Standard Operating Procedure #001
YSI 556 Multi Probe System

Version 1.1
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Prepared by:
Water Resources Division
Natural Resources Department
Lummi Indian Business Council

Prepared for:
EPA Region 10

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REVISION RECORD

Approval	Date	Responsible Person	Description of Change	Location of Change
1	October 2018	Kara Kuhlman	Initial Approval and Release of Version 1.0	N/A
1.1	December 2019	Kara Kuhlman	Added staff to distribution list	Distribution
			Specific Conductivity zero accuracy check acceptance criteria changed from <3 to <10 µS/cm	Table 3.2, Sections 3.2.1.2, 3.2.3.2
			pH reading can be recorded after five minutes in sample water at low ionic strength water sites	Sections 4.4, 5.8.1, 6.1.4, 9
			Deleted duplicate equipment listing	Section 7.2

SIGNATURE PAGE

Document: YSI 556 SOP #001

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The following technical staff have read this manual. A copy of this page will be distributed to the employee training record file.

Signature	Date
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1. INTRODUCTION

The Yellow Spring Instruments 556 Multi Probe System meter (hereafter the "YSI 556") is used for surface water (fresh and marine) and ground water quality monitoring. The instrument has three sensors which can measure one or more parameters: 1) pH; 2) temperature, conductivity, and salinity; and 3) dissolved oxygen.

1.1 Scope and Application

The Standard Operating Procedures (SOP) for the YSI 556 should be used anytime the YSI 556 is used for water quality parameter measurement. This document describes the standard operating procedures and best practices for using the YSI 556, including instrument preparation, calibration, quality assurance/quality control (QA/QC) activities, water quality parameter measurement, troubleshooting, instrument specifications, maintenance activities, and supplies and consumables. This document is to be used in conjunction with the relevant project Quality Assurance Project Plan (QAPP) and the YSI 556 User's Manual (YSI undated).

Use of this SOP requires various data to be entered directly into Water Database or recorded on field datasheets and subsequently transcribed into Water Database. Details on data entry are provided in the Quality Management Plan (QMP) (LWRD 2019e) and Water Database User Guide (LWRD 2018).

1.2 Method Summary

Prior to and during use of the YSI 556 in the field, calibration and QA/QC activities must be performed. Calibration is required for pH and dissolved oxygen (DO) each time the instrument is used to measure these parameters. Pre-run and post-run accuracy checks are required for pH, DO, specific conductivity, salinity, and temperature prior to and following each use. During the measurement of water quality parameters in the field, the YSI 556 must meet equilibration/stabilization criteria prior to the parameter value being recorded in Water Database or on field datasheet. Mid-run accuracy checks for pH and DO are required during the sampling trip. In addition, quarterly accuracy checks for specific conductivity and monthly maintenance activities for the DO sensor are required. Periodic cleaning and other maintenance activities are recommended on an as-needed basis.

1.3 Health and Safety Warnings

No water quality measurement is worth risking injury or death. Field personnel must be aware of the environment, use common sense and training, and not exceed their abilities or limits. Field work is never conducted alone. All Lummi Natural Resources (LNR) Water Resources Division (LWRD) Health and Safety Plan (LWRD 2015) requirements and guidelines are followed at all times while conducting fieldwork.

Calibration and accuracy check solutions can be harmful to the health of the user. Safety Data Sheets (SDS) are stored in an accessible location in the LNR laboratory. Read SDS and container

safety information before using laboratory equipment including: specific conductivity standard solutions, pH buffer solutions, and 0% DO solution.

1.4 Quality Assurance/Quality Control (QA/QC)

Quality assurance/quality control activities are integral to equipment maintenance and provide information to the sampler and analyst about equipment condition and data reliability. The QA/QC activities for assessment of equipment operation occur before, during, and after sample runs. Equipment problems or failure to meet QA/QC activity acceptance criteria initiates corrective actions (Section 5.8).

The sampler can take corrective actions based on the results of QA/QC activities to ensure that measurements have a known accuracy, precision, and traceability. All problems, corrective actions, outcomes, and resolution are documented in Water Database or on field datasheets.

Calibration and pre- and post-run accuracy checks are performed in the LNR laboratory, while mid-run accuracy checks are performed in the field. Calibrations are most effective if standard solutions are used at room temperature (20-25°C).

If additional accuracy information is desired for a particular parameter at a sample site, accuracy checks are conducted before and/or after the sample measurement using accuracy checks solutions in the range of the sample water. All additional calibrations and accuracy checks are documented in Water Database or on field datasheets, including the reason performed.

Only certified NIST-traceable standards are used, except the distilled water standard. The reference thermometer is a mercury-in-glass or spirit-in-glass, certified NIST-traceable thermometer that meets the requirements listed in Section 7.2.1.

Table 1.1 summarizes the QA/QC activities required for each parameter measured by the YSI 556, including calibrations, accuracy checks and routine maintenance.

Table 1.1 Summary of QA/QC Activities: Calibration, Accuracy Checks, Additional QA/QC Activities, and Routine Maintenance Requirements

Parameter	Calibration (Frequency; Standards)	Accuracy Checks			Routine Maintenance and Additional QA/QC Activities
		Pre-Run	Mid-Run	Post-Run	
pH	Every time used; pH 7 and 10	pH 10, 7, and 4	pH 7	pH 7	Periodic cleaning
Dissolved Oxygen	Every time used; 100% DO	100% and 0% DO	100% and 0% DO	100% and 0% DO	Membrane cap and electrolyte solution replaced monthly
Specific Conductivity	Twice annually; 50,000 µS/cm	0 µS/cm using distilled water	None	0 µS/cm using distilled water	1,000 and 50,000 µS/cm accuracy check quarterly, periodic cleaning
Salinity	Concurrent with specific conductivity calibration	0 ppt using distilled water	None	0 ppt using distilled water	Periodic cleaning
Water Temperature	None	Reference thermometer	None	Reference thermometer	Annual recertification of reference thermometer

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2. INSTRUMENT OVERVIEW AND PREPARATION FOR USE

This section provides an overview of the YSI 556, including sensors, and preparation for instrument use, including instrument setup and checking battery function, as well as instrument storage and equipment.

2.1 Instrument Components

Figure 2.1 and Figure 2.2 illustrate the YSI 556 components and keys. The YSI 556 instrument consists of the hand-held instrument, with display and keys, cable, and sonde. The sonde is fitted with several sensors, described in more detail in Section 2.1.1, and is covered with a probe guard during use in the field. Note that the YSI 556 is stored with the calibration cup fitted over the sensors (Section 2.3).

Figure 2.1 Photo of YSI 556 Showing Hand-Held Instrument, Cable, and Sonde Fitted with Probe Guard

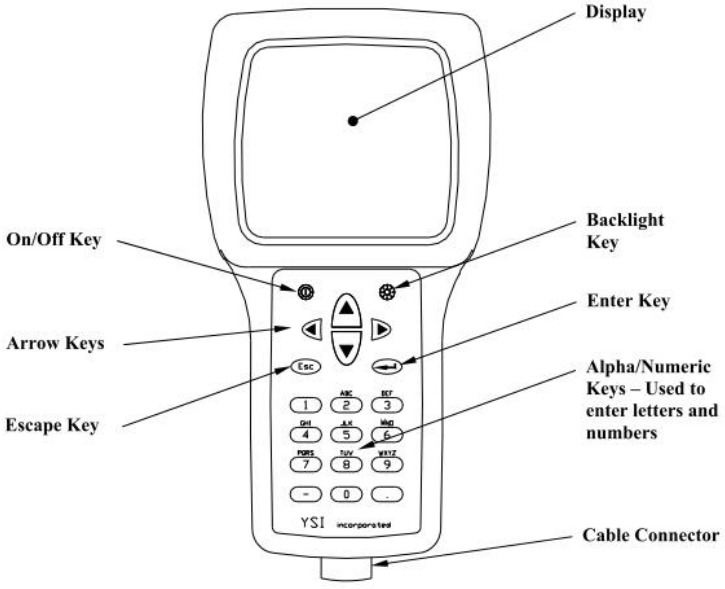

Figure 2.2 Schematic of YSI 556 Showing Features and Keys

2.1.1 Transport/Calibration Cup

The transport/calibration cup is a threaded plastic cup that is used to cover and store the sensors when the probe is not in use, and to hold calibration and accuracy check solutions during instrument QA/QC activities. Ensure that an o-ring is installed in the o-ring groove of the transport/calibration cup bottom cap, and that the bottom cap is securely tightened.

Note: Do not over tighten when securing the calibration cup to the probe, as this could cause damage to the threaded portions, which requires repair by the manufacturer.

2.1.2 Probe Guard

A heavy duty probe guard with attached sinking weight is used to cover the YSI 556 sensors when collecting field measurements.

2.2 Instrument Specifications

Table 2.1 lists the instrument specifications for the current configuration of the YSI 556 with a 4 meter cable. As previously described, the YSI 556 has three sensors which can measure one or more parameters: 1) pH; 2) temperature, specific conductivity, and salinity; and 3) dissolved oxygen. Details about these sensors are included in Sections 2.2.1-2.2.3 below.

Table 2.1 Range, Accuracy, and Resolution for YSI 556 for Specific Conductivity, Salinity, Water Temperature, pH, Dissolved Oxygen (mg/L and % Saturation), and Barometer

Parameter	Range	Accuracy	Resolution
pH	0 to 14 pH units	±0.2 pH units	0.01 pH units
Temperature	- 5°C to 45°C	±0.15 °C	0.01 °C
Specific Conductivity	0 to 200,000 µS/cm	±0.5% or ±1 µS/cm; whichever is greater	1 to 100 mS/cm (range-dependent)
Salinity	0 to 70 ppt	±1.0% of reading or 0.1 ppt, whichever is greater	0.01 ppt
Dissolved Oxygen (mg/L)	0 to 50 mg/L	0 to 20 mg/L: ±2% of reading or 0.2 mg/L, whichever is greater 20 to 50 mg/L: ±6% of reading	0.01 mg/L
Dissolved Oxygen (% saturation)	0 to 500% Saturation	0 to 200% air saturation: ±2% of reading or 2% air saturation, whichever is greater 200 to 500% air saturation: ± 6% of reading	0.1%
Barometer	-500 to 800 mmHg	±3 mm Hg within ±10°C temperature range from calibration point	0.1 mm Hg

Additional instrument specifications, including memory, size and power source, are listed in Table 2.2.

Table 2.2 Additional Equipment Details

Category	Specifications
Memory size	1.5 MB Flash Memory 49,000 data sets (at 6 parameters per set plus time stamp) 100 sites
Size	11.9 cm wide by 22.9 cm long (4.7 inches by 9 inches)
Weight with batteries	0.92 kg (2.1 lbs)
Power	4 alkaline C-cells
Cable	4 m

2.2.1 pH

The YSI 556 uses a glass combination electrode pH sensor with a gelled electrolyte. QA/QC activities for the pH sensor include calibration prior to each use and pre-, mid-, and post-run accuracy checks. If the pH sensor does not meet its acclimation/stabilization criterion during use due to reasons other than natural variability or the pH sensor is reporting inaccurate readings, corrective actions must be taken and documented per the Water Database User Guide and QMP prior to recording additional pH measurements. Periodic pH sensor maintenance activities include sensor cleaning and reconditioning.

2.2.2 Specific Conductivity, Salinity, Temperature

Specific conductivity, salinity, and temperature are grouped because they are measured with the same sensor on the YSI 556. The conductivity sensor is a 4-electrode auto-ranging cell, the water temperature sensor is a YSI Precision™ thermistor, and salinity is calculated by the instrument from conductivity and temperature.

Specific conductivity, salinity, and temperature QA/QC activities include twice-annual calibration of specific conductivity (and concurrently salinity); quarterly specific conductivity accuracy checks; and pre- and post-run accuracy checks for specific conductivity, salinity, and temperature.

If the specific conductivity, salinity, and temperature do not meet acclimation/stabilization criteria during use due to reasons other than natural variability or are reporting inaccurate readings, corrective measures must be taken and documented per the Water Database User Guide and QMP prior to recording additional measurements. Periodic probe maintenance activities include sensor cleaning.

2.2.3 DO

The YSI 556 uses a steady-state polarographic dissolved oxygen (DO) sensor equipped with a blue 2 mil polyethylene DO sensor membrane cap. The sensor consists of an anode (silver) and cathode (gold) that are confined in electrolyte solution by an oxygen-permeable membrane. During measurement, oxygen is consumed at the cathode and the ability of the sensor to measure DO is dependent on flow. During low flows, the sensor must be moved through the sample water at a rate of 3 inches per second to maintain sufficient flow past the sensor for accurate DO readings.

The sensor measures DO in percent saturation and mg/L, which are related based on temperature, salinity and atmospheric pressure. The YSI 556 DO sensor automatically adjusts the percent saturation reading based on salinity and temperature, and barometric pressure.

Because the YSI 556 DO sensor uses an anode and cathode to measure DO, the sensor needs to become polarized before use. The YSI 556 must be on for 20 minutes prior to calibration activities or other uses. The DO membrane should be inspected before and after every sample run for damage, and replaced as necessary.

QA/QC activities for the DO sensor include calibration prior to each use and pre-, mid-, and post-run accuracy checks. If the DO sensor does not meet its acclimation/stabilization criteria during use due to reasons other than natural variability or the DO sensor is reporting inaccurate readings, corrective actions must be taken and documented per the Water Database User Guide and QMP prior to additional DO measurements. Periodic DO sensor maintenance activities include monthly replacement of the DO sensor membrane cap and electrolyte solution, and reconditioning as needed.

2.2.4 Barometer

The YSI 556 has an internal barometer. The barometer can be calibrated as needed following annual accuracy checks.

2.3 Instrument Storage

Between sample runs, the YSI 556 probe is stored with 1/8 inch distilled water in a transport/calibration cup. For long-term storage, the pH sensor can be removed and stored in 2M potassium chloride (KCl) solution.

2.4 Instrument Preparation

The YSI 556 is inspected for basic proper function (*e.g.,* battery, calibration, and accuracy checks) before every use of the equipment. The QA/QC activities performed before, during, and after sample runs provide information necessary to quantify data quality and determine if the YSI 556 is functioning properly. The person using the YSI 556 records all use, QA/QC activities, corrective actions, maintenance, outcomes, and resolution in Water Database.

2.4.1 Instrument Setup

All default system setup options should be used, as per the YSI 556 User's Manual, except that the automatic shutoff is adjusted to "0" in the system setup so that the instrument does not automatically turn off. Other system setup features include date and time setup and barometer units. See YSI 556 User's Manual for details.

2.4.2 Batteries

The battery charge level should be checked before every sample run and changed prior to use when charge is below one-quarter. The YSI 556 uses four alkaline C-cell batteries. Note that calibration information is saved by the instrument; the YSI 556 does not have to be recalibrated when the batteries are changed.

2.5 Equipment

The following equipment items are needed for measurement of all water quality parameters in the field:

- YSI 556
- Probe guard
- Calibration cup
- Distilled water in marked squeeze bottles
- Distilled water
- Unexpired NIST-traceable standards:
    - pH 7.00 buffer – used for pH calibration and pre-, mid-, and post-run accuracy checks
    - pH 10.00 buffer – used for pH calibration and pre-run accuracy check
    - pH 4.00 buffer – used for pH pre-run accuracy check
    - 1,000 µS/cm conductivity standard – used for quarterly specific conductivity accuracy checks
    - 50,000 µS/cm conductivity standard – used for twice-annual specific conductivity calibration and quarterly accuracy checks
    - Zero dissolved oxygen standard – used for DO calibration and pre-, mid-, and post-run accuracy checks
- NIST-traceable reference thermometer – used for pre- and post-run temperature accuracy checks
- Kim wipes
- Sample wand
- Flat head screwdriver
- Replacement batteries for YSI 556 (four C-cell batteries)

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3. QUALITY ASSURANCE/QUALITY CONTROL (QA/QC)

Quality assurance/quality control procedures for the YSI 556 include calibration and accuracy checks.

3.1 Calibration

The YSI 556 can be calibrated for pH, DO (% saturation), and specific conductivity (see Table 3.1). DO (% saturation) and pH should be calibrated each time the YSI 556 is to be used. DO (mg/L) is automatically calibrated concurrently with % saturation. Specific conductivity should be calibrated twice annually at six month intervals. Salinity is calibrated concurrently with specific conductivity as it is automatically calculated by the instrument from specific conductivity and temperature. The temperature sensor cannot be calibrated and requires replacement by the manufacturer if QA/QC acceptance criteria are not met. Detailed calibration methods are listed in Sections 3.1.1-3.1.4.

Table 3.1 Summary of Calibration Activities for YSI 556

Parameter	Calibration Frequency	Standards Used
pH	Prior to every sample run	Unexpired NIST-traceable pH 7 and pH 10 buffers
Specific Conductivity	Twice annually	Unexpired NIST-traceable 50,000 µS/cm standard
Salinity	N/A	Calibrated automatically when specific conductivity is calibrated
Water Temperature	N/A	N/A
Dissolved oxygen (% saturation)	Prior to every sample run	Small amount of distilled water in calibration cup to create 100% saturated environment
Dissolved oxygen (mg/L)	N/A	Calibrated automatically when dissolved oxygen % saturation is calibrated
Barometer	As needed	True barometer reading

3.1.1 pH

Prior to use for field measurements, the YSI 556 must be calibrated for pH using a two-point calibration with unexpired NIST-traceable pH buffers. A 7.00 pH buffer is used first for the

calibration, followed by the pH 10.00 buffer.[1] Step-by-step instructions for calibration of the YSI 556 for pH are provided below:

> v Note: the pH value of the buffer solutions depends on temperature. As the buffers are stored at room temperature, the pH of the buffer solution will be the pH at approximately 20°C. Use the temperature adjusted pH listed on the pH buffer solution label for calibrations. In the remainder of this SOP, pH buffer concentration is listed at 20°C when listed to hundredths (*e.g.,* pH 7.02).

1. Turn on the YSI 556.
2. Press Esc and use the arrow keys to navigate to Calibration > pH > 2 point. Then press Enter (↵).
3. Enter the first pH buffer value (7.02) > ↵.
4. Rinse the calibration cup and probe with tap water. Discard in sink.
5. Rinse the calibration cup and probe with pH 7 buffer by pouring a small amount into the calibration cup, attaching the cup to the probe, and gently swirling and shaking the pH buffer around the pH sensor. Discard in sink. Note: pH buffers are water soluble and non-toxic; therefore, they can be discarded in the sink with running water.
6. Fill calibration cup about 1/4-1/3 full (~30 ml) with pH 7 buffer and immerse the sensor into the solution. Gently rotate and/or move the probe up and down to remove any bubbles from the pH sensor. Screw the calibration cup to the probe and moderately tighten. Make sure that the pH sensor (glass bulb) is covered with buffer solution.
7. Wait for the pH reading to stabilize (at least one minute), then press ↵ to calibrate and ↵ again to continue.
8. Note the calibration value, reading, lot number, and expiration date of pH buffer in Water Database.
9. Enter the second pH buffer value (10.05) > ↵.
10. Rinse the calibration cup and probe with tap water, then with a small amount of pH 10 buffer. Discard. Fill calibration cup about 1/4-1/3 full (~30 ml) with pH 10 buffer and immerse the sensor into the solution. Gently rotate and/or move the probe up and down to remove any bubbles from the pH sensor. Screw the calibration cup to the probe and moderately tighten. Make sure that the pH sensor (glass bulb) is covered with buffer solution.
11. Wait for the pH reading to stabilize (at least one minute), then press ↵ to calibrate and again to continue.
12. Note the calibration value, reading, lot number, and expiration date of pH buffer in Water Database.
13. You will be returned to the pH calibration screen, press Esc to return to the measurement screen.

[1] Note that beginning the calibration with the pH 7 buffer is required.

14. Proceed with pH accuracy checks starting with pH 10, which is already in the calibration cup (Section 3.2.1.1).

If an "out of range" message appears on the YSI 556 screen after pH calibration, attempt the calibration again using the procedures in this SOP. If calibration remains unsuccessful, attempt corrective actions listed in Section 5.8.1.

3.1.2 Specific Conductivity, Salinity, Temperature

Specific conductivity is a very stable parameter. The YSI 556 is calibrated for specific conductivity twice annually at six month increments and on an as-needed basis. Step-by-step instructions for calibration of the YSI 556 for specific conductivity are provided below:

1. Press Esc and use the arrow keys to navigate to Calibration > Conductivity > Specific Conductance. Then press Enter (↵).
2. Enter the calibration value of the standard (50,000 µS/cm = 50 mS/cm)[2] > ↵.
3. Rinse the calibration cup and probe with tap water. Discard in sink.
4. Rinse the calibration cup and probe with a small amount of the 50,000 µS/cm unexpired, NIST-traceable specific conductivity standard. Discard in sink.
    - Note: specific conductivity standards are non-toxic, and therefore can be discarded in the sink.
5. Fill calibration cup with 50,000 µS/cm conductivity solution (at least 55 ml) and immerse the sensor into the solution. A small amount of conductivity solution will overflow. Gently rotate and/or move the sensor up and down to remove any bubbles from the conductivity cell. Screw the calibration cup to the probe and moderately tighten.
6. Make sure that the top vent hole of the conductivity sensor is immersed.
7. Wait for the conductivity reading to stabilize (at least one minute), then press ↵ to calibrate and ↵ again to continue.
8. Note the calibration value reading, lot number, and expiration date of the conductivity solution in Water Database.
9. Press Esc to return to the measurement screen.
10. Proceed with the quarterly specific conductivity accuracy checks starting with 50,000 µS/cm standard, which is already being measured by the sensor (Section 3.2.4.1).

If an "out of range" message appears on the YSI 556 screen after specific conductivity calibration, attempt the calibration again using the procedures contained in this SOP. If calibration remains unsuccessful, attempt corrective actions listed in Section 5.8.2.

Salinity is calibrated concurrently with specific conductivity as it is automatically calculated by the instrument from specific conductivity and temperature. The temperature sensor cannot be

[2] Verify the exact concentration by obtaining a certificate of analysis for the specific conductivity standard used in the calibration. A certificate of analysis for a particular lot or batch of standard can be requested from the vendor or manufacturer. The Water Resources Specialist II stores and keeps track of certificates of analysis.

re-calibrated and requires replacement by the manufacturer if QA/QC acceptance criteria are not met.

3.1.3 DO

The YSI 556 must be on for 20 minutes prior to DO calibration and allowed to stabilize for approximately 10 minutes for the air in the calibration cup to become fully water-saturated during calibration. It is recommended that DO calibration be performed last, after all other calibrations and accuracy checks have been conducted, to allow sufficient time for the DO sensor to polarize after the YSI 556 has been turned on.

Prior to use for field measurements, the YSI 556 must be calibrated for DO using a one-point calibration at 100% saturation. Step-by-step instructions for calibration of the YSI 556 for DO are provided below:

1. Turn the YSI 556 on and wait for 20 minutes to allow the DO sensor to polarize. Other parameter calibrations and accuracy checks can be conducted during this time.
2. Press Esc and use the arrow keys to navigate to Calibration > Dissolved Oxygen > DO %. Then press Enter (↵).
3. The barometric pressure screen will be displayed. The YSI 556 has an internal barometer. If the barometric pressure value is incorrect, it needs to be recalibrated (Section 3.1.4 or YSI 556 User's Manual).
    - Note: Barometric pressure at sea level is typically around 760 mm Hg.
    - Press ↵ to accept the barometric pressure displayed.
4. Dry the DO sensor gently with a Kim Wipe.
5. Place a small amount (1/8 inch) of distilled water in the bottom of the calibration cup and lightly screw on the probe. A loose seal is required to allow pressure equilibration before calibration. Engage only 1 or 2 threads and hang the probe over the faucet in the lab to equilibrate.
6. Allow approximately 10 minutes for the DO to equilibrate. Press ↵ to calibrate and ↵ again to continue.
7. Note the calibration value and reading in Water Database.
8. Press Esc until return to the measurement screen.
9. Proceed with DO accuracy checks starting with 100% DO, which is already being measured by the sensor.

If an "out of range" message appears on the YSI 556 screen after DO calibration, attempt the calibration again using the procedures contained in this SOP. If calibration remains unsuccessful, attempt corrective actions listed in Section 5.8.3.

3.1.4 Barometer

The barometer is calibrated at the factory, but may need re-calibration if it does not meet acceptance criteria for annual accuracy checks. The DO sensor requires an accurate barometer

reading in order to function properly. See YSI 556 User's Manual for details on barometer calibration.

3.2 Accuracy Checks

Accuracy checks are required for all parameters following calibration (if applicable) prior to every sample run (pre-run) and after every sample run has been completed (post-run) (see Table 3.2). In addition, some parameters are checked approximately half-way through the sampling run (mid-run).

After calibration, a pre-run accuracy check is required for the pH sensor using pH 4, 7, and 10 buffers. Mid- and post-run accuracy checks are also required using pH 7 buffer.

Pre- and post-run accuracy checks are required for specific conductivity, salinity, and water temperature sensor. In addition, a quarterly specific conductivity accuracy check should be conducted immediately after calibration, and mid-way between twice-annual calibrations. For example, if specific conductivity calibration is conducted in January, the next accuracy check should be conducted in April.

Pre-, mid-, and post-run accuracy checks are required for the DO sensor. In addition, if DO % saturation exceeds 200% in any measurement during a field visit, an additional 100% saturation accuracy check at the sample site is required.

Detailed step-by-step instructions for pre-, mid-, and post-run accuracy checks are provided in Sections 3.2.1-3.2.4.

Table 3.2 Summary of Acceptance Criteria and Standards Used for Accuracy Checks to be Performed Prior to Sample Run (pre-run), Half-Way Through the Sample Run (mid-run), and at the End of the Sample Run (post-run)

Parameter	Accuracy Check	Acceptance Criteria	Standards Used
pH	Pre-run	±0.2 pH units	Unexpired NIST-traceable pH 10 and pH 7 buffers
		±0.4 pH units	Unexpired NIST-traceable pH 4 buffer
	Mid-run and post-run	±0.2 pH units	Unexpired NIST-traceable pH 7 buffer
Specific Conductivity	Pre-run and post-run	<10 µS/cm	Distilled water
	Quarterly	±3%	Unexpired NIST-traceable 1,000 µS/cm and 50,000 µS/cm conductivity standards
Salinity	Pre-run and post-run	0 ppt	Distilled water
Water Temperature	Pre-run and post-run	±0.2°C	1L bottle of room temperature water, shaken prior to measurement, using NIST-traceable reference thermometer
Dissolved Oxygen (% Saturation)	Pre-run, mid-run, and post-run	±10%	Small amount of distilled water in calibration cup to create 100% saturated environment
		<5%	Unexpired NIST-traceable 0% dissolved oxygen standard
	During sample run, as needed, when field measured dissolved oxygen is >200%	±10%	Small amount of distilled water in calibration cup to create 100% saturated environment
Barometer	Annually	±5 mm Hg	True barometer reading

3.2.1 Pre-Run Accuracy Checks

Pre-run accuracy checks are required for pH (following calibration), specific conductivity and salinity (concurrently), temperature, and DO (following calibration).

3.2.1.1 pH

During the pre-run accuracy check, the accuracy of pH readings are tested using unexpired NIST-traceable pH 10, 7, and 4 buffers. Detailed instructions for conducting the pH accuracy checks follow:

v Note: the pH of the buffer solutions depends on the temperature of the buffer. As the buffers are stored at room temperature, the pH of the buffer solution will be the pH at

approximately 20°C. Use the temperature adjusted pH value listed on the pH buffer solution label as the buffer value for all accuracy checks. In the remainder of this SOP, pH buffer concentration is listed at 20°C when listed to hundredths (*e.g.,* pH 10.05).

1. Perform the pH 10 accuracy check immediately following pH calibration, as the pH 10 buffer is already in the calibration cup. Do not remove calibration cup from sensor between calibration and accuracy check. Wait for the pH reading to stabilize (at least one minute).
    - pH 10.05 accuracy check meets QA if value reads within ± 0.2 pH units of buffer value (*i.e.,* 9.85 to 10.25).
    - Note the accuracy check value, reading, lot number, and expiration date of pH buffer in Water Database.
    - Discard buffer in sink.
2. For the pH 7 accuracy check:
    - Rinse the calibration cup and probe with tap water. Discard in sink.
    - Rinse the calibration cup and probe with a small amount of pH 7 buffer. Discard in sink.
    - Fill calibration cup about 1/4-1/3 full (~30 ml) with pH 7 buffer and immerse the sensor into the solution. Gently rotate and/or move the probe up and down to remove any bubbles from the pH sensor. Screw the calibration cup to the probe and moderately tighten.
    - Make sure that the pH sensor (glass bulb) is covered with buffer solution.
    - Wait for the pH reading to stabilize (at least one minute).
    - pH 7.02 accuracy check meets QA if value reads within ± 0.2 pH units of buffer value (*i.e.,* 6.82 to 7.22).
    - Note accuracy check value, reading, lot number, and expiration date of pH buffer in Water Database.
    - Discard buffer in sink and rinse probe and calibration cup with tap water.
3. For the pH 4 accuracy check, repeat steps for pH 7 buffer with the pH 4 buffer.
    - pH 4.00 accuracy check meets QA if value reads within ±0.4 pH units of buffer value (*i.e.,* 3.6 to 4.4).
    - Note the value of pH 4 buffer at 20°C is 4.00.
    - Note the accuracy check value, reading, lot number, and expiration date of pH buffer in Water Database.
    - Discard buffer in sink and rinse probe and calibration cup with tap water.

If pre-run pH accuracy checks are unsuccessful, attempt accuracy checks again using the procedures contained in this SOP. If accuracy checks remain unsuccessful, re-calibrate the YSI 556 for pH using the procedures listed in Section 3.1.1 of this SOP. If pre-run pH accuracy checks remain unsuccessful after re-calibration, attempt corrective actions listed in Section 5.8.1.

3.2.1.2 Specific Conductivity, Salinity, Temperature

During the pre-run accuracy check for specific conductivity and salinity, the accuracy of the YSI 556 is tested using a blank solution (zero specific conductivity and salinity). Detailed instructions for conducting the specific conductivity and salinity zero accuracy checks follow:

1. Rinse the calibration cup and probe with tap water. Discard in sink.
2. Rinse the calibration cup and probe with distilled water. Discard in sink. Repeat several times as needed.
3. Fill calibration cup with distilled water and immerse the sensor into the water. A small amount of water will overflow. Gently rotate and/or move the sensor up and down to remove any bubbles from the conductivity cell. Screw the calibration cup to the probe and moderately tighten.
4. Make sure that the top vent hole of the conductivity sensor is immersed.
5. Wait for the conductivity reading to stabilize (at least one minute).
6. Specific conductivity meets QA if value reads < 10 µS/cm (*i.e.,* 0-9 µS/cm).
7. Salinity meets QA if value reads 0.0 ppt.
8. Record the accuracy check value and reading, and mark "distilled" as reagent batch in Water Database. Mark the last day of the calendar year as the expiration date.

If pre-run specific conductivity and/or salinity accuracy checks are unsuccessful, attempt accuracy checks again using the procedures contained in this SOP. If accuracy checks remain unsuccessful, re-calibrate the YSI 556 for specific conductivity using the procedures listed in Section 3.1.2 of this SOP. If pre-run specific conductivity or salinity accuracy checks remain unsuccessful after re-calibration, attempt corrective actions listed in Section 5.8.2.

During the pre-run accuracy check for temperature, the accuracy of the YSI 556 temperature reading is compared to the temperature reading of a NIST-traceable reference lab thermometer (Section 7.2.1 for requirements). Detailed instructions for conducting the temperature accuracy check follow:

1. Shake up 1L water bottle (room temperature, expressly used for water temperature accuracy check). Place YSI 556 sensor (without calibration cup or probe guard) directly into bottle. Place reference thermometer into bottle. Allow temperature to stabilize for 1-3 minutes, occasionally stirring gently to prevent temperature stratification.
2. Ensure that YSI 556 temperature sensor and reference thermometer bulb are at the same level in water and are not touching the sides or bottom of the container.
3. The reference thermometer temperature is measured and recorded after stabilization when the same temperature is observed during three rapid and consecutive viewings of the mercury or alcohol column (within a few seconds of each other) without removing the thermometer from the sample bottle. Parallax error is eliminated by viewing the thermometer at eye-level and lining up (or blocking) the graduation mark in the thermometer with its reflection. The temperature indicated by the sensor is measured immediately after the reference thermometer is recorded.

- If using a partial immersion thermometer, ensure that the thermometer is immersed to the immersion line.
- If using a total immersion thermometer, ensure that the column of mercury or alcohol is fully immersed.

4. Meets QA if YSI 556 reads ±0.2°C of reference thermometer.
5. Note the accuracy check value, reading, reference thermometer serial number, and the expiration date of the NIST-traceable manufacturer's or calibration certificate in Water Database.

If pre-run temperature accuracy checks are unsuccessful, attempt accuracy checks again using the procedures contained in this SOP. If accuracy checks remain unsuccessful, attempt corrective actions listed in Section 5.8.2.

3.2.1.3 DO

During the pre-run accuracy check, the accuracy of DO readings are tested at 100% and 0% DO saturation. Detailed instructions for conducting the DO accuracy checks follow:

1. Perform the 100% DO accuracy check immediately following DO calibration. Do not remove calibration cup from sensor between calibration and accuracy check.
    - Meets QA if value reads ±10% (*i.e.,* 90 to 110%).
    - Note the accuracy check value and reading in Water Database.
2. Perform 0% DO accuracy check:
    - Rinse sensor and calibration cup with small amount of 0% DO solution. Discard in sink. Note: the 0% DO standard is water soluble and non-toxic; therefore, it can be discarded in the sink with running water.
    - Fill calibration cup about 1/4 full (~30 ml). Screw the calibration cup to the probe and moderately tighten.
    - Turn the probe upside-down. The DO sensor should be completely covered by the 0% DO solution.
    - Meets QA if value reads <5%.
    - Note the accuracy check value, reading, lot number, and expiration date in Water Database.
    - Discard solution in sink and rinse probe and calibration cup with tap water.

If pre-run DO accuracy checks are unsuccessful, attempt accuracy checks again using the procedures contained in this SOP. If accuracy checks remain unsuccessful, re-calibrate the YSI 556 for DO using the procedures listed in Section 3.1.3 of this SOP. If pre-run DO accuracy checks remain unsuccessful after re-calibration, attempt corrective actions listed in Section 5.8.3.

3.2.2 Mid-Run Accuracy Checks

Mid-run accuracy checks are required for pH and DO. Mid-run accuracy checks are typically conducted in the field mid-way through the sampling trip.

3.2.2.1 pH

During the mid-run accuracy check, the accuracy of pH readings is tested at pH 7 only. Detailed instructions for conducting the pH accuracy checks follow:

1. Rinse the calibration cup and probe with distilled water. Discard.
2. Rinse the calibration cup and probe with a small amount of pH 7 buffer. Discard into the designated waste bottle (1L plastic bottle). The waste bottle can be emptied into the sink and rinsed with tap water upon return to the lab as pH buffer solutions are non-toxic and water soluble. Buffer and rinse waste should not be discarded in the field.
3. Fill calibration cup 1/4-1/3 full (~30 ml) with pH 7 buffer and immerse the sensor into the solution. Gently rotate and/or move the probe up and down to remove any bubbles from the pH sensor. Screw the calibration cup to the probe and moderately tighten.
4. Make sure that the pH sensor (glass bulb) is covered with buffer solution.
5. Wait for the pH reading to stabilize (at least one minute).
6. Note the accuracy check value, reading, lot number, and expiration date of pH buffer in Water Database or on field datasheet.
7. Discard pH buffer waste in waste bottle. Rinse sensor and calibration cup with distilled water, and discard rinse water into waste bottle.
8. pH 7 accuracy check meets QA if value reads within ± 0.2 pH units of buffer value. Check the temperature of the buffer solution to determine the exact pH for the reference value.

If mid-run accuracy check is unsuccessful, attempt accuracy checks again using the procedures contained in this SOP. If mid-run accuracy checks remain unsuccessful see Section 5.8.1 for corrective actions.

3.2.2.2 Specific Conductivity, Salinity, Temperature

No mid-run accuracy checks are required for specific conductivity, salinity or temperature.

3.2.2.3 DO

During the mid-run accuracy check, the accuracy of DO readings are tested at 100% and 0% DO saturation. Detailed instructions for conducting DO accuracy checks follow:

1. Perform 100% DO accuracy check:
    - Dry the DO sensor gently with a Kim Wipe.
    - Place a small amount (1/8 inch) of distilled water in the bottom of the calibration cup and lightly screw on the probe. A loose seal is required to allow pressure equilibration. Engage only 1 or 2 threads and hang the probe in the sample cooler or other sheltered area. This protects the sensor from wind, which can

disrupt pressure equilibration within the calibration cup and can lead to unstable or incorrect DO readings.

- Allow approximately 10 minutes for the air in the calibration cup to fully saturate and DO readings to equilibrate.
- Meets QA if value reads ±10% (*i.e.,* 90 to 110%).
- Note the accuracy check value and reading in Water Database or on field datasheet.

2. Perform 0% DO accuracy check as described above for pre-run accuracy checks.
    - Rinse sensor and calibration cup with distilled water. Discard.
    - Rinse sensor and calibration cup with small amount of 0% DO solution. Discard into the designated waste bottle (1L plastic bottle). The waste bottle can be emptied into the sink and rinsed with tap water upon return to the lab as the 0% DO solution is non-toxic and water soluble. Dissolved oxygen solution and rinse waste should not be discarded in the field.
    - Fill calibration cup about 1/4 full (~ 30 ml). Screw the calibration cup to the probe and moderately tighten.
    - Turn the probe upside-down. The DO sensor should be completely covered by the 0% DO solution.
    - Meets QA if value reads <5%.
    - Note accuracy check value, reading, lot number, and expiration date in Water Database or on field datasheet.
    - Discard solution in waste bottle. Rinse probe and calibration cup with distilled water, and discard rinse water into waste bottle.

If mid-run accuracy check is unsuccessful, attempt accuracy checks again using the procedures contained in this SOP. If mid-run DO accuracy checks remain unsuccessful, see Section 5.8.3 for corrective actions.

3.2.3 Post-Run Accuracy Checks

Post-run accuracy checks are required for pH, specific conductivity and salinity (concurrently), temperature, and DO.

3.2.3.1 pH

During the post-run accuracy check, the accuracy of pH readings is tested at pH 7 only. Detailed instructions for conducting pH accuracy check follow:

1. Perform post-run pH 7 accuracy check as described above for pre-run pH accuracy checks (Section 3.2.1.1).
2. pH 7.02 (at 20°C) accuracy check meets QA if value reads within ± 0.2 pH units of buffer value (*i.e.,* 6.82 to 7.22).
3. Note the accuracy check value, reading, lot number, and expiration date in Water Database.

If post-run accuracy checks are unsuccessful, attempt accuracy checks again using the procedures contained in this SOP. If repeated accuracy checks do not meet acceptance criteria, remedy the problem prior to the next field visit by attempting corrective actions listed in Section 5.8.1.

3.2.3.2 Specific Conductivity, Salinity, Temperature

During the post-run accuracy check for specific conductivity and salinity, the accuracy of the YSI 556 is tested using a blank (zero specific conductivity and salinity). Detailed instructions for conducting the specific conductivity and salinity zero accuracy checks follow:

1. Perform post-run zero specific conductivity and salinity accuracy check as described above for pre-run accuracy checks (Section 3.2.1.2).
2. Specific conductivity meets QA if value reads < 10 µS/cm (*i.e.,* 0-9 µS/cm).
3. Salinity meets QA if value reads 0.0 ppt.
4. Note the accuracy check value and reading in Water Database. Mark "distilled" as reagent batch and the last day of the calendar year as the expiration date.

During the post-run accuracy check for temperature, the accuracy of the YSI 556 temperature reading is compared to the temperature reading of a NIST-traceable reference lab thermometer (Section 7.2.1 for requirements). Detailed instructions for conducting the temperature accuracy check follow:

1. Perform post-run temperature accuracy check as described above for pre-run accuracy check (Section 3.2.1.2).
2. Meets QA if YSI 556 reads ±0.2°C of reference thermometer.
3. Note the accuracy check value, reading, reference thermometer serial number, and the expiration date of the NIST-traceable manufacturer's or calibration certificate in Water Database.

If post-run accuracy checks are unsuccessful, attempt accuracy checks again using the procedures contained in this SOP. If repeated accuracy checks do not meet acceptance criteria, remedy the problem prior to the next field visit by attempting corrective actions listed in Section 5.8.2.

3.2.3.3 DO

During the post-run accuracy check, the accuracy of DO readings are tested at 100% and 0% DO saturation. Detailed instructions for conducting DO accuracy checks follow:

1. Perform post-run 100% DO accuracy check as described above for pre-run accuracy checks (Section 3.2.1.3).
    - Hang the probe over the sink to equilibrate.
    - Allow approximately 10 minutes for the air in the calibration cup to fully saturate and DO readings to equilibrate.
    - Meets QA if value reads ±10% (i.e., 90 to 110%).
    - Note the accuracy check value and reading in Water Database.

2. Perform post-run 0% DO accuracy check as described above for pre-run accuracy checks (Section 3.2.1.3).
    - Meets QA if value reads <5%.
    - Note the accuracy check value, reading, lot number, and expiration date in Water Database.

If post-run accuracy checks are unsuccessful, attempt accuracy checks again using the procedures contained in this SOP. If repeated accuracy checks do not meet acceptance criteria, remedy the problem prior to the next field visit by attempting corrective actions listed in Section 5.8.3.

3.2.4 Additional Accuracy Checks

Additional accuracy checks are required for specific conductivity, DO, and the barometer. Duplicates may be required, depending on the relevant project QAPP.

3.2.4.1 Specific Conductivity

An accuracy check of specific conductivity is required quarterly. Accuracy checks are conducted immediately after calibration and mid-way between twice-annual calibrations. Detailed instructions for conducting the quarterly specific conductivity accuracy checks follow:

> v Note: if performing specific conductivity accuracy checks immediately following calibration, begin with 50,000 µS/cm standard, which is already being read by the sensor. Follow with the 1,000 µS/cm standard after a thorough rinse of the probe and calibration cup with tap water. If conducting accuracy check mid-way between twice annual calibrations, begin with the 1,000 µS/cm standard.

1. 1,000 µS/cm specific conductivity accuracy check:
    - Rinse the calibration cup and probe with tap water. Discard in sink.
    - Rinse the calibration cup and probe with a small amount of the 1,000 µS/cm specific conductivity standard. Discard in sink.
    - Fill calibration cup with 1,000 µS/cm conductivity solution (at least 55 ml) and immerse the sensor into the solution. A small amount of conductivity solution will overflow. Gently rotate and/or move the sensor up and down to remove any bubbles from the conductivity cell. Screw the calibration cup to the probe and moderately tighten.
    - Make sure that the top vent hole of the conductivity sensor is immersed.
    - Wait for the conductivity reading to stabilize (at least one minute).
    - Meets QA if value is within 3% of standard solution (*i.e.,* 970 – 1,030 µS/cm).[3]
    - Note accuracy check value, reading, lot number, and expiration date in Water Database.

[3] Verify the exact concentration by obtaining a certificate of analysis for the specific conductivity standard used in the accuracy check. A certificate of analysis for a particular lot or batch of standard can be requested from the vendor or manufacturer. The Water Resources Specialist II stores and keeps track of certificates of analysis.

- Discard solution in sink and rinse probe and calibration cup with tap water.

2. 50,000 µS/cm specific conductivity accuracy check:
    - Rinse the calibration cup and probe with a small amount of the 50,000 µS/cm specific conductivity standard. Discard in sink.
    - Fill calibration cup with 50,000 µS/cm conductivity solution (at least 55 ml) and immerse the sensor into the solution. A small amount of conductivity solution will overflow. Gently rotate and/or move the sensor up and down to remove any bubbles from the conductivity cell. Screw the calibration cup to the probe and moderately tighten.
    - Make sure that the top vent hole of the conductivity sensor is immersed.
    - Wait for the conductivity reading to stabilize (at least one minute).
    - Meets QA if value is within 3% of standard solution (*i.e.,* 48,500 – 51,500 µS/cm).[4]
    - Note accuracy check value, reading, lot number, and expiration date in Water Database.
    - Discard solution in sink and rinse probe and calibration cup with tap water.

Salinity can be informally checked concurrently with specific conductivity, as salinity is calculated from specific conductivity and temperature. The 1,000 µS/cm specific conductivity standard is equivalent to a salinity of 0.49 ppt (Wagner et al. 2006). The 50,000 µS/cm specific conductivity standard is equivalent to a salinity of 32.72 ppt (Wagner et al. 2006).

3.2.4.2 DO

If any field measurement exceeds 200% DO saturation, conduct an additional 100% DO saturation accuracy check as outlined in the mid-run accuracy check section above (Section 3.2.2.3). The accuracy check meets QA if it reads ±10% (*i.e.,* 90 to 110%). If the additional 100% DO saturation accuracy check does not meet QA, follow instructions provided for DO mid-run accuracy check above (Section 3.2.2.3) and Section 5.8.3 for corrective actions.

3.2.4.3 Barometer

The internal barometer is accuracy checked annually to ensure proper function. A true (uncorrected) barometer reading is needed as a reference value. Note that weather service readings are usually not true, as they are corrected to sea level, and will need to be uncorrected. See YSI 556 User's Manual for details.

3.2.4.4 Field Duplicates

If field duplicates are required by the project QAPP, results are used as an indicator of both field variability and precision of the instrument. If field duplicates exceed stabilization criteria (Section 4.4), field personnel use professional judgment to determine whether variability is caused by poor precision or natural field variability. See appropriate project QAPP for additional details.

4. SAMPLE COLLECTION

This section details the use of the YSI 556 in the field. Parameter measurement can be conducted either *in-situ* or *ex-situ*, depending on the site and project, as detailed below. This section also summarizes the proper use of the probe guard and parameter stabilization.

4.1 Probe Guard

When used in the field, the YSI 556 sensors should be enclosed in a heavy duty probe guard with attached sinking weight. The probe guard provides protection from debris and holes allow water to flow around the sensors.

The probe guard should be attached to the sensors moderately tightly. It should be tightened to "hand tightness" to ensure that the guard stays securely in place during field visits but also allows for easy removal by hand.

4.2 In-situ Parameter Measurement

In the field, the following steps should be followed when collecting parameter measurements from surface water in situ using the YSI 556:

1. Suspend the probe by the cable from the sampling wand. The probe should hang somewhat from the wand so as to allow the probe to be submerged in water without immersing the wand. See Figure 4.1.

Figure 4.1 Surface Water Quality Sample Collection Using a Sampling Wand

2. Place probe in representative portion of waterbody using sampling wand unless unsafe or impractical. (Note: representative portion of waterbody is described in the appropriate project QAPP). Take care to minimize disturbance of the water when placing the probe and moving it in the water.

3. The probe should be submerged upright in the sample water. The top of the probe casing should be just below the surface of the water. If sufficient water depth is not available for full immersion of the upright probe, it can be turned on its side, perpendicular to flow direction.
4. If very low flow is present, the probe should be gently moved through the water to ensure that water is flowing past the DO sensor. A flow rate of 3 inches per second is required to ensure accurate DO readings.
5. Wait for parameter reading to stabilize for at least one minute. The parameter reading is considered stable if there is no significant movement in the parameter reading for 30 seconds. See Section 4.4 for details on parameter stabilization.
6. Record parameter readings in Water Database or on field datasheet.
7. Rinse probe with distilled water and store in a sheltered location out of direct sunlight.

4.3 Ex-situ Parameter Measurement

If well water, or other water that cannot be measured in situ, is to be analyzed, collect a sample in a 1 L plastic bottle that has been thoroughly rinsed per the project QAPP and analyze the water quality parameters using the YSI 556 as follows:

1. Rinse the probe with distilled water.
2. Rinse the probe with sample water.
3. Place probe into sample container and allow parameter readings to stabilize, stirring gently, for at least one minute. See Section 4.4 for parameter stabilization requirements.
    - Note: Temperature should not increase by more than 0.2°C while parameters stabilize. See Section 5.8 for corrective actions.
4. Rinse probe with distilled water and store in a sheltered location out of direct sunlight.

4.4 Parameter Stabilization

For a parameter reading to be considered stable, the value must have had no significant change for approximately 30 seconds. No significant change is defined by an acclimation/stabilization criterion for each parameter. The following acclimation/stabilization criteria apply to the following parameters:

- pH: readings within 0.3 pH range
- Dissolved oxygen: readings within 0.3 mg/L range
- Specific conductivity: readings within 3% range
- Salinity: readings within 0.2 ppt range
- Temperature: readings within 0.2°C range

If the parameter reading is changing, but not trending up or down or ranging outside of the parameter acclimation/stabilization criteria, the reading is considered stable and can be

recorded. Record the approximate average of the range of parameter readings observed over 30 seconds in the site visit section of Water Database or on field datasheet.

If the parameter readings appear to follow a trend (*e.g.,* increasing or decreasing) or are ranging beyond the acclimation/stabilization criteria, wait a few minutes for the parameter readings to stabilize. If the parameter readings do not stabilize within the acclimation/stabilization criteria due to natural variation in the sample water (*e.g.,* tidal influence), record the average and the range of the last five values. Document any apparent trends and any apparent or suspected causes of variation in the site comments section of Water Database or on field datasheet. Slow stabilization time for pH measurements in low ionic strength water is common; for these sites, the pH reading can be recorded after five minutes even if readings are following a trend or ranging beyond the acclimation/stabilization criteria (Spence 2018 pers comm).

If readings are not within acclimation/stabilization criteria due to a reason other than variation of the sample water, determine whether it is caused by operator error or instrument malfunction. The error must be identified, corrected, and documented prior to proceeding with readings. See Section 5 for details on identifying causes of error, steps to take to correct the problem, and instructions on steps to take if the problem cannot be corrected.

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5. TROUBLESHOOTING

For all troubleshooting activities, document observations, corrective actions, and outcomes in Water Database or on field datasheet, as specified by the relevant project QAPP and Water Database User Guide. The sections below provide steps to be taken to identify and remedy equipment problems as they arise during performance of QA/QC activities and use of the YSI 556 in the field. See YSI 556 User's Manual pages 115-117 for troubleshooting assistance on general instrument functions, including no display, software lockup, and water damage.

5.1 Calibration

If an "out of range" message appears after calibration, attempt the calibration again using the procedures contained in this SOP. If calibration remains unsuccessful, determine if error is due to contaminated standard, operator error, or equipment malfunction. If:

- Contaminated standard: Use new, unexpired standard and attempt accuracy checks again.
- Operator error: Correct operator error and attempt accuracy checks again.
- Equipment malfunction: See parameter-specific procedures contained in this SOP and Section 5.8 for details on corrective actions for each parameter/sensor. Attempt corrective actions prior to proceeding to field run.

Do not proceed to field run if calibrations or pre-run accuracy checks are unsuccessful. Contact manufacturer for sensor replacement or servicing as recommended.

5.2 Pre-run

If a pre-run accuracy check is unsuccessful, attempt accuracy check again using the procedures listed in Section 3.2.1 of this SOP. If accuracy check remains unsuccessful, re-calibrate the YSI 556 for parameter again (if applicable) using best practices. If pre-run accuracy checks continue to remain unsuccessful, determine if error is due to contaminated standard, operator error, or equipment malfunction. If:

- Contaminated standard: Use new, unexpired standard and attempt accuracy checks again. If needed, repeat calibration with new standard prior to attempting accuracy checks again.
- Operator error: Correct operator error and attempt accuracy checks again.
- Equipment malfunction: See parameter-specific procedures contained in this SOP and Section 5.8 for details on corrective actions for each parameter/sensor. Attempt corrective actions prior to proceeding to field run.

Do not proceed to field run if calibrations or pre-run accuracy checks are unsuccessful. Contact manufacturer for sensor replacement or servicing as recommended.

5.3 Mid-run

If a mid-run accuracy check is unsuccessful,[4] attempt accuracy check again using the procedures contained in this SOP. If accuracy check remains unsuccessful, determine if error is due to contaminated standard, operator error, or equipment malfunction. If:

- Contaminated standard: Use new, unexpired standard, if available, and attempt accuracy checks again. If new standard not available, proceed with field visits.
- Operator error: Correct operator error and attempt accuracy checks again. Proceed with field visits.
- Equipment malfunction: See parameter-specific procedures contained in this SOP and Section 5.8 for details on corrective actions for each parameter/sensor. In general, options include:
    - Re-calibrate instrument, redo accuracy checks. Data qualifier must be added to all previous field measurements in Water Database. Detailed procedures on assigning data qualifiers are provided in the QMP and Water Database User Guide.
    - Redo accuracy checks at each site. Repeating accuracy check at each site allows for calculation of error of the instrument. If consistent throughout the remainder of the sample run, the error of the measurements can be adjusted using a correction factor.
    - Proceed with field visits.

Use best professional judgment when determining the best course of action for remedying suspected equipment malfunction during a field visit. Recalibrating the YSI 556 at mid-run requires assigning a data qualifier to all previously collected data for that parameter (see QMP and Water Database User Guide for details on data qualifiers). If parameter is not re-calibrated at mid-run despite a failing mid-run accuracy check, a successful post-run accuracy check can still result in fulfillment of the minimum QA/QC requirements, assuming that the parameter passed all pre-run accuracy checks and calibrations (as required). Alternatively, if the parameter is not re-calibrated at mid-run after a failing mid-run accuracy check, an unsuccessful post-run accuracy check will result in an automatic rejection of all data collected for that parameter that day.

5.4 Post-run

If a post-run accuracy check is unsuccessful, attempt accuracy checks again using the procedures contained in this SOP. If accuracy check remains unsuccessful, determine if error is due to contaminated standard, operator error, or equipment malfunction. If:

- Contaminated standard: Use new, unexpired standard and attempt accuracy checks again.

[4] Includes additional 100% DO saturation checks (when field DO reading exceeds 200% saturation), as needed.

- Operator error: Correct operator error and attempt accuracy checks again.
- Equipment malfunction: See parameter-specific procedures contained in this SOP and Section 5.8 for details on corrective actions for each parameter/sensor. Attempt corrective actions prior to next field visit to prevent equipment malfunction in the future.

5.5 Field sample collection

If water quality values will not stabilize, determine if environment, operator error, or equipment malfunction is at fault. If:

- Environment: If environmental variability is preventing parameter values from stabilizing, record the average in the site visit section and the range of the last five values in the site comments section of Water Database or on field datasheet. Document any apparent trends and any apparent or suspected causes of variation in the site comments section of Water Database or on field datasheet.
- Operator error:
    - Representative location: see project QAPP for details on representative location for collection of water quality sample.
    - Water sample collection methods: see relevant project QAPP for details on how to collect a proper water sample (in container). See Section 4 for details on *in situ* water sampling using the YSI 556.
- Equipment malfunction: See parameter-specific procedures contained in this SOP and Section 5.8 for details on corrective actions for each parameter/sensor.

If operator error or equipment malfunction is suspected as the cause, remedy if possible and document problems, corrective actions, outcomes, and resolution per relevant project QAPP, QMP, and Water Database User Guide.

For container-based measurement, if temperature is changing in one direction by more than 0.2°C (coming into equilibrium with atmospheric conditions), discard sample, repeat sample collection, and perform measurements before temperature changes more than 0.2°C. If it is not possible to measure without small temperature change, perform measurement and flag data with data qualifier because of temperature change. See QMP for details regarding data qualifiers.

If problem is caused by equipment malfunction that cannot be corrected or an unknown and unresolved issue, discontinue measurement until problem is resolved, and assign data qualifier to results collected up to time of problem as suspect, including the reason for assigning data qualifier. If equipment malfunction cannot be corrected in the lab, have it serviced or replaced per manufacturer's recommendations as soon as possible.

5.6 Field Duplicates

If field duplicates exceed stabilization criteria, determine if environment, operator error, or equipment malfunction is at fault. Note that field duplicates provide an indication of both natural field variability and instrument precision. If:

- Environment: If environmental variability is causing duplicate measurements to exceed stabilization criteria, record the reading as observed in the site comments section of Water Database or on field datasheet. Document any apparent trends and any apparent or suspected causes of variation in the site comments section of Water Database or on field datasheet.
- Operator error:
    - Representative location: see project QAPP for details on representative location for collection of water quality sample.
    - Water sample collection methods: see relevant project QAPP for details on how to collect a proper water sample (in container). See Section 4 for details on *in situ* water sampling using the YSI 556.
- Equipment malfunction: If poor precision of the instrument suspected as cause, see parameter-specific procedures contained in this SOP and Section 5.8 for details on corrective actions for each parameter/sensor. Do not record field measurements that are of questionable quality, or assign a data qualifier to suspect data.

See appropriate project QAPP for additional details on using professional judgment to interpret duplicate results.

5.7 Continued Use of Faulty Equipment

If YSI 556 error cannot be remedied, it is recommended that the faulty sensor not be used to collect further measurements for the inaccurate parameter. However, because measurement of salinity is required when collecting bacteria samples, in extreme cases (*e.g.,* YSI 556 salinity error cannot be remedied and no backup instruments are available) continued use of faulty equipment is allowed if the error can be quantified and appears to be constant. Note that the YSI 556 calculates salinity from specific conductivity and temperature measurements; incorrect salinity measurements indicate a malfunction in either the specific conductivity or temperature sensors.

To use the YSI 556 to measure salinity even if it does not meet the QA acceptance criteria, accuracy checks for salinity, specific conductivity, and temperature are performed with every sampling measurement and duplicate sample readings are taken for each field measurement. A non-mercury non-toxic reference thermometer, distilled water, and the specific conductivity standards are taken into the field to conduct the accuracy checks. Accuracy checks and duplicate sample readings will allow for calculation of precision and accuracy of the measurements, and may provide information as to which sensor is malfunctioning (*i.e.,* temperature or specific conductivity). Precision and accuracy must be quantifiable and provide the resolution necessary to detect differences at the scale necessary (*e.g.,* difference between

fresh water and marine water). The problem, reason for use of the sub-optimally functioning meter, and all QA activity information are documented in Water Database or field datasheet. All collected data are associated with data qualifiers due to poor QA performance (details on data qualifiers are provided in the QMP and Water Database User Guide). Upon return to the lab, corrective actions are taken and/or the instrument is serviced or replaced so that the use of faulty equipment is not repeated.

5.8 Corrective Actions

All equipment problems, corrective actions taken, outcomes of actions taken, and resolution are recorded in the trip comments section of Water Database or on field datasheet.

5.8.1 pH

If pH 4 pre-run accuracy check does not meet QA, the pH calibration can be adjusted by conducting an additional 1-point pH calibration. Select 1-point calibration from the pH calibration menu. The steps for this calibration are identical to the 2-point pH calibration (Section 3.1.1), except the calibration is performed using the pH 4 buffer only. Conduct an additional pH 4 accuracy check immediately following the 1-point pH calibration adjustment, and follow with accuracy checks at pH 7 and 10, recording accuracy check values, readings, lot numbers, and expiration dates in Water Database or on field datasheet.

The pH sensor stabilizes very slowly in low ionic strength solutions (*i.e.,* low specific conductivity) (Michaels 2015 pers comm). If the sensor does not appear to stabilize within several minutes, check the specific conductivity of the water body or water sample. If time allows, wait for the sensor to stabilize, or record the pH reading at 5 minutes. Section 6.1.4 provides details on measuring pH in low ionic strength waters.

If pH readings are unstable or inaccurate, an "out of range" message appears during calibration, or equipment malfunction is suspected, attempt the following solutions:

1. Re-calibrate sensor (Section 3.1.1) and/or redo accuracy checks (Section 3.2.1.1) using the following best practices:
    - Use proper rinsing techniques: rinse with tap water, then with a small amount of buffer
    - Use fresh, unexpired, uncontaminated standards
    - Ensure glass bulb of the pH sensor is covered by buffer solution
    - Check the temperature of the pH buffer. Note that pH varies with temperature. Calibrate and perform accuracy checks against the temperature-corrected pH listed on the buffer container.
    - Allow adequate time for the pH sensor to stabilize before calibrating or recording pH for accuracy check (at least one minute)
    - Gently rotate and/or move the probe up and down to remove any bubbles from the pH sensor (glass bulb)
2. Use new buffer solutions

3. Determine response time and slope of the pH sensor (Section 6.1.3)
4. Clean sensor (Section 6.1.1)
5. Soak sensor in tap water or buffer until readings become stable
6. Recondition sensor (Section 6.1.2)
7. Dry sensor connector
8. Return sensor to YSI for service
9. Replace sensor (Section 6.1.5)

5.8.2 Specific Conductivity, Salinity, Temperature

If specific conductivity or salinity readings are unstable or inaccurate, an "out of range" message appears during specific conductivity calibration, or if equipment malfunction is suspected, attempt the following solutions:

1. Re-calibrate sensor (Section 3.1.2) and/or redo accuracy checks (Section 3.2.1.2) using the following best practices:
    - Rinse sensor and calibration cup several times with distilled water for zero accuracy check
    - Fully immerse sensor during calibration
    - Gently rotate and/or move the sensor up and down to remove any bubbles
    - Use fresh, unexpired, uncontaminated standards
    - Make sure that the top vent hole of the conductivity sensor is immersed
    - Allow adequate time for the conductivity reading to stabilize before calibrating or recording value for accuracy check (at least one minute)
    - Ensure correct calibration value was used
    - Ensure that the calibration was conducted in specific conductance mode
2. Use new calibration solutions
3. Check the conductivity cell constant for the calibration. An acceptable range is 5 ±1.0.
4. Clean sensor
5. Check for proper function in dry air. The sensor should read less than 3 µS/cm if it is clean
6. Soak sensor in tap water or calibration solution until readings become stable
7. Return sensor to YSI for service
8. Replace sensor (Section 6.2.2)

If temperature readings are unstable or inaccurate, attempt the following solutions:

1. Carefully redo accuracy check using the following best practices:
    - Ensure that the temperature sensor and reference thermometer bulb are at same level in water, not touching the sides or bottom of the container
    - Ensure that the water is not thermally stratified by mixing gently during equilibration

2. Dry sensor connector
3. Return sensor to YSI for service
4. Replace sensor (Section 6.2.2)

5.8.3 DO

If DO readings are unstable or inaccurate, an "out of range" message appears during calibration, or if equipment malfunction is suspected, attempt the following solutions:

1. Re-calibrate sensor (Section 3.1.3) and/or redo accuracy checks (Section 3.2.1.3) using the following best practices:
    - Make sure instrument has been on for at least 20 minutes prior to DO calibration. The DO sensor takes time to polarize and become ready for use.
    - Gently, make sure DO membrane is dry
    - Check barometric pressure value during DO calibration
    - Avoid extreme temperatures during calibration
    - Make sure calibration cup is loosely screwed on to probe
    - Make sure calibration cup is attached to probe for approximately 10 minutes to allow for pressure equilibration and for the DO readings to stabilize before calibrating or recording accuracy check
    - Use fresh, unexpired, uncontaminated standards
    - Ensure barometer is reading properly. See Sections 3.1.4 and 3.2.4.3 of this SOP and the YSI 556 User's Manual for details.
    - See The Dissolved Oxygen Handbook (YSI Incorporated 2009) for additional tips
2. Ensure that the correct sensor type and membrane type are enabled in the Sensor Setup Menu. See YSI 556 User's Manual for details
3. Try accuracy check with new 0% DO standard
4. Replace DO sensor membrane and electrolyte solution (Section 6.3.1)
5. Clean DO sensor with clean water
6. Check silver anode and gold cathode for contamination, tarnishing or plating. Clean the anode and cathode (Sections 6.3.2 and 6.3.3)
7. Dry sensor connector
8. Return sensor to YSI for service
9. Replace sensor (Section 6.3.4)

If DO readings become erratic, check the membrane. Erratic readings can be caused by loose, wrinkled, damaged, or fouled membranes, or from large (more than 1/8 inch diameter) bubbles in the electrolyte reservoir. Other causes of erratic readings can include membrane coating with oxygen-consuming (*e.g.,* bacteria) or oxygen-producing organisms (*e.g.,* algae), oxygen-behaving gases (*e.g.,* chlorine, sulfur dioxide, nitric oxide, nitrous oxide), reactive substances (*e.g.,* concentrated acids, caustics, strong solvents). Replace the membrane and electrolyte solution if visible membrane damage occurs or DO readings become erratic.

The DO sensor contains a silver anode and gold cathode. If the silver anode is contaminated, it will prevent successful calibration. After extended use, a thick layer of silver chloride (AgCl) builds up on the silver anode, reducing the sensitivity of the sensor. The gold cathode can become tarnished or plated with silver after extended use, preventing correct sensor operation. The silver anode and gold cathode can be restored per manufacturer's instructions (Sections 6.3.2 and 6.3.3; YSI undated).

6. MAINTENANCE

Table 6.1 summarizes sensor maintenance activities and the typical replacement interval for the YSI 556 sensors. The instructions in this section should be supplemented by detailed information in the YSI 556 User's Manual, and all cleaning should follow the manufacturer's instructions. Improper cleaning can damage the sensors.

Table 6.1 Sensor Maintenance, Frequency, and Typical Replacement Interval

Sensor	Maintenance Activity	Frequency	Typical Replacement Interval
pH	Cleaning, reconditioning	Approximately monthly, as needed	2 years
Specific Conductivity, Salinity, Temperature	Cleaning	As needed (typically monthly)	3-5 years
Dissolved Oxygen	Replace membrane cap and electrolyte solution	Monthly	2-3 years
	Silver anode and gold cathode cleaning	As needed	

6.1 pH

Maintenance activities for the pH sensor, including sensor cleaning and reconditioning, are described below. The instructions in this section should be supplemented by detailed information in the YSI 556 User's Manual and YSI Making Good pH Measurements presentation (Lizotte and Moeggenberg 2011).

6.1.1 Sensor cleaning

The pH sensor should be gently cleaned on a regular basis (approximately monthly), and as needed when deposits or contaminants appear on the glass or when the response of the sensor is slow. If cleaning is needed, follow the detailed cleaning instructions listed in the YSI 556 User's Manual (page 105-106). Cleaning options to be attempted, in order, are listed below:

- Clean with clean water and clean cloth, lens cleaning tissue, or cotton swab
- Remove material blocking reference electrode junction
- Soak sensor in clean, warm water with a few drops of dishwashing liquid and gently clean with cotton swab
- Soak sensor for 30-60 minutes in 1M HCl and gently clean with cotton swab
- Soak sensor for one hour in 1:1 solution of chlorine bleach and tap water
- Rinse sensor with tap and distilled water to remove cleaning products

6.1.2 Sensor reconditioning

If the sensor is not working properly due to drying out of reference electrode junctions, the sensor can be rehydrated by soaking for several hours (or overnight) in a 2M KCl solution. The pH sensor is shipped in a storage vessel, which contains 2M KCl.

Sensor drying can be prevented by storing the sensor in a humid environment (Section 2.3).

6.1.3 Response time and slope test

Sensor performance can be evaluated by conducting a response time and slope test (Lizotte and Moeggenberg 2011).

Following rinse with tap water and pH 7 buffer solution, place the sensor in pH 7 buffer solution (do not calibrate the sensor). Time how long it takes for the readings to stabilize and record the pH and millivolt (mV) output. Repeat with pH 4 and/or pH 10 buffer solutions.

If the sensor is working properly, the stabilization time for each of the buffer solutions should be approximately two minutes or less. If slower, clean or recondition the sensor.

The slope is determined by the mV difference between the buffers. The pH 7 buffer should read 0 mV (±50 mV) if working properly. The absolute value of the difference in mV readings between the pH 7 and pH 10 buffers and between the pH 7 and pH 4 buffers should be 165-180 mV. If the mV reading for the pH 7 buffer exceeds ±50 mV or the slope is less than ±165 or exceeds ±180 mV, the sensor should be reconditioned or replaced.

6.1.4 Low ionic strength sample water

The pH sensor responds slowly to low ionic strength solutions (*i.e.,* low specific conductivity). Sensor response time in low ionic strength solutions can be tested after pH calibration by placing the pH sensor in tap water and timing how long it takes for the sensor to stabilize. The sensor should be expected to take longer than this to stabilize in even lower ionic strength water.

To improve response time in low ionic strength water, the pH sensor can be submerged in tap water for transport to the field. In the field, keeping the sensor wet with site water when possible can also decrease response time. The pH reading can be recorded after five minutes of parameter stabilization time at sites with low ionic strength water even if readings are trending or do not meet stabilization criteria.

6.1.5 Sensor replacement

The pH sensor should be replaced when it no longer holds calibration through a sample run or calibration is not successful. Typically, the pH sensor should be replaced every 2 years.

6.2 Specific Conductivity, Salinity, Temperature

Maintenance activities for the specific conductivity, salinity and temperature sensor includes cleaning. The instructions in this section should be supplemented by detailed information in the YSI 556 User's Manual.

6.2.1 Sensor cleaning

The YSI 556 specific conductivity, salinity, and temperature sensor should be cleaned regularly (approximately once per month) and as needed when a dirty sensor is suspected.

A dirty sensor can result in inaccurate specific conductivity and/or salinity measurements due to contamination. The conductivity cell should be cleaned by dipping the cleaning brush (provided in the maintenance kit) in clean water and inserting it into each hole 15-20 times. If deposits have formed on the electrodes, the cell should be cleaned with a mild detergent solution by dipping and agitating the conductivity cell in cleaning solution for 2-3 minutes and gently scrubbing with the supplied nylon brush. The sensor is thoroughly rinsed with tap water after cleaning. See YSI 556 User's Manual for details (pages 95-96).

6.2.2 Sensor replacement

The specific conductivity, salinity, temperature sensor should be replaced when it no longer holds calibration through a sample run or calibration is not successful. Typically, this sensor should be replaced every 3-5 years.

6.3 DO

Maintenance activities for the DO sensor, including membrane cap and electrolyte solution replacement and sensor cleaning, are described below. The instructions in this section should be supplemented by detailed information in the YSI 556 User's Manual (pages 90-94).

6.3.1 Membrane cap and electrolyte solution replacement

The DO sensor membrane cap should be inspected prior to each use of the DO sensor. The DO sensor requires monthly replacement of the sensor membrane cap (2 mil polyethylene blue color) and electrolyte solution. The membrane cap should also be replaced if any fouling is evident. O-rings should be replaced when worn. Step-by-step instructions for replacement of the DO sensor membrane cap are listed below, and are also included in the membrane cap and electrolyte solution kits from YSI:

- Unscrew, remove, and discard the old membrane cap
- Thoroughly rinse the sensor tip with distilled water
- Prepare the electrolyte solution according to the directions on the bottle
- Hold the new membrane cap and fill it at least ½ full with the electrolyte solution
- Screw the membrane cap onto the sensor.
    - Unscrew slightly to release pressure, then screw on moderately tight
    - A small amount of electrolyte should overflow
- Note: Do not touch the membrane surface

6.3.2 Silver anode cleaning

The silver anode can be restored using chemical or mechanical cleaning.

For chemical cleaning, soak the entire anode section in 14% ammonium hydroxide solution for 2-3 minutes. Rinse thoroughly with distilled water. Wipe the anode with wet paper towel to remove the residual layer from the anode.

For mechanical cleaning, sand off the dark layer from the silver anode with 400-grit wet/dry sandpaper. Wrap the sandpaper around the anode and twist the sensor. Rinse thoroughly with distilled water. Wipe the anode with wet paper towel to remove the residual layer from the anode.

If calibration and use of the instrument is required immediately after the cleaning, turn the instrument on and allow the system to stabilize for a minimum of 30 minutes.

6.3.3 Gold cathode cleaning

The gold cathode can be cleaned using the adhesive backed sanding disc and tool provided in the YSI Probe Reconditioning Kit. Wet sand the gold cathode with a twisting motion 3 times or until all silver deposits are removed and the gold appears to have a matte finish. Rinse the cathode with distilled water. Wipe the cathode with wet paper towel.

Contact manufacturer for sensor replacement or repair options if the cathode remains tarnished.

6.3.4 Sensor replacement

The DO sensor should be replaced when it no longer holds calibration through a sample run or calibration is not successful. Typically, the DO sensor should be replaced every 2-3 years.

7. SUPPLIES AND CONSUMABLES

7.1 pH

Supplies and consumables needed for operation of the pH sensor include:

- pH sensor
- Calibration cup
- pH buffers: 4, 7, and 10
- Mild cleanser (as needed for cleaning)
- 1M HCl (as needed for sensor cleaning)
- Chlorine bleach (as needed for sensor cleaning)
- 2M KCl (as needed for sensor reconditioning)
- Dishwashing liquid
- Cotton swabs
- Distilled water

7.2 Specific Conductivity, Salinity, Temperature

Supplies and consumables needed for operation of the specific conductivity, salinity, and temperature sensor include:

- Specific conductivity, salinity, and temperature sensor
- Calibration cup
- Specific conductivity standards: 1,000 and 50,000 µS/cm
- Distilled water
- Reference thermometer
- Mild cleanser (as needed for cleaning)
- Cleaning brush (supplied in maintenance kit)

7.2.1 Reference Thermometer

The reference thermometer can be either a non-toxic spirit-in-glass or mercury-in-glass thermometer that is:

- NIST-certified,
- Manufacturer-certified as NIST-traceable and carrying a current NIST certification, or
- NIST-traceable certification that is no more than 2 years old or still current according to the manufacturer.

In the event that a reference thermometer meeting the required criteria is not available, a secondary standard for the reference thermometer is as follows: NIST-traceable certificate of

calibration with expiration date no greater than 5 years prior. The reference thermometer must remain within ±0.2°C of 0°C in ice water bath. Note the use of a reference thermometer meeting the secondary standard in Water Database or on field datasheet.

7.3 DO

Supplies and consumables needed for operation of the DO sensor include:

- DO sensor
- Calibration cup
- 0% DO solution
- DO sensor caps (2 mil polyethylene blue color) and electrolyte solution
- 14% ammonium hydroxide solution (as needed for sensor cleaning)
- 400-grit wet/dry sandpaper
- YSI Probe Reconditioning Kit (5238)
- Distilled water

8. ACRONYMS AND ABBREVIATIONS

DO	Dissolved Oxygen
LNR	Lummi Natural Resources
LWRD	Lummi Water Resources Division
mV	Millivolt
NIST	National Institute of Standards and Technology
QAPP	Quality Assurance Project Plan
QA/QC	Quality Assurance/Quality Control
QMP	Quality Management Plan
SDS	Safety Data Sheet
SOP	Standard Operating Procedure
YSI 556	Yellow Spring Instruments 556 Multi Probe System

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