Water Quality Monitoring at Lake Mead, Arizona and Nevada - Quality Assurance Plan

U.S. Geological Survey

Nevada Water Science Center

Henderson, Nevada

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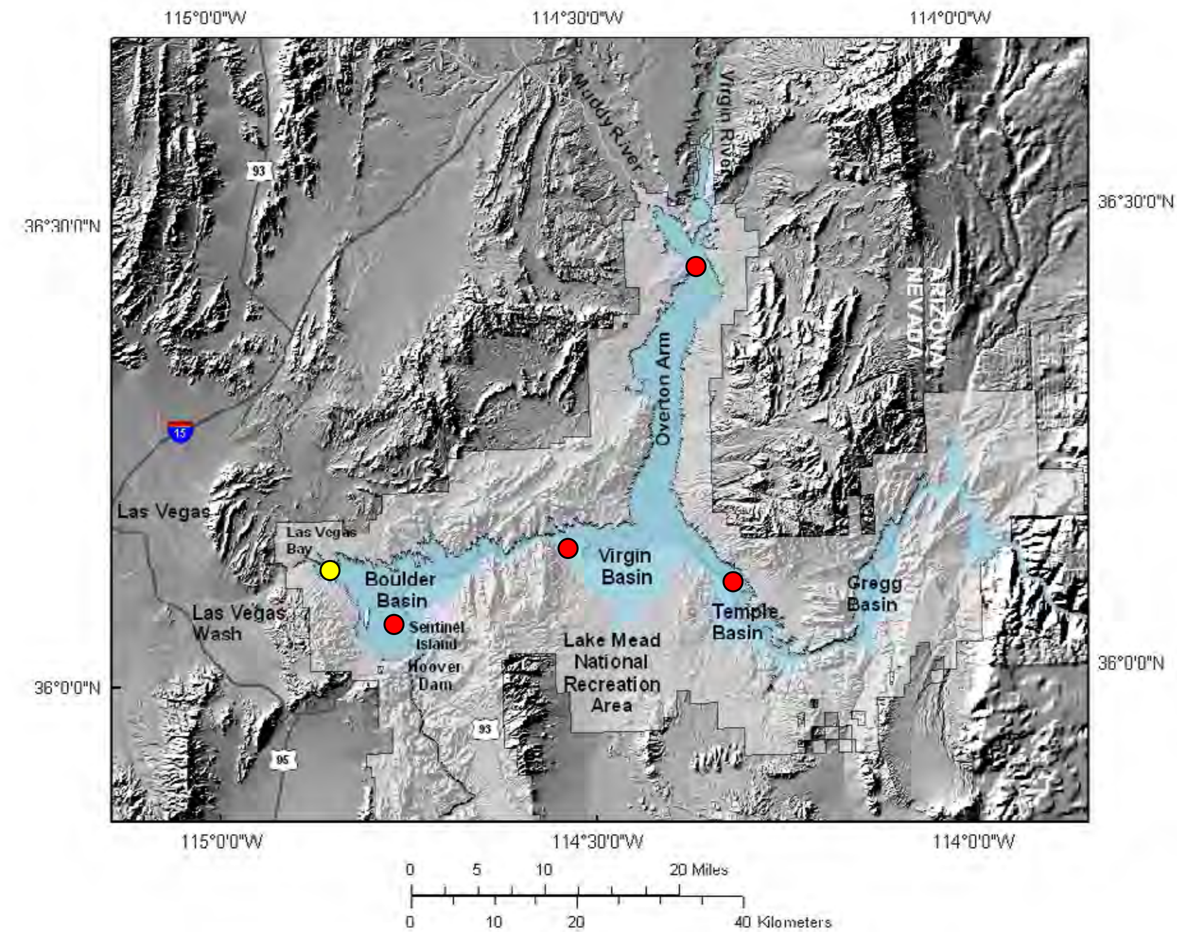
1.0 Introduction

The U.S. Geological Survey (USGS) has established five near-continual, water-quality profiling stations on Lake Mead (fig. 1.) Instrumentation at the USGS stations collect depth dependent, near-real-time water-quality data at programmed depth increments and time intervals. The physical and chemical parameters measured by the profiling equipment at each site include depth, temperature, pH, dissolved oxygen, specific conductance, turbidity, and fluorescence.

The objectives of the project are (1) collect near-continual (every 6 hours), depth dependent measurements of selected water-quality field parameters at monitoring stations on Lake Mead, (2) assess temporal trends in water-quality field parameters measured at each monitoring site, and (3) report near real-time water-quality field-parameter data on the internet.

This quality assurance (QA) plan is based on established project procedures and bureau standards for continuous water quality monitoring that were published in 2006 in USGS Techniques and Methods 1–D3 (TM1D3), *Guidelines and Standard Procedures for Continuous Water-Quality Monitors: Station Operation, Record Computation, and Data Reporting*. The TM1D3 is available online at http://pubs.usgs.gov/tm/2006/tm1D3/. Project procedures for calibration and care of the multiprobe and its sensors are also based on vendor-provided specifications. All personnel that work on the project must review this QA plan and TM1D3.



Explanation

- Water quality and meteorological monitoring platform
- Water quality monitoring platform

Figure 1. Locations of monitoring platforms.

This QA plan presents procedures for operating the profiling equipment and servicing the water quality sensors. Section 2.0 discusses the monitoring equipment at each platform. Section 3.0 lists the standard operating procedures (SOP's) that will be followed during each service visit in an abbreviated format and in a detailed format. Section 4.0 describes additional SOP's that will be completed once each quarter. Section 5.0 describes the procedures for computing the water quality record collected at the platforms. Finally, section 6.0 contains copies of the field forms that will be filled out during site visits.

2.0 Monitoring Equipment

Water Quality Monitoring Equipment

Each platform is equipped with an YSI[*] profiling system consisting of the following hardware (fig. 2):

- YSI* variable profiler winch assembly;
- YSI 6600* multiparameter water quality probe;
- Campbell Scientific CR10X* data logger/sensor control module;
- 12 volt, 95 amp hour battery;
- Wavecom GSM* cellular modem package (except at Virgin Basin); and a
- 30 watt solar panel for charging the battery.

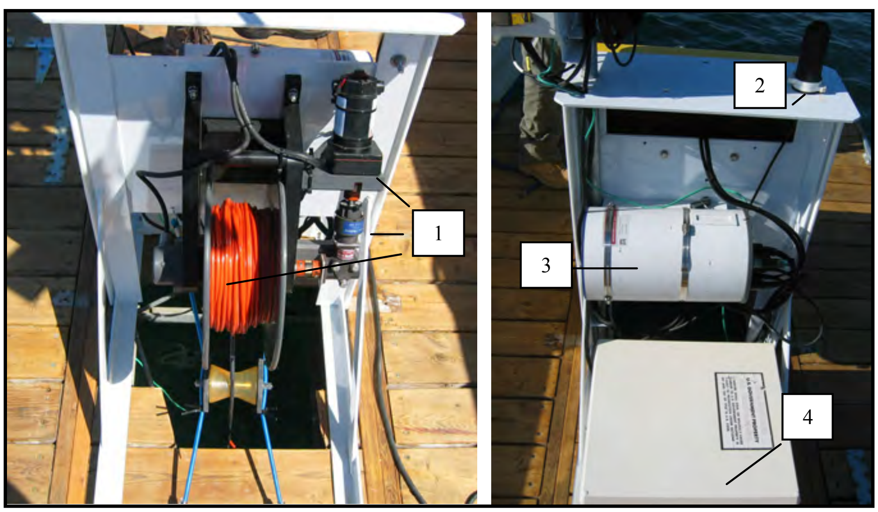


Figure 2. Profiling system components.

(1, variable profiler winch assembly; 2, modem antenna; 3, water tight housing for CR10X and wavecom modem; and 4, water tight housing for 12 volt, 95 amp hour battery)

[*] Use of product or trade names does not constitute an endorsement.

The YSI 6600 is equipped with the following sensors:

- depth,
- temperature,
- conductivity,
- pH,
- dissolved oxygen,
- turbidity, and
- fluorescence.

The YSI 6600 user's manual provides information regarding communication and power options, sensor principles of operation, maintenance, and calibration. This QA plan was written with the assumption that USGS personnel working on the project are familiar with the contents of the YSI 6600 user's manual.

The variable profiler winch assembly transports the multiprobe to programmed depths. The CR10X is the microprocessor that controls the winch assembly, operates the multiprobe, stores the data collected by the multiprobe, and controls the modem that transmits the data to the base station in the USGS Henderson, Nevada, field office. In this QA plan, the equipment package, including the multiprobe, will be referred to as a profiling system.

Meteorological Monitoring Equipment

Four of the five monitoring stations (fig. 1) also are equipped with the following meteorological instruments (The Las Vegas Bay water quality platform is not equipped with meteorological instruments):

- RM Young 05106-5* wind speed and direction anemometer,
- Li-COR LI200X Pyranometer* (solar radiation sensor),
- Vaisala PTB101B* barometer, and
- Vaisala HMP45C-L* air temperature/relative humidity sensor.

The meteorological instruments are controlled by the same CR10X that controls the profiling system. Meteorological data stored by the CR10X are hourly averages of readings taken every 60 seconds. This QA plan does not address the meteorological data collection at the platforms.

3.0 Standard Operating Procedures for Service Visits

The SOP's that will be followed during each service visit are summarized below. Detailed information regarding each step is given at the end of the list. Note that used calibration solutions and rinse water will be poured into a waste container and not into the lake.

1) Inspect the platform for damage or items in need of repair. Record observations on the site visit sheet (attachment 1.)
2) Record the in situ parking depth pre-cleaned sensor readings on the site visit sheet (attachment 1.)
3) Bring the multiprobe to the surface.
4) Inspect the multiprobe and cable connection.
5) Clean the sensors.
6) Deploy the multiprobe in situ to the parking depth. Record the post-cleaned sensor readings on the site visit sheet (attachment 1.)
7) Check the calibration of the Dissolved Oxygen (DO) sensor using the water-saturated air method. Calibrate the sensor if it exceeds the calibration criteria. Record the data on the multiprobe calibration/check sheet (attachment 2.)

8) Check the calibration of the other sensors (See Section 3.0, Step 8.) Calibrate the sensors if they exceed the calibration criteria. Record the data on the multiprobe calibration/check sheet (attachment 2.)
9) Collect and filter a 15-foot integrated sample of lake water for laboratory chlorophyll analysis. Measure the percent fluorescence of the sample. Record the data on the multiprobe calibration/check sheet (attachment 2.) Place the filter in a Petri dish and wrap with aluminum foil. Store the sample on ice.
10) Reconnect the multiprobe to the profiling system and deploy to parking depth and record post-calibrated readings.

For this project, lake conditions at parking depth have shown to be stable during service visits. An independent check of environmental conditions using a field sonde is not performed during service visits. Profile comparisons are performed using a field sonde on a quarterly basis (see Section 4.0.)

Step 1: Platform Inspection

Upon arrival at the site, a basic inspection of the platform shall be completed. The condition of the solar panel, anchor chain attachment points, platform surface, and weather box shall be noted on a site visit sheet (attachment 1.) If there are items that need repair and cannot be repaired during the service visit, they need to be brought to the attention of the project chief as soon as possible. Equipment on the platform that is not maintained could be dangerous and may damage the profiling system.

Step 2: Pre-Cleaned Sensor Readings

The data collected during this step are used to determine the amount of sensor fouling. Fouling is the difference between the pre-cleaned sensor readings in an environmental sample and the cleaned sensor readings in the same environmental sample.

Connect the laptop to the profiling system. Establish communications with the multiprobe using Loggernet*. Make sure the multiprobe is at the parking depth. Check that the sensor readings are stabilized according to the criteria in table 1 by resetting the SDI and RS232 functions of the Loggernet software. Record three sets of values from each sensor on the site visit sheet once the sensor readings are stable. Before each set of data are recorded, a reset of the SDI is required. These data are the pre-cleaned sensor readings.

Table 1. Stabilization criteria for recording field measurements.

Sensor	**Stabilization criteria for measurements (variability should be within the value shown)**
Temperature	±0.2 º C
Specific Conductivity: when ≤ 100 µS/cm when > 100 µS/cm	 ± 5 percent ± 3 percent
pH	± 0.1 unit
Dissolved Oxygen	± 0.3 mg/L
Turbidity	± 10 percent
Fluorescence	± 1 percent

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Step 3: Bring the Profiler to the Surface

After the pre-cleaned readings are obtained, bring the multiprobe to within ~1 meter of the surface using the Loggernet software (or the magnetic switch on top of the water tight container of the CR10X and modem.)

Step 4: Multiprobe and Communication Cable Inspection

Visually inspect the cable connection on top of the multiprobe for signs of corrosion; i.e., green precipitates around the connections. If green corrosion precipitates are present on the cable connection, the cable must be disconnected and the connection cleaned. Clean the cable connection by spraying the conductors with a contact cleaner and gently swabbing the conductor surfaces with a q-tip. Dry the conductors with canned air.

Remove and visually inspect the o-ring inside the cable connection on top of the multiprobe. Replace the o-ring if any damage is seen or suspected. Apply a thin coat of silicone grease to the o-ring before returning it to the multiprobe cable connection.

Step 5: Cleaning the Sensors

Remove the sensor guard and carefully clean the sensor bodies with a soft bristle tooth brush and a mild detergent, such as a dilute (1 percent by volume) liquinox solution. Use the small brush provided by YSI to clean the electrodes of the conductivity sensor. Use a q-tip saturated with the liquinox solution to clean the surface of the dissolved oxygen sensor. Use a q-tip saturated with isopropyl alcohol to clean the surface of the glass bulb on the pH electrode and the lenses of the turbidity and chlorophyll sensors. Inspect the wipers on the dissolved oxygen, turbidity and chlorophyll sensors and replace as needed.

Inspect the pressure sensor opening, which is a small hole on the side of the multiprobe, just above the sensors. Clean out the pressure sensor cavity with canned air. Use a larger brush to clean the sides and top of the multiprobe body, as well as the sensor guard. Rinse the entire multiprobe with lake water after replacing the sensor guard.

Step 6: Post-Cleaned Sensor Readings

The environmental readings after the sensors have been cleaned can now be obtained. Establish communication with the multiprobe using the YSI 650* hand-held device. Deploy the multiprobe to the parking depth into the lake. Allow time for the sensors to thermally equilibrate (this can take up to 10 minutes.) Check that the sensor readings are stabilized according to the criteria in table 1. After the readings have stabilized, record three sets of readings on the site visit sheet. Between each reading, clean the sensors using the cleaning function of the YSI 650*. The multiprobe is now ready for calibration checks after being retrieved from the parking depth.

Step 7: Dissolved Oxygen Calibration Check

The DO sensor is an YSI 6150* optical luminescence-based sensor. The following is an excerpt from the YSI Principles of Operation section for the 6150 Optical DO sensor describing how the sensor operates. *"In general, optical dissolved oxygen sensors from a variety of manufacturers are based on the well-documented principle that dissolved oxygen quenches both the intensity and the lifetime of the luminescence associated with carefully-chosen chemical dyes. The 6150 sensor operates by shining a blue light of the proper wavelength on this luminescent dye which is immobilized in a matrix and formed*

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into a disk about 0.5 inches in diameter. This dye-containing disk will be evident on inspection of the sensor face. The blue light causes the immobilized dye to luminesce and the lifetime of this dye luminescence is measured via a photodiode in the probe. To increase the accuracy and stability of the technique, the dye is also irradiated with red light during part of the measurement cycle to act as a reference in the determination of the luminescence lifetime. When there is no oxygen present, the lifetime of the signal is maximal; as oxygen is introduced to the membrane surface of the sensor, the lifetime becomes shorter. Thus, the lifetime of the luminescence is <u>*inversely proportional*</u> *to the amount of oxygen present and the relationship between the oxygen pressure outside the sensor and the lifetime can be quantified by the Stern-Volmer equation. For most lifetime-based optical DO sensors (including the YSI 6150), this Stern-Volmer relationship (((Tzero/T) – 1)) versus* O_2 *pressure) is not strictly linear (particularly at higher oxygen pressures) and the data must be processed using analysis by polynomial non-linear regression rather than the simple linear regression used for most polarographic oxygen sensors. Fortunately, the non-linearity does not change significantly with time so that, as long as each sensor is characterized with regard to its response to changing oxygen pressure, the curvature in the relationship does not affect the ability of the sensor to accurately measure oxygen for an extended period of time."* The sensor has a range of 0 to 50 mg/L and an accuracy of ± 1 percent of the reading (about 0.1 mg/L) in the 0 to 20 mg/L range and ± 15 percent in the 20 to 50 mg/L range (table 2.)

Table 2. Dissolved oxygen sensor specifications for the YSI 6600 multiprobe.

Sensor Type	Optical Luminescence-Based Sensor, with mechanical cleaning
Range	0 to 50 mg/L
Accuracy	0 to 20 mg/L; ± 1 percent of the reading or ± 0.1 mg/L, whichever is greater. 20 to 50 mg/L; ± 15 percent of the reading.
Resolution	0.01 mg/L
Depth	61 meters
Project calibration criteria	± 0.3 mg/L

Check the calibration of the DO sensor in water-saturated air. Replace the sensor guard with the calibration cup. Add about 50 milliliters (ml) of deionized water and/or lake water to the calibration cup. With the multiprobe (and sensors) pointing down, install the calibration cup on the multiprobe by engaging only two or three threads so that the air inside the calibration cup is connected to the atmosphere (it is important that the air inside the calibration cup is connected to the atmosphere so that atmospheric pressure is maintained inside the cup.) Place the multiprobe, with the sensors pointing down, into the lake water (if conditions prevent this, place in a bucket of lake water.) The water should not be above the top of the calibration cup where it is threaded onto the multiprobe. Allow the sensors, air, and water inside the calibration cup adequate time to thermally equilibrate with the water. This can take up 10 minutes. Do not rush this process.

Once the DO readings stabilize, record the time, DO in mg/L, temperature, barometric pressure, and DO % Saturation, on the field multiprobe calibration/check sheet. In the space provided on the multiprobe calibration/check sheet, record the theoretical DO concentration at the temperature and pressure inside the calibration cup (the pressure in the cup should be at atmospheric pressure.) The difference between the theoretical value and the DO sensor reading in mg/L is due to electronic drift. Calibrate the sensor if it exceeds the calibration criteria (table 2).

This calibration method depends on accurate absolute barometric pressure values in millimeters of mercury (mmHg), and relatively steady temperature values. Refer to the YSI 6600 user's manual for more instruction on how to complete the calibration.

A salinity correction is not required for DO data collected at Lake Mead. In general, waters with specific conductance values less than 8,000 µS/cm have salinity correction factors that are less than the accuracy of the DO sensor.

Step 8: Calibration Check and Calibration

Electronic drift is the difference between the cleaned sensor reading in a standard and the standard value. Drift is determined for each sensor via a calibration check after the sensors have been cleaned and rinsed. A sensor must be calibrated (or replaced, if it is the temperature sensor) if its output value in a standard exceeds the calibration criteria shown in table 3. The calibration criteria for temperature, specific conductance, dissolved oxygen, pH, and turbidity are from TM1D3. The calibration criteria for fluorescence and depth are specific to this project.

Table 3. Calibration criteria for continuous water quality monitors.

Temperature	± 0.2 ºC
Specific conductance	The greater of ± 5 µS/cm or ± 3 percent of the measured value
Dissolved oxygen	± 0.3 mg/L
pH	± 0.2 pH unit
Turbidity	The greater of ± 0.5 FNU or ± 5 percent of the measured value
Fluorescence	± 0.5 percent fluorescence in deionized water
Depth	± 0.3 m

The procedures for checking the calibration of each sensor are given below.

Depth

The YSI 6600 multiprobe is equipped with a non-vented, deep-level pressure sensor. The operational range of the sensor is 0 to 200 meters (m) with accuracy of ± 0.3 m throughout the range of the sensor (table 4.)

Table 4. Pressure sensor specifications for YSI 6600 multiprobe.

Sensor Type	Stainless steel strain gage
Range	0 – 200 meters
Accuracy	± 0.3 meters
Resolution	0.001 meters
Project calibration criteria	Mean value of ± 0.3 meters

Pressure sensors usually require little maintenance and are generally accurate. The following procedure should be adequate to check and maintain the calibration of the sensor. The multiprobe will be attached to a 30 m communication cable that is marked in a manner that 0 m is at the opening for the depth sensor on the multiprobe. Using the depth marks on the communications cable, the multiprobe will be lowered to 1, 3, and 5 m below the lake's surface at shallow sites and 5, 15, and 25m at deep sites. The sensor readings at each depth will be recorded on the multiprobe calibration/check sheet (attachment 2.) The multiprobe has a weight affixed that ensures that the cable is vertical during the calibration check. If any of the sensor readings exceed ± 0.3 m of the specified depth, the sensor must be calibrated. Calibration of the depth sensor is at the known 1 meter depth using the absolute pressure calibration routine. After the sensor is calibrated, repeat the calibration check.

Temperature

The temperature sensor on the YSI 6600 utilizes a thermistor of sintered metallic oxide that changes predictably in resistance with temperature variation. The range of the sensor is -5 to 45 ºC and is accurate to within ± 0.15 ºC (table 5.)

Table 5. Temperature sensor specifications for YSI 6600 multiprobe.

Sensor Type	Thermistor
Range	-5 to 45 ºC
Accuracy	± 0.15 ºC
Resolution	0.01 ºC
Depth	200 meters
Project replacement criteria	± 0.2 ºC of calibrated field thermometer value

Temperature is a fundamental property of any medium. The output values of the DO, specific conductance, and pH sensors depend on a properly functioning temperature sensor. Semiannual five-point calibrations are conducted in the lab. Insitu field sensors will be rotated out with lab-calibrated sensors until project inventory have all been checked. The calibration is checked over the temperature range of 0 to 40 °C in a temperature-controlled water bath with circulation (using an insulated bucket.) Place both the temperature sensor and a NIST-traceable thermometer in the water bath. Record each of the temperature points to the nearest tenth of a degree for both the temperature sensor and the NIST-traceable thermometer after respective stabilization on the temperature using the temperature calibration/check sheet (attachment 3.) The temperature sensor readings must be within ± 0.2 ºC of the thermometer. If the sensor fails the calibration check, it must be replaced (temperature sensors cannot be calibrated.)

Specific Conductance

The YSI 6600 utilizes a cell with four pure nickel electrodes for the measurement of solution conductance. Two of the electrodes are current driven and two are used to measure the voltage drop. The measured voltage drop is then converted into a conductance value in milli-Siemens (mS), which is equivalent to millimhos. This value is multiplied by the cell constant, which is approximately 5.0 cm^{-1} for the YSI 6600; to give conductance in mS/cm. Conductivity values are highly dependent on temperature, varying as much as 3 percent per 1 ºC. For this reason, the multiprobes used for this project are set to record specific conductance, which uses the raw conductance value and the temperature at the time of measurement to produce a specific conductance value compensated to 25 ºC (note that the values for specific conductance are only as good as the temperature sensor values.)

The range of the sensor is 0 to 100,000 µS/cm (note that multiprobes for this project are set to report µS/cm) and is accurate to within ± 0.5 percent + 1 µS/cm (table 6.) The calibration criteria for the sensor are the greater of ± 5 µS/cm or ± 3 percent of the measured value. For example, for a standard of 100 µS/cm, the criteria is plus or minus 5 µS/cm because this value is greater than 3 percent of the measured value; i.e., 3 µS/cm. In a standard of 1000 µS/cm, the calibration criteria is ± 3 percent of the measured value; i.e., 30 µS/cm, because this value is greater than 5 µS/cm.

Table 6. Conductivity sensor specifications for YSI 6600 multiprobe.

Sensor type	4 electrode cell with auto ranging
Range	0 to 100,000 µS/cm
Accuracy	± 0.5% of reading + 1 µS/cm
Project Calibration criteria	The greater of ± 5 µS/cm or ± 3 percent of the measured value

The calibration of the conductivity sensor will be checked with three standards with the following values; 750, 1800, and 2500 µS/cm.

If the calibration criteria are exceeded in any standard (table 6) the sensor must be calibrated. The multiprobes conductivity sensor accepts only a one-point calibration. The standard used for the one point calibration is dependant on the measured conductivity. After the sensor is calibrated to that standard, the calibration should be checked with at least 2 other standards. The calibration data will be entered in to the multiprobe calibration/check sheet.

pH

The YSI 6600 uses a field replaceable pH electrode for determination of hydrogen ion activity, which is reported in pH units. The probe is a combination electrode consisting of a proton selective glass reservoir filled with buffer at pH 7 and an Ag/AgCl reference electrode immersed in a gel electrolyte solution. Protons on both sides of the glass (media and buffer solution) selectively interact with the glass, setting up a potential gradient across the glass membrane. Since the hydrogen ion concentration in the internal buffer solution is invariant, this potential difference, determined relative to the Ag/AgCl reference electrode, is proportional to the pH of the media. The pH sensor is accurate to ± 0.2 pH units and has a range of 0 to 14 pH units (table 7.)

Table 7. pH sensor specifications for the YSI 6600 multiprobe.

Sensor Type	Glass combination electrode
Range	0 to 14 units
Accuracy	± 0.2 units
Resolution	0.01 units
Depth	200 meters
Project calibration criteria	± 0.2 unit

The calibration of the pH sensor is checked with 7 and 10 standard solutions. If the sensor readings in one or both standards exceed the calibration criteria (table 7), the sensor must be calibrated. A two-point calibration is necessary. Use standards that bracket the values expected in the profile; i.e., pH 7 and pH 10 standards.

The millivolt response of the sensor needs to be recorded in addition to the pH value. This will help identify pH sensors that are near the end of their operational lifetime. The pH calibration data will be entered into the multiprobe calibration/check sheet.

Turbidity

Turbidity is a measure of the “cloudiness” of a water sample. The turbidity sensor equipped with the YSI 6600 emits light near the infrared region of the spectrum (830-890 nm) with a light emitting diode (LED.) The amount of this light scattered by particles in the water sample at an angle normal to the light source is detected by a high sensitivity photodiode. The output values of the turbidity sensor are in formazin nephelometric turbidity units (FNUs.) The output value is dependent on the type of sensor deployed [USGS National Field Manual, Chapter A6.7, Turbidity (9/2005) - Table 6.7-4]. The range of the turbidity sensor is 0-1,000 FNUs (table 8.)

Table 8. Turbidity sensor specifications for the YSI 6600 multiprobe.

Sensor type	Optical, 90º scatter, with mechanical cleaning
Range	0 to 1,000 FNU
Accuracy	The greater of ± 2 FNU or ± 5 percent of the measured value
Resolution	0.1 FNU
Depth	200 meters
Project calibration criteria	The greater of ± 0.5 FNU or ± 5 percent of the measured value

The calibration of the turbidity sensor is checked with 0, 20, and 100 FNU secondary standards. The 20 and 100 FNU secondary standards are dilutions of a 4,000 FNU stock formazine solution. The zero standard is filtered, deionized water. The concentration of the secondary field standards are determined in the lab prior to use with a Hach 2100P Turbidimeter that is calibrated as necessary. The range of the sensor is 0-1000 FNU; within its range, the Hach 2100P Turbidimeter is accurate within 2% with a resolution of 0.01 FNU.

Check the calibration of the turbidity sensor in standard using the DO water-saturated air methodology. Replace the sensor guard with the calibration cup. Add about 550 milliliters (ml) of standard to the calibration cup. With the multiprobe (and sensors) pointing down, install the calibration cup on the multiprobe by engaging only two or three threads so that the air inside the calibration cup is connected to the atmosphere. Place the multiprobe, with the sensors pointing down, into the lake water (if conditions prevent this, place in a bucket of lake water.) The water should not be above the top of the calibration cup where it is threaded onto the multiprobe.

If the calibration criterion is exceeded with any one standard (table 8) the sensor must be calibrated. A three point calibration is used. The calibration of the turbidity sensor is performed using the 0, 20, and 100 FNU secondary standards. Refer to the YSI 6600 user's manual for more information regarding turbidity sensor calibration. The calibration check and, if necessary, the calibration data will be recorded on the multiprobe calibration/check sheet.

Fluorescence

The operating principal of the sensor utilizes the fact that chlorophyll will fluoresce when it is irradiated with ultraviolet (uv) light. The sensor emits uv energy with a peak wavelength of approximately 470 nanometers (nm.) In response, chlorophyll present in the irradiated water sample emits light in the 650-700 nm range of the energy spectrum. A photo detector in the sensor measures the intensity of this light. The sensor is equipped with an optical filter that prevents energy outside the 650-700 nm range from reaching the photo detector. In general, the intensity of the light emitted by chlorophyll in the sample is proportional to the amount of chlorophyll in the sample; however, the in situ method of measuring chlorophyll is subject to numerous errors. YSI explains these sources of error, which are summarized below.

- Differing species of algae with differing shape and size will likely fluoresce differently even if the type and concentration of chlorophyll are identical (this significantly limits the accuracy of in situ measurements.)

- Phytoplankton fluorescence increases as temperature decreases and each species of phytoplankton is likely to have slightly different temperature dependence.

- Empirical data indicate that, at constant phytoplankton level, the fluorescent signal can change significantly on a diurnal schedule, showing less fluorescence when oxygen is being produced and more fluorescence during the resting phase of the organisms. This effect would produce errors in the absolute values of chlorophyll.

- While it is probable that most of the fluorescence is due to suspended plant and algal matter and that much of the fluorescence from this biomass is due to chlorophyll, it is impossible to exclude interferences from other fluorescent species using this approach.

YSI does not provide accuracy specifications for the fluorescence sensor (table 9.) This is due in part to sources of error listed above and because universal chlorophyll calibration standards do not exist. Because of this, the project calibration criteria for the turbidity sensor are used for the fluorescence sensor. At this time, only a zero calibration check is performed for fluorescence. The zero calibration check is performed at the same time as the turbidity zero calibration check using filtered, deionized water. The data will be recorded on the multiprobe calibration/check sheet.

Table 9. Fluorescence sensor specifications for the YSI 6600 multiprobe.

Sensor type	Optical, fluorescence, with mechanical cleaning
Range	0 to 400 µg/L; 0-100 percent full scale fluorescence units
Accuracy	No specifications provided
Resolution	0.1 µg/L; 0.1 % FS
Depth	200 meters
Project calibration criteria	± 0.5 percent fluorescence in deionized water

Due to the numerous sources of variability, it is not scientifically defendable to report chlorophyll concentrations using the default relationship between fluorescence and chlorophyll programmed in the multiprobe. A practical alternative to reporting chlorophyll in µg/L is to take advantage of the ability of the sensor to output %FS. In this mode, the sensor will report only relative values of fluorescence in the sample being measured. %FS can then be converted to chlorophyll concentration using a post calibration procedure.

This procedure requires that a 15-foot integrated sample is collected from the lake at each site during service visits. A 500-1,000 milliliter aliquot will be filtered. The filter will be sent to the USGS National Water Quality Laboratory (NWQL) in Lakewood, Colorado, and analyzed for chlorophyll-a and Pheophytin A, phytoplankton (NWQL lab code 3152.) The %FS of an unfiltered aliquot from the 15-foot integrated sample will be measured by the fluorescence sensor on the dedicated multiprobe. A relationship between chlorophyll-a and %FS may be quantified by plotting the lab measured values for chlorophyll and the field measurements of %FS in the water filtered for the lab samples.

Step 9: Collect/Read Chlorophyll Sample

Field procedures for collecting the chlorophyll sample and reading the sample with the multiprobe are given below. The data from this procedure will be recorded on the multiprobe calibration/check sheet.

Collecting the Sample

1) Collect a 15-foot integrated water sample from the lake,

2) Fill a 500 ml volumetric flask with water from the sample,

3) Filter the contents of the flask through a 47 mm glass fiber filter,

4) Add deionized water to the flask, agitate, and filter to ensure the entire sample collected in the volumetric flask is represented on the filter.

5) Place the filter in a Petri dish, cap, wrap in aluminum foil, and store on ice.

Reading the Sample

1) Rinse the multiprobe sensors and calibration cup three times with water from the sample, and

2) Measure the %FS of water from the sample with the multiprobe using the DO water-saturated air methodology.

3) Check the temperature sensor (refer to Temperature section in Step 8.)

Step 10: Reconnecting/Deploying the Multiprobe

The final step during the service visit is to deploy the multiprobe. Power down the YSI 650 hand-held device and disconnect the multiprobe from the communications cable. Connect the multiprobe to the winch cable, then power down the platform battery by disconnecting the inline fuse. Connect the lap top communications cable to the CR10X. Power up the lap top computer and start the Loggernet program. Reconnect the power cable to the CR10X/modem housing. Within the Loggernet program, connect to the CR10X and verify that the multiprobe is communicating to the CR10X. The multiprobe should now be in service mode and needs to be reinitialized. Once initialized, the multiprobe should be placed at its parking depth and taken out of service mode. Disconnect from the CR10X from within the Loggernet program. Close Loggernet, power down the lap top, and disconnect the lap top communications cable from the CR10X/modem housing.

4.0 Additional Standard Operating Procedure

The SOP's established in section 3.0 will ensure that high quality data are collected at each water quality platform; however, an additional QA procedures will be implemented that will verify the overall quality of the water quality data collected during a profile.

Profile Comparisons

Once each quarter, simultaneous profiles will be completed at each platform with two multiprobes. One of the multiprobes will be the YSI 6600 dedicated to the platform of interest, and the second multiprobe will be any carefully serviced and calibrated unit capable of measuring temperature, depth, specific conductance, pH, dissolved oxygen, turbidity, and %FS. The actual depth of the profilers in the water column shall be determined from the communications cables, which should be marked at identical depth intervals, attached to the multiprobes. The purpose of this QA procedure is to verify water quality trends in the profile, such as the depth of the epilimnion, metalimnion, and hypolimnion. Data collected during the simultaneous profiles will be recorded on the quarterly profile comparison field sheet (attachment 4.) The data collected during this QA procedure will not be used to compute the water quality record at the platforms.

5.0 Records Computation

Water quality data files logged by the profiling system at each site are transmitted daily to a base station computer at the Henderson field office. These data are checked for viruses and run through several scripts that perform various data file formatting operations. The data are then entered into the USGS NWIS (National Water Information System) database via Automated Data-Processing System (ADAPS) and posted on the project website, which can be accessed at the http://nevada.usgs.gov/lmqw/index.htm website. Data processing and preparation of the data review package are the two components of records computation.

Data Processing

Data processing consists of 1) initial data evaluation, 2) application of corrections and shifts, and 3) final data evaluation.

Initial Data Evaluation

Initial data evaluation will be completed daily by project personnel. The daily data transmissions from the sites will be checked for completeness and for obvious inaccuracies, such as spikes in the chlorophyll data that may result from a malfunctioning wiper on the sensor. Up-to-date plots of the raw data will be maintained and used to help identify spurious data and event related changes in the water quality data. An event related change in water quality in Las Vegas Bay could result from a high flow event in Las Vegas Wash. Every attempt should be made to identify causes for changes in water quality data collected at the platforms.

Application of Corrections and Shifts

The fouling and drift corrections will be applied to the data within one week of the service visit by project personnel. Criteria for water quality data corrections and shifts are similar to the calibration criteria. All data corrections and shifts will be applied even when the fouling and/or drift checks show the sensor readings do not exceed the criteria shown in table 10.

Table 10. Criteria for water quality data corrections and shifts.

Temperature	> ± 0.2 ºC
Specific conductance	The greater of ± 5 µS/cm or ± 3 percent of the measured value
Dissolved oxygen	> ± 0.3 mg/L
pH	> ± 0.2 pH unit
Turbidity	The greater of ± 0.5 FNU or ± 5 percent of the measured value
Fluorescence	± 0.5 percent fluorescence in zero fluorescence solution
Depth	> ± 0.3 m

Fouling Corrections

As stated in section 3.0, fouling is the difference between the sensor measurements in the same environmental sample before and after the sensors are cleaned. Fouling corrections are applicable to specific conductance, DO, pH, turbidity, and %FS data. Fouling corrections in ADAPS are prorated over time between service visits. This typically assumes that the source of fouling; i.e., algae growth on a sensor or poisoning of a sensor anode, occurs at a steady rate between sensor inspections. Two-point variable corrections based on percent are used with DO and specific conductance. Turbidity, pH, and %FS are corrected using a one-point variable correction. Occasionally, an unexpected change in field values may signal the onset of fouling related to a specific event and punctuated by other changes like a sudden fluctuation in temperature. Please refer to TM1D3 for more information regarding the application of fouling corrections.

Drift Corrections

Electronic drift is the difference between the cleaned sensor reading in a calibration standard and the calibration standard value (see section 3.0.) Drift is assumed to occur at a constant rate between service intervals; therefore, a drift correction is typically applied as a linear interpolation over the time between calibrations. Drift corrections are applicable to specific conductance, DO, pH, depth, and turbidity data. Drift corrections are generally not applied to %FS data because universal standards for this parameter do not exist.

In ADAPS, drift corrections are usually applied as two-point variable shifts. Three point variable shifts are the preferred method for application of non-linear drift corrections because this method accounts for varying sensor response to calibration standards of different values.

Four kinds of variable shifts may be used for drift corrections: one-point variable, two point variable based on percent, two-point variable not based on percent, and three-point variable "V-shift" if drift is non-linear. One-point variable shifts are sometimes used with fluorescence due to the small range of recorded values. A percentage shift is used when the response of a sensor in the calibration standards of differing values is linear, where linearity is defined as a best fit line to the sensor and calibration standard data with an R^2 value of 0.90 or greater. Two point variable corrections based on percent are used for turbidity, DO, and specific conductivity. Two-point variable shifts not based on percent are used for pH. A three point variable V-shift is used when the sensor response of a given sensor to multiple calibration standards is not linear; this type of correction is rarely required. Each point in a V-shift is simply the difference between the sensor reading and calibration standard value. Please refer to TM1D3 for more information regarding the application of drift corrections.

Maximum Allowable Limits for Applying Data Corrections and Variable Shifts

Data corrections and variable shifts are excellent tools for managing data that are logged on a continuous or near continuous basis; however, there is a point when sensors are so badly fouled or out of calibration that application of a correction and/or shift to the data logged since the last service interval does not improve the record. Maximum allowable limits (MAL) are often established to define when data are too poor to correct or publish. This project will use the MAL published in TM1D3 and a project specific limit for fluorescence and depth (table 11.) The MAL for turbidity is used for fluorescence.

Table 11. Maximum allowable limits for applying corrections and publishing water quality data.

Temperature	± 2.0 ºC
Specific conductance	± 30 percent
Dissolved oxygen	The greater of 2.0 mg/l or 20 percent
pH	± 2 pH units
Turbidity	The greater of ± 3 FNU or 30 percent
Fluorescence	The greater of ± 3 units or 30 percent
Depth	± 1.0 m

If the sum of the absolute value of the fouling check and calibration check exceed the MAL shown in table 11, corrections will be applied as usual unless determined to be erroneous based on professional discretion. If the correction is accepted and used, data will be flagged in ADAPS as erroneous from when the correction values exceed MAL until the next service visit. If the correction is declined based on bad data, the record logged since the last service visit will be carefully examined to determine when the sensor(s) of interest failed. Data collected after the sensor failed will be flagged as erroneous in ADAPS. Remaining data will be rated based on the correction applied to the unit values using the criteria found in table 12.

Final Data Evaluation

Final data evaluation consists of reviewing the data record, checking shifts, and making any needed final corrections. When completed, the data are verified for publication by ensuring they fall within MAL (table 11) and then rated for quality. The accuracy rating is based on the sum of the absolute value of the results of the fouling and calibration check. Temperature, specific conductance, DO, pH, and turbidity data are rated as excellent, good, fair, or poor according to the criteria given in TM1D3, which are shown in table 12. The accuracy rating is based on data values recorded before any shifts or corrections are applied.

Table 12. Criteria for rating near continuous water quality data.

Measured physical property	**Excellent**	**Good**	**Fair**	**Poor**
Temperature (ºC)	≤±0.2	>±0.2 to 0.5	>±0.5 to 0.8	>±0.8
Specific conductance (%)	≤±3	>±3 to 10	>±10 to 15	>±15
DO	The greater of ≤±0.3 mg/L or ≤±5%	The greater of >±0.3 to 0.5 mg/L or >±5 to 10%	The greater of >±0.5 to 0.8 mg/L or >±10 to 15%	The greater of >±0.8 mg/L or >±15%
pH (units)	≤±0.2	>±0.2 to 0.5	>±0.5 to 0.8	>±0.8
Turbidity	The greater of ≤±0.5 FNU or ≤±5%	The greater of >±0.5 to1 FNU or >±5 to 10%	The greater of >±1 to 1.5 FNU or >±10 to 15%	The greater of >±1.5 FNU or >±15%
Depth (m)	≤±0.3	>±0.3 to 0.5	>±0.5 to 0.8	>±0.8
%FS	The greater of ≤±0.5 units or ≤±5%	The greater of >±0.5 to1 units or >±5 to 10%	The greater of >±1 to 1.5 units or >±10 to 15%	The greater of >±1.5 units or >±15%

Preparation of the Review Package

Preparation of the review package will be completed annually by project personnel. The review package will contain the following items:

- Station analysis with site description
- Site visit sheets (attachment 1)
- Multiprobe calibration/check sheets (attachment 2)
- Quarterly profile comparison field sheets (attachment 4)

- Primary computations table from ADAPS
- Water quality correction tables from ADAPS
- Graphs of individual, uncorrected water quality parameters for review
- Graphs of individual, corrected water quality parameters for review
- End of year summary table from ADAPS
- Station analysis from ADAPS

To efficiently manage the large amount of data collected at the water quality platforms, project personnel will update the review package within one week of each service visit. The review package will be checked and reviewed on a monthly basis. The review package will be finalized at the end of the water year by project personnel. The final review package will be checked and reviewed by a qualified water quality technician and the district water quality specialist, respectively.

6.0 Attachments

Attachment 1- Site Visit Sheet

(see next page)

Site Visit Sheet
Lake Mead Water Quality Platforms

Site:_______________ Date:_________________(JD: ____________)

Arrival time:_________ Departure time:_________

Participants:____

Weather:______________________________ Air Temp: ________________________

Water (clear, turbid, calm, etc):____

Condition of sensors prior to service:____

Condition of profiling system:____

Condition of platform:____

Total depth:________________ (circle one: tape measure or depth finder)

Additional Remarks (use back of sheet if necessary):_____________________________
____
____

Fouling Check **Multiprobe ID_______**

Pre-Cleaned Sensor Readings

Time (Watch)	Depth (m)	Temp (C)	pH (units)	Sp.Cond (μS/cm)	DO (mg/L)	DOsat. (%sat)	Turb (FNU)	%FS	Steady?
Median									

Post-cleaned Sensor Readings

Time (Watch)	Depth (m)	Temp (C)	pH (units)	Sp.Cond (μS/cm)	DO (mg/L)	DOsat. (%sat)	Turb (FNU)	%FS	Steady?
Median									

Attachment 2- Multiprobe Calibration/Check Sheet

(see the next 2 pages)

LAME - Multiprobe Calibration/Check Sheet Page 1 of 2

Site: _______________ Multiprobe ID: _____________________

Date: _______________ (JD: _________)

Calibration/check performed by: ___________ Are you in the Field or Lab?

Dissolved Oxygen (mg/L) Criteria: ± 0.3 mg/L

Time	Reading (mg/L)	Reading (%Sat)	Temperature	Pressure	Calibration Value	Remarks (include difference)

Percent Fluorescence (percent): Criteria: ± 0.5

Time	Reading	Standard	Remarks
		zero	
		Integrated	Volume filtered________

Turbidity (FNU) Criteria: The greater of ± 0.5 FNU or ± 5 %

Time	Reading	Standard	Standard ID	Remarks (include difference)

Remarks:____

LAME - Multiprobe Calibration/Check Sheet Page 2 of 2

Date: _______________ (JD: _________)

Specific Conductance: Criteria: The greater of ± 5 μS/cm or ± 3% of measured value.

Time	Temp	Reading	Standard	Lot #/MFG Date	Remarks (include difference)

pH (units): Criteria: ± 0.2 unit

Time	Temp	Reading (pH unit)	Reading (mV)	Standard	Lot#/ Exp	Remarks (include difference)

Temperature Criteria: ± 0.2 °C

Time	Reading	NIST Reading	Remarks

Depth Criteria: For deep transducer (0-200 m), ± 0.3 meter.

Time	Reading	Depth	Remarks

Remarks____

____

Attachment 3: Temperature Calibration/Check Sheet

(see the next page)

LAME - Temperature Calibration/Check Sheet

Date: _______________ (JD: _________)

Temperature Sensor Model #: _______________ S/N: _________________________

Multiprobe ID: ___________________________ S/N: _________________________

NIST-Traceable Thermometer Model #: ______________ S/N: ________________

NIST-Traceable Thermometer Calibration Date: _________

Calibration/check performed by: ____

NIST Thermometer Reading in Ice-Bath in °C: __________

NIST Thermometer (Criteria: ± 0.2 °C)

Time	Temperature Point (°C)	Reading	NIST Reading	Difference
	≤ 20			
	~ 25			
	~ 30			
	~ 35			
	~ 40			

Remarks:
____
____
____
____

Attachment 4: Quarterly Profile Comparison Field Sheet

(see the next page)

Quarterly Profile Comparison Field Sheet

Site Name:_______________________________ Date:___________________

Party:____

Profile Begin Time_______________________ Profile End Time_________________

Multiprobe 1 ID:____

Multiprobe 2 ID:____

Note: Both multiprobes should be serviced and calibrated prior to the simultaneous profile.

Multiprobe 1

Depth (m)	Temp (ºC)	pH	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	Turbidity (FNU)	%FS

Multiprobe 2

Depth (m)	Temp (ºC)	pH	Specific Conductance (µS/cm)	Dissolved Oxygen (mg/L)	Turbidity (FNU)	%FS