6.3.6 Repeat steps 7.6.3.1, 7.6.3.2, and 7.6.3.3, - using pH buffer 4.00 or 10.00.
- 7.6.3.7 Observe the actual pH 4.00 or 10.00 measurement readings for stability (for calibrations, the hand-held has an indicator to alert the user when readings have stabilized). Record actual pH reading (pre-calibration) and temperature reading in the EXO Calibration Worksheet (Appendix B) and then select **Accept Calibration**. If the calibration was successful a “Calibration successful” will be displayed in the message area. If a calibration is unsuccessful a calibration error message will be displayed.
- 7.6.3.8 After calibrating the second point, select **Finish Calibration**.
- 7.6.3.9 A *View Cal Records* screen will appear. Record the following information in the EXO Calibration Worksheet (Appendix B).

- Cal Value 7.00
- Sensor Value pH mV
- Temperature
- Cal Value 4.00 or 10.00
- Sensor Value pH mV
- Temperature

Push the **Esc** button to return to the **Dashboard** screen and record the 4.00 or 10.00 buffer value reading in the Calibration Worksheet’s (Appendix B) pH Post Calibration Value.

- 7.6.3.10 Obtain the QC color score for the calibration by pushing the **Calibration Button**. Then select **Smart QC** and record the QC color score into the calibration worksheet (Appendix B).
- 7.6.3.11 After calibration is complete, rinse all sensors and calibration cup with tap water.
- 7.6.4 Optical DO Single-Point Percent Saturation (% Sat.) Calibration
The DO sensor can be calibrated using percent saturation in water-saturated air or air-saturated water.

Water-saturated air DO standard Preparation

- 7.6.4.1 Place about 1/8-inch water in the calibration cup. Dry the DO membrane interface and temperature sensor with a Kimwipes. Place the probe in the cup, with the sensors pointed down. Make certain that the DO and temperature sensors are not immersed in water.
- 7.6.4.2 Engage only one thread of the calibration cup to ensure the DO probe is vented to atmospheric pressure. Wait at least 15 minutes for the air in the calibration cup to become water saturated and for the temperature to equilibrate. Proceed to step 7.6.4.3.

Air-Saturated Water DO Standard Preparation

- 7.6.4.2a Fill a five-gallon bucket mostly full of fresh tap water. Place bubbler at the bottom of the bucket. The water must be aerated for a minimum of two-hours prior to calibration. Place multi-probe in bucket and after the sensor has equilibrated Proceed to step 7.6.4.3.
- 7.6.4.3 From the Dashboard screen. Push the **Calibration Button** on the v2 Handheld, then select **ODO**, select **Calibrate**, Select **DO%**.
- 7.6.4.4 A Calibrate ODO screen will appear. The v2 Handheld will calculate a % Sat. standard value automatically from the v2 Handheld's on-board barometer. This value is displayed on the screen as the Calibration value []. The user can choose to enter a barometric pressure value from another source by scrolling down and selecting "Barometer" and entering a value.

Note: When using NWS barometric pressure measurements, the reading will need to be uncorrected from sea level to actual barometric pressure. See equation in Section 8.1. The v2 Hand Held barometric pressure sensor displays actual barometric pressure.

- 7.6.4.5 Observe the actual % Sat. measurement readings for stability (for calibrations, the hand-held has an indicator to alert the user when readings have stabilized), then, select **Accept Calibration**. If the calibration was successful a "Calibration successful" will be displayed in the message area. If a calibration is unsuccessful a calibration error message will be displayed.
- 7.6.4.6 A *View Cal Records* screen will appear. Record the following information in the EXO Calibration Worksheet (Appendix B).
- Cal Value
 - Sensor Value (Pre-Cal Value)

- Temperature
- ODO Gain

Push the **Esc** button to return to the **Dashboard** screen and record the %Sat. value in the Calibration Worksheet's (Appendix B) DO Post-Calibration Value.

7.6.4.7 Obtain the QC color score for the calibration by pushing the **Calibration Button**. Then select **Smart QC** and record the QC color score into the calibration worksheet's (Appendix B).

7.6.4.8 The DO gain must be between 0.75 – 1.50 for the calibration to be considered valid. If outside this range the sensor cannot be used to collect data. Record the numeric result into the calibration worksheet (Appendix B).

7.6.5 Depth Sensor Calibration

The depth sensor should be calibrated at the same frequency as the other sensors. The depth sensor is non-vented. The calibration consists of zeroing the absolute sensor relative to the local barometric pressure. Calibrate the sensor at the station since atmospheric pressure will change with altitude. When a depth sensor is being calibrated, the multi-probe's orientation should remain constant while readings are being taken.

7.6.5.1 Push the **Calibration Button**, then select **Depth, select calibrate**.

7.6.5.2 Observe the actual depth measurement readings for stability (for calibrations, the hand-held has an indicator to alert the user when readings have stabilized), then select **Accept Calibration**. If the calibration was successful a "Calibration successful" will be displayed in the message area. If a calibration is unsuccessful a calibration error message will be displayed.

8.0 CALCULATIONS

8.1 Sea Level-Corrected Barometric Pressure to Actual Barometric Pressure

This equation is used to un-correct barometric pressure that was previously corrected to sea level, the result of which is actual barometric pressure. Local barometric pressure must be converted from inches to mm before un-correcting to actual barometric pressure using the equation below (inches Hg x 25.4 = mm Hg).

$$ABP = CBP - (2.5mmHg) \left(\frac{A}{100} \right)$$

Where:

ABP = Actual Barometric Pressure in mm Hg;
 CBP = Barometric Pressure corrected to sea level in mm Hg; and
 A = local altitude in feet above mean sea level

2.5 mm Hg = constant.

- 8.2 The following equation is used to determine theoretical DO percent saturation value.

$$\text{Percent Saturation} = \frac{\text{Actual Barometric Pressure}}{760 \text{ mmHg}} (100)$$

- 8.3 The following equation is used to determine DO theoretical CVS concentration in mg/l.

$$DO \text{ (mg/l)} = \text{DO Saturation Value (mg/l)} \times CF$$

Where:

$DO \text{ Saturation Value (mg/l)}$ = Oxygen Solubility at a given temperature
(Appendix A)

$$CF = \frac{\text{Actual Barometric Pressure mm/Hg}}{760 \text{ mm Hg}}$$

- 8.4 Sample-Specific Conductance

Electrical Conductivity is reported as SC (KCl solutions)

$$SC = \frac{AC}{1 + 0.0191 \times (t - 25.0)}$$

Where:

SC = normalized conductivity in $\mu\text{S/cm}$;
AC = actual conductivity; and
t = solution temperature in $^{\circ}\text{C}$.

- 8.5 QC Calculations

Measurement Accuracy

- 8.5.1 Measurement accuracy is expressed in terms of the Absolute Error (AE) or Relative Percent Error (RPE) and is defined as:

$$AE = \text{MeasuredValue} - \text{ActualValue}$$

$$RPE = \frac{\text{Measured value} - \text{Actual Value}}{\text{Actual Value}} * 100$$

Sensor Calibration Drift Calculations

- 8.5.2 Multi-probe conductivity sensor calibration drift (C_d) is evaluated using RPE:

$$C_d = \frac{(S_r - S_v)}{S_v} (100)$$

Where:

S_r = sensor response; and

S_v = specific conductance KCl standard value.

- 8.5.3 DO and pH C_d is evaluated using AE:

$$C_d = (S_r - S_v)$$

Where:

S_r = DO or pH sensor response; and

S_v = DO mg/l theoretical value; pH buffer value

Sensor Fouling Calculations

- 8.5.4 Change in water quality (C_w) during the fouling measurement procedure (for DO, pH, SC, and temperature) is determined by the field meter. Measurement results are used to correct fouling measurements for changes in water quality.

$$C_w = F_i - F_f$$

Where:

F_i = field meter response initial; and

F_f = field meter response final.

- 8.5.5 Multi-probe percent conductivity sensor fouling (F) is evaluated by using RPE to compare not cleaned and cleaned conductivity sensor responses:

$$F = \left(\frac{(S_i - S_f) - (F_i - F_f)}{S_f} \right) 100$$

Where:

S_i = sensor response initial (not cleaned);

S_f = sensor response final (cleaned);

F_i = field meter response initial; and

F_f = field meter response final.

8.5.6 Multi-probe temperature, DO (mg/l), and pH (SU) sensor fouling (F) is evaluated by using AE to compare not cleaned and cleaned sensor responses:

$$F = (S_i - S_f) - (F_i - F_f)$$

Where:

S_i = sensor response initial (not cleaned);

S_f = sensor response final (cleaned);

F_i = field response initial; and

F_f = field response final.

Total Error Calculation

8.5.7 Total error (T) for DO, pH, and conductivity is expressed as the sum of fouling (F) and calibration drift (C_d).

$$T = F + C_d$$

Where:

F = fouling; and

C_d = calibration drift.

9.0 Quality Control

9.1 QC Samples

QC samples are used to ensure acceptable data quality is maintained throughout the measurement process and to assess the data based on quality. As part of the procedure, post deployment fouling and drift measurements are made at every routine station service interval. See Table 9-1 (QC Checks) for QC criteria.

9.2 Multi-probe Sensor Fouling QC

DO, SC, pH, and temperature sensor fouling is determined by comparing non-cleaned and cleaned sensor responses of the deployed multi-probe in the water body. This Section discusses limitations and guidance associated with performing the procedure. Section 9.3 contains the procedure.

Rapidly Changing or Fluctuating Water Quality Conditions

Fouling measurement procedures are intended for use in situations when water quality conditions are not rapidly changing or fluctuating. Rapidly changing or fluctuating water quality can cause fouling measurement errors. Avoid collecting fouling measurements directly after heavy rain fall run off events.

When the procedures are performed, a lack of water flow across deployment tube/sensors can cause fluctuations and impact water quality measurements due to the dislodgment of biological material and/or sediment (creating a debris cloud) because of deployment tube cleaning activities.

Extreme Sediment Fouling

In some streams, multi-probe and deployment tube extreme sedimentation fouling events can cause multi-probe sensors and deployment tubes to become plugged with sediment and isolated from the water body. For these events, all collected data are invalidated back to the last station service visit. The PDW comment Section and Operator Logs are used to communicate these events to the data validator.

Sensor Cleaning

Section 9.3 details a nominal cleaning procedure. Station-specific sensor cleaning procedures may need to be developed when sensors are fouled by chemical coatings. Since fouling measurements are based on comparing sensor responses of non-cleaned and cleaned sensors, cleaning procedures must be effective, or errors will occur with the fouling measurement.

Changes in Water Quality Criteria

Amount of change in water quality conditions is determined from measurements made by the field multi-probe during the servicing event. These measurements are used to correct fouling measurements for changes in water quality. The USGS defines (*TMID3*) rapidly changing for DO, SC, pH and temperature as follows: *Rapid change is relative to the length of time needed to service the monitor and generally is defined as a change that exceeds the (USGS) calibration criteria within 5 minutes* (Table 2). If changes in water quality exceed Table 2 criteria, the

fouling measurement is not considered valid. This is general criteria and station-specific change in water quality criteria can be developed.

Table 2

Parameter	USGS Calibration Criteria
Temperature	± 0.20 °C
SC	± 5 µS/cm or 3% use greatest
DO	± 0.30 mg/L
pH	± 0.20 pH

Temperature Sensor Fouling

Temperature sensor fouling measurements are collected for informational purposes. Temperature sensors are not typically affected by fouling (as compared to SWQM DQO criterion ± 0.50 °C) unless an extreme fouling event has occurred that has plugged sensors and deployment tubes with sediment. When this occurs, all collected data are invalidated back to the last service event.

Sensor Stability and EXO Data Averaging and Filtering

When performing the procedure, sensor measurements must be stable. Erroneous data spikes or drop outs will cause errors in fouling measurement results. The EXO has embedded filtering software for real-time data that utilizes rolling averages and filters. In theory, these data averaging and filtering capabilities should minimize the effects of data spikes and drop outs on fouling measurements results. For continuous water quality monitoring applications, the Factory Default for averaging is used. The Factory Default allows for 40 seconds of averaging and filtering. Consequently, at least 40 seconds of time should be allowed to elapse before recording each of the following fouling measurement results.

- Multi-probe/tube Final (not cleaned)
- Multi-probe/tube Final (cleaned)
- Field Multi-probe Initial
- Field Multi-probe Final

9.3 Multi-probe Sensor Fouling Procedure

Fouling Measurement results are recorded in the Field Fouling Worksheet (see Appendix D) and Excel PDWs.

9.3.1 A calibrated field multi-probe is placed directly adjacent to the deployment tube at the location of the deployed multi-probe sensors. The deployed

multi-probe must not be disturbed. After field multi-probe readings have stabilized, initial field multi-probe readings are recorded. Allow at least 40 seconds in time to elapse before recording these measurements.

9.3.2 Readings (multi-probe/tube initial) are then recorded from the undisturbed deployed multi-probe. Allow at least 40 seconds in time to elapse before recording these measurements.

9.3.3 The deployed multi-probe is gently removed from the deployment tube. After removal, the multi-probe is cleaned. Field cleaning includes the thorough cleaning of the sensor interface, sensor body, and multi-probe body using cleaning supplies listed in Section 6.2.

9.3.3.1 For EXO2 and EXO3 multi-probes remove central wiper brush.

9.3.3.2 Spray entire multi-probe, sensor bodies, and sensor interfaces with an all-purpose cleaning solution.

9.3.3.3 Clean multi-probe and sensor bodies using the large and small soft-bristle brushes. Clean the standard CT cell using the conductivity sensor brush or clean the wiped CT cell using cotton swabs. Carefully clean pH and DO sensor interfaces using cotton swabs and/or Kimwipes.

9.3.3.4 Thoroughly rinse multi-probe, sensor bodies, and sensor interfaces with tap water or water from the water body. Inspect multi-probe (especially sensor interfaces) and repeat steps 9.2.3.2, 9.2.3.3, and 9.2.3.4 if necessary. **Note:** ensure the sensors are thoroughly rinsed and free of cleaner residue. Cleaner residue can contaminate measurements (particularly pH) collected in step 9.3.5

9.3.3.5 Clean (or install new brush) and reinstall the central wiper brush.

9.3.4 The deployment tube is cleaned with the chimney brush and the cleaned, previously-deployed multi-probe is gently returned to the cleaned deployment tube.

9.3.5 The cleaned multi-probe is allowed to stabilize, and readings are recorded (multi-probe/tube final). Allow at least 40 seconds in time to elapse before recording these measurements.

9.3.6 Final field multi-probe readings are recorded. Allow at least 40 seconds in time to elapse before recording these measurements. The deployed multi-probe is taken to a temperature-controlled environment where CVSs are

analyzed. The clean freshly calibrated field multi-probe is deployed into the deployment tube.

9.4 DO, SC, and pH Sensor Drift Measurement Procedures

Sensor CVSs are analyzed to assess analytical drift from the previous calibration. Analyze CVSs as close to 25.0 °C as possible. Allow the multi-probe to equilibrate to room temperature for a minimum of two hours before analyzing CVSs. SC CVS analysis must occur before pH CVS analysis to lessen the likelihood of pH buffers contaminating SC standards. For SC and pH, the CVS should be the same standards used to generate the initial calibration. CVS results are entered into CVS worksheet (see Appendix C), and Excel PDWs.

SC Sensor CVS

9.4.1 The CVS KCl solution is introduced using the cal cup. **Note:** Rinse Cal cup and sensor twice with DI water and calibration standard before measuring standard. Observe readings for stability. Allow at least 40 seconds of time to elapse before recording this measurement.

DO Sensor CVS

9.4.2 A DO CVS is analyzed to assess analytical drift from the previous calibration. The CVS consists of water-saturated air or air saturated water in mg/L using procedures in Sections 7.6.4. Observe readings for stability. Allow at least 40 seconds of time to elapse before recording this measurement in mg/L.

9.4.3 DO CVS results and the theoretical DO standard concentration are also entered into the PDW in mg/L. The following steps are used to determine DO CVS theoretical concentration in mg/L.

9.4.3.1 Determine barometric pressure calibration factor (CF). Divide actual barometric pressure in mm Hg by 760 Hg (Section 8.2).

9.4.3.2 Using the temperature measurement of the DO CVS, determine the DO saturation value (Appendix A).

9.4.3.3 Multiply the barometric CF by the DO saturation value (Section 8.3).

pH Sensor CVS

9.4.4 The pH CVS consists of buffers of 4.00 or 10.00 and 7.00 pH units. The buffer solutions are introduced using the calibration cup. **Note:** Rinse Cal cup and sensor twice with DI water and twice with calibration standard

before measuring the standards. Observe readings for stability. Allow at least 40 seconds of time to elapse before recording these measurements.

9.5 Temperature Sensor Check

After every deployment period, check the accuracy of the multi-probe temperature sensor with a NIST certified or traceable thermistor. In a temperature-controlled environment, fill a vessel with water and immerse the multi-probe's temperature sensor. Place the end of the thermistor thermocouple next to the multi-probe's temperature sensor (allow the measuring device time to stabilize). Allow at least 40 seconds in time to elapse before recording the EXO temperature measurement.

The multi-probe temperature measurement must be within ± 0.50 °C of the NIST certified or traceable thermometer or thermistor. If it is determined that the multi-probe's temperature sensor does not meet acceptance criteria, the sensor can be replaced with a new combination conductivity and temperature sensor. The temperature check results are entered into the CVS worksheet and Excel PDW.

9.6 Barometer Check

If the EXO Hand Held or other barometers are used to determine theoretical DO standard concentrations, the barometer must be checked at a minimum of once a month. The barometer is checked against NWS barometric pressure readings. The barometer should be within ± 10 mm Hg from the NWS reading. See equation in Section 8.1 to calculate NWS sea level corrected barometric pressure to actual barometric pressure. The barometer and laboratory barometers measure actual barometric pressure. The barometer check is recorded into the barometer worksheet (Appendix E).

Table 9-1: QC Checks

QC Check	Purpose	Frequency	Acceptance Criteria	Response Action
SC zero check in ambient air	To assess sensor zero response and to assess internal sensor water leakage	Prior to calibration	$\leq 3 \mu\text{S}/\text{cm}$	<ol style="list-style-type: none"> 1) Allow conductivity cell to dry out or remove water with compressed air 2) Analyze standard again outdoors away from all potential electrical interference sources 3) Ground sensor while outdoors (place multi-probe on ground) 4) Replace sensor
Visual Optical DO Membrane Coating Inspection	To assess membrane coating	Prior to calibration	Membrane coating is not scratched off by more than 25%	Replace membrane
Single-Point SC Calibration (Standard CT Sensor)	To establish slope used for quantitation	Prior to deployments	Green or Yellow QC score. If the Cell Constant is greater than 5.1 ± 0.51 a Red QC score will occur.	<ol style="list-style-type: none"> 1) Analyze standard again and re-calibrate 2) Check for contaminated standard 3) Clean sensor 4) Replace sensor
Single-Point SC Calibration (Wiped CT Sensor)	To establish slope used for quantitation	Prior to deployments	Green or Yellow QC score. If the Cell Constant is greater than 0.469 ± 0.05 a Red QC score will occur.	<ol style="list-style-type: none"> 1) Analyze standard again and re-calibrate 2) Check for contaminated standard 3) Clean sensor 4) Replace sensor
Single-Point DO Calibration	To establish slope used for quantitation	Prior to deployments	Green or Yellow QC score. If the Gain is outside 0.75 – 1.50 a Red QC score will occur.	<ol style="list-style-type: none"> 1) Analyze standard again and re-calibrate 2) Replace/repair sensor
Two-Point pH Calibration	To establish slope used for quantitation	Prior to deployments	Green or Yellow QC score.	<ol style="list-style-type: none"> 1) Analyze standard again and re-calibrate 2) Check for contaminated standard 3) Clean sensor 4) Replace sensor
Field meter/multi-probe measurements	Measures the amount of allowable change in water quality during the fouling measurement procedure	At the conclusion of deployments (during fouling measurement procedure)	Section 9.2, Table 2 or station specific criteria	Validate data accordingly
SC, DO, and pH sensor fouling	To assess sensor fouling	At the conclusion of deployments	Project-specific, see CWQMN QAPP Section A7	Validate data accordingly
SC, DO, and pH sensor CVS	To assess sensor electronic drift	At the conclusion of deployments	Project-specific, see CWQMN QAPP Section A7	Validate data accordingly
Temperature Sensor check	To assess temperature sensor accuracy	At the conclusion of deployments	$\pm 0.50 \text{ }^\circ\text{C}$	<ol style="list-style-type: none"> 1) Invalidate temperature, DO, SC, and calculated TDS values 2) Replace sensor
Barometer	To assess barometer accuracy	A minimum of once a month	$\pm 10 \text{ mm Hg}$	<ol style="list-style-type: none"> 1) Perform corrective action as necessary 2) Re-calibrate

10.0 DEFINITIONS

See Appendix A of the *Continuous Water Quality Monitoring Network Quality Assurance Project Plan*.

11.0 REFERENCES

TCEQ Continuous Water Quality Monitoring Network Quality Assurance Project Plan
U.S. Geological Survey Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting TM1D3
EXO User Manual, Rev. H
EXO Handheld Operation Manual E117 Mini-Manual Revision A
TCEQ YSI CWQMN SOP: Analysis of In Situ Dissolved Oxygen, Electrical Conductivity, pH, Water Temperature, and Sample Depth in Ambient Surface Water Using Yellow Springs Instrument 6-Series Multi-probes, Rev. 4
TCEQ EXO multi-probe Operation Guidance Emails from Yellow Springs Instrument
TCEQ Surface Water Quality Monitoring Procedures Manual, Volume I
TCEQ Operating Policies and Procedures, Chapter 6.13

12.0 POLLUTION PREVENTION AND WASTE MANAGEMENT

Supervisors, sampling personnel, and laboratory analysts should identify and implement innovative and cost-saving waste reduction procedures as part of the method development, review, and revision of standard operating procedures. Wastes that do result from these procedures are managed and disposed of in accordance with appropriate state and federal regulations.

Refer to Chapter 6.13 of the *TCEQ Operating Policies and Procedures* for guidelines on general recycling, waste reduction, and water and energy conservation. Review these procedures for specific employee responsibilities and mechanisms for office-related waste prevention and management. Consult the *Monitoring Operations Hazardous Waste Disposal Plan* for laboratory-specific waste minimization recommendations and requirements for proper handling of hazardous waste that result from laboratory procedures.

The reagents, washes, standards, and waste associated with this procedure do not require special disposal. Before disposing waste into a municipal sewer system, operators should check with respective municipal sewer system personnel on what concentration levels are allowed to be put into their system.

Appendix A

**DO Saturation Values
 Oxygen Content of Air-Saturated Freshwater at 760 mm Hg**

Temp	DO ppm Solubility at 760 mm Hg									
	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
3	13.43	13.4	13.36	13.33	13.29	13.26	13.22	13.19	13.15	13.12
4	13.08	13.05	13.01	12.98	12.94	12.91	12.88	12.84	12.81	12.77
5	12.74	12.71	12.68	12.64	12.61	12.58	12.55	12.52	12.48	12.45
6	12.42	12.39	12.36	12.33	12.3	12.27	12.23	12.2	12.17	12.14
7	12.11	12.08	12.05	12.02	11.99	11.96	11.93	11.9	11.87	11.84
8	11.81	11.78	11.75	11.73	11.7	11.67	11.64	11.61	11.59	11.56
9	11.53	11.5	11.48	11.45	11.42	11.4	11.37	11.34	11.31	11.29
10	11.26	11.23	11.21	11.18	11.15	11.13	11.1	11.07	11.04	11.02
11	10.99	10.97	10.94	10.92	10.89	10.87	10.84	10.82	10.79	10.77
12	10.74	10.72	10.69	10.67	10.64	10.62	10.6	10.57	10.55	10.52
13	10.5	10.48	10.45	10.43	10.41	10.39	10.36	10.34	10.32	10.29
14	10.27	10.25	10.23	10.2	10.18	10.16	10.14	10.12	10.09	10.07
15	10.05	10.03	10.01	9.98	9.96	9.94	9.92	9.9	9.87	9.85
16	9.83	9.81	9.79	9.77	9.75	9.73	9.71	9.69	9.67	9.65
17	9.63	9.61	9.59	9.57	9.55	9.53	9.51	9.49	9.47	9.45
18	9.43	9.41	9.39	9.37	9.35	9.34	9.32	9.3	9.28	9.26
19	9.24	9.22	9.2	9.19	9.17	9.15	9.13	9.11	9.1	9.08
20	9.06	9.04	9.02	9.01	8.99	8.97	8.95	8.93	8.92	8.9
21	8.88	8.86	8.85	8.83	8.81	8.8	8.78	8.76	8.74	8.73
22	8.71	8.69	8.68	8.66	8.65	8.63	8.61	8.6	8.58	8.57
23	8.55	8.53	8.52	8.5	8.49	8.47	8.45	8.44	8.42	8.41
24	8.39	8.38	8.36	8.35	8.33	8.32	8.3	8.29	8.27	8.26
25	8.24	8.23	8.21	8.2	8.18	8.17	8.15	8.14	8.12	8.11
26	8.09	8.08	8.06	8.05	8.03	8.02	8.01	7.99	7.98	7.96
27	7.95	7.94	7.92	7.91	7.89	7.88	7.87	7.85	7.84	7.82
28	7.81	7.8	7.78	7.77	7.76	7.75	7.73	7.72	7.71	7.69
29	7.68	7.67	7.65	7.64	7.63	7.62	7.6	7.59	7.58	7.56
30	7.55	7.54	7.52	7.51	7.5	7.49	7.47	7.46	7.45	7.43
31	7.42	7.41	7.4	7.38	7.37	7.36	7.35	7.34	7.32	7.31
32	7.3	7.29	7.28	7.26	7.25	7.24	7.23	7.22	7.2	7.19
33	7.18	7.17	7.16	7.15	7.14	7.13	7.11	7.1	7.09	7.08
34	7.07	7.06	7.05	7.03	7.02	7.01	7.00	6.99	6.97	6.96
35	6.95	6.94	6.93	6.92	6.91	6.9	6.88	6.87	6.86	6.85

Appendix B

EXO MULTI-PROBE CALIBRATION WORKSHEET					
Operator:		Date:	Time:	Date Deployed:	
CAMS:		Multi-probe Serial Number:		EXO Hand Held Serial Number:	
Optical DO Membrane Serial No:		Optical DO Membrane Date of Manufacture:		Date Membrane Installed to DO sensor:	
Conductivity Sensor Type:		Barometric Pressure (Actual) Used for DO Calibration (mm/Hg):		CT Ambient Air Zero Check Result:	
Standard	Manufacturer	Lot No.		Expiration Date	
Conductivity					
pH 7.00					
pH 4.00 or 10.00					
Parameter	Temperature	Calibration Standard Value	Pre - Calibration Value	Post - Calibration Value	CT Cell Constant / pH mV / DO Gain / QC Color Score Results
Specific Conductance (μS/cm)					Cell Constant / QC Color Score
pH 7.00					pH mV
pH slope 4.00 or 10.00					pH mV / QC Color Score
Dissolved Oxygen (% Saturation)					DO Gain / QC Color Score
¹ Turbidity (FNU)		0 NTU			QC Color Score
		100 NTU			
Criteria Conductivity Ambient Air Zero Check: ≤ 3 μS/cm QC Color Criteria = Green or Yellow Standard CT Cell Constant: 5.1 ± 0.51 Wiped CT Cell Constant: 0.469 ± 0.05 ODO Gain: 0.75 – 1.50			pH mV Ranges: pH 7.00 Range 0 ± 50 mV pH 10.00 Range: -180 ± 50 mV pH 4.00 Range: +180 ± 50 mV		
			Depth Sensor Calibration Zero Values: Pre-Calibration: Post-Calibration:		

¹ Turbidity information for CAMS 749.

Appendix C

EXO MULTI-PROBE CALIBRATION VERIFICATION WORKSHEET					
Analyst:	Date:	Time:	Thermistor Serial No.:		
Date Retrieved:	Multi-probe Serial Number:		Barometric Pressure (Actual) Used for DO CVS (mm Hg):		
Standard	Manufacturer		Lot No.	Expiration Date	
SC					
pH 7.00					
pH 4.00 or 10.00					
Parameter	Standard Temperature	CVS Standard Value	CVS / Temperature Result	Results	Criteria
Specific Conductance (µS/cm)					± 5.0 RPE
pH 7.00					± 0.50 pH
pH 4.00 or 10.00					
Dissolved Oxygen (mg/l)					± 0.50 mg/l
Dissolved Oxygen (% Saturation)					± 6 % Saturation
Temperature (°C)	NA	NIST Thermistor			± 0.50 °C
¹ Turbidity (FNU)		0 NTU			± 3.0 AE
		100 NTU			± 5.0 RPE
DO CVS mg/L VALUE DETERMINATION					
$CF = \frac{(ABP) \text{ mm Hg}}{760 \text{ mm Hg}}$			$DO \text{ CVS (mg/l)} = CF \times DO \text{ Saturation Value}$ $\text{_____} CF \times \text{_____} DO \text{ Saturation Value}$ $= DO \text{ CVS } \text{_____} \text{ mg/l}$		

¹ Turbidity information for CAMS 749.

Appendix D

FIELD FOULING WORKSHEET			
CAMS:		CAMS LOCATION:	
OPERATORS:		MULTI-PROBE #:	
DATE:		RETRIEVAL DATE:	
SERVICE START TIME:		DEPLOYMENT DATE:	
SERVICE END TIME:		FIELD METER #:	
MEASUREMENT DEPTH (meters)			
Multi-probe/Tube Initial (not cleaned)	Multi-probe /Tube Final (cleaned)	Field Multi-probe Initial	Field Multi-probe Final
TEMPERATURE (°C)			
Multi-probe/Tube Initial (not cleaned)	Multi-probe /Tube Final (cleaned)	Field Multi-probe Initial	Field Multi-probe Final
SPECIFIC CONDUCTANCE (µS/cm)			
Multi-probe /Tube Initial (not cleaned)	Multi-probe /Tube Final (cleaned)	Field Multi-probe Initial	Field Multi-probe Final
DISSOLVED OXYGEN (mg/L)			
Multi-probe /Tube Initial (not cleaned)	Multi-probe /Tube Final (cleaned)	Field Multi-probe Initial	Field Multi-probe Final
pH			
Multi-probe /Tube Initial (not cleaned)	Multi-probe /Tube Final (cleaned)	Field Multi-probe Initial	Field Multi-probe Final
TURBIDITY			
Multi-probe /Tube Initial (not cleaned)	Multi-probe /Tube Final (cleaned)	Field Multi-probe Initial	Field Multi-probe Final
COMMENTS:			

¹ Turbidity information for CAMS 749.

Appendix E

BAROMETER CHECK WORKSHEET

Date:

Operator:

Barometer type (*EXO V2 Hand-held, other.*):

Barometric Pressure (mm Hg)	Reference Standard Barometer Pressure (mm Hg)	Result	Criterion
			± 10 mm Hg

Barometric Pressure Formulas	
Altitude (A) = _____ feet above mean sea level	
National Weather Service Barometric Pressure corrected to sea level in inches of Hg.	Barometric pressure (inches) _____ x 25.4 = BP _____ mm Hg
	Actual BP = corrected BP _____ mm - 2.5 (altitude _____/100)

