

# Wisconsin DNR – Lake Level Monitoring Surveyor Protocol

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## I. Program Contacts

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## II. Project Background

This project will engage volunteers with the Citizen Lake Monitoring Network (CLMN) and other local partnerships to monitor inland lake levels in Wisconsin and is coordinated by the Wisconsin Department of Natural Resources (WDNR). Water level measurements will be attained from a staff gage installed near shore that is surveyed each spring and fall. A staff gage is a graduated measuring instrument (made out of enameled steel and marked in feet and tenths) placed in the lake bed to show the elevation of the water surface and can be visually read from the shore or by boat (see Figure 1A). The staff gage is calibrated by referencing the numbered height on the gage to the surveyed elevation of the water surface at the time of installation (Harrelson et al., 1994). Surveying the staff gage each year is essential as it enables water level readings to be linked to one another across years of the monitoring effort.

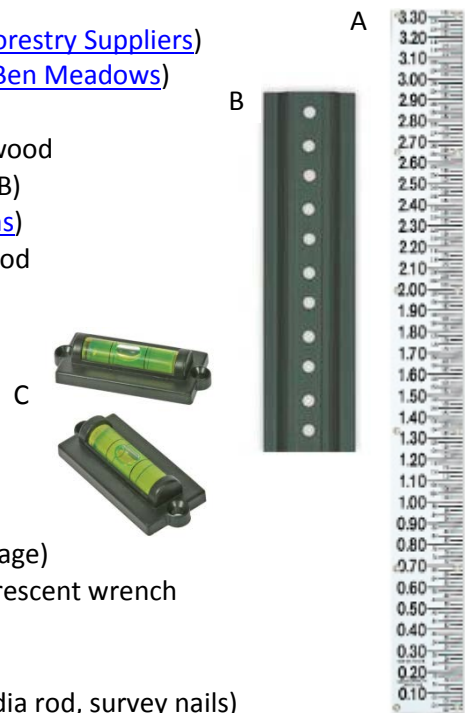
Staff gages are often mounted on permanent structures such as a bridge piling or weir, but for this project, most staff gages will be attached to fence posts and sunk into the lake bottom (Elias et al., 2008). Staff gages should be installed and surveyed in the spring of each year (April, or ice-out) and surveyed again before they are removed in October (or November) to prevent ice damage. Staff gages need to be resurveyed and referenced to the same bench mark each year upon installation (Kenney, 2010). Keep in mind that if the staff gage is being used for WDNR purposes, is placed outside a navigation zone, and is visually unobtrusive, a permit from the WDNR is not necessary.

Staff gage installation and the surveying of the staff gage should not be undertaken by volunteers unless they are professionally trained. The WDNR will provide training on the proper surveying/installation methods to potential surveying staff including: consulting firms, North Lakeland Discovery Center (NLDC), the Natural Resources Conservation Service (NRCS), UW-Extension (UWEX), WDNR, US Forest Service (USFS), and local counties. All project consultants will need to be trained using these protocols prior to installing and surveying staff gages. The Wisconsin Society of Land Surveyors is a good resource for finding potential surveyors in your area (<http://www.wsls.org/>).

### III. Equipment

Listed below is the necessary equipment for the installation and surveying of a staff gage:

- Staff Gage (Figure 1A)
  - WaterMark® Style “A” Stream Gauge - 0-3.33ft ([Forestry Suppliers](#))
  - BEN MEADOWS™ Style A Stream Gauge, 0-3.33' ([Ben Meadows](#))
- Wooden Gage Board (nominally 1" x 8" x 4' in size)
  - Good materials include: oak or pressure-treated wood
- Metal fence post (U-style, 2-3 inch wide, 8ft tall) (Figure 1B)
  - 8' x 3.00 lbs/Ft. Steel U Channel Post ([Gopher Signs](#))
- '12x1' flathead stainless steel screws to attach gage to wood
- Stainless steel screws to attach wood to fence post
  - 3.5" x 5/16" hex bolt and 5/16" hex nut
  - Flat washer and lock washer
- Stainless steel 2.5 inch lag bolt for '0' marker
- Extra stainless steel bolts/nuts, washers
- Mini Level (Figure 1C) and small screws
  - Camco 25523 Standard Levels ([Amazon](#))
- DNR Contact Information Card (to be affixed to the staff gage)
- Clamps and builder's level, screwdriver, wrench/socket, crescent wrench
- Fencepost pounder and maul
- GPS and Digital Camera
- Surveying equipment (auto level or laser level, tripod, stadia rod, survey nails)
- Staff gage installation and calibration data sheet(s)
- Calculator, clipboard, and pencil
- Waders or hip boots
- AIS decontamination/cleaning equipment



### IV. Choosing an Installation Location

First, determine the location where the staff gage will be installed. In order to be able to monitor the staff gage throughout the field season, the gage needs to be installed at a depth that can accommodate a large change in water level, but still be near shore for accessibility. The staff gage needs to be placed in areas away from general use navigation zones, but still be visible from land (binoculars can be used if monitoring from land or dock) or accessible by boat (depending on how the volunteer chooses to monitor the gage) throughout the field season. It may also be a good idea to coordinate placement/orientation of the gage with the lake level volunteer and/or lake association to ensure that the volunteer can efficiently monitor (i.e. facing a dock, towards the shore, or lake if reading via boat) (NLDC 2013). Do not install a staff gage too close to shore if the lake bottom remains shallow over a long distance, as the gage may come out of the water during times of low water (USACE Fact Sheet 2015).

It is strongly encouraged that the staff gage is placed in the lake adjacent to public land. If the staff gage is located on private land, please ensure that you have a written agreement (“Release of Claims”) for staff to gain access to the property in order to avoid trespassing issues during the monitoring season. Whenever possible, place the staff gage near an existing elevation bench mark for ease of surveying.

## V. Installation of Staff Gage

Once your installation site is selected, please use the following steps to properly install the staff gage in the lake bottom:

1. While on land, fasten the staff gage, the two mini levels, and the DNR Contact Information Card to the wooden board (Figure 2).

- a. One mini level should be installed in the upper right corner of the board near the top of the staff gage. The other level should be installed on the side of the board near the top.
- b. The levels need to remain highly visible and stay above water throughout the monitoring season to aid the volunteers in confirming movement of the gage.



2. Install a heavy stainless steel lag bolt at the '0.00' line on the staff gage for the leveling rod to set on when surveying the gage. Be sure to have the highest point of the lag bolt (which the leveling rod will rest on) to be even with the top of the '0.00' line on the staff gage (Figure 3).



3. Attach the wooden board to the fence post using a single bolt at the bottom of the board. Doing this keeps the top part of the post free when using the fence post driver to install the post in the lake bed.
  - a. Prior to installation, you may also want to drill additional holes into the fence post to allow for the proper spacing of bolts when securing the wooden board to the post.
4. With the staff gage attached as described above, carry the gage and fence post out to where the gage reading is approximately 1.7 ft.
5. From there, pound the post down until the gage reads 2 ft.
  - a. Be sure to drive the fence post or pipe into the ground so that the gage will stay stable through high water or bad weather. The staff gage installer should not be able to move the post with their hands when it is properly installed.
  - b. The sign post needs to be as straight as possible (use a builder's level to help determine straightness), so that when the wooden board and staff gage are securely attached to the post, both can be properly surveyed using the survey equipment.
6. Once the post is set, fasten the board onto the post using stainless steel bolts at top and middle of gage (the bottom is already attached – see Step 2).
7. Use the mini levels and a builder's level to double check that the staff gage is vertical.
  - a. Reinstall the gage if it is not vertical.
8. Record the location of the staff gage using a GPS and take photographs of it from the shore.

## VI. Establishing Reference Marks and Surveying the Staff Gage

In order to determine the water surface elevation, the staff gage needs to be leveled and tied into a surveying reference mark (a fixed object that can be referred to each year). All reference marks should be very stable and permanent to ensure consistent measurements from one year to the next. Reference marks can be on bridges or other permanent structures, or if the site is relatively secluded, can be: a steel rod driven into a firm soil base, a capped pipe driven into the lake-bed below the water surface and freezing area, lag bolts in power poles, chiseled squares in concrete, file marks in bridge rails, or a cross or circle on a prominent point on a boulder in close proximity to the installation site (U.S. EPA, 2014). A nail in a tree should only be used as a last resort as trees can grow substantially and can grow right over the nails over the years. Please contact Lindsey Albright or Katie Hein if you have any questions about suitable reference marks for this program.

The purpose of conducting a survey of the reference marks and the staff gage is to detect changes in elevation of the staff gage relative to that of the reference marks. Therefore, knowing the absolute elevation of each reference mark is unnecessary, and the reference marks can be assigned a relative elevation to be used as part of the elevation calculations described below.

Bench marks are permanent structures with known elevation (vertical and (or) horizontal coordinates). If possible, one of the reference marks used should be a bench mark. Existing bench marks that are tied to formal datums (e.g., NAVD88) can be found here (make sure that the bench mark of interest lists its vertical elevation): <http://www.sco.wisc.edu/controlfinder/controlfinder.html>. Bathymetric lake maps are available at <http://dnr.wi.gov/lakes/documents/LakeMaps.aspx> - many of them show the location of DNR bench marks (many with an arbitrarily assigned elevation of 100 ft).

Surveying equipment, including a tripod, a leveling instrument, and a stadia rod, will be used to survey the staff gage into the reference bench marks. The survey equipment needs to be calibrated *no less than one week* before surveying bench marks and staff gages for this program. FYI: the surveying process needs to be *duplicated* on the day of installation in order to guarantee against large error in the survey readings. The survey should be conducted in pairs, with the survey equipment *recalibrated* between the two surveying events.

During the survey process (establishing reference marks, leveling survey equipment, surveying the reference marks and staff gage), use the surveying data sheet to record all relevant documentation information.

Please use the following steps to properly survey the staff gage at the monitoring location:

1. Before beginning the survey, establish three different reference marks (RM) along the lakeshore to calibrate the staff gage. *These reference marks must be used as part of all future lake level monitoring activities at this location unless the reference mark is damaged or removed.*
  - a. Record the location of each reference mark using a GPS and take pictures of the bench mark and surrounding area. Be sure to include identifying features in the photo.
  - b. Sketch the locations of the reference marks in relation to the location of the staff gage. By clearly documenting both the location of the reference marks and any relevant site features, it will be easy to locate them during subsequent surveys.

2. If the reference mark is a bench mark, then the vertical elevation is known. If not, assign an arbitrary elevation of either 10 ft or 100 ft to each RM and record the elevations on the datasheet (see Appendix B).
3. Set up the tripod in a centralized location where the staff gage and reference marks are visible and attach the leveling instrument. Be sure to follow the levelling procedures for the auto level before continuing with the survey.
4. Have a partner take the stadia rod and place it on the first RM (RM1). Then read the height of the rod through the instrument (intersection of the cross-hair with the image of the staff). This reading is called your back sight reading, BS (Figure 4).
  - a. The number read from the rod is added to the known elevation of the reference mark and is called the height of the instrument, HI ( $HI = \text{'Assigned Elevation'} + BS$ ).

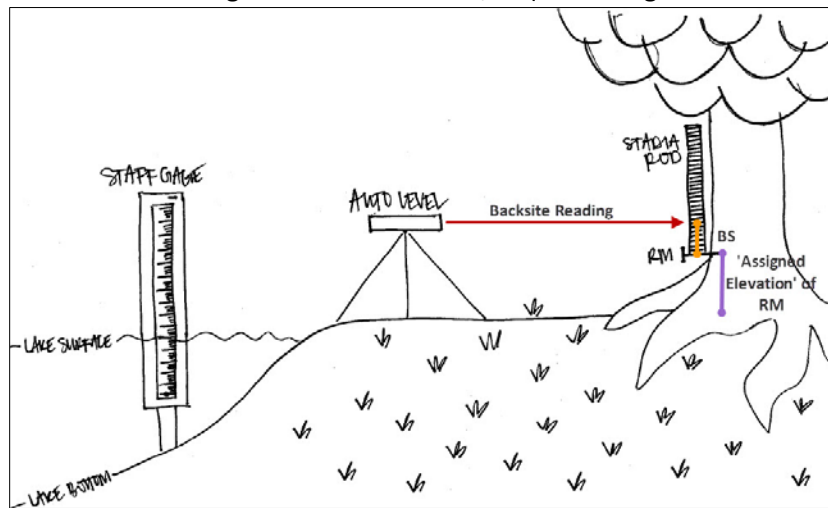


Figure 8. Taking a backsight reading (BS) of a reference mark (RM) with an auto level and stadia rod

5. Record the BS and HI values on the data sheet.
6. Place the rod on the heavy stainless steel lag bolt at '0.00' marker of the staff gage and read the rod through the survey instrument. This reading is called your fore sight reading, FS (Figure 5).
  - a. The elevation of the staff gage =  $HI - FS$ .

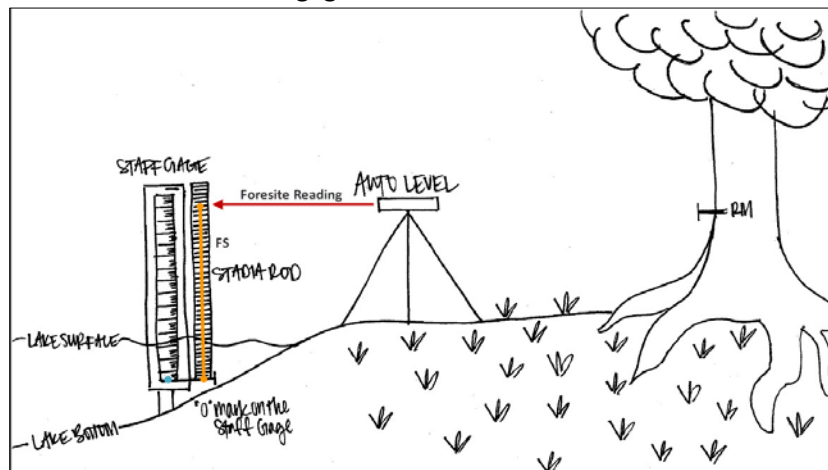


Figure 9. Taking a foresite reading (FS) of a staff gage with an auto level and stadia rod

7. Record the FS and calculated elevation value for the staff gage on the data sheet.
8. Repeat steps 6 through 8 for all additional reference marks in your survey (RM2 and RM3)
9. Place the rod back on RM1 and read the rod through the survey instrument once again and record the final BS reading on the data sheet. See Figure 6 for a diagram of the survey site.

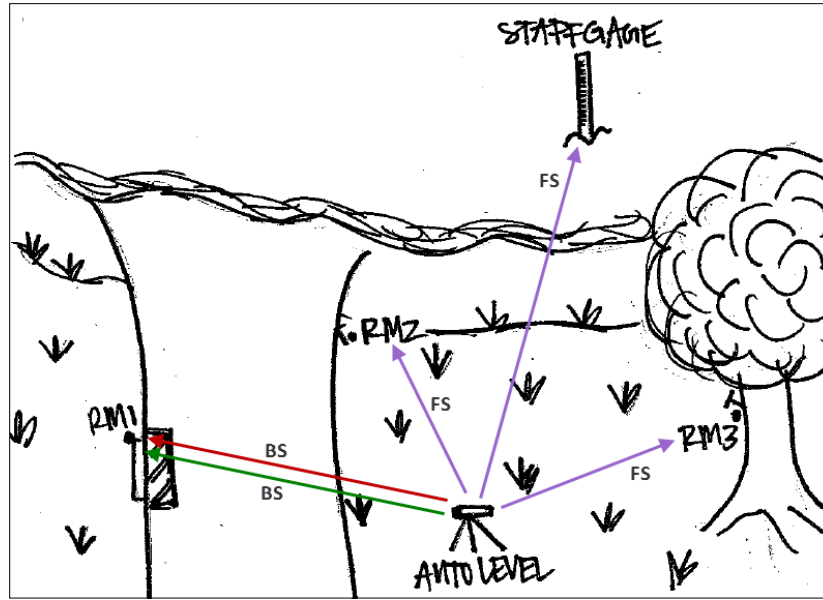


Figure 10. Diagram of the survey site.

- a. Compare the beginning and ending BS values for the RM1 to ensure no movement of the surveying equipment during the survey.
  - b. If the values do not match (within 0.01 ft), repeat the entire survey.
10. For quality assurance, re-set the surveying equipment and survey the three reference marks and staff gage again (repeating steps 4 through 9) to guarantee against large error.
  - a. The two readings should agree with one another with no more than 0.01 ft difference between them.
  - b. For consistency, accept the first of the two readings and use this value for the remainder of the season when making comparisons with observations during subsequent calibrations.
11. Upon completing the survey, take a water level reading and record it on the data sheet.

The above procedure is sufficient for surveying the staff gage, but if the reference marks do not have known vertical elevations, the water level cannot be tied to mean sea level. To ensure the longevity of these records, we recommend obtaining the mean sea level of your reference marks using a real-time-kinematic GPS (RTK-GPS). This process should be done for all three reference marks when a lake group, the county, or the WDNR initiates water level monitoring. A survey using the RTK-GPS should be replicated on the 11<sup>th</sup> year of the monitoring program and every 10 years thereafter. Please contact professionals with the proper equipment (e.g., NRCS) to tie your reference marks to mean sea level.

## VII. Mid-Season Resurveying of the Staff Gage

During the field season, large storm events or human tampering could move the gage, introducing error to lake level readings for the remainder of the summer. It is not the responsibility of the installer to check on the gage throughout the monitoring season as CLMN volunteers will be trained to monitor the stability and placement of the staff gage using the mini levels attached to the gage board.

If the volunteer or local coordinator notices that the staff gage has moved at any point during the field season, the staff gage and reference marks will need to be resurveyed following the procedures laid out

in **Section VI. Establishing Reference Marks and Surveying the Staff Gage**. If the gage is still within 0.01 ft of the original survey (survey results should be documented in SWIMS or be made available in hard copy format), then staff gage monitoring can continue as is. However, if the gage has moved more than 0.01 ft since the original survey was conducted, follow this procedure to resurvey the gage:

1. Use the mini levels on the gage to determine if the gage is straight.
  - a. If straight, the gage does not need to be resurveyed at this time (skip the following procedure) and just record a water level reading.
  - b. If crooked or unstable, prepare to reposition and resurvey the gage (continue to Step 2).
2. Take a water level reading off of the staff gage.
3. Resurvey the staff gage and three reference marks and fill out the datasheet accordingly.
4. Reposition the gage so that it is vertical. If necessary, remove the fencepost and gage, repair, and reinstall in the lake bed.
5. Resurvey the staff gage and three reference marks and fill out the datasheet accordingly.
6. Take a water level reading off of the staff gage.
7. Enter the newly collected survey and water level information into the Surface Water Integrated Monitoring System (SWIMS) database.
8. Be sure that lake level readings after this date are tied to the mid-season survey information, not the original survey conducted at the time of the spring installation.
  - a. Contact Lindsey Albright or Jennifer Filbert if you have any questions about this process.

If the staff gage moves during the field season and is resurveyed along with the reference marks, the RTK-GPS survey does not need to be repeated during the resurveying effort. This process should only be done at installation during the first year of the monitoring program and every 10 years thereafter.

## VIII. Staff Gage Removal

At the conclusion of the field season, the staff gage will need to be resurveyed (using the same reference marks established in the spring) and then removed from the lake and stored for the winter. Please follow the aforementioned surveying protocol described in **Section VI. Establishing Reference Marks and Surveying the Staff Gage** for more information about the proper surveying methods.

Upon removing the staff gage from the lake, perform a quick visual inspection of the gage plate, wooden board, and fence post. Remove any attached mud, debris, or organic materials. Determine if the bolts need to be replaced and if the fence post is straight. Be sure to note on the data sheet what maintenance is recommended for the staff gage during the offseason.

Once fieldwork is concluded for the season, the staff gage can be delivered to either the local or statewide coordinator for further maintenance (if required) and winter storage.

## IX. Equipment Upkeep

Following the conclusion of the monitoring season, the surveying equipment will need to be properly calibrated before being used as part of the WDNR's lake level monitoring program the following spring. Please review the calibration instructions associated with your leveling equipment to ensure your equipment is properly maintained during the off season.

After the staff gage has been removed from the lake, detach the wooden board from the fence post and evaluate it for any necessary repairs. You do not need to remove the gage from the wooden board in preparation for winter storage. Clean both the gage and the fence post with a scrub brush before storing for the winter, making sure to remove and rinse off any mud, plant material, mussels, or other visible organic material that is attached to the gage and/or fence post. Pay particular attention to any holes or crevices in the equipment during the cleaning process. For staff gages that are especially dirty, baking soda can be used to help clean the gage plate.

## X. Data Management

Staff gage survey information must be collected following the protocol listed above in order for it to be used as part of the WDNR's lake level monitoring program. Proper record keeping in the field is integral to the success of this program as the survey data (reference mark coordinates) will be used as part of all future lake level monitoring efforts at a particular lake.

After the survey is complete, you should be in possession of the following documents:

- Survey Calibration Data Sheet (complete)
- Photographs of the three reference marks and the staff gage
- GPS coordinates of the three reference marks and the staff gage
- Site Diagram including the location of the staff gage and the three reference marks
- Mean sea level for primary reference mark

Depending on the preference of the local or statewide coordinator, you will either be directed to enter the survey information directly into the SWIMS database or to provide all documentation to the local statewide coordinator for them to enter the data into the system. If entering the data yourself, please use the following directions when entering the survey metadata and uploading calibration survey data sheets and reference mark photographs into SWIMS.

**\*\* When entering survey data into SWIMS, please keep in mind that all '0' values will be recorded as data points which could lead to mis-interpretation of the results down the line. If you did not measure it, please leave the data entry screen blank and do not enter a '0' value'.**

### *Recording staff gage location in SWIMS:*

Before you can enter data from that staff gage calibration process into SWIMS, a SWIMS station needs to be created for the staff gage location. After you have completed the install and surveying, **please email the coordinates for the staff gage to Lindsey Albright in order for the station to be created.** Once this process is complete, you will be directed to enter the remaining calibration information into SWIMS.

### *Entering metadata into SWIMS:*

1. Open Internet Explorer and log into the SWIMS database (<https://dnrx.wisconsin.gov/swims>) with your WAMS ID and password.

**Wisconsin Department of Natural Resources**

**Surface Water Integrated Monitoring System (SWIMS)**



Enter your User ID and Password to sign in

User ID

Password

---

**DNR Staff:**  
Log in with your Oracle ID and Password

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**Volunteers and Others:**  
Our log-in screen has changed. Log in with your Wisconsin User ID and Password above.  
[Forgot your password?](#)  
[Get a Wisconsin User ID and Password](#)

2. Click on the 'Submit Data' tab at the top of the screen.

**Wisconsin Department of Natural Resources**

**Surface Water Integrated Monitoring System (SWIMS)**

My Projects Find Data **Submit Data** Stations Forms Reports, Maps, and Data

**My Projects**

3. Click the 'Add New' link in the second box on the screen.

My Projects Find Data Submit Data Stations

**Submit Data**

**Monitoring Data**

Use the 'View List' link in the top box to view and edit previously entered

4. Select the **Project** and then the **Station**

Project \* Citizen Water Level Monitoring - Axhandle Lake - Calibration

Data Collectors \*

Station \* 10001971, Axhandle Lake

- a. From the **Project** dropdown menu, you need to select the correct monitoring project for the lake. The project is called '**Citizen Water Level Monitoring – LAKE – Calibration**'.
- b. Select the station you wish to enter data from the Station dropdown menu.

- c. If your monitoring location is not listed in the Station dropdown menu, please do not enter your lake level data at this time, but instead contact Lindsey Albright or Jennifer Filbert to get your SWIMS account assigned to the correct station(s).
5. Select yourself or your group of **Data Collectors**.

**Create Monitoring Data**  
Fields denoted with an asterisk (\*) are REQUIRED.

Project \* Citizen Water Level Monitoring - Axhandle Lake - Calibration

Data Collectors \* LINDSEY ALBRIGHT

Station \* 10001971, Axhandle Lake Show Map

- a. If the correct list of data collectors is not in the list, contact Lindsey Albright or Jennifer Filbert to get the correct collectors added to the dropdown menu.
6. Click the 'Select Date' button to enter the **Start Date**.

Start Date \*

Time

Form \*

- a. The monitoring date must be entered in the mm/dd/yyyy format
7. Enter the **Time** that you started your data collection work.

Start Date \*

Time

Form \*

- a. SWIMS requires the start time information (enter AM or PM) for all monitoring data.
8. Select the **Staff Gage Calibration Data Sheet** form.

**Create Monitoring Data**  
Fields denoted with an asterisk (\*) are REQUIRED.

Project \* Citizen Water Level Monitoring - Axhandle Lake - Calibration

Data Collectors \* LINDSEY ALBRIGHT

Station \* 10001971, Axhandle Lake Show Map

Start Date \* 07/06/2015

Time 10 00 AM

Form \* Staff Gage Calibration Data Sheet

- a. If it is not available, you will need to contact Lindsey Albright or Jennifer Filbert to correct this before you will be able to enter your monitoring data.
9. You can ignore the End Date and Time field. It is not necessary that you enter this information.

End Date

Time

Comments

10. Add any **Comments** you recorded from your field data sheet and then click **Next** to go to the field work data entry screen.

Comments

Fill in the weather here, lake or streamside observations, wildlife spotted, names of additional helpers etc..

Save and Return Save **Next**

11. For **Reference Marks 1, 2, and 3** fill in the following information from the datasheet:

| Staff Gage Calibration Data Sheet |                          |        |       |
|-----------------------------------|--------------------------|--------|-------|
|                                   | Parameter                | Result | Units |
| Reference mark 1                  | Reference Mark Type      |        |       |
|                                   | Latitude                 |        |       |
|                                   | Longitude                |        |       |
|                                   | Mean Sea Level?          | ▼      |       |
|                                   | Mean Sea Level Elevation |        | ▼     |
|                                   | Photograph?              | ▼      |       |
|                                   | Location Description     |        |       |

- Mean Sea Level:** 'Yes' or 'No' options depending on if the RTK-GPS survey was conducted for the reference mark.
- Mean Sea Level Elevation:** Feet is the only option for units.
- Photograph:** 'Yes' or 'No' options.

12. **Record the survey information** for each reference mark and the staff gage:

|             |                           |  |   |
|-------------|---------------------------|--|---|
| Calibration | Calibration event         |  |   |
| RM1         | Assigned Elevation        |  | ▼ |
|             | Backsite (BS)             |  | ▼ |
|             | Height of instrument (HI) |  | ▼ |
|             | Foresite (FS)             |  | ▼ |
|             | Calculated Elevation      |  | ▼ |

- RM1** – backsite measurement
- RM2** – foresite measurement
- RM3** – foresite measurement
- Staff gage** – foresite measurement
- RM1** – repeat backsite measurement
- If you did not measure it, please leave it blank. Entering a '0' value as a placeholder is still considered a data value and will be recorded as such in the database.

13. **Record all maintenance issues** with the staff gage, wooden board, and sign post into SWIMS.

|                       |                                            |   |
|-----------------------|--------------------------------------------|---|
| Equipment Maintenance | Replace bolts/ screws on staff gage?       | ▼ |
|                       | Replace bolts/ screws on staff gage - Date |   |
|                       | Replace bolts/ screws on staff gage - Name |   |
|                       | Replace gage plate on staff gage?          | ▼ |
|                       | Replace gage plate on staff gage - Date    |   |
|                       | Replace gage plate on staff gage - Name    |   |
|                       | Replace post or wooden board?              | ▼ |
|                       | Replace post or wooden board - Date        |   |
|                       | Replace post or wooden board - Name        |   |

14. Once you are done entering survey date select one of the following options:

Next Date Next Station Save and Return to List

- a. Click **Next Date** to enter more lake level data for same site. If you have data for several dates at the same site, choose this option.
- b. Choose **Next Station** to enter data for a different site on the same date.
- c. Click **Save and Return to List** to enter data for other sites. If you choose this option, you will see a list of all data you have entered for your sites.

Please contact Lindsey Albright or Jennifer Filbert if you have any questions about or issues with the data entry process in SWIMS.

*Uploading survey documentation (data sheet and photographs) into SWIMS:*

As of right now, photographs and PDFs cannot be uploaded to SWIMS through the data entry portal, so please scan and email all data sheets and field photographs to Lindsey Albright or Jennifer Filbert to be uploaded to SWIMS directly. Contact Lindsey or Jennifer with any questions.

## **XI. Quality Assurance and Quality Control**

*Field Quality Assurance and Quality Control*

On the day of installation, the survey of the staff gage and reference marks should be replicated. This is to be done by re-setting the surveying equipment after completing the first survey and then surveying the three reference marks and staff gage again in order to guarantee against large error. The two readings must agree with no more than 0.02 ft (or 5 mm) difference between them or the survey must be completed for a third time. The first of the two readings is to be used for the remainder of the season during subsequent calibrations when reviewing lake level data.

Surveyors are not responsible for returning to the staff gage during the field season to check the verticalness unless requested to do so by the local or statewide coordinator. Volunteers will be trained to evaluate the verticalness of the gage using the mini levels on the board.

*Data Entry Quality Assurance and Quality Control*

Please be sure to double-check the information that you are entering into the SWIMS database. The results from the survey will be used for the remainder of the season (unless the staff gage moves and needs to be resurveyed) so it is integral to the success of the program that the information be accurate.

## XII. References

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- U.S. Army Corps of Engineers Fact Sheet (accessed 2/4/2015)  
<http://www.nwo.usace.army.mil/Media/FactSheets/FactSheetArticleView/tabid/2034/Article/487672/staff-gage-setup-instructions.aspx>
- U.S. EPA. Best Practices for Continuous Monitoring of Temperature and Flow in Wadeable Streams (Final Report). U.S. Environmental Protection Agency, Office of Research and Development, National Center for Environmental Assessment, Washington, DC, EPA/600/R-13/170F, 2014.

## Glossary

**Backsight Reading (BS):** a reading on the stadia rod, to the nearest 1/100th foot, taken when looking through the instrument (level) back toward a point of known elevation that is used to establish a height of an instrument.

**Bench Mark (BM):** a permanent marker with known survey control of vertical and (or) horizontal coordinates in an established geodetic system, such as the North American Vertical Datum of 1988. Bench marks used during survey activities are often established by the United States Geological Survey (USGS). Common bench marks include: a bronze tablet set in concrete or a “X” or “+” etched in concrete, rock, or some other permanent type structure. At secluded locations, a Reference Mark (RM) is often used in place of a Bench Mark.

**Engineer’s Level:** a surveying instrument consisting of a minimum of a telescopic sight and a sensitive leveling device to make the line of sight horizontal.

**Foresight Reading (FS):** a reading on the stadia rod, to the nearest 1/100th foot, taken when looking through the instrument (level) forward toward a point of unknown elevation (staff gage).

**Gage Datum:** the zero elevation reference surface at a gaging station to which all gages are set.

**Height of Instrument (HI):** the elevation of the horizontal line of sight (crosshairs), or viewing elevation of the level.

**Reference Mark (RM):** a permanent marker, typically an “X” or “+” sign etched in concrete, a bolt, or other “permanent” feature whose elevation above a set datum is known. A Reference Mark can be used to check and make sure that all gages and reference points are properly set to gage datum.

**Stadia rod:** a survey tool used when running levels at gaging stations or staff gages. Used in conjunction with the engineer’s level to read the elevations of bench marks, reference marks, and establish the height of unknown location(s).

**Staff Gage:** a graduated measuring instrument that can be visually read from the shore or by boat

\*Glossary terms and definitions cited from Kenney, 2010 and Lipe, “Step-By-Step Instructions for Leveling a Staff Gage” (accessed 2/10/2015)

### Mathematical Equations in Surveying:

Height of Instrument (HI) = Reference Mark (RM) + Backsight Reading (BS)

Elevation of Staff Gage = Height of Instrument (HI) – Foresight Reading (FS)

## Appendix A. Staff Gage Surveying Field Instructions

Use the following procedure when calibrating the staff gage and reference marks.

1. Establish three different reference marks (RM) along the lakeshore to calibrate the staff gage.
  - a. Record the location of each RM using a GPS.
  - b. Take pictures of each RM. Be sure to include identifying features of surrounding area.
  - c. Sketch the locations of the RMs and staff gage on the datasheet.
2. Assign an arbitrary elevation of either 10 ft or 100 ft to each RM (unless the vertical elevation is known) and record the elevations on the datasheet.
3. Set up the tripod in a centralized location and attach the leveling instrument. Be sure to follow the leveling procedures for the auto level before continuing with the survey.
4. Place the stadia rod on the first RM (RM1) and read the height of the rod through the instrument. This reading is called your backsight reading, BS (Figure 6).
  - a. The height of the instrument (HI) is calculated by adding the backsight reading to the known elevation of the reference mark and is called ( $HI = \text{'Assigned Elevation' + BS}$ ).

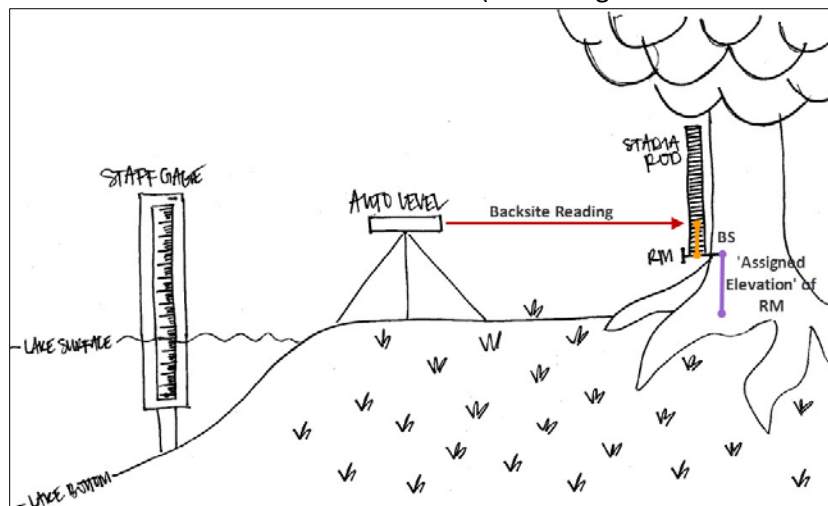


Figure 6. Taking a backsight reading (BS) of a reference mark (RM) with an auto level and stadia rod

5. Record the BS and HI values on the data sheet.
6. Place the rod on the heavy stainless steel lag bolt at '0.00' marker of the staff gage and read the rod through the survey instrument. This reading is called your foresite reading, FS (Figure 7).
  - a. The elevation of the staff gage =  $HI - FS$ .

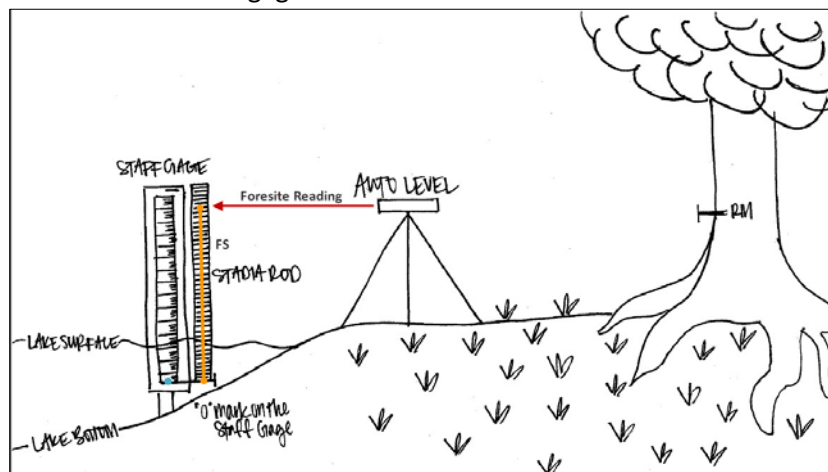


Figure 7. Taking a foresite reading (FS) of a staff gage with an auto level and stadia rod

7. Record the FS and calculated elevation value for the staff gage on the data sheet.
8. Repeat steps 6 through 8 for all additional reference marks in your survey (RM2 and RM3)
9. Place the rod back on RM1 and read the rod through the survey instrument once again and record the final BS reading on the data sheet. See Figure 8 for a visual depiction of the survey.

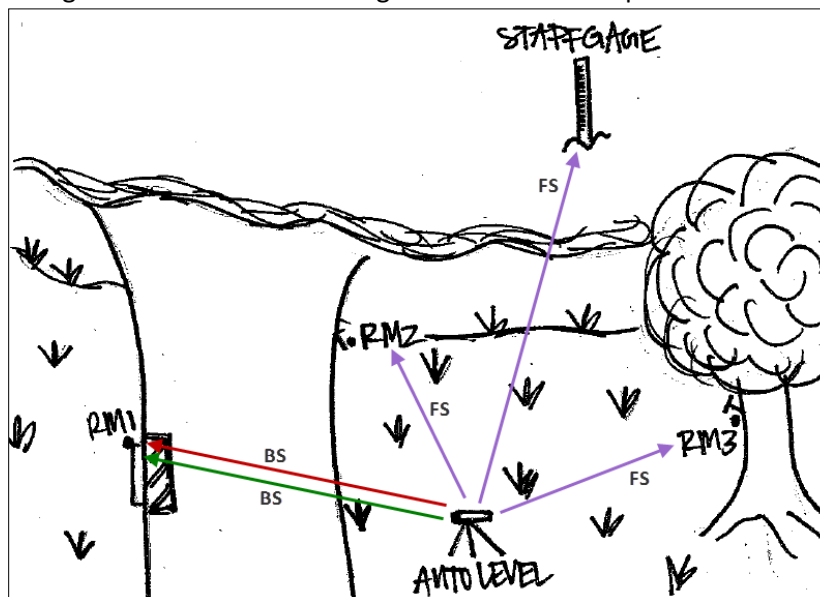


Figure 8. Visual depiction of a completed survey

- a. Compare the beginning and ending BS values for the RM1 to ensure no movement of the surveying equipment during the survey.
- b. If the values do not match (within 0.01 ft), repeat the entire survey.
10. For quality assurance, re-set the surveying equipment and survey the three reference marks and staff gage again (repeating steps 4 through 9) to guarantee against large error.
  - a. The two readings should agree with one another with no more than 0.01 ft difference between them.
  - b. For consistency, accept the first of the two readings and use this value for the remainder of the season when making comparisons with observations during subsequent calibrations.
11. Upon completing the survey, take a water level reading and record it on the data sheet.

The above procedure is sufficient for surveying the staff gage, but if the reference marks do not have known vertical elevations, the water level cannot be tied to mean sea level. To ensure the longevity of these records, we recommend obtaining the mean sea level of your reference marks using a real-time-kinematic GPS (RTK-GPS). This process should be done for all three reference marks when a lake group, the county, or the WDNR initiates water level monitoring. A survey using the RTK-GPS should be replicated on the 11<sup>th</sup> year of the monitoring program and every 10 years thereafter. Please contact professionals with the proper equipment (e.g., NRCS) to tie your reference marks to mean sea level.

## Appendix B. Staff Gage Calibration Data Sheet

### Wisconsin DNR – Lake Level Monitoring Staff Gage Calibration Data Sheet

#### Lake Information

Lake Name \_\_\_\_\_ County \_\_\_\_\_

#### Data Collectors

Primary Data Collector \_\_\_\_\_ Email \_\_\_\_\_ Phone No. \_\_\_\_\_  
( ) -  
Additional Data Collector(s) \_\_\_\_\_

#### Reference Mark and Staff Gage Information

**Reference Mark #1 (RM1)** Reference Mark Type: \_\_\_\_\_  
Latitude: \_\_\_\_\_ Longitude: \_\_\_\_\_ Mean Sea Level Yes ☐ No ☐ Elevation: \_\_\_\_\_ Photograph ☐  
Location Description: \_\_\_\_\_

**Reference Mark #2 (RM2)** Reference Mark Type: \_\_\_\_\_  
Latitude: \_\_\_\_\_ Longitude: \_\_\_\_\_ Mean Sea Level Yes ☐ No ☐ Elevation: \_\_\_\_\_ Photograph ☐  
Location Description: \_\_\_\_\_

**Reference Mark #3 (RM3)** Reference Mark Type: \_\_\_\_\_  
Latitude: \_\_\_\_\_ Longitude: \_\_\_\_\_ Mean Sea Level Yes ☐ No ☐ Elevation: \_\_\_\_\_ Photograph ☐  
Location Description: \_\_\_\_\_

#### Staff Gage

Latitude: \_\_\_\_\_ Longitude: \_\_\_\_\_ Mean Sea Level Yes ☐ No ☐ Elevation: \_\_\_\_\_ Photograph ☐  
Location Description: \_\_\_\_\_

#### Initial Calibration\*

Date: \_\_\_\_\_ Time: \_\_\_\_\_ AM/PM Check one: Install ☐ Midseason ☐ Removal ☐  
Survey Equations:  $HI = \text{Assigned Elevation} + BS$   $\text{Calculated Elevation} = HI - FS$

| Reference Mark | Assigned Elevation (ft) | Backsite (BS) | Height (ft) of Instrument (HI) | Foresite (FS) | Calculated Elevation (ft) |
|----------------|-------------------------|---------------|--------------------------------|---------------|---------------------------|
| RM1            |                         |               |                                |               |                           |
| RM2            |                         |               |                                |               |                           |
| RM3            |                         |               |                                |               |                           |
| Staff Gage     |                         |               |                                |               |                           |
| RM1            |                         |               |                                |               |                           |

#### Secondary Calibration

Date: \_\_\_\_\_ Time: \_\_\_\_\_ AM/PM Check one: Install ☐ Midseason ☐ Removal ☐  
Survey Equations:  $HI = BS + \text{Assigned Elevation}$   $\text{Calculated Elevation} = HI - FS$

| Reference Mark | Assigned Elevation (ft) | Backsight (BS) | Height of Instrument (HI) | Foresight (FS) | Calculated Elevation (ft) |
|----------------|-------------------------|----------------|---------------------------|----------------|---------------------------|
| RM1            |                         |                |                           |                |                           |
| RM2            |                         |                |                           |                |                           |
| RM3            |                         |                |                           |                |                           |
| Staff Gage     |                         |                |                           |                |                           |
| RM1            |                         |                |                           |                |                           |

\*Accept the initial calibration - use value for the remainder of the season to compare observations from subsequent calibrations (unless the gage moves).

\*\*Shaded boxes do not need to be filled in during the survey process

Lake Level Reading: \_\_\_\_\_ ft

### Site Diagram (including Staff Gage and Reference Marks)

[illegible]

Survey Data uploaded to SWIMS? Yes ☐ No ☐ Date: \_\_\_\_\_ Name: \_\_\_\_\_

Photographs uploaded to SWIMS? Yes ☐ No ☐ Date: \_\_\_\_\_ Name: \_\_\_\_\_

Data Sheet scan uploaded to SWIMS? Yes ☐ No ☐ Date: \_\_\_\_\_ Name: \_\_\_\_\_

Replace bolts/screws on staff gage? Yes ☐ No ☐ Date: \_\_\_\_\_ Name: \_\_\_\_\_

Replace gage plate on staff gage? Yes ☐ No ☐ Date: \_\_\_\_\_ Name: \_\_\_\_\_

Replace post or wooden board? Yes ☐ No ☐ Date: \_\_\_\_\_ Name: \_\_\_\_\_