# Best Practices – A Quick Guide to Water Surface Elevation and Temperature Data Collection

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# 1. Purpose

To aid in the collection of accurate water surface elevation data for restoration and reference site monitoring.

# 2. Choosing Data Logger Locations

First define the project goals for collecting the water surface elevation data to help determine the number and location of data loggers for monitoring.

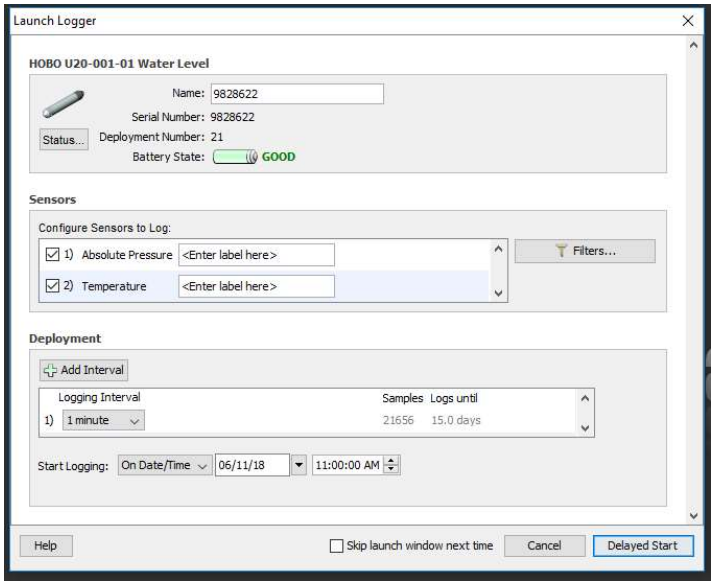
1. For a restoration project this might entail identifying which locations on the site are expected to experience a significant shift in flooding (timing and/or duration) pre- and post-project construction. You will also want to consider how easy it will be to access these locations pre-/post-restoration. Data loggers should be placed, at a minimum, in locations expected to experience significant hydrological changes and in a location that can be easily monitored both before and after construction. If data loggers must be removed during construction they will need to be relocated in approximately the same place after construction is completed for comparable data to be collected. A control or reference logger should be place in a main channel outside of the site, for the duration of the pre and post project monitoring. This control logger data can then be used to evaluate the effectiveness of the restoration project at restoring hydrologic reconnection.
2. The number of data loggers placed on a site should depend on the number of locations significant change is expected (post-restoration). Monitoring areas that are not expected to change can also be informative in terms of collecting baseline hydrologic data for modeling and a more extensive restoration outcomes analysis. At a minimum one data logger should be located in the main channel (or ditch pre-restoration) of a site and in the adjoining stream/river that the site is going to be re-connected with.
3. Data loggers should be placed as deep as possible in a ditch or channel to avoid complete exposure to the air. This can be tricky for tidal locations, if possible place the logger below the low tide elevation. Frequently exposed (no longer under water) data loggers generate incomplete data sets and are less accurate than data loggers which remain underwater during the duration of the sampling period. Additionally, if data loggers are exposed during the winter, there is a chance the logger will freeze resulting in data gaps and broken equipment. If data logger exposure is a potential issue consider also deploying a groundwater well to track above and below ground water fluctuations.
4. If available, an additional WSE data logger should be deployed to collect ambient air temperature and pressure data to correct and obtain depth data from the submerged data loggers. This data logger should be deployed in a location that is easy to access as you are leaving a site and will not get flooded (such as on a nearby tree branch or fence post) – as you will want to pull this logger after collecting the others at the site to maximize the amount of data you obtained during the sampling period. Air pressure and temperature data loggers need to be shielded from direct solar exposure.

# 3. Pre-Deployment Data Logger QA/QC

Before deployment the data loggers should always be check for accuracy. The below QA/QC method can be used to check both water level and temperature accuracy. A temperature calibration check requires the use of an external thermometer, preferably one that is NIST certified (most YSI probes will work for this). If your project goals include creating thermal refugia or require water temperature monitoring, you should conduct a full temp calibration following Oregon DEQ protocols[1] or the Washington Department of Ecology protocols[2]. The below protocols outline an approach that aims to meet the requirements of both the State of Oregon and Washington when all three water bath temperatures are evaluated. This should be conducted before and after a data logger deployment.

## Water Surface Elevation and Temp QA/QC

1. First deploy data loggers to collect data at one minute intervals, also deploy a data logger of known accuracy to collect ambient air pressure data at one minute intervals at the same time.




2. Fill a cooler with water and add the loggers, water should be at least 20 cm above the data loggers. Make note of the time, temperature, water depth above the data loggers and let loggers sit in the water undisturbed for 20 mins, or until the temperature measurements with the NIST thermometer stabilize. It is important to give the data loggers adequate time to equilibrate to the water bath temperatures. The goal of a temperature calibration is to get 10 continuous - 1 minute interval temperature measurements with the NIST thermometer that are comparable to the temperatures

[1] Oregon Plan for Salmon and Watersheds, Water Quality Monitoring Guidebook, Temperature Protocols Chapter 6: http://docs.streamnetlibrary.org/Protocols/021.pdf

[2] Washington Department of Ecology Quality Assurance Monitoring Plan: Continuous Monitoring for Oxygen, Temperature, pH, and Conductivity in Statewide Rivers and Streams https://fortress.wa.gov/ecy/publications/summarypages/0903122.html

measured with the data loggers during the same timeframe. Similarly, the measured water depth should be comparable to the water depth measured by the sensors during the duration of the water bath.

3. For a full temperature and water depth check repeat the above (#2) procedure with all three suggested temperature baths 0°C, 10°C, 20°C. The bath temperatures should be within a few degrees of these targets. For best results make sure the loggers are completely submerged in water, using a colander to hold the data loggers inside the water bath can help with this.
4. Download the logger data starting with the ambient air pressure logger and then correcting each logger using the ambient air pressure logger to determine **sensor depth**.
5. On average across all baths the logger temperature should be recording within ± 0.5°C (state guidelines are ± 0.5°C for OR and ± 0.2°C for WA) of the NIST thermometer.
6. Additionally, if the data logger's average water depth error is greater than ± 5 cm then redo the sensor depth calculation. Data loggers which have been deployed previously can have issues with their pressure gages which prevent accurate sensor depth measurements to be calculated without a reference water level. If using a reference water level does not correct the issue with depth measurements the data logger may no longer be usable.
7. Once QA/QC is completed results should be recorded for each data logger in the shared data logger tracking spreadsheet.

## QA/QC Worksheet 1

**Trial 1: 0°C Bath**

| Min | Time | Testing Depth | Sensor Measured Depth | Difference (Depth) | NIST Temperature | Sensor Measured Temperature | Difference (Temp) |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | | | | | | | |
| | | | Average | | | Average | |

**Trial 2: 10°C Bath**

| Min | Time | Testing Depth | Sensor Measured Depth | Difference (Depth) | NIST Temperature | Sensor Measured Temperature | Difference (Temp) |
|---|---|---|---|---|---|---|---|
| 1 | | | | | | | |
| 2 | | | | | | | |
| 3 | | | | | | | |
| 4 | | | | | | | |
| 5 | | | | | | | |
| 6 | | | | | | | |
| 7 | | | | | | | |
| 8 | | | | | | | |
| 9 | | | | | | | |
| 10 | | | | | | | |
| | | | Average | | | Average | |

**Trial 3: 20°C Bath**

| Min | Time | Testing Depth | Sensor Measured Depth | Difference (Depth) | NIST Temperature | Sensor Measured Temperature | Difference (Temp) |
|---|---|---|---|---|---|---|---|
| 1 | | 0 | | | | | |
| 2 | | 0 | | | | | |
| 3 | | 0 | | | | | |
| 4 | | 0 | | | | | |
| 5 | | 0 | | | | | |
| 6 | | 0 | | | | | |
| 7 | | 0 | | | | | |
| 8 | | 0 | | | | | |
| 9 | | 0 | | | | | |
| 10 | | 0 | | | | | |
| | | | Average | | | Average | |

### QA/QC Worksheet 2

| Trials | | Average Depth Difference | Average Temp Difference |
|---|---|---|---|
| 1 | 0°C Bath | | |
| 2 | 10°C Bath | | |
| 3 | 20°C Bath | | |
| Average Error | | | |

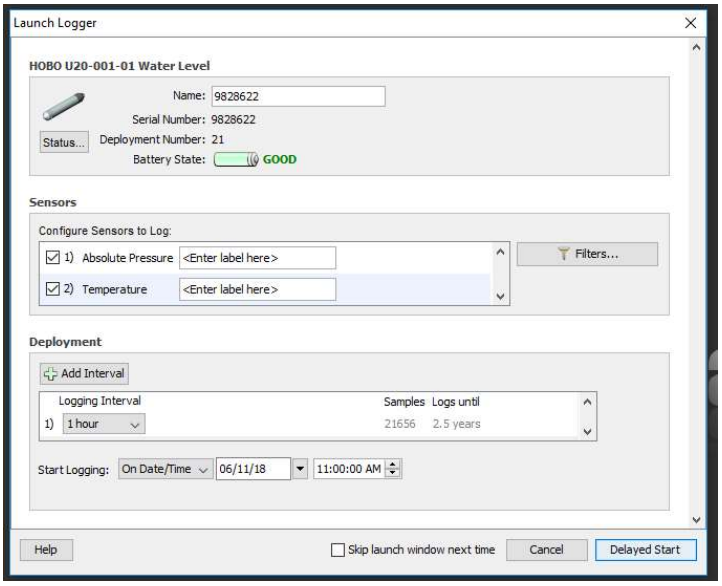
## 4. Deployment and Retrieval Protocols

***Setting up the loggers for data collection:*** Data loggers should be deployed to collect data at an interval which meets the project monitoring goals and objectives. Typically, hourly data collection is adequate for long-term monitoring. If the data is going to be collected for a short duration (days instead of months) and/or used for hydrologic modeling then a more frequent time interval can be used. Data collection interval should always be double checked before launching the logger and delayed to start on the hour. The time zone adjustment also needs to be checked before deployment: Hoboware will automatically adjust the time zone to Standard or Daylight Savings based on the computer's current time, it is recommended to always keep data loggers in Standard Time such as PST (GMT-8)[3] to avoid issues with daylight savings. It is also important to check and make sure the data logger battery is in the green before deployment.

***Collecting calibration water levels before, during, and after deployment:***

1. **Before the data loggers have been placed in the field, water level measurements can be made in the office.** This can easily be done by setting up the data loggers, including an atmospheric (ATM) data logger, to start collecting data a day or two before deployment and placing the water level data loggers in a bucket of water for a few hours (with the ATM logger nearby but not in the water), note the times and water levels of the reference measurements. These measurements can be used to evaluate performance or calibrate measurements post deployment.

[3] See section 7 for more details on dealing with time zones.




2. **At deployment, after data logger instillation, time, water level, and temperature should be collected.** The time of logger deployment, water level and temperature at logger deployment should be collected as close to the same time as the data logger is logging a data point; be aware of when this is, such as on the hour or half hour interval, and plan your deployment calibration check accordingly. Depending on the tidal nature of the site the exact timings of calibration measurements may not be as crucial, stable environments such as ditches and non-tidal streams can have data collection times outside of the on the hour or half hour logging interval.
3. **During deployment additional water level data can be collected.** Once the logger is deployed additional water level measurements can be made at the logger location and/or throughout the site when using an RTK (or at locations of known elevations). These measurements can be used further evaluate how well the logger depths are representing water depths observed across the site. This works best if collected at the same time as the data logger is logging a data point.
4. **At the time of data logger retrieval, the time, water depth, and temperature should be recorded before data logger removal or the data is pulled from the data logger.** The time of logger deployment, water level and temperature at logger deployment should be collected as close to the same time as the data logger is logging a data point; be aware of when this is, such as on the hour or half hour interval, and plan your retrieval calibration check accordingly. Depending on the tidal nature of the site the exact timings of calibration measurements may not be as crucial, stable environments such as ditches and non-tidal streams can have data collection times outside of the on the hour or half hour logging interval.
5. **If data collection is ongoing, the data logger should be replaced with a new calibrated data logger (see section 3) before the current logger is out of memory**. All data loggers should be retrieved and replaced on the same day including the ATM logger. Once back in the office the water level data loggers should be placed in a bucket of water for a few hours (with the retrieved ATM logger nearby but not in the water), making a note of

the times and water levels. This is an essential step of the retrieval process as data loggers can develop issues during deployment and these post deployment measurements can be used to correct the data.

- *If data loggers cannot be replaced and the shuttle is used to retrieve data and relaunch the logger in the field, then at a minimum a water level measurement needs to be made in the field before retrieving the data from the logger. To ensure these last water level calibration measurements can be used to correct the data the ATM data logger should not have the data pulled until after all the other water level data loggers have been retrieved.*

6. **Once the post deployment water levels measurements have been made, the data should be uploaded and corrected for sensor depth using the ATM data.** If the sensor depth appears to be accurate (< ± 5 cm) in comparison to the water depth measurements made before, during, and after the deployment then this accuracy can be reported and **used in lieu of the pre-calibration check (section 3)**[4] for the next deployment. If the data is not accurate or the accuracy changes during deployment then the data should be rechecked using the water level data (instead of sensor depth) and re-evaluated for accuracy.

## 5. Deployment Installation

**Setting up the data logger housing for in the field:** There are a variety of different installation deployment strategies that can be used in the field, no matter what manner the data logger is deployed in the field, the installation should always accommodate the following necessities:

- The data logger should be secure so no post-deployment movement occurs even during high flows and storm events.
- The data logger should be placed high enough above the stream or wetland substrate to not become buried in sediment.
- The data logger should be placed deep enough under water to prevent exposure even during low tide events.
- The data logger should be shielded from solar exposure.
- The data logger should be easily retrieved and redeployed without substantial movement occurring in data logger placement/housing.

### Measurements to make when installing and retrieving the data logger using the standard set up (see Figures 1-3):

A. Distance from the sediment to the top of cap

B. (B1) Distance from top of sensor housing to the top of post (Figure 2) and if post is shorter than housing (Figure 3) then measure (B2) from housing cap to top of post

[4] If detailed temperature calibration is not required

C. Distance from top of cap to sensor (i.e. length of metal cord and sensor in logger see Figure 4)
D. Depth of water in channel
E. RTK top of post
F. RTK bottom of post (if top of post is too difficult)

- The measurements referred to above (See Figure 1-3 for reference) should also be re-measured at the time of data logger retrieval to identify if the housing shifted during deployment. Measuring the water depth above the logger is essential to calibrate/check the data collected. If significant movement (such as housing has been pushed over and/or moved down stream) the most important measurements at the time of retrieval are the elevation (RTK) of the data logger and the depth of the water above the data logger sensor. If these can be taken directly then no other measurements need to be made – however upon reinstallation/deployment all measurements need to be collected again.

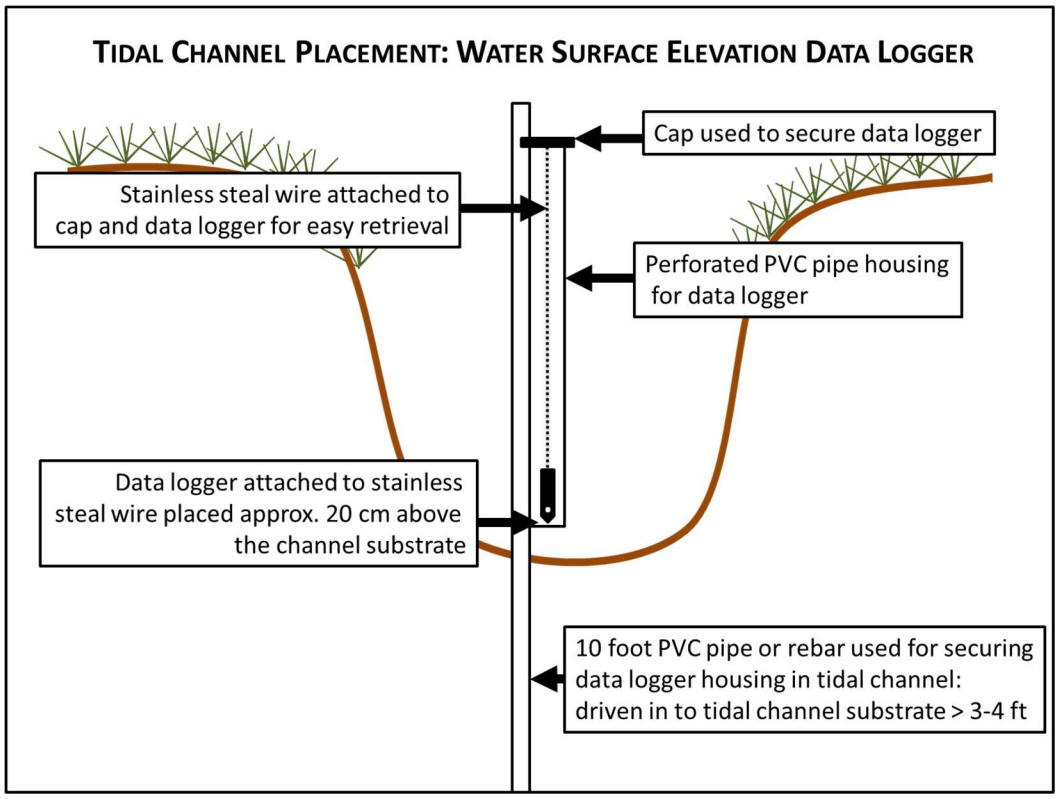



*Figure 1: Standard data logger installation set up for tidal wetland channels*

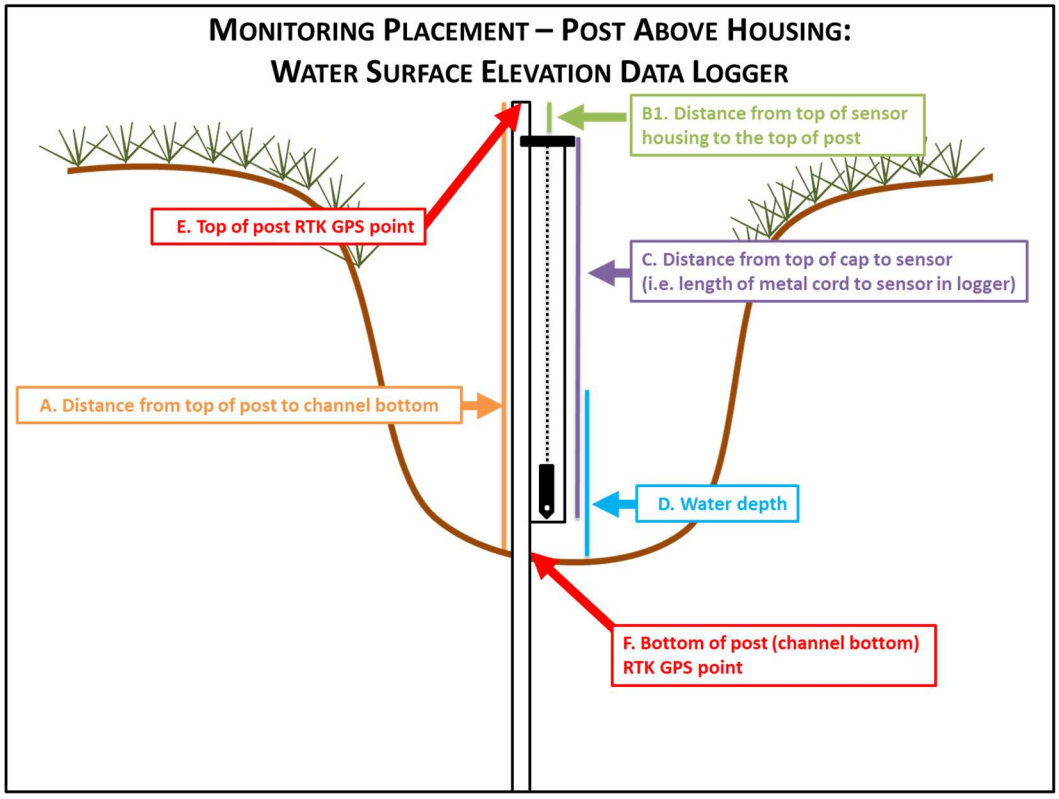



*Figure 2: Measurements when data logger housing is below placement post.*

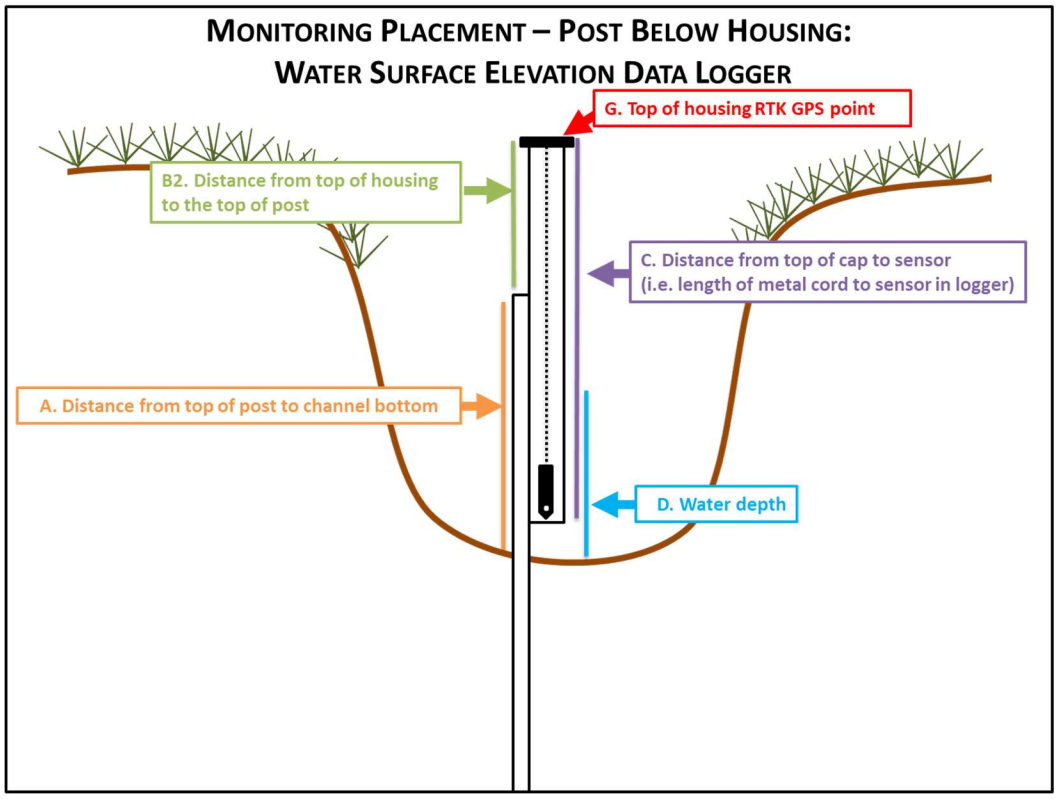



*Figure 3: Measurements when data logger housing is above placement post.*

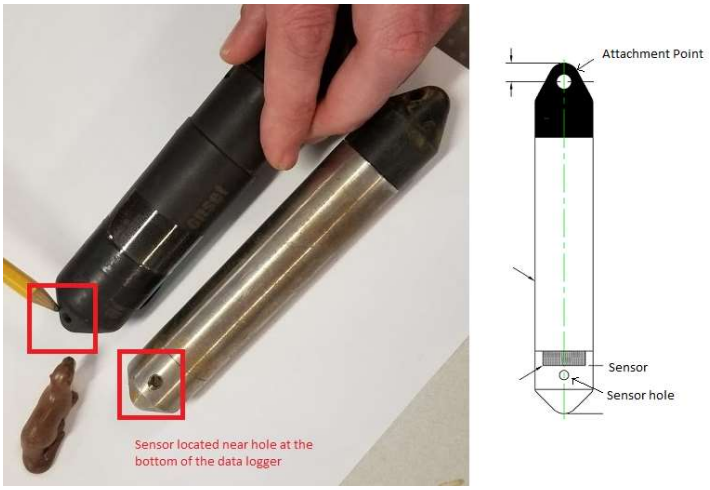



*Figure 4: HOBO Water Surface Elevation Data Logger, location of sensor. In HOBO WSE data loggers the sensor is located next to the hole in the data logger below attachment point.*

## 6. Measurements and Calculating Elevation

The data collected during data logger installation and retrieval can be used to identify if the data logger housing has shifted during deployment and are used to determine the elevation of the data logger and the depth of water above the data logger for post-processing. Below are some methods for calculating various water surface elevations or water depths depending on measurements taken in the field. Reference letters correspond to measurements illustrated in Figure 3.

1. Calculating the elevation of the data logger: if top of post RTK is collected (E) then the elevation of the data logger can be derived by subtracting the distance from the data logger sensor to the top of post from this elevation.
   - **Elevation of data logger = E – (B1 + C)**

   If bottom of post RTK is collected (F) then the logger the distance from the data logger sensor to the top of the sediment can be added to this to get the data logger elevation.
   - **Elevation of data logger = F + (A- (B1+C))**

   If top of cap RTK is collected (G) then the elevation of the data logger can be derived by subtracting the distance from the data logger sensor from the top of the cap from this elevation.
   - **Elevation of data logger = G – C**

2. Calculating water depth above data logger sensor (without directly measuring this is in the field):
   - Post is taller than data logger housing (Figure 2):
     **Water depth above sensor = D – (A-(B1+C))**
   - Data logger housing is taller than post (Figure 3):
     **Water depth above sensor = D – ((A+B2)-C)**
3. Calculating water surface elevation from sensor depth data:
   - Data logger housing is taller than post (Figure 3):

**Water depth above sensor = D – ((A+B2)-C)**

4. Calculating movement of data logger housing during deployment
    - Compare measurements A, B1, B2 and the RTK elevations pre and post deployment, if measurements are significantly different then the data logger housing has shifted and the WSE data may need to be corrected or not usable. Data correction can be done if the precise timing of data logger housing movement can be identified in the hydrologic data and then the new data logger elevation (collected upon retrieval) applied to all data after the shift occurred (See example Figure 5).

## 7. Post-processing and Analysis

Once the data logger has been retrieved from the site and post- deployment water depth measurements have been made (See 4.6) the data can be processed and used to evaluate the conditions on the site. Below are some tips for processing the data in HOBOware:

1. Understanding GMT and Correcting for Daylight Savings

    It is best practice to always be aware of which time zone the data logger is collecting in. HOBOware does not automatically correct for daylight savings. Additionally, the data logger will be launched in whichever time zone your computer clock is in at the time of deployment unless it is adjusted manually. This means if you deploy your data logger in the summer (Daylight Savings Time) and then retrieve your data logger in the winter (Standard Time) your data will be read out in Daylight Savings Time, all time stamps after the fall time boundary (such as November 4 at 2 am) will be an hour off (one hour behind) because HOBOware does not adjust for shifts between Daylight Savings and Standard Time. This adjustment will need to be done manually in Excel, once exported from HOBOware. Correcting data for the end or beginning of daylight savings time can cause issues with time series data analysis because it involves deleting or duplicating a date and time when the data crosses a time boundary. Specifically, when daylight saving times begins clocks are moved forward one hour, meaning the 2 am date time on that day is deleted, while when daylight savings time ends the clocks go back one hour, meaning the 2 am time stamp is repeated. To avoid issues with duplicate and deleted time stamps data should be collected and stored in Standard Time, in the Pacific Time Zone this is GMT-8.

    It is particularly important to understand how these shifts between daylight savings ending and beginning impact your date and time stamps when trying to compare your reference water levels and temperatures collected to your data logger data. For example is you are collecting all your data in Standard Time (i.e. GMT-8) you will need to make a small adjustment to your reference measurement date and time stamps collected during daylight savings time (i.e. Mar – Nov, see an annual daylight savings table for exact dates) so that the reference measurement time and dates match the loggers time and dates. To shift a daylight savings time stamp (i.e. GMT-7) to a standard time stamp (i.e. GMT-8) you only need to add one hour.

    Lastly, understanding the time zone your data is collected in is critical for comparing time series data sets such as multiple loggers to one another or to a gage station, and when correcting your data with barometric data. It is essential to make sure all data sets are in the same time zone for meaningful analyses to be conducted.

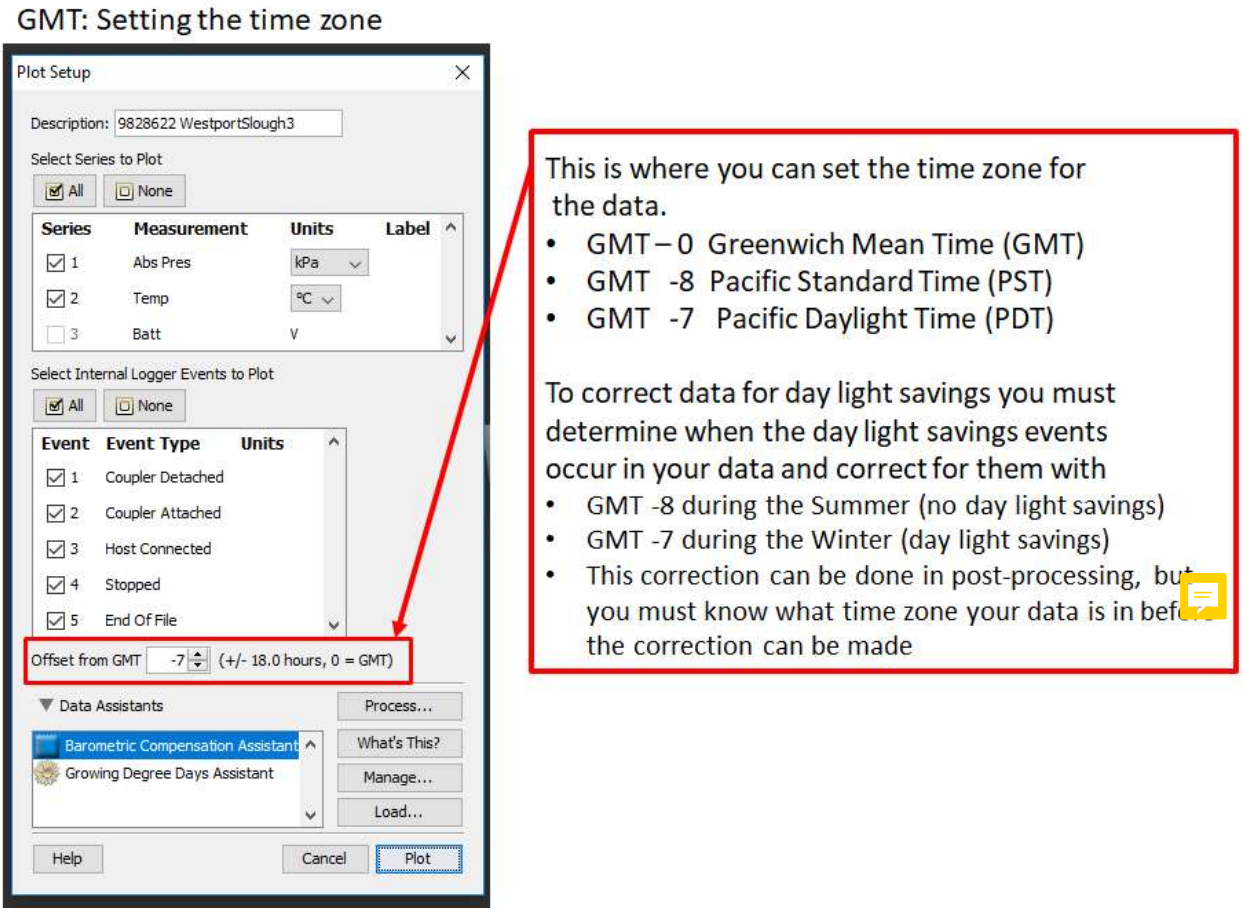



*Figure 5: Hoboware pop-up for opening a data logger file. You can change the GMT offset before viewing the data when you open the file.*

2. Using the Barometric Compensation Assistant
   - Make sure you have your ATM data handy, it will need to overlap your sampling period to work properly. The first step is to select the Barometric Compensation Assistant and then within this tool select the correct fluid density. If working with freshwater or oligohaline data using the “Derived From Temp” option works well.

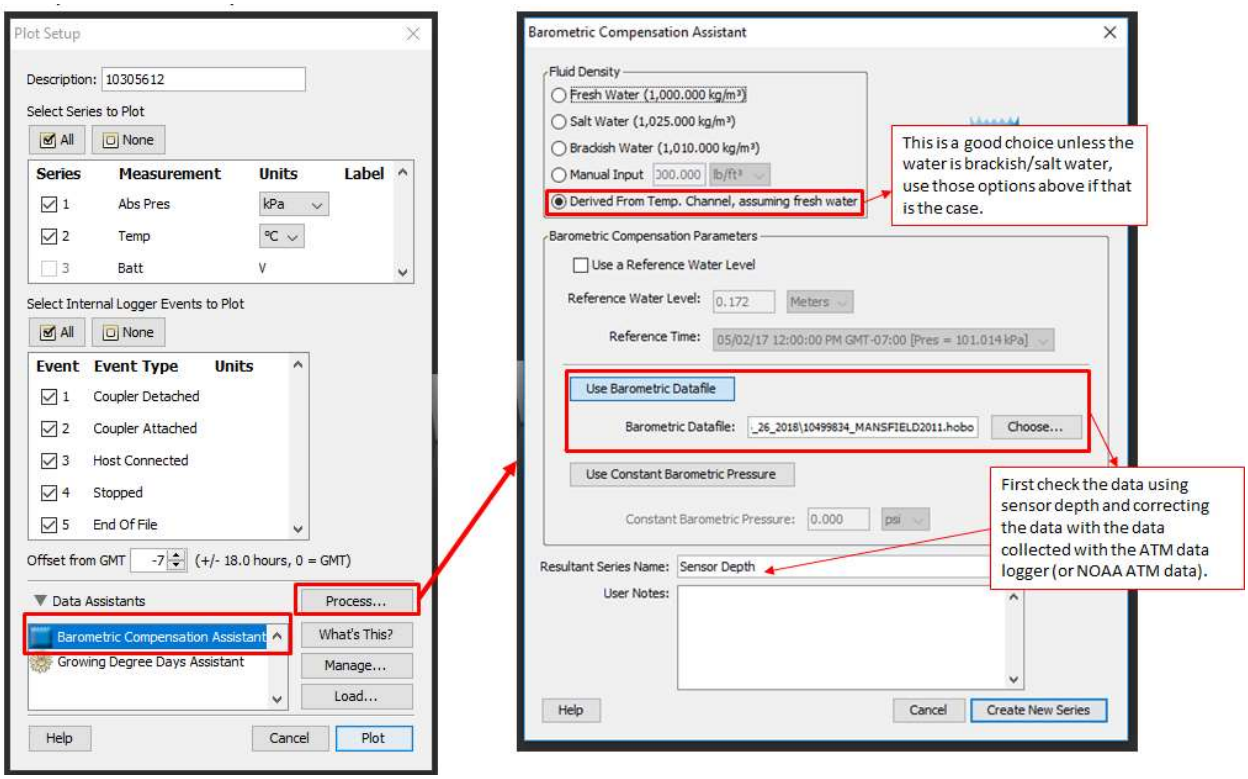
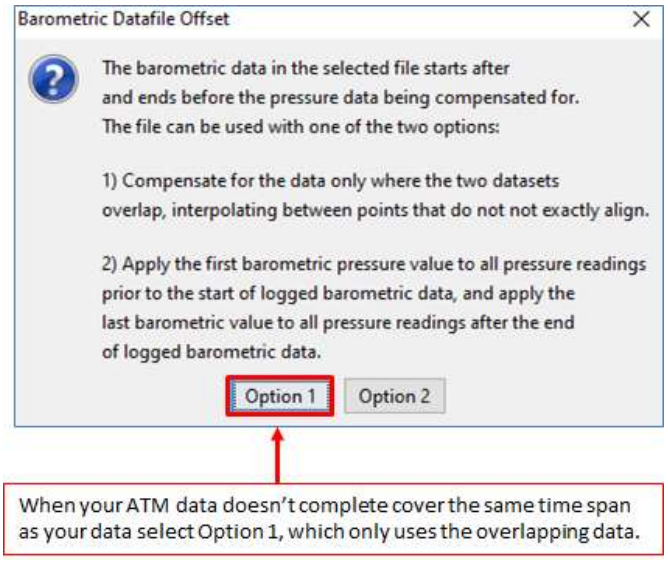



*Figure 6: Barometric compensation assistant*

- Then select the ATM data file to have the data corrected for Sensor Depth, this process does NOT require a reference water level and can be used to evaluate how the data logger is functioning by checking sensor depth results with the calibration sensor depth data collected directly in the field.



3. Trouble shooting data issues
    - If the sensor depth data is off by more than ± 5 cm of your field or office reference measurements (see Section 4 & 5 for more on making reference measurements) you may need to correct your data with a reference water level (instead of just using the derived sensor depth). This is easily done by going back into the Barometric Compensation Assistant and entering a reference water level (in meters) instead of selecting sensor depth (Figure 6). It is important to have multiple reference measurements during the deployment, so when you use one to correct the data and have others to check against and evaluate the accuracy of the correction.

    - During winter deployments data loggers can freeze and this can cause a systemic error to occur with the sensor depth calculations (Figure 7). If this occurs the data will need to be corrected multiple times (before and after the error occurs) using deployment and retrieval reference water levels. Then the two sets of corrected data can be joined in excel during post-processing.

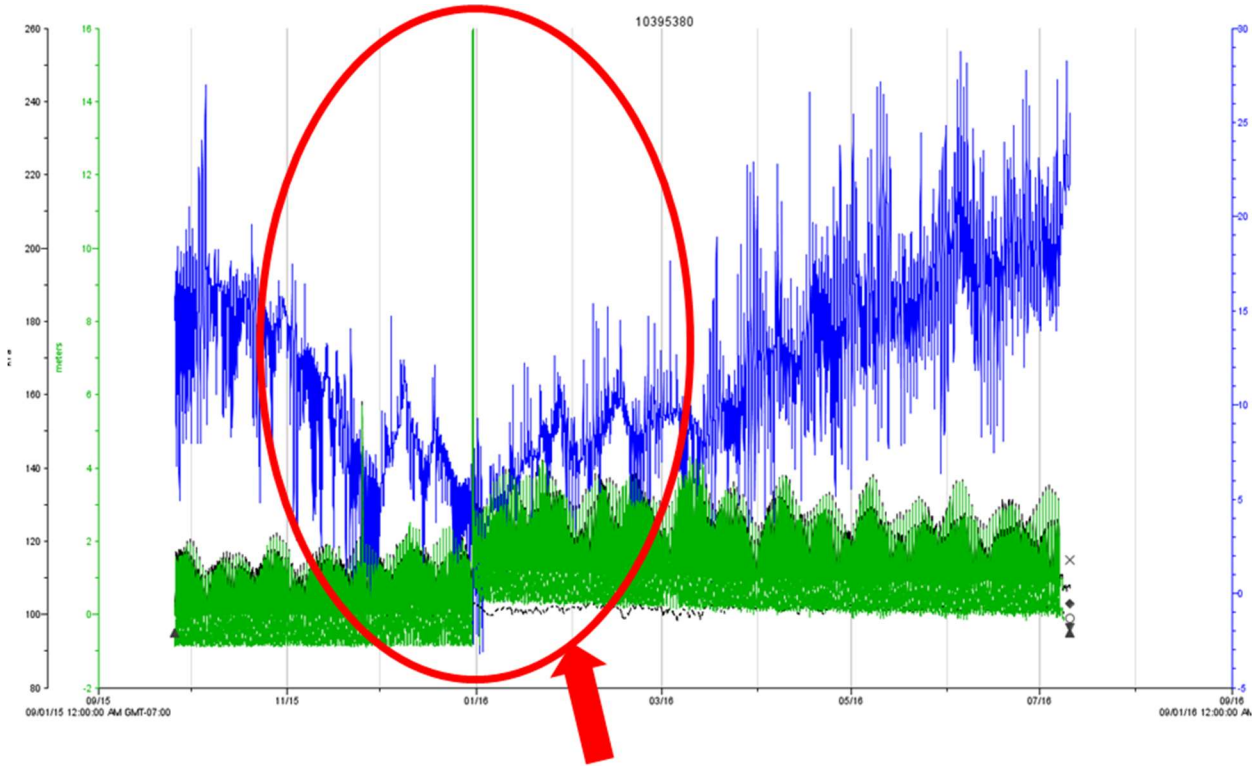



*Figure 7. Error in data caused by a sensor freezing during deployment.*

4. Metadata and evaluating the quality of data collected
    - It is important to always keep track of the accuracy of each logger before, during, and after deployment. All pre/post deployment calibration checks, reference field and office measurement comparison data should be included with any metadata developed for each logger deployment.

# 8. Helpful Resources

Continuous Water Level Data Collection and Management Using Onset HOBO® Data Loggers Natural Resource Report NPS/NCBN/NRR—2017/1370 https://irma.nps.gov/DataStore/DownloadFile/563851

Lower Columbia Estuary Partnership. 2018. Refining Monitoring Protocols for Action Effectiveness, Science Workgroup Meeting: http://www.estuarypartnership.org/resource/refining-monitoring-protocols-action-effectiveness-sep-2018-swg

Oregon Plan for Salmon and Watersheds, Water Quality Monitoring Guidebook, Temperature Protocols Chapter 6: http://docs.streamnetlibrary.org/Protocols/021.pdf

Washington Department of Ecology Quality Assurance Monitoring Plan: Continuous Monitoring for Oxygen, Temperature, pH, and Conductivity in Statewide Rivers and Streams https://fortress.wa.gov/ecy/publications/summarypages/0903122.html

HOBOware User's Guide: http://www.onsetcomp.com/support/manuals/12730-MANBHW-UG

HOBOware Pro Barometric Compensation Assistant User's Guide: http://www.onsetcomp.com/files/manual_pdfs/Barometric-Compensation-AssistantUsers-Guide-10572.pdf

HOBO® U20 Water Level Logger Manual:http://www.onsetcomp.com/files/manual_pdfs/12315-F-MAN-U20.pdf

Specifications for HOBO® U20 Water Level Loggers:http://www.onsetcomp.com/files/datasheet/Onset%20HOBO%20U20%20Water%20Level%20Data%20Loggers.pdf

Specifications for HOBO® U20L Water Level Loggers: http://www.onsetcomp.com/files/datasheet/Onset-HOBO-U20L-Water-Level-DataLogger-Series.pdf

US Geological Survey. 2012. Water level continuous standard operating procedures. Unpublished protocols. USGS, Western Ecological Research Center, San Francisco Bay Estuary Field Station, Vallejo, CA. http://www.tidalmarshmonitoring.org/monitoring-methods-hydrology.php