Monitoring Wetlands with Data Loggers: A Best Practices Guide
Introduction

New reasons for restoring, conserving, building, and monitoring wetlands are discovered every year. Wetlands act as a natural filter for polluted water and therefore play an essential role in water quality protection. Wetlands also serve as floodwater storage and they minimize erosion. Moreover, wetlands create a habitat for many fish and wildlife.

Unfortunately, commercial developments, extraction of natural resources, and waste disposal have decreased the number of wetlands in the U.S. by almost half since 1950. These activities drain wetlands, exploit underground water tables, or leave sites polluted. The loss of wetlands contributes to an increased number of flooding events, and polluted wetlands not only compromise the well-being of wildlife, but also can cause human health problems, such as respiratory conditions.

On the upside, many organizations make it their mission to either restore wetlands to their original flourishing ecosystems or create new wetlands to replace those that have been eliminated.

In addition, wetland mitigation banks are popping up throughout the U.S. These third-party wetland conservation projects allow companies that negatively impact wetlands to comply with Section 404 of the Clean Water Act\(^1\) by funding projects that restore and build new wetlands.

To ensure success, it is necessary to monitor wetland environmental conditions such as water level, temperature, and rainfall. These data help professionals determine progress and evaluate setbacks. Portable data loggers are deployed by numerous experts in the field of wetland monitoring. For example, the U.S. Department of Agriculture uses water level data loggers to monitor wetlands used to absorb pollutants in runoff water from agriculture sites.

Monitoring also plays a key role in health assessment of existing wetlands. For example, governments use wetland water level and temperature data to make decisions on zoning and development. Logged data are also used to create water quality standards. For example, the Baylor Experimental Aquatic Research (BEAR) facility develops nutrient criteria for wadable streams in Texas. BEAR researchers use portable data loggers to acquire data after manipulating environmental parameters within their manmade wetland system.

This white paper shares best practices for configuring and deploying portable data loggers. Tips regarding installation and maintenance are also included.

\(^1\) Wetlands Compensatory Mitigation published by Environmental Protection Agency.
An Overview of Data Loggers, and Proven Techniques for Installation in Wetlands

A variety of methods and constructions are used to install portable data loggers in wetland areas. Choosing the method that best meets a project’s criteria depends on a number of factors, including the project’s location, sunlight, and water current. The following provides an introduction to data loggers and best practices for a range of installation solutions.

Data Logger Overview

Data loggers typically incorporate micro-processors, sensors, and battery power in a rugged enclosure designed for long-term deployment. The loggers can be deployed and left unattended for months at a time, collecting data at user-defined intervals and storing them digitally in logger memory. By operating in a continuous 24/7 monitoring mode, data loggers eliminate many of the hassles of manual data collection, and facilitate monitoring of multiple locations at the same time.

Data loggers also automate the process of archiving and reporting data. Users can simply offload the logger data to a mobile device or computer and easily create detailed graphs or data files. The charts can be easily printed or shared electronically for documentation purposes, while the electronic data can be shared with other programs or archived.

Some of the most common data loggers used to monitor wetlands are water level, rainfall, water temperature, water conductivity, dissolved oxygen, pH, and air temperature/relative humidity loggers. The following suggests possible uses for data collection in these applications.

- **Water level**
  Water level data help researchers determine a variety of factors, such as how much water wetlands retain, rising water rates, and whether runoff volume reduction efforts are effective.

- **Rainfall**
  Researches often need rainfall data for comparisons to the water retained and water that runs off. Due to the spatial variability of rain, it is recommended to measure rainfall at multiple sites to come up with an average rainfall for the area.

- **Water temperature**
  Water temperature data are often used to help researchers determine if wetlands are adequately moderating water temperatures before entering waterways.
• Water conductivity
Logging conductivity can help identify the causes of water quality changes. Although conductivity does not tell you directly what contaminants are present, it is possible to look at the timing of conductivity changes versus other events to determine what caused the contamination. (For example, if the conductivity changed after a rainfall event, it may be runoff from a nearby parking lot that is causing problems.) Combining this knowledge with analyzing water samples can help to paint a picture of what is happening.

• Dissolved oxygen
Dissolved oxygen (DO) is an important indicator of water quality in a wetland, with higher DO levels indicative of an environment that can support a variety of plant and animal life, and lower levels pointing to a stressed habitat.

• pH
Another important indicator for water quality is pH. The bioavailability of nutrients is largely dependent on the pH of the water in which they are dissolved. Sometimes there is an excess of these essential nutrients (like nitrogen or phosphorous, for instance) that can have harmful effects on aquatic ecosystems. Wetlands help to mitigate the effects of these contaminants.

• Air temperature/humidity
Air temperature and relative humidity data are typically used to understand a wetland’s impact on the region’s temperature and humidity.

• Data retrieval
Collected data can be retrieved either by downloading it to a laptop or a hand-held data shuttle in the field, by remote communications/telemetry, or by Bluetooth Low Energy (BLE) technology, depending on the type of data logger. Remote communications allow for real-time Internet-based access to data. Rather than going out into the field, the user simply logs on to a website to view and download data. This saves travel time and minimizes potential data gaps due to equipment failure.

Installation and Mounting Options

When accumulating data from a wetland over several months, one of the biggest challenges is installing the logger in a secure location. Here are suggested installations for underwater and in direct sunlight as well as installations with several data loggers. All of which offer great security.

Installing water level and water quality loggers underwater

Cinderblock: Securing a data logger to a cinderblock is a good option for two reasons. The weight of the block keeps the logger in one location over a long period of time, and if set up correctly, water passes through easily. To do this, select a PVC pipe large enough to house the logger. Then drill a hole in...
the cinderblock large enough to hold the PVC pipe and slip the pipe through the hole. Or you can attach the PVC pipe to the side of the cinder block with zip ties or hose clamps. Use zip ties to attach the logger inside the pipe, and position the cinderblock on its side to allow water to flow through its openings.

**Arm Hook:** The arm hook construction is best for monitoring waters with minimal flow rates. The advantage of this configuration is that the logger can be easily accessed for data offload. Since the logger is only suspended at one end, this construction is generally not good for waters with strong currents. To create the arm hook, drill a hole in an 18-inch piece of flat, sturdy, unbendable scrap metal. This piece will become the arm. Drill a hole wide enough to accommodate a ¼-inch ring. Then weld the arm to a T fence post at the intended logger level position at a 90-degree angle. Part of the post will go into the ground so you should include this additional height when calculating the arm position. After the post has been pounded into the soil at the desired location and depth, attach the data logger to a durable mounting hook that fits through the mounting eyelet of the logger. The mounting hook should have captive ends that insure the logger will stay in place. Then slip the hook through the hole on the arm.

**Stilling Well:** A stilling well provides an area of stable water for measuring water level more accurately. For example, stilling wells are used to protect against waves. First, pound a metal T post into the ground at the desired location. Quiet backwaters are often a good location for stilling wells, as long as they track the full range of the water levels being monitored. Use hefty zip ties to attach a slotted PVC pipe or PVC pipe with holes to the T post. If you cannot find either of these, you can easily drill holes in a PVC pipe. Next, attach a wire cable to the data logger and attach the other end of the cable to the top of the pipe. Then, drop the logger into the pipe. Using a bolt through holes or slots at the top of the pipe is a common way to suspend a cable or logger.

**Simple PVC Pipe:** Use zip ties to attach logger cables to the outside of a 3-inch diameter PVC pipe. Pound the PVC pipe into the ground at the desired location. A PVC pipe could also be used as stilling well with the logger inside, as long as you use slotted PVC pipe or holes have been drilled in the side of it.

**Installing Tripod Weather Stations**

Weather stations can be used to monitor related outdoor environmental parameters such as rain, wind, and temperature and relative humidity. Typically, they are situated adjacent to wetlands, on land that remains dry. Anchor legs with rebar stakes through the feet of the tripod, then add guy wires and flag them so that people and animals don’t trip on them or run into them. Another option is to mount the weather station on footings that penetrate deep enough to be in stable soil.
Installation Tips

In addition to making sure data loggers are securely installed, it’s important to keep the loggers out of direct sunlight and protected from damage caused by weather, chemical conditions, and wildlife.

Avoiding fouling: Take advantage of antifouling options from the manufacturer. For instance, the HOBO MX2501 pH Data Logger includes an optional electrode copper guard to help the electrode resist biofouling. The same can be accomplished with the copper sensor guard for the HOBO U26 Dissolved Oxygen Data Logger.

Avoiding sunlight: Sunlight can lead to a number of problems, including increased fouling, artificially-high temperature readings due to solar radiation heating, and excess temperature variations that can lead to greater temperature compensation errors for other measurements.

To help avoid inaccuracy, use only white PVC pipe for both stilling wells and simple PVC pipe installations. White reflects light and therefore reduces solar radiation heating. When deploying a logger on a stake or the outside of a PVC pipe installation, attach it on the north side (in the northern hemisphere) so that the logger is not exposed to direct sunlight over the day. When using the stilling well method, inspect the pipe regularly for algae buildup. If enough algae grow on the pipe, temperatures within the pipe can rise. To remedy this, clean the pipe regularly.

Another way to avoid elevated temperatures is to place data loggers in a cinderblock, as discussed. This method keeps data loggers shaded while submerged in water. When monitoring temperature and humidity measurements in the air, a good solar radiation shield will protect the logger from heating caused by direct or reflected sunlight, while allowing the surrounding air to circulate freely to the sensor.

Avoiding corrosion of metal parts: Be sure to use mounting accessories that are thick enough to hold up despite corrosion that can occur in wetland conditions due to fluctuation between aerobic and anaerobic conditions. Try to select materials that won’t corrode, like PVC, or stainless steel for freshwater applications. For metal hooks, chains, and other metal pieces that can easily corrode over time in a wetland, reduce the rate of corrosion by spraying metal posts with primer and metal hooks and chains with vinyl spray paint such as Spray-on Vinyl.

Protecting equipment from animals: To prevent rodents and other animals from chewing through data logger cables, run the cables through conduit. To prevent bird excrement from clogging rain gauges, use a rain gauge that comes equipped with bird-deterrent spikes or add your own around the outside of the rain gauge collector funnel. Otherwise, be sure to clean out the rain gauge periodically.
Field Deployment Checklist

The following are checklist items to work through periodically before, during, or after data logger deployment:

• Make sure the computer used to launch the loggers has the latest software version installed and is set to the proper time zone.

• Check battery status before launching loggers.

• Confirm loggers are set to the proper logging interval. (If a logger is set to “every second” by mistake, data storage will fill up quickly and anticipated data won’t be recorded.)

• Verify proper operation by checking all loggers five minutes after they have been launched to confirm that they have been set up correctly.

• Make sure that any data shuttles that you will use have the latest firmware and have been synchronized with the computer clock.

• Take manual measurements of conditions such as water level, conductivity, and dissolved oxygen when you deploy the loggers and each time you offload data. These measurements can be used for field calibration of data and to check the accuracy of the data. Fouling can lead to measurement drift, and these measurements can be used to adjust for that.

• Log the specific location of each logger in your field notebook so the loggers can be easily found. This can be accomplished by noting their GPS locations and taking photos of their locations.

• Check the location to confirm the logger has not moved.

• Periodically offload data to provide backup in the event the loggers are lost or damaged later.

• Look for algal growth and clean as needed.

• Look for corrosion.

• Check protective casing for breakage.

• Check zip ties for damage.
Additional Tips

Here are additional tips to help attain accurate results:

**Delayed Start**

Most portable USB data loggers provide a delayed start function. This function allows users to set logging options in the comfort of an office, lab, or other location where double-checking settings is easier. Using a delayed start is highly recommended, and helps when field weather conditions could damage computer equipment. With delayed start, users do not need to take computers on site to deploy loggers.

In addition, delayed start is a good way to ensure that readings taken by loggers are synchronized to each other and to normal clock times. For example, when logging at 15-minute intervals, you’ll likely want readings taken at times like 10:00, 10:15, 10:30, etc. Using what some vendors call “interval start” is another way to achieve this.

**Quality User-Training**

Before launching loggers off site, fully train new users assigned to set up and deploy data loggers. For example, new users can launch water level and temperature loggers in a fish tank. They can also practice downloading data in the lab. Many vendors provide on-line training for new users.

**Data-Consistency Checks**

Before installing multiple loggers of the same type, launch all the loggers to start logging immediately and locate them together in one area (such as a fish tank, or sitting on a bench). Let the loggers run for 24 hours to check their data for consistency. If inconsistencies are found, replace the deviant loggers.

Likewise, if multiple loggers of the same type have been deployed, do not turn loggers off immediately after they are retrieved from a deployment. Instead, set all loggers in one place and let them run for an additional 24 hours. Then offload the logger data and check for inconsistent data. If data are inconsistent, use the acquired data to calculate a correction factor for the deviant loggers.
Protective Accessory Products

In addition to making loggers with rugged housings, data logger suppliers often offer supplementary accessories to ensure devices are secure in every climate and weather condition. Here are some examples:

• When using loggers with optic communications, such as the HOBO Water Temp Pro v2 from Onset, optional caps are offered to cover the communication window to prevent residue buildup that could affect communications. A protective boot is also available for even more protection.

• Protective housings, like the one designed for the HOBO U24 Conductivity Logger, are often available to safeguard the loggers while still allowing easy access to them for data offload.

• A locking well cap provides safe, convenient mounting for HOBO data loggers in wells. A plastic well cap used with the HOBO MX2001 BLE Water Level Data Logger can support the logger at the top of the well for optimal wireless transmission range.

Communications Options

Optical and wireless communications are better suited for wetlands, as they avoid the need to connect cables. Both enable reliable data offload when loggers are wet or it’s raining. With wireless Bluetooth Low Energy (BLE) loggers, there’s the advantage of being able to offload data while the logger is still in a well, which saves time. In addition, data can be offloaded at a distance from the logger in situations that otherwise might have required obtaining access by boat or by wading through a wetlands area.
Conclusion

Wetland monitoring is being performed more widely and becoming a necessity in many areas. Various organizations use wetland monitoring to assess wetland health, create environmental standards, and study climate change. Restoration and mitigation are also growing fields of research and business. The best practices in this white paper have been shared by multiple experts in their respective fields. The collaboration of experienced professionals fuels innovation – and in this case, a better, healthier environment.

About Onset

Onset is a leading supplier of data logger and monitoring solutions used to measure, record, and manage data for improving the environment and preserving the quality of temperature-sensitive products. Based on Cape Cod, Massachusetts, Onset has been designing and manufacturing its products on site since the company's founding in 1981.


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