**Lake Superior (LKS)** **NERR Water Quality Metadata**

**January through December 2017**

**Latest Update:** October 1st 2018

**I. Data Set and Research Descriptors**

**1) Principal investigator(s) and contact persons –**

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SWMP Technician – Anna Hall (UMN-Duluth)

**2) Entry verification –**

Deployment data are uploaded from the YSI data logger to a Personal Computer (IBM compatible). Files are exported from EcoWatch in a comma-delimited format (.CDF) or KOR Software in an Excel File (.XLS) and uploaded to the CDMO where they undergo automated primary QAQC; automated depth/level corrections for changes in barometric pressure (cDepth or cLevel parameters); and become part of the CDMO’s online provisional database. All pre- and post-deployment data are removed from the file prior to upload. During primary QAQC, data are flagged if they are missing or out of sensor range. The edited file is then returned to the Reserve for secondary QAQC where it is opened in Microsoft Excel and processed using the CDMO’s NERRQAQC Excel macro. The macro inserts station codes, creates metadata worksheets for flagged data and summary statistics, and graphs the data for review. It allows the user to apply QAQC flags and codes to the data, remove any overlapping deployment data, append files, and export the resulting data file for upload to the CDMO. Upload after secondary QAQC results in ingestion into the database as provisional plus data, recalculation of cDepth or cLevel parameters, and finally tertiary QAQC by the CDMO and assimilation into the CDMO’s authoritative online database. Where deployment overlap occurs between files, the data produced by the newly calibrated sonde is generally accepted as being the most accurate. For more information on QAQC flags and codes, see Sections 11 and 12.

The Monitoring Coordinator, Hannah Ramage is responsible for data management.

**3) Research objectives –**

The Lake Superior NERR is situated on the freshwater estuary at the confluence of the St. Louis River and Lake Superior, the largest and most pristine of the Great Lakes. The Reserve is a diverse, 16,697-acre complex that contains a variety of representative terrestrial and aquatic habitats, allowing for extensive research and educational opportunities. The Reserve provides opportunities for research and monitoring, experiential learning, and training and will continuing to contribute to the protection of the ecological health of the St. Louis River Freshwater Estuary and Lake Superior coastal habitats.

The Lake Superior NERR implements the NERR System-Wide Monitoring Program (SWMP). This includes four continuous water quality monitoring stations with monthly nutrient and chlorophyll sampling, a meteorological (MET) station, and monthly sampling at one site consisting of 12 nutrient and chlorophyll samples collected over a 24-hour period. Additional elective parameters include total suspended solids and total dissolved solids (TSS and TDS), total dissolved phosphorus (TDP), and total dissolved nitrogen (TDN). The objective of SWMP site locations is to obtain long-term data representative of the different sections of the river and tributaries that exhibit characteristics common to the southern shore of Lake Superior. Data will be archived at the Centralized Data Management Office (CDMO) as per established protocols. In 2017, due to winter ice conditions, continuous monitoring stations with monthly nutrient and chlorophyll sampling began operation in April/May and ended in October/November.

From 2013 through summer 2016, two SWMP sites were transmitting 15-minute water quality data by telemetry via cellphone to a PC with software that transmits a report to the Lake Superior NERR website and CDMO. In the summer of 2016 the cellphone telemetry system was no longer viable. In 2017, the Barkers Islands (BA) station began transmitting 15-minute water quality data once every hour, via the GOES satellite system. The CDMO real-time data application is able to access this data and make it available on the CDMO website. The MET station also transmits 15-minute data through the GOES satellite system, which began in 2013. Researchers, natural resource managers, and the public can access this data through the CDMO website. The Lake Superior NERR Education Coordinator regularly uses this water quality and meteorological data for educational programing including the Rivers2Lake teacher mentoring program.

The Lake Superior NERR climate change effects research site (Sentinel Site) is now operational with the focus of measuring the impacts of storm events on sediment delivery, basin morphology, and the consequences to aquatic plant communities and specifically wild rice. Required SWMP components that are integrated into the Sentinel Site include; the weather station located at the center of the site, a sonde mounted beside the weather station, and monthly nutrient and chlorophyll sampling. Permanent vegetation transects (80 plots) were established through five upper Pokegama bays surrounding the weather station in 2014, and will be sampled annually. Elevations of sondes were surveyed in 2014 and sonde water depth was linked to elevation to determine water level (NADV88, vertical control). However, due to ice-jacking of the MET station platform, the water elevations for 2015 were not accurate. The platform was repaired when longer pilings (30 ft helical anchors) were set in February 2016. The welding on two legs failed again due to ice-jacking in the winter of 2017. Preparations for a new design/maintenance on the platform are ongoing. Four SETs were installed in 2012, but elevation surveys indicated they were also being ice-jacked (upward movement due to freeze-thaw). We intend to rely on elevation transects and feldspar marker horizons to determine surface deposition and movement. Elevation transects were conducted in 2014 and marker horizons were installed at four locations in 2012. We plan to use the infrastructure to link rain events to sediment deposition, sediment deposition to changes in marsh surface elevation and water depth, and the resulting changes in water depth to changes in aquatic plant populations.

The “Lake Superior Estuarium” opened September 30th 2017, which is a new interpretive and learning center focused on the St. Louis River Estuary. The SWMP program information is featured in one of the panels and SWMP data is featured in an interactive display where users can look at live data through the CDMO website.

**4) Research methods –**

All sondes deployed in 2017 were YSI datasondes. Two 6600V2s purchased in 2011 were used in March and April, however the LKS NERR has phased out their use in favor of EXO2s. Four EXO2s were purchased in 2012 and 2013, and two in 2016. Data were collected in 15-minute intervals beginning March 24. The sondes have not been painted or otherwise protected from fouling and biological growth. The Lake Superior NERR is a freshwater estuary on Lake Superior, therefore bio-fouling is minimal compared to that encountered by marine coast NERRs, and deployments currently last between three and four weeks.

All sondes were calibrated prior to deployment using the following commercial standard solutions:

pH – Ricca Buffer Solutions; 7.0 and 10.0

Turbidity – “0” in Type I reagent water and YSI Turbidity Standard (124 or 126 NTU)

Conductivity – Ricca Conductivity Standard, 1.00 mS/cm

Temperature – factory calibration

Dissolved Oxygen – air saturated water, DO% calibration to local barometric pressure as

reported by the Lake Superior MET station and uncorrected from the sea level correction

Depth – barometric pressure related to sea level by way of an offset (bp at MET station)

Sondes are housed in custom made 8” x 7.5” x 38” stainless steel enclosures open on the top. A hinged stainless steel covering encloses the structure and covers the top allowing for the housings be locked. Sondes are attached to steel cable that is connected to the housing, lowered into the housing from the top, the covering is closed and is locked in place. The BA housing is bolted to a stainless steel plate and wench system set up on a concrete dock piling. The wench is used to remove the housing over the winter months to avoid ice damage. Blatnik Bridge (BL) housing was installed on sheet pile dolphin covering a bridge cell. ¾” holes were drilled for installation of 3/8” toggle anchors and bolts to hold the housing in place. The sonde housing at Oliver Bridge (OL) is attached to a concrete bridge footing using ½” Tapcon concrete anchors and bolts. The PO housing is bolted to a 3.5” x 3.5” steel piling of the meteorological station. BA and PO sonde cable lengths are designed to follow NERR protocol and hold the sondes 0.25 to 0.5 from the bottom, thus the BA sonde is 1.5 m water depth and PO is 0.6 m water depth. In 2017, the MET station and PO sonde housing was damaged by ice. A temporary housing was installed by pounding an 8’ U-channel T-post with attached PVC pipe into the sediment under the meteorological station. The sonde fits into the perforated PVC and is attach via a cable, attached to the meteorological station platform above, which holds the sonde at the correct depth. At all stations, during sonde deployments, sondes and housings are checked to maintain the appropriate water level/depth. The BL and OL sonde housings and cables are designed to hold the sondes at ~1.5m water depth and therefore do not follow NERR protocols (see below).

Sonde deployments for BL and OL sites do not follow NERRS protocols; specifically they are not deployed between 0.25-0.50 meters from the bottom. This departure from SOP was approved by the NERRS Oversight Committee (OC) for the following reasons:

Due to the status of the St. Louis River Estuary as an Area of Concern (AOC) in the Great Lakes, there is significant interest in the water quality of the estuary and it is critical that SWMP data be both relevant in the process of Delisting of the Beneficial Use Impairments (BUIs) and for future environmental condition assessments. The overall consensus of stakeholders was that it was very important to continue sampling the Blatnik and Oliver Bridge sites due to legacy sampling that began in the 1940’s and continued sporadically up to the designation of the Lake Superior NERR.

The water depth at both the BL and OL sites is approximately 8m. Sampling near the surface allowed for the most direct comparison with the collection methods of prior samples (grab samples taken near the surface) and there was concern that sampling at 7m of depth or more would not be considered comparable. In addition, the entire estuary is frozen over from late November to early May each year and ice can cause major damage. To prevent damage to sondes, sonde housings were constructed from thick walled stainless steel and the weight of these precluded constructing and attaching 7m housings to the bridge cells (BL) or bridge footings (OL). Due to both the interest in collecting samples that were directly comparable to previous samples and the need to maintain infrastructure, including maintaining vertical control, in a very physically challenging environment the LSNERR proposed to set the depth of the sondes near the surface (approximately 1.5-2m) rather than near the bottom (7m). In order to demonstrate that the water is well mixed at the two bridge sties, LSNERR voluntarily takes sonde depth profiles from the top to the bottom of the water column monthly during the ice free season. Profile data will be included in the Other Remarks section in the annual metadata document.

One water quality data sonde, BA, transmits data using GOES telemetry systems. The CDMO accesses this data through The Hydrometerological Automated Data System (HADS) and pulls it into the NERRs real-time data application. The transmissions are scheduled hourly and contain four (4) data sets reflecting fifteen minute data sampling intervals. Upon receipt by the CDMO, the data undergoes the same automated primary QAQC process detailed in Section 2 above. The “real-time” telemetry data becomes part of the provisional dataset until undergoing secondary and tertiary QAQC and assimilation in the CDMO’s authoritative online database. Provisional and authoritative data are available at [http://cdmo.baruch.sc.edu](http://cdmo.baruch.sc.edu/).

**5) Site location and character –**

The Lake Superior NERR is located within the estuary of the St. Louis River. The St. Louis River Watershed covers approximately 3,634 square miles in northeast Minnesota and 263 square miles in northwest Wisconsin. The watershed is mostly forested, with some urban areas, especially at the estuary, and active iron mining in the upper reaches. In the upper watershed the river flows through lake clays and glacial deposits for approximately 100 miles. Near the city of Thomson, the river channel narrows and the river flows through a rocky rapid-filled gorge. Approximately 23 river miles upstream from Lake Superior is the Fond du Lac dam, the most downstream of several dams. Below the gorge and dams the river begins to take on the characteristics of a freshwater estuary. Near the mouth of the river on Lake Superior is the largest working harbor on the Great Lakes (by tonnage). A long baymouth sand bar protects the estuary form the wind and waves of Lake Superior. The natural entry through the bar is the Superior Entry to the southeast, while the Duluth Entry is an engineered entry with a lift bridge toward the northwest end.

Lake Superior does not produce a noticeable “tide” as on the ocean coasts, however, seiches, which occur when wind or atmospheric pressure causes oscillations in the water of Lake Superior, are common. For example, the USGS Sontek at the Duluth entry to the harbor has measured streamflow at between 4.0 cfs and -3.5 cfs. There tends to be a larger seiche period of about eight hours, while smaller seiches can be seen at approximately four and two hours. The change in water level as a result is usually less than a foot, however, a strong seiche can reverse the direction of the river’s flow as far upstream as Fond du Lac (approximately 12 river miles). The USGS stream gage on the St. Louis River at Scanlon (upstream of the Fond du Lac dam) recorded an annual mean discharge of 2,384 cfs for the period of record (1909 to 2017). In comparison, 2017 was a high water year, with an annual mean discharge of 3,575 cfs.

Oliver Bridge (OL)

a) -92.20166, 46.65685

b) This site is located on the downstream side of a bridge piling at Oliver, WI. The site is 11 miles upstream of Lake Superior and upstream of the majority of the estuary, receives downstream river flow below the Fond du Lac dam, but is influenced to some extent by Lake seiche.

c) salinity range 0.08 – 0.2 PPT

d) freshwater estuary site, receives flow of the St. Louis River (relatively undeveloped riparian area)

e) river approximately 8m deep, 126m wide

f) bottom habitat or type currently undocumented (suspected sand or soft sediment)

g) approximately 12 miles downstream of the Fond du Lac dam, historic paper mills above dam

h) this site is the furthest upstream site monitored in the St. Louis River Estuary by LKS, approximately 11 miles upstream from the mouth at Lake Superior, this site does experience seiche

i) the sonde is deployed at a depth of 1.5 m from the surface at this site

Blatnik Bridge site (BL)

a) -92.10027, 46.748649

b) this site is located on the downstream side of a mid-river bridge protection cell off of Rice’s Point,

and is influenced by seiche

c) salinity range 0.1 – 0.25 PPT

d) freshwater estuary site, receives flow of the St. Louis River and tributaries to the estuary (urban)

e) water depth approximately 7m, river approximately 360 meters wide

f) bottom habitat or type currently undocumented (suspect mostly sand)

g) site is located within the urban area of Superior, WI, and Duluth, MN; site is immediately

downstream of the Western Lake Superior Sanitary District WWTP discharge.

h) this site is within the lower estuary, in the industrial harbor, the site is influenced by Lake seiche

i) the sonde is deployed at a depth of 1.5 m from the surface at this site

Barkers Island site (BA)

a) -92.06352, 46.721772

b) this site is located on the northwest end of Barkers Island in the St. Louis River, upstream of the Superior entry to the estuary, and is influenced by Lake seiche

c) salinity range 0.08 to 0.2 PPT

d) freshwater estuary, receives flow from the St. Louis River and tributaries (urban)

e) water depth approximately 2 m, approximately 1207m across Superior Bay at this location, navigation channel is at least 7m deep

f) bottom habitat or type mix of sand and soft sediments

g) site is downstream of the Superior WWTP and WLSSD WWTP

h) this site is the furthest downstream site monitored by LKS NERR in the St. Louis River Estuary, also within the lower industrial harbor. The Nemadji River (433 square mile watershed, mostly forested) also enters the St. Louis River Estuary near the Superior entry

i) the sonde is deployed at a depth of 1.5 m from the surface at this site

Pokegama Bay site (PO)

a) -92.135614, 46.672360

b) this site is located in the Pokegama River, upstream of its mouth at the St. Louis River

c) salinity range 0.06 – 0.21 PPT

d) freshwater estuary, receives flow from a 20,144-acre sub-watershed of the St. Louis River

e) water depth approximately 1 to 2 m in the channel as it winds through shallower wetlands

f) bottom type is mostly red clay and silt, Pokegama Bay wetlands include large beds of wildrice

g) the Pokegama River is a tributary to the St. Louis River, entering the estuary on the Wisconsin side of Clough Island. The Pokegama River watershed measures approximately 20,144 acres, 51% of which is wetland, 37% forested, 4% developed and 6% agricultural use (the remainder is open water or bare land)

h) this site is on a red clay tributary to the St. Louis River, the mouth of which enters between the Oliver and Blatnik sites, and is affected by Lake seiche.

i) the sonde is deployed at a depth of approximately 0.6 m from the surface at this site

|  |  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- | --- |
| Station Code | SWMP Status | Station Name | Location | Active Dates | Reason Decommissioned | Notes |
| BA | P | LKSBAWQ | 46° 43' 18.38 N, 92° 03' 48.67 W | 08/09/2012 00:00 -current | NA | NA |
| BL | P | LKSBLWQ | 46° 44' 55.14 N, 92° 06' 0.97 W | 08/09/2012 00:00 -current | NA | NA |
| OL | P | LKSOLWQ | 46° 39' 24.66 N, 92° 12' 5.98 W | 07/27/2012 00:00 -current | NA | NA |
| PO | P | LKSPOWQ | 46° 40' 20.50 N, 92° 8' 8.21 W | 10/01/2013 00:00 -current | NA | NA |

**6) Data collection period –**

|  |  |  |  |  |  |
| --- | --- | --- | --- | --- | --- |
| SITE  Initial Deployment | Deploy date | Deploy time | Retrieve date | Retrieve time | Sonde Model Number (Nickname) |
| **Barkers Island (BA)** | 3/24/2017 | 14:45 | 5/03/2017 | 15:15 | 6600V2 (Sonde#3) |
| 06/15/2012 | 5/03/2017 | 15:30 | 5/30/2017 | 9:30 | EXO2 (Sonde D) |
|  | 5/30/2017 | 9:45 | 6/27/2017 | 11:30 | EXO2 (Sonde A) |
|  | 6/27/2017 | 11:45 | 7/10/2017 | 15:15 | EXO2 (Sonde B) |
|  | 7/10/2017 | 15:30 | 7/27/2017 | 9:00 | EXO2 (Sonde C) |
|  | 7/27/2017 | 9:15 | 8/22/2017 | 11:15 | EXO2 (Sonde F) |
|  | 8/22/2017 | 11:45 | 8/25/2017 | 10:15 | EXO2 (Sonde D) |
|  | 8/25/2017 | 10:45 | 9/28/2017 | 11:45 | EXO2 (Sonde F) |
|  | 9/28/2017 | 12:00 | 10/30/2017 | 13:45 | EXO2 (Sonde B) |
|  | 10/30/2017 | 14:00 | 11/09/2017 | 14:00 | EXO2 (Sonde D) |
| **Blatnik Bridge (BL)** | 4/11/2017 | 10:00 | 5/13/2017 | 9:30 | EXO2 (Sonde A) |
| 07/03/2012 | 5/13/2017 | 9:45 | 6/9/2017 | 9:45 | EXO2 (Sonde B) |
|  | 6/9/2017 | 10:00 | 7/5/2017 | 12:15 | EXO2 (Sonde F) |
|  | 7/5/2017 | 12:45 | 7/21/2017 | 09:00 | EXO2 (Sonde D) |
|  | 7/21/2017 | 9:15 | 8/8/201 | 13:15 | EXO2 (Sonde A) |
|  | 8/8/2017 | 13:30 | 9/11/2017 | 13:15 | EXO2 (Sonde B) |
|  | 9/11/2017 | 13:30 | 5/4/2018 | 10:00 | EXO2 (Sonde C) Data logged until 12/23/2017 14:45 |
| **Oliver Bridge (OL)** | 4/11/2017 | 10:30 | 5/13/2017 | 10:45 | 6600V2 (Sonde#4) |
| 07/03/2012 | 5/13/2017 | 11:00 | 5/31/2017 | 10:15 | EXO2 (Sonde C) |
|  | 5/31/2017 | 10:45 | 7/4/2017 | 9:00 | EXO2 (Sonde D) |
|  | 7/4/2017 | 9:15 | 7/17/2017 | 14:30 | EXO2 (Sonde A) |
|  | 7/17/2017 | 14:45 | 8/8/2017 | 9:30 | EXO2 (Sonde B) |
|  | 8/8/2017 | 9:45 | 9/8/2017 | 13:00 | EXO2 (Sonde C) |
|  | 9/8/2017 | 13:15 | 10/18/2017 | 10:15 | EXO2 (Sonde D) |
|  | 10/18/2017 | 10:30 | 5/4/2018 | 10:30 | EXO2 (Sonde A) Data logged until 2/11/2018 17:30 |
| **Pokegama Bay (PO)** | 5/19/2017 | 10:15 | 6/1/2017 | 10:00 | EXO2 (Sonde F) Wiper missing |
| 09/18/2013 | 6/1/2017 | 10:30 | 7/6/2017 | 9:30 | EXO2 (Sonde C) |
|  | 7/6/2047 | 9:45 | 7/25/2017 | 10:45 | EXO2 (Sonde F) |
|  | 7/25/2017 | 11:00 | 8/18/2017 | 10:30 | EXO2 (Sonde D) |
|  | 8/18/2017 | 10:45 | 9/29/2017 | 12:45 | EXO2 (Sonde A) |
|  | 9/29/2017 | 13:00 | 11/09/2017 | 12:00 | EXO2 (Sonde F) |

**7) Distribution –**

NOAA retains the right to analyze, synthesize and publish summaries of the NERRS System-wide Monitoring Program data.  The NERRS retains the right to be fully credited for having collected and processed the data.  Following academic courtesy standards, the NERR site where the data were collected should be contacted and fully acknowledged in any subsequent publications in which any part of the data are used.  The data set enclosed within this package/transmission is only as good as the quality assurance and quality control procedures outlined by the enclosed metadata reporting statement.  The user bears all responsibility for its subsequent use/misuse in any further analyses or comparisons.  The Federal government does not assume liability to the Recipient or third persons, nor will the Federal government reimburse or indemnify the Recipient for its liability due to any losses resulting in any way from the use of this data.

Requested citation format:

NOAA National Estuarine Research Reserve System (NERRS). System-wide Monitoring Program. Data accessed from the NOAA NERRS Centralized Data Management Office website: <http://www.nerrsdata.org/>; *accessed* (date).

NERR water quality data and metadata can be obtained from the Research Coordinator at the individual NERR site (please see Principal Investigators and Contact Persons), from the Data Manager at the Centralized Data Management Office (please see personnel directory under the general information link on the CDMO home page) and online at the CDMO home page [www.nerrsdata.org](http://www.nerrsdata.org).  Data are available in comma delimited format.

**8) Associated researchers and projects –**

Samples were taken monthly at these four sites (OL, PO, BL, BA) for the SWMP required nutrient and chlorophyll *a* analyses from April to June 2017 and analyzed in the in-house laboratory (established 2014). Additional under-ice sampling occurred in February 2017.

Under-ice sampling at 30 sites was carried out with researchers from UM-Duluth’s Natural Resources Research Institute (NRRI) and Large Lakes Observatory (LLO). The objective of this project is to follow algal community changes under ice, and document areas of low dissolved oxygen in winter. There are few winter sampling projects undertaken along Lake Superior. Partners who participated in sample analyses were; Lake Superior NERR, GLERL, LLO, USGS and NRRI.

The SWMP weather station and data sonde site was established in Pokegama Bay and is the central location of a developing Great Lakes climate change Sentinel Site. Permanent vegetation surveys were established in the wetlands surrounding the SWMP site, with vegetation community data collection beginning in summer 2014. Vegetation surveys were again completed at these locations in 2016. One focus of this project is wild rice, and the resulting data will be used to measure reference site conditions to compare to wild rice restoration efforts throughout the estuary.

The USGS is working on a biophysical model of the St. Louis River Estuary. The USGS will be collecting data throughout the estuary until 2018 to build this model. The Lake Superior NERR is assisting by coordinating collection of SWMP data to alternate with USGS sampling and tending additional equipment, such as a non-SWMP sonde at the Superior Entry to the estuary.

The LKS NERR Research Coordinator, assisted by the Monitoring Coordinator, plan to coordinate a monitoring network in the estuary in order to best match management needs with monitoring data. The result will be a list of prioritized needs matched with organizations best suited to meet those needs.

The St. Louis River Estuary has recently been chosen as a NOAA Blueprint Habitat Focus Area (<http://www.habitat.noaa.gov/habitatblueprint/pdf/hb_st_louis_river_factsheet.pdf>). NOAA offices will work in cooperation with local entities to meet multiple habitat objectives on a watershed scale.

**II. Physical Structure Descriptors**

**9) Sensor specifications –**

In 2017, LKS NERR deployed 6600-V2 for the first deployments at OL and BA, and EXO2s at BL and PO, then deployed EXO2s at all sites.

YSI 6600-V2-04 – Sondes #3 and 4 (mechanical wiper sensors)

YSI EXO2 – Sondes A, B, C, D, E, and F (central wiper)

YSI 6600 data sonde specifications:

Parameter: Temperature

Units: Celsius (C)

Sensor Type: Thermistor

Model#: 6560

Range: -5 to 50 C

Accuracy: +/- 0.15

Resolution: 0.01 C

Parameter: Conductivity

Units: milli-Siemens per cm (mS/cm)

Sensor Type: 4-electrode cell with autoranging

Model#: 6560

Range: 0 to 100 mS/cm

Accuracy: +/- 0.5% of reading + 0.001 mS/cm

Resolution: 0.001 mS/cm to 0.1 mS/cm (range dependent)

Parameter: Salinity

Units: parts per thousand (ppt)

Sensor Type: Calculated from conductivity and temperature

Range: 0 to 70 ppt

Accuracy: +/- 1.0% of reading or 0.1 ppt, whichever is greater

Resolution: 0.01 ppt

Parameter: Dissolved Oxygen % saturation

Units: percent air saturation (%)

Sensor Type: Optical probe w/ mechanical cleaning

Model#: 6150 ROX

Range: 0 to 500% air saturation

Accuracy: 0-200% air saturation: +/- 1% of the reading or 1% air saturation, whichever is greater 200-500% air saturation: +/- 15% or reading

Resolution: 0.1% air saturation

Parameter: Dissolved Oxygen mg/L (Calculated from % air saturation, temperature, and salinity)

Units: milligrams/Liter (mg/L)

Sensor Type: Optical probe w/ mechanical cleaning

Model#: 6150 ROX

Range: 0 to 50 mg/L

Accuracy: 0-20 mg/L: +/-0.1 mg/l or 1% of the reading, whichever is greater

20 to 50 mg/L: +/- 15% of the reading

Resolution: 0.01 mg/L

Parameter: Non-vented Level - Shallow (Depth)

Units: feet or meters (ft or m)

Sensor Type: Stainless steel strain gauge

Range: 0 to 30 ft (9.1 m)

Accuracy: +/- 0.06 ft (0.018 m)

Resolution: 0.001 ft (0.001 m)

Parameter: pH – bulb probe

Units: pH units

Sensor Type: Glass combination electrode

Model#: 6561 or 6561FG

Range: 0 to 14 units

Accuracy: +/- 0.2 units

Resolution: 0.01 units

Parameter: Turbidity

Units: nephelometric turbidity units (NTU)

Sensor Type: Optical, 90 degree scatter, with mechanical cleaning

Model#: 6136

Range: 0 to 1000 NTU

Accuracy: +/- 2% of reading or 0.3 NTU (whichever is greater)

Resolution: 0.1 NTU

Parameter: Chlorophyll Fluorescence

Units: micrograms/Liter

Sensor Type: Optical probe w/ mechanical cleaning

Model#: 6025

Range: 0 to 400 ug/Liter

Accuracy: Dependent on methodology

Resolution: 0.1 ug/L chl a, 0.1% FS

YSI EXO Sonde:

Parameter: Temperature

Units: Celsius (C)

Sensor Type: Thermistor

Model#: 599870-01

Range: -5 to 50 C

Accuracy: -5 to 35: +/- 0.01, 35 to 50: +/- .005

Resolution: 0.01 C

Parameter: Conductivity

Units: milli-Siemens per cm (mS/cm)

Sensor Type: 4-electrode cell with autoranging

Model#: 599870-01

Range: 0 to 200 mS/cm

Accuracy: 0 to 100: +/- 0.5% of reading or 0.001 mS/cm; 100 to 200: +/- 1% of reading

Resolution: 0.001 mS/cm to 0.1 mS/cm (range dependant)

Parameter: Salinity

Units: practical salinity units (psu)/parts per thousand (ppt)

Sensor Type: Calculated from conductivity and temperature

Range: 0 to 70 psu

Accuracy: +/- 1.0% of reading pr 0.1 ppt, whichever is greater

Resolution: 0.01 psu

Parameter: Dissolved Oxygen % saturation

Sensor Type: Optical probe w/ mechanical cleaning

Model#: 599100-01

Range: 0 to 500% air saturation

Accuracy: 0-200% air saturation: +/- 1% of the reading or 1% air saturation, whichever is greater 200-500% air saturation: +/- 5% or reading

Resolution: 0.1% air saturation

Parameter: Dissolved Oxygen mg/L (Calculated from % air saturation, temperature, and salinity)

Units: milligrams/Liter (mg/L)

Sensor Type: Optical probe w/ mechanical cleaning

Model#: 599100-01

Range: 0 to 50 mg/L

Accuracy: 0-20 mg/L: +/-0.1 mg/l or 1% of the reading, whichever is greater

20 to 50 mg/L: +/- 5% of the reading

Resolution: 0.01 mg/L

Parameter: Non-vented Level (Depth)

Units: feet or meters (ft or m)

Sensor Type: Stainless steel strain gauge

Range: 0 to 820ft (250m)

Accuracy: +/- 0.04%FS;+/- 0.33 ft (0.10 m)

Resolution: 0.001 ft (0.001 m)

Parameter: pH

Units: pH units

Sensor Type: Glass combination electrode

Model#: 599701(guarded) or 599702(wiped)

Range: 0 to 14 units

Accuracy: +/- 0.01 units within +/- 10° of calibration temperature, +/- 0.02 units for entire temperature range

Resolution: 0.01 units

Parameter: Turbidity

Units: formazin nephelometric units (FNU)

Sensor Type: Optical, 90 degree scatter

Model#: 599101-01

Range: 0 to 4000 FNU

Accuracy: 0 to 999 FNU: 0.3 FNU or +/-2% of reading (whichever is greater); 1000 to 4000 FNU +/-5% of reading

Resolution: 0 to 999 FNU: 0.01 FNU, 1000 to 4000 FNU: 0.1 FNU

Parameter: Chlorophyll

Units: micrograms/Liter

Sensor Type: Optical probe

Model#: 599102-01

Range: 0 to 400 ug/Liter

Accuracy: Dependent on methodology

Resolution: 0.1 ug/L chl a, 0.1% FS

**Dissolved Oxygen Qualifier (Rapid Pulse / Clark type sensor):**

The reliability of dissolved oxygen (DO) data collected with the rapid pulse / Clark type sensor after 96 hours post-deployment for non-EDS (Extended Deployment System) data sondes may be problematic due to fouling which forms on the DO probe membrane during some deployments (Wenner et al. 2001). Some Reserves utilize the YSI 6600 EDS data sondes, which increase DO accuracy and longevity by reducing the environmental effects of fouling. Optical DO probes have further improved data reliability. The user is therefore advised to consult the metadata for sensor type information and to exercise caution when utilizing rapid pulse / Clark type sensor DO data beyond the initial 96-hour time period. Potential drift is not always problematic for some uses of the data, i.e. periodicity analysis. It should also be noted that the amount of fouling is very site specific and that not all data are affected. If there are concerns about fouling impacts on DO data beyond any information documented in the metadata and/or QAQC flags/codes, please contact the Research Coordinator at the specific NERR site regarding site and seasonal variation in fouling of the DO sensor.

**Depth Qualifier:**

The NERR System-Wide Monitoring Program utilizes YSI data sondes that can be equipped with either vented or non-vented depth/level sensors.  Readings for both vented and non-vented sensors are automatically compensated for water density change due to variations in temperature and salinity; but for all non-vented depth measurements, changes in atmospheric pressure between calibrations appear as changes in water depth.  The error is equal to approximately 1.02 cm for every 1 millibar change in atmospheric pressure, and is eliminated for vented sensors because they are vented to the atmosphere throughout the deployment time interval.

Beginning in 2006, NERR SWMP standard calibration protocol calls for all non-vented depth sensors to read 0 meters at a (local) barometric pressure of 1013.25 mb (760 mm/hg).  To achieve this, each site calibrates their depth sensor with a depth offset number, which is calculated using the actual atmospheric pressure at the time of calibration and the equation provided in the SWMP calibration sheet or digital calibration log.  This offset procedure standardizes each depth calibration for the entire NERR System.  If accurate atmospheric pressure data are available, non-vented sensor depth measurements at any NERR can be corrected.

In 2010, the CDMO began automatically correcting depth/level data for changes in barometric pressure as measured by the Reserve’s associated meteorological station during data ingestion. These corrected depth/level data are reported as cDepth and cLevel, and are assigned QAQC flags and codes based on QAQC protocols. Please see sections 11 and 12 for QAQC flag and code definitions.

**NOTE: older depth data cannot be corrected without verifying that the depth offset was in place and whether a vented or non-vented depth sensor was in use. No SWMP data prior to 2006 can be corrected using this method.** The following equation is used for corrected depth/level data provided by the CDMO beginning in 2010:

((1013-BP)\*0.0102)+Depth/Level = cDepth/cLevel.

**Salinity Units Qualifier:**

In 2013, EXO sondes were approved for SWMP use and began to be utilized by Reserves. While the 6600 series sondes report salinity in parts per thousand (ppt) units, the EXO sondes report practical salinity units (psu). These units are essentially the same and for SWMP purposes are understood to be equivalent, however psu is considered the more appropriate designation. Moving forward the NERR System will assign psu salinity units for all data regardless of sonde type.

**Turbidity Qualifier:**

In 2013, EXO sondes were approved for SWMP use and began to be utilized by Reserves. While the 6600 series sondes report turbidity in nephelometric turbidity units (NTU), the EXO sondes use formazin nephelometric units (FNU). These units are essentially the same but indicate a difference in sensor methodology, for SWMP purposes they will be considered equivalent. Moving forward, the NERR System will use FNU/NTU as the designated units for all turbidity data regardless of sonde type. If turbidity units and sensor methodology are of concern, please see the Sensor Specifications portion of the metadata.

**Chlorophyll Fluorescence Disclaimer:**

YSI chlorophyll sensors (6025 or 599102-01) are designed to serve as a proxy for chlorophyll concentrations in the field for monitoring applications and complement traditional lab extraction methods; therefore, there are accuracy limitations associated with the data that are detailed in the YSI manual including interference from other fluorescent species, differences in calibration method, and effects of cell structure, particle size, organism type, temperature, and light on sensor measurements.

**10) Coded variable definitions –** List the sampling station, sampling site code, and station code used in the data.

Sampling station: Sampling site code: Station code:

Oliver Bridge OL lksolwq

Blatnik Bridge BL lksblwq

Barkers Island BA lksbawq

Pokegama Bay PO lkspowq

**11) QAQC flag definitions –** This section details the automated and secondary QAQC flag definitions. Include the following excerpt**:**

QAQC flags provide documentation of the data and are applied to individual data points by insertion into the parameter’s associated flag column (header preceded by an F\_). During primary automated QAQC (performed by the CDMO), -5, -4, and -2 flags are applied automatically to indicate data that is missing and above or below sensor range. All remaining data are then flagged 0, passing initial QAQC checks. During secondary and tertiary QAQC 1, -3, and 5 flags may be used to note data as suspect, rejected due to QAQC, or corrected.

-5 Outside High Sensor Range

-4 Outside Low Sensor Range

-3 Data Rejected due to QAQC

-2 Missing Data

-1 Optional SWMP Supported Parameter

0 Data Passed Initial QAQC Checks

1 Suspect Data

2 *Open - reserved for later flag*

3 Calculated data: non-vented depth/level sensor correction for changes in barometric pressure

4 Historical Data: Pre-Auto QAQC

5 Corrected Data

**12) QAQC code definitions** – This section details the secondary QAQC Code definitions used in combination with the flags above. Include the following excerpt:

QAQC codes are used in conjunction with QAQC flags to provide further documentation of the data and are also applied by insertion into the associated flag column. There are three (3) different code categories, general, sensor, and comment. General errors document general problems with the deployment or YSI datasonde, sensor errors are sensor specific, and comment codes are used to further document conditions or a problem with the data. Only one general or sensor error and one comment code can be applied to a particular data point, but some comment codes (marked with an \* below) can be applied to the entire record in the F\_Record column.

General Errors

GIC No instrument deployed due to ice

GIM Instrument malfunction

GIT Instrument recording error; recovered telemetry data

GMC No instrument deployed due to maintenance/calibration

GNF Deployment tube clogged / no flow

GOW Out of water event

GPF Power failure / low battery

GQR Data rejected due to QA/QC checks

GSM See metadata

Corrected Depth/Level Data Codes

GCC Calculated with data that were corrected during QA/QC

GCM Calculated value could not be determined due to missing data

GCR Calculated value could not be determined due to rejected data

GCS Calculated value suspect due to questionable data

GCU Calculated value could not be determined due to unavailable data

Sensor Errors

SBO Blocked optic

SCF Conductivity sensor failure

SCS Chlorophyll spike

SDF Depth port frozen

SDG Suspect due to sensor diagnostics

SDO DO suspect

SDP DO membrane puncture

SIC Incorrect calibration / contaminated standard

SNV Negative value

SOW Sensor out of water

SPC Post calibration out of range

SQR Data rejected due to QAQC checks

SSD Sensor drift

SSM Sensor malfunction

SSR Sensor removed / not deployed

STF Catastrophic temperature sensor failure

STS Turbidity spike

SWM Wiper malfunction / loss

Comments

CAB\* Algal bloom

CAF Acceptable calibration/accuracy error of sensor

CAP Depth sensor in water, affected by atmospheric pressure

CBF Biofouling

CCU Cause unknown

CDA\* DO hypoxia (<3 mg/L)

CDB\* Disturbed bottom

CDF Data appear to fit conditions

CFK\* Fish kill

CIP \* Surface ice present at sample station

CLT\* Low tide

CMC\* In field maintenance/cleaning

CMD\* Mud in probe guard

CND New deployment begins

CRE\* Significant rain event

CSM\* See metadata

CTS Turbidity spike

CVT\* Possible vandalism/tampering

CWD\* Data collected at wrong depth

CWE\* Significant weather event

**13) Post deployment information** –









**14) Other remarks/notes –**

Data are missing due to equipment or associated specific probes not being deployed, equipment failure, time of maintenance or calibration of equipment, or repair/replacement of a sampling station platform. Any NANs in the dataset stand for “not a number” and are the result of low power, disconnected wires, or out of range readings. If additional information on missing data is needed, contact the Research Coordinator at the reserve submitting the data.

A strong storm on 10/26 – 10/27/2017 hit the region and is apparent in several parameters at all of our SWMP sites. The University of Minnesota Duluth buoy in Lake Superior recorded steady winds of 35 – 40 mph and waves up to 16 feet. The off-lake winds associated with the storm caused a noticeable storm surge, rapidly increasing water depth at all sights beginning 10/26 21:45 and peaking at 10/27 00:45 (at BA our closest to Lake sight). Specific conductivity, dissolved oxygen, pH, turbidity, and depth were all affected to varying degrees at each site and are individually flagged CWE where relevant in the data.

Barkers Island Site:

The sondes during the first two deployments (3/24/2017 14:45 through 5/30/2017 9:30) were programmed to Coordinated Universal Time (UTC) instead of the usual Central Standard Time (CST). The DateTimeStamp, therefore was changed to CST by subtracting 6 hours from UTC time. Thus, the submitted raw data file does not match the original .bin file obtained from the sondes.

The sonde deployed on 3/24/2017, 14:45 was deployed for 41 days, 13 days past the required 28 day threshold. However, due to cold water temperatures, only moderate fouling was present and no drift was evident for any of the parameters.

Sondes deployed between 5/03/2017 and 05/30/2017 logged specific conductivity in uS/cm instead of mS/cm. Because ingestion into the CDMO database requires mS/cm. the conversion (division by 1000) was made to the raw files. Thus, the raw data files do not match the raw .bin files.

The sonde for the 05/03/2017 deployment was miscalibrated for depth because of an erroneous barometric pressure reading. Depth was calibrated using a barometric pressure reading of 746.5 mmHg, therefore a -0.184m offset was applied to the data. However, the barometer pressure was actually 762.0 mmHg requiring a 0.027m offset. The data was corrected for this error by adding 0.211m to every value (the difference between the two offsets).

The sonde for the 6/27/2017 deployment was miscalibrated for depth and oxygen because of an erroneous barometric pressure reading. Depth was calibrated using a corrected for altitude, barometric pressure reading of 810.75 mmHg, therefore a 0.68m offset was applied to the data. The corrected for altitude, barometric pressure was however, really 760.7 mmHg, meaning no offset was required. Depth data was corrected by subtracting 0.68m. An altitude uncorrected barometer pressure reading of 795.5 mmHg was used to calibrate dissolved oxygen, however the real barometer pressure was 745.5 mmHg. Because dissolved oxygen saturation increases with increasing pressure, the values for percent saturation and mg/L are overestimated due to the miscalibration.

The sonde deployed on 9/28/2017, 12:00 was deployed for 33 days, 5 days past the required 28 day threshold. However, only moderate fouling was present and no drift was evident for any of the parameters.

The sonde deployed on 8/25/2017, 10:30 was deployed for 35 days, 7 days past the required 28 day threshold. However, only moderate fouling was present and no drift was evident for any of the parameters.

This site was incorporated into the GOES satellite system on July 20th 2017. Water quality data is transmitted once every hour and is now available through the CDMO real-time data application.

A sonde was not deployed after 11/10/2017 14:00 due to ice formation.

Blatnik Bridge Site:

The sondes during the first two deployments (4/11/2017 10:00 through 6/9/2017 9:45) were set to Coordinated Universal Time (UTC) instead of the usual Central Standard Time (CST). The DateTimeStamp, therefore was changed to CST by subtracting 6 hours from UTC time. Thus, the submitted raw data file does not reflect the original .bin file obtained from the sondes.

The sonde deployed on 4/11/2017, 10:00 was deployed for 33 days, 5 days past the required 28 day threshold. However, only moderate fouling was present and no drift was evident for any of the parameters.

The sonde deployed on 8/8/2017, 10:00 was deployed for 35 days, 7 days past the required 28 day threshold. However, only light fouling was present and no drift was evident for any of the parameters.

A sonde was deployed on 9/11/2017 which was trapped in ice in October due to an extreme cold snap. The sonde was retrieved after ice out in May 2018. It logged until December 23rd when the batteries failed. All data past October 9th is beyond the recommended 28 deployment length, however, the post-deployment calibration checks were good and no major drift was evident for any parameters.

Sondes deployed between 4/11/2017 and 06/09/2017 logged specific conductivity in uS/cm instead of mS/cm. Because ingestion into the CDMO database requires mS/cm. the conversion (division by 1000) was made to the raw files. Thus, the raw data files do not match the raw .bin files.

Oliver Bridge Site:

The first deployment starting 4/11/2017, 10:30 lasted 33 days, 5 days past the required 28 day threshold. However, no fouling was present and no drift was present on any parameters except turbidity. There was a large turbidity spike at the end of the deployment uncorrelated to any weather events As this spike was not matched by the incoming, newly calibrated sonde, this data was rejected.

The sonde during the second deployment (5/13/2017 11:00 through 5/31/2017 10:15 was set to Coordinated Universal Time (UTC) instead of the usual Central Standard Time (CST). The DateTimeStamp has therefore been changed to CST by subtracting 6 hours from UTC time. Thus, the submitted raw data file does not match the original .bin file obtained from the sondes.

Sondes deployed between 5/13/2017 and 05/31/2017 logged specific conductivity in uS/cm instead of mS/cm. Because ingestion into the CDMO database requires mS/cm. the conversion (division by 1000) was made to the raw files. Thus, the raw data files do not match the raw .bin files.

The sonde deployed on 5/31/2017, 10:45 was deployed for 34 days, past the required 28 day threshold. However, only moderate fouling was present and no drift was evident for any of the parameters.

The sonde deployed on 8/08/2017, 9:45 was deployed for 40 days, 12 days, past the required 28 day threshold. In addition, a central wiper was not attached to the sonde. Because this site rarely sees biofouling, the data from this deployment aligns well with the sonde that replaced it. The post-deployment check was also good. Because of the compound issue of a long deployment plus no central wiper, dissolved oxygen, pH, and turbidity data are flagged suspect past the 28 day threshold.

The sonde for the 9/08/2017 deployment was miscalibrated for depth and oxygen because of an erroneous barometric pressure reading. Depth was calibrated using a corrected for altitude, barometric pressure reading of 770.25 mmHg, therefore a 0.136m offset was applied to the data. The corrected for altitude, barometric pressure was however, really 762.06 mmHg at the time of deployment, meaning an offset of 0.028 should have been applied. Depth data was corrected by subtracting 0.108m (the different between the offsets). An altitude uncorrected barometer pressure reading of 755 mmHg was used to calibrate dissolved oxygen, however the real barometer pressure was 747 mmHg. Because dissolved oxygen saturation increases with increasing pressure, the values for percent saturation and mg/L are overestimated due to the miscalibration.

A sonde was deployed on 10/18/2017 which was trapped in ice in October due to an extreme cold snap. The sonde was retrieved after ice out in May 2018. It logged until February 11th when the batteries failed. All data past November 15th is beyond the recommended 28 deployment length, however, the post-deployment calibration checks were good and no major drift was evident for any parameters.

Pokegama Bay Site:

The sonde during the first deployment (5/19/2017 9:30 through 6/1/2017 10:00) was set to Coordinated Universal Time (UTC) instead of the usual Central Standard Time (CST). The DateTimeStamp has therefore been changed to CST by subtracting 6 hours from UTC time. Thus, the submitted raw data file does not reflect the original .bin file obtained from the sondes. Also, the central wiper was not attached to the sonde during the first deployment. The sensors were only moderately fouled upon retrieval. Therefore, dissolved oxygen and turbidity readings were flagged as suspect, mostly due to discontinuity between the values from this sonde and the newly calibrated sonde replacing it. However, temperature, specific conductivity, salinity and pH were unaffected.

Sondes deployed between 5/19/2017 and 06/01/2017 logged specific conductivity in uS/cm instead of mS/cm. Because ingestion into the CDMO database requires mS/cm. the conversion (division by 1000) was made to the raw files. Thus, the raw data files do not match the raw .bin files.

The sonde deployed on 6/01/2017, 10:15 was deployed for 36 days, 8 days past the required 28 day threshold. However, only light fouling was present and all parameters match the new calibrated sonde on 7/06/2017.

The sonde deployed on 8/18/2017, 10:45 was deployed for 43 days, 15 days past the required 28 day threshold. However, only light fouling was present. All parameters match the new calibrated sonde on 9/29/2017 except pH, therefore pH is flagged suspect for the 15 days due to potential drift/fouling.

Depth Profile Data:

Sondes used for depth profile data were calibrated as SOP indicates for normal pre- and post-deployment. Measures taken at all sites at the coordinates specified in the site descriptions. Depth profile data is included for all sites, even those deployed at depths specified in the NERRS SWMP protocols. This data was collected to show that the level of our sonde deployments reflects placement in a well mixed water column. There is a separate table for each month we collected depth profile data which are timed with our nutrient sampling events.













