AIS STANDARD OPERATING PROCEDURE: CONDUCTING AIS SITE SURVEYS AT NEON AQUATIC SITES

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Change Record

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A	11/14/2024	ECO-07115	Initial release

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1 DESCRIPTION

1.1 Purpose

High-resolution total station surveys are conducted at NEON aquatic sites to accurately identify the locations of key infrastructure and sampling points. Initially, these surveys establish control points (or benchmarks) that serve as a geospatial reference to be used during subsequent surveys. Over time, additional surveys are conducted that reference the benchmark locations to establish new locations, validate previous locations, or relate a new location to a previous one. These surveys provide continuity in NEON datasets and establish the spatial relationships between key locations over time.

1.2 Scope

This document provides a change-controlled version of an Observatory procedure. Documentation of content changes (i.e. changes in particular tasks or safety practices) will occur via this change-controlled document, not through field manuals or training materials.

1.3 Applies To

The procedure described in this document is used in the following protocols:

Doc #	Title
NEON.DOC.003162	AOS Protocol and Procedure: Wadeable Stream Morphology
NEON.DOC.001085	AOS Protocol and Procedure: DSC – Stream Discharge
NEON.DOC.001328	NEON Algorithm Theoretical Basis Document (ATBD): Groundwater Temperature, Elevation and Specific Conductance
NEON.DOC.001198	NEON Algorithm Theoretical Basis Document (ATBD): Surface Water Elevation

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

Applicable documents contain higher-level information that is implemented in the current document. Examples include designs, plans, or standards.

AD[01]	NEON.DOC.004300	EHS Safety Policy and Program Manual
AD[02]	NEON.DOC.004316	Operations Field Safety and Security Plan
AD[03]	NEON.DOC.000724	Domain Chemical Hygiene Plan and Biosafety Manual
AD[04]	NEON.DOC.050005	Field Operations Job Instruction Training Plan
AD[05]	NEON.DOC.004104	NEON Science Data Quality Plan

2.2 Reference Documents

Reference documents contain information that supports or complements the current document. Examples include related protocols, datasheets, or general-information references.

RD[01]	NEON.DOC.000008	NEON Acronym List
RD[02]	NEON.DOC.000243	NEON Glossary of Terms
RD[03]	NEON.DOC.002652	NEON Data Products Catalog
RD[04]	NEON.DOC.005400	Datasheets for AIS Standard Operating Procedure: AIS Site Survey
RD[05]	NEON.DOC.005221	AOS/TOS Standard Operating Procedure: Trimble GEOXH Receivers Setup and Use

2.3 Acronyms

Acronym	Definition
AQU	NEON Aquatics Program
BM	Benchmark
COP	Control point
GPS	Global Positioning System
HR	Height of Rod
TS	Total station

2.4 Definitions

Fulcrum: Software tool used to create NEON electronic data entry applications.

ServiceNow: Software tool used for problem/incident tracking and resolution.

3 SAFETY

This document identifies procedure-specific safety hazards and associated safety requirements. It does not describe general safety practices or site-specific safety practices.

Personnel working at a NEON site must be compliant with safe field work practices as outlined in the EHS Safety Policy and Program Manual (AD[01]) and Operations Field Safety and Security Plan (AD[02]). Additional safety issues associated with this field procedure are outlined below. If an employee witnesses any unsafe conditions or uncontrolled hazards that present an imminent danger, they should immediately take action to stop work and report such conditions to their manager. Employees must also report all workplace injuries, illnesses, incidents, or releases to the environment as soon as possible, regardless of the severity.

When operating the total station avoid eye contact with the laser that emanates from the total station head. Be careful when transporting the total station as shifting weight can lead to slips, trips, and falls. Exercise caution when installing control points and the magnetic spikes are sharp and injuries can occur if safety standards are not followed. Always be careful when working in the riparian environments as these areas contain wet, unstable ground and thick vegetation.

4 PERSONNEL

4.1 Training Requirements

All technicians must complete protocol-specific training as required in the Field Operations Job Instruction Training Plan (AD[04]). Additional protocol-specific required skills and safety training are described here.

Before completing procedures described in this SOP, all personnel must be trained on:

- Calibration, configuration, and leveling of the total station
- Calibration and use of the prism rod and prism head.
- Setting the initial total station location using permanent benchmark coordinates
- Performing the missing line workflow if permanent benchmarks are not available or need to be re-surveyed.
- Traversing with the total station, install control points, and setting total station locations using foresight and backsight shots
- Mapping AQU infrastructure and sampling locations
- Surveying cross-section profiles
- Closing survey loops
- Survey data entry and verification

4.2 Specialized Skills

Specialized skills or subject matter expertise required to implement this procedure include:

- Use of Hilti POS-180 robotic head total station
- Use of POC-100 or POC-200 hand-held dataloggers
- Use of GPS units such as the Trimble Geo Explorer and Tornado antennas

5 CONTINGENCIES AND NOTES

Surveying should not be conducted during unsafe weather conditions and staff should never enter the stream channel when it is unsafe to do. Surveying can be completed during light precipitation if safety conditions allow, but efforts should be made to protect the total station head and ensure that moisture does not accumulate on the prism rod.

If a survey is not complete by the end of the day, installing and mapping new control points as foresights will allow for the total station location to be easily re-established the next day.

6 STANDARD OPERATING PROCEDURES

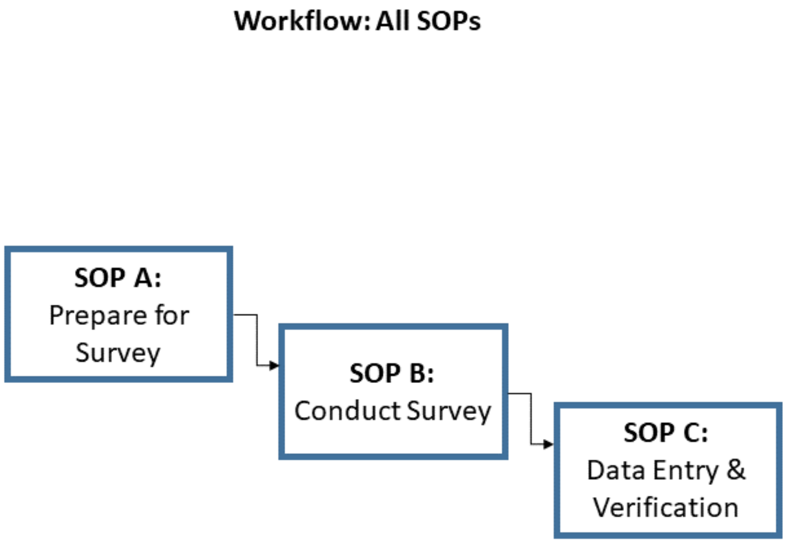


Figure 1. A high level workflow diagram that visually shows how the separate SOP sections are sequentially connected.

SOP A Preparing for the Survey

Prior to each AIS survey, objectives, logistics, and methods must be clearly defined and well-understood by all staff involved in the survey. The following sections describe tasks that must be completed prior to each survey to ensure workflows are efficient and high-quality data are collected.

A.1 Conduct a Pre-survey Meeting to Review Survey Objectives

Prior to the survey, a meeting must be conducted that includes stakeholders from all teams involved (e.g., Field Science and Science staff). Field staff should come prepared to speak to the agenda items and bring related questions. This preparation will help ensure effective survey planning, clarification of survey goals, and a thorough review of the site logistics and safety. The following items should be discussed during the pre-survey meeting:

- Survey Objectives
  - Review the survey-specific SOW to address the scope of work and plan the survey route.
    - Discuss which locations are to be surveyed and where should the shots be taken.
  - Review all available site maps. Discuss site access, orientation, safety factors, known hazards, and emergency access plans.
  - Discuss prior survey history.
- Benchmark Location
  - Discuss which benchmarks are to be used for the preliminary total station setup and loop closure.
  - Ensure that the relevant benchmark coordinate files can be accessed by all staff.
- GPS data
  - Discuss whether GPS data collection are required and, if so, where this information should be collected.
  - Discuss how many GPS logs are required to meet uncertainty objectives at the site.
  - Discuss satellite conditions at the site and how they may change throughout the day.

A.2 Review Materials, Gather Equipment, and Configure POC Settings

Prior to the survey, all staff must review the following materials:

- This SOP for general information regarding AIS surveys.
- The survey-specific SOW (provided by Science) for survey-specific objectives.
- The permanent benchmark layer in ArcGIS online, which displays real-world locations for the permanent benchmarks at each site.

  - Note that real-world coordinates are NOT used to the setup the initial total station location. Raw coordinates files are used, see **SOP A.3**.
- The "AIS Site Survey" Fulcrum application

Staff must also ensure that:

- All equipment is available (**Appendix B**) and properly decontaminated.
- All batteries are charged and available for the POC and POS units.
- The prism rod is properly calibrated (**SOP A.4**).
- POC settings are properly configured (**Table 1**).

Table 1. Required settings for the POC-100 and POC-200 handheld dataloggers. *POC coordinate display and input settings must match the heading order of the benchmark coordinate file that is loaded into the POC.

POC Model	POC Field	Required Setting	Notes
POC-100 / POC-200	Coord/Disp/Inp	ENH*	Home screen > "Config" > "Settings"
POC-100 / POC-200	Decimal Format	1000.0	Home screen > "Config" > "Settings"
POC-100 / POC-200	Angle Units	DMS	Home screen > "Config" > "Settings"
POC-100 / POC-200	Angle Resolution	1	Home screen > "Config" > "Settings"
POC-100 / POC-200	Dist Units	Metric	Home screen > "Config" > "Settings"
POC-100	Time and Date	Current time/date	Home screen > "Config" > "Time/Date"
POC-200	Time and Date	Current time/date	Home screen > "-" > select and edit time/date in lower right corner

A.3 Start a New Survey Job on the POC

Once settings have been properly configured, follow the steps below to start a new job and load the benchmark coordinate file onto the POC unit.

For both POC-100 and POC-200 units:

1. Start a new Job file.
    a. On the Home screen, select the "Jobs" tab.
    b. Select the "New" tab.
    c. Select the "ABC" button by "Job" to name the new Job file.
        i. Name the Job file appropriately using the site and date.
    d. Select "OK" to save the Job file.
2. Review and save a local copy of the site-specific permanent benchmark coordinate file.
    a. Create a folder on a USB flash drive called "Hilti Jobs".
    b. Locate the site-specific permanent benchmark coordinate file and save the .CSV file in the "Hilti Jobs" folder.

i. Contact Science if you have questions accessing the site-specific permanent benchmark folder.

c. Open the .CSV file and review the following:

i. Check that the column names in the file include 'Name', 'E', 'N', 'H', 'Attr1', 'Attr2', 'Attr3', 'Attr4', 'Attr5', 'HA', 'VA', 'HD', 'hr', 'ppm'.

1) Ensure that each of the site benchmark names/labels are contained under the 'Names' column.

ii. Ensure that the heading order of the 'E', 'N', and 'H' values matches the order in the "Coord/Disp/Inp" setting of the POC (**Table 1**).

1) Critical survey errors will occur if these values are mis-matched.

3. Upload the benchmark coordinate file to the POC.

a. Insert the USB drive that contains the .CSV file into the POC.

b. On the POC Home screen, select the "File" tab.

c. Select "Import".

d. For POC-100 units:

i. Select "To Job" to designate the name of the job defined in Step 1c.

ii. Ensure file units are set to Meters.

iii. Ensure "Data Format" is *.csv.

iv. Select the box next to "From File".

v. Choose the .CSV file that was loaded onto the USB drive.

1) An error here may indicate that the .CSV file was not saved under a folder entitled "Hilti Jobs" folder on the USB flash drive.

vi. Click "OK".

vii. On the 'Import Design Points' screen, click "OK".

viii. The "Importing Points" screen will appear followed by "X points were imported".

ix. Click "OK".

x. On the 'Select Task' screen, click "OK".

xi. The benchmark coordinates should now be loaded into the Job file.

e. POC-200 units:

i. Select the "Select File" box.

ii. Select the "USB" button on the top of the screen.

iii. Choose the .CSV file that was loaded onto the USB drive.

iv. Click “OK”.

v. Ensure file units are set to Meters.

vi. Ensure that the correct Job File is selected.

1) Load the correct Job file if needed by selecting the dialog box.

vii. Click “OK”.

viii. The benchmark coordinates should now be loaded into the Job file.

A.4 Calibrate the Prism Rod and Prism Head

A calibration of the prism head (Hilti POA 20) and prism rod (Hilti POA 52) is required prior to the beginning of each NEON total station survey. This procedure directly impacts the precision of the survey data. This calibration is best done in the office prior to the total station survey. It is critical that when the prism rod is level, the prism head is also level, and vice versa. The prism head and prism rod each contain a bubble level to evaluate the level of the rod during surveying. One level is located towards the top of the prism rod (prism rod level), the second is located on top of the 360° prism (prism head level).

Once an initial calibration has been performed it is not necessary to perform another calibration of the prism or prism rod during the total station survey unless either instrument has been dropped, potentially damaged, or is noticeably out of level during use.

The following tools are required:

- One-foot or two-foot bubble level
- Allen wrench (2.5mm)

To calibrate the prism head and prism rod (**Figure 2**):

1. Attach the 360° prism head to the prism rod and level the prism rod using the bipod.
2. Ensure that the prism rod level bubble is perfectly centered.
3. Place the one/two-foot level on one side of the prism rod to check the level on this plane.
    a. If the rod is out of level make slight adjustments at the base of the rod to bring it into level.
    b. Setting up the rod on a carpeted surface is helpful as it gives the tip of the rod something to stick to.
4. Rotate the one/two-foot level 90° and check the level on the other plane of the prism rod.
    a. If the rod is out of level make slight adjustments at the base of the rod to bring it into level.

5. Re-check the prism rod level bubble.
6. Release the prism rod clamp (used to adjust the height of rod) slightly and rotate the prism rod 360°.
7. Re-check the prism rod level bubble.
    a. If the prism rod is level on both planes using the one/two-foot level, and the prism rod level bubble remains perfectly centered following the rotation, proceed to **Step 11.**
    b. If the prism rod level bubble does not remain perfectly centered following the rotation, proceed to **Step 8.**
8. Tighten the prism rod clamp.
9. Using the Allen wrench, adjust the three screws under the prism rod level bubble until the bubble is in the exact center of the circle.
    a. Be sure not to bump the prism rod while doing this.
    b. It is critical that the prism rod remains perfectly level in both planes while adjusting the prism rod bubble level.
10. Once the prism rod level bubble has been adjusted, release the prism rod clamp (used to adjust the height of rod) slightly and rotate the prism rod 360°.
    a. If the prism rod level bubble remains perfectly centered following the rotation, proceed to **Step 11.**
    b. If the prism rod level bubble does not remain perfectly centered following the rotation, return to **Step 8** and re-adjust the prism rod level bubble with the Allen wrench**.**
11. Check the prism head level at the top of the 360° prism head.
    a. If the prism head is level (bubble is in the exact center of the circle), calibration of the prism and prism rod is complete.
    b. If the prism head is not level (bubble is not in the exact center of the circle), proceed to **Step 12**.
12. Using the Allen wrench, adjust the three screws surrounding prism head level bubble until the bubble is in the exact center of the circle.
    a. Be sure not to bump the prism rod while doing this.
    b. It is critical that the prism rod remains perfectly level in both planes while adjusting the prism rod bubble level.
13. Check the prism level at the top of the 360° prism head.
    a. If the prism head is level (bubble is in the exact center of the circle), proceed to **Step 14**.

   b. If the prism head is not level (bubble is not in the center of the circle), return to **Step 12.**

14. Confirm that the prism rod has remained level on both planes with the one/two-foot level.
   a. If level, calibration of the prism rod and prism head is complete.
   b. If out of level, return to **Step 5** and repeat calibration process.

Figure 2. Calibrating the prism rod and prism head. A one-foot or two-foot level may be used to check the level of the prism rod.

A.5 Field Calibrate the Total Station

A calibration of the total station is required prior to the beginning of each NEON total station survey. Field calibration should be completed, at minimum, one month prior to a survey event (well in advance is suggested, e.g., 60 days) to allow adequate time if factory calibration or repair is needed. This calibration procedure is best performed outdoors, it can be conducted outside the office or in the field. Shipping and rough handling are the most common causes for failing calibration; care should be made to reduce jostling of the POS (the robotic head) during transportation and the survey.

Once an initial total station calibration has been performed it is not necessary to perform another field calibration during the survey unless the instrument has been dropped, potentially damaged, or is exhibiting signs of malfunction. Contact Science if any of these situations occur.

To perform a field calibration of the total station:

1. Set up and level the total station (TS) (see **SOP B.1**) in an area with a clear view to a target location 30 meters away.

   a. Avoid direct sunlight on the objective lens aperture.
   b. Spin the TS head in all directions to confirm that the TS is perfectly level.
   c. If finding an acceptable location where a 30-meter distance cannot be achieved near the site, perform the calibration along a road or parking lot.
2. Open the Calibration table in the Fulcrum app to record pre and post calibration values.
3. Check that the laser point aligns with the TS cross hairs.
   a. Use a measuring tape to set up the target plate (**Figure 3**) 30 meters from the TS.
   b. The plate can be taped to a prism-bipod setup so that the plate is flat, and TS cross hairs can align with the triangles.
   c. Set the plate at roughly the same height as the TS.
   d. Note: If there is no test plate with your TS kit one can be made by drawing a 10mm diameter circle on a sheet of paper and marking a dot at the exact center (**Figure 2**).
   e. Manually sight in the plate so that the cross hairs in the scope sight are perfectly in line with the center of the target plate.
      i. Use the dials on the side of the robotic head to adjust the focus (top knob) and move the head up/down (center knob) and left/right (lower knob).
   f. Switch on the laser pointer from the POC controller into RL (reflector-less laser) mode.
      i. (WARNING: Never stare directly into the laser beam).
   g. Push the lower right button on the POC controller  to take you to the prism search screen.
   h. In the upper right portion of the screen select the “EDM” option. Click and advance through the following options until you reach “DR: Laser On”.
      i. Prism Auto: Automatic prism tracking and continual distance measurement.
      ii. Prism Manual: Distance measurement at the touch of a button.
      iii. DR: Laser On: Reflector less distance measurement with laser pointer switched on (ensure that this option is selected).
      iv. Deviation from the center should be no more than 5mm at the 30m distance.
         1) This threshold can be visualized by the triangles on the target plate, i.e. it is considered a failed calibration if the laser enters the triangles a 30m distance.
         2) If the deviation is greater than 5mm, contact Science as Hilti repair service may be required.

3) Note that it may be difficult to see the laser from the TS, walk up to the target plate to confirm laser location.

v. Enter whether the laser was within the target threshold in the app.

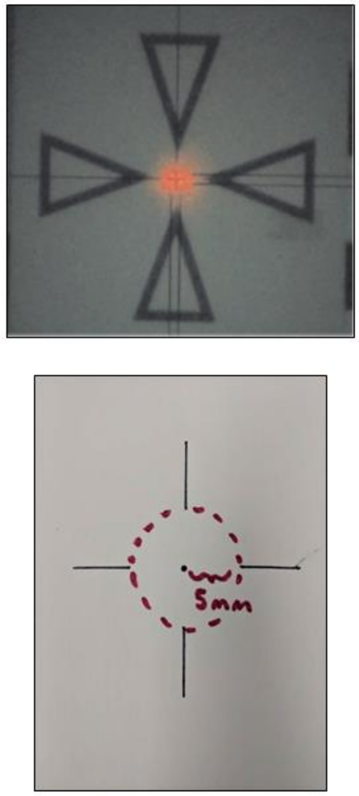


Figure 3. Above: Hilti target test plate with laser in the center. Below: Hand drawn target plate that includes a 10mm diameter circle with center point with 5mm delineation added.

4. During the remaining TS calibration steps:
    a. Setup and level the prism on bi-pod 50m away from the TS with a clear line of site.
    b. Best practice is to avoid direct sunlight on the prism or in the objective lens aperture.
    c. Placing your hand or a large folder over the prism, while being very careful not to touch or un-level the prism, is one way to shade the prism in extremely sunny conditions.
    d. Confirm that the bipod is level throughout the calibration process.
    e. On the Main screen of POC select “Config” > “Calibration”.
    f. Record these values that are displayed on the first screen into the app:
        i. HA – Collimation
        ii. VA – Collimation

iii. Comp – L
iv. Comp – T
v. Prism Track

g. Click "New".
h. Manually sight in the prism so that the crosshairs in the scope sight are perfectly in line with the center of the white lines in the prism.
    i. Note that the TS robotic head will not be connected to the prism during this test, so you have to sight everything in manually.
i. Calibrate the tilt sensor compensators, COMP-L and COMP-T.
    i. With this first calibration, you are calibrating the two internal compensators which are aligned at an angle of 90° to each other.
j. Manually sight in the prism as precisely as possible.
k. Click the "Comp" tab.
l. The TS will carry out measurements and rotate several times independently.
    i. Do not realign the TS to the prism.
    ii. The TS will calculate the offset and correct the value.
m. Record the new Comp values into the app.
n. Calibrate the HA and VA Collimation error.
    i. Here you are ensuring that the measurements taken by two internal faces are exactly 360° apart.
o. Return to configuration menu.
p. Manually sight in the prism as precisely as possible.
q. Click the "H-Coll" tab.
r. Press Meas.
s. Once the measurement in position 1 has been completed, the TS rotates automatically to position 2.
    i. Note that the TS head will never return to the center of the prism for position 2 with 100% precision automatically.
    ii. You will always need to adjust the TS head following this rotation.
t. Without moving the bipod, manually sight in the exact same spot on the prism again.
u. Press Meas.

v. The TS will rotate back to position 1 and calculates and displays the new correction values.

w. The TS will calculate the offset and correct the value.

   i. If this is not done very precisely, the calibration will fail and the software will use the old values.

x. Record the new values into the app.

5. Calibrate the prism tracker.
   a. The prism tracker error results when the prism tracker target axis deviates from the optical target.
      i. Note that this this calibration procedure requires the greatest degree of precision by the operator and is notoriously difficult to pass (per the manufacturer).
      ii. Avoid reflective surfaces and stray light sources which can potentially bias the test.
      iii. Only attempt this test once regardless of pass/fail.
   b. Return to configuration menu.
   c. Manually sight in the prism as precisely as possible.
   d. Click the “P-Track” tab.
   e. Press Meas.
   f. Once the measurement in position 1 has been completed, the TS rotates automatically to position 2.
   g. Without moving the bipod, manually sight in the exact same spot on the prism again.
   h. Press Meas.
      i. The TS rotates back to position 1 and calculates and displays the new correction values.
      ii. The TS will calculate the offset and correct the value. C and I values are the offset values for the prism tracker calibration.
      iii. Do not be surprised if the cross-hairs (after lock) are not 100% in the center of the prism.
      iv. These offset values are stored in the file and will be applied to future measurements.
   i. If successful, record new prism track calibration values in the app. If unsuccessful, continue onto the next section.

j. TS calibration is now complete.

   i. If you receive the message "The remaining C and I values of the tracker are too big – service may be required" this indicates that the prism track calibration has failed. Prism track calibration failure is a known issue, Hilti is currently reviewing the test parameters and is in the process of reducing the stringency for passing.

   ii. The laser-total station crosshairs alignment and HA/VA Collimation tests are most critical to ensure a successful calibration.

SOP B Conducting the Survey

The following sections describe elements of the survey that are completed in the field, including:

- Leveling the total station
- Establishing the first total station location
- Mapping points from a total station location
- Moving the total station to the next location
- Closing the survey

B.1 Leveling the Total Station

The total station (TS) must remain level during station set up and while mapping points. Take your time to level the TS carefully, precision in this step is critical for accurate measurements throughout the survey. To level the TS, follow the steps below:

1. For the first TS setup, place the TS in an area where each of the three permanent benchmarks are in view.
   a. For most AIS site surveys, the first TS location should also be within the line of site of the staff gauge, Level TROLL, and discharge cross-section. Reference the survey-specific SOW for details.
   b. If the site does not contain any permanent benchmarks, reference instructions in the survey-specific SOW.
2. Fully unfold the tripod so the legs are spaced at even intervals.
   a. If setting up the TS on soft or penetrable surfaces, make sure that the tripod legs are secure by stepping on the foot pedals until they are pushed into the ground surface, stable, and secure.
   b. If setting up the TS on impervious surfaces such as a flat boulder or a road, make sure the tripod is stable and secure. Wind or slippery surfaces can compromise the TS levability. The unit is top heavy so take care that it does not fall over on a smooth or uneven surfaces.
3. Place the TS head onto the tripod head and tighten the centering screw on the bottom of the unit (**Figure 4**). Ensure that it is properly secured to the tripod.
   a. Always keep one hand on the top of the TS head while it is being secured.
4. Adjust the tripod legs up and down until the level bubble on the bottom of the TS head is fixed completely in the center area (**Figure 5**).
5. Ensure that a battery is in the TS and turn the unit on.

6. View the TS keypad and screen to view the fine-tuning level of the TS (**Figure 6**).
7. Fine-tune the level of the TS using two of the three tribrach screw knobs until the display screen indicates the TS is level (**Figure 6**).
8. Spin the TS head and make sure it maintains level in all directions.
9. Press [OK]. The TS is now level and ready for use.

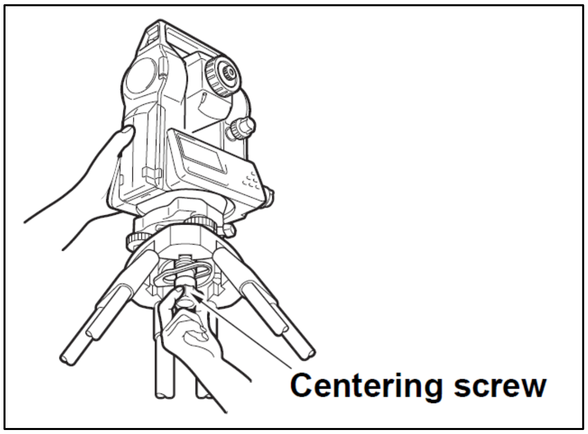


Figure 4. Attaching the Total Station head to the top of the tripod.

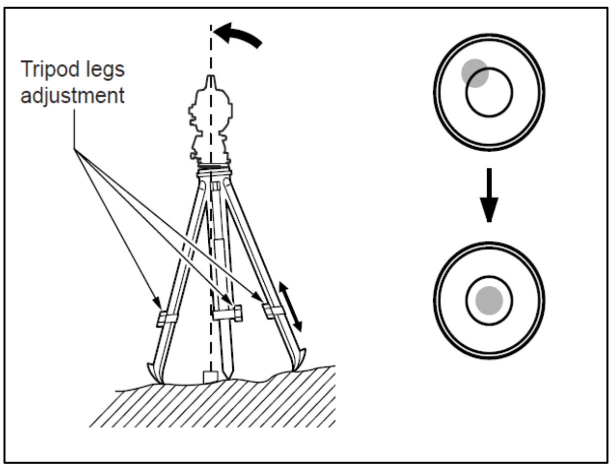


Figure 5. Leveling the tripod using the bubble level.

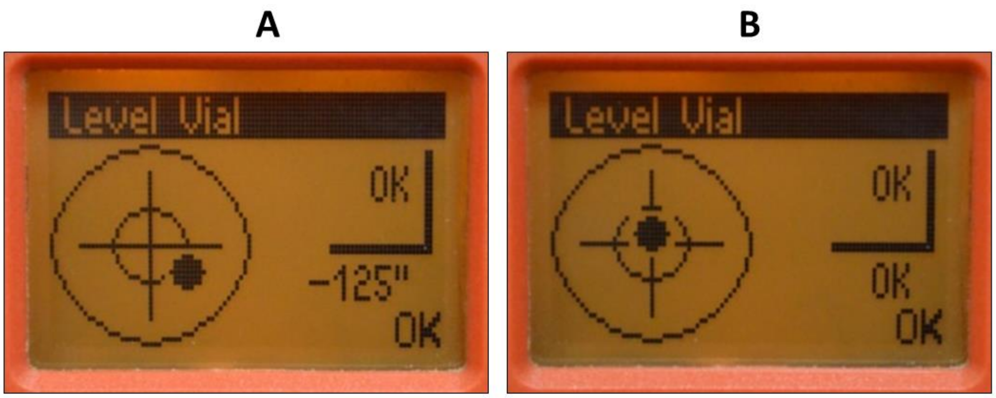


Figure 6. Total station fine-tuning leveling screen. A) The total station is not level; B) The total station is level.

B.2 Establishing the First Total Station Location

Once a new job has been created, POC settings have been verified, the benchmark coordinates have been loaded, and the total station has been calibrated and leveled, follow the steps below to set the first TS location of the survey. If, during the pre-survey meeting it is decided that the Missing Line workflow is required, replace the Steps 1-29 below with instructions found in **Appendix F**. Reference Step 30 to verify that TS1 has been setup properly once the Missing Line workflow is complete.

1. Ensure that the prism connected to the prism rod is linked to the POC and TS.
    a. Stand at least 5m from the TS holding the prism pole upright with the prism in direct line of sight of the station.
    b. Adjust your position until both colors (red/green) of the guide light are visible.
    c. Hold prism pole in place and press the prism search button on the outside of the POC.
    d. Set "G'light" and "Prism" to "Auto".
    e. Select "Prism" tab.
    f. Select the appropriate prism type. This will be "360° Stand Prism" for the larger prism rod or the "Sliding Prism" when using the miniature rod.
    g. Select "OK".
    h. You will hear a "ding" noise when the robotic head of the TS and the prism are linked up.
    i. Return to the Home screen.
2. Locate each of the three permanent benchmarks.
    a. For non-bedrock installations permanent benchmark IDs are engraved on hinged monument lids that protect each datum.

b. Note the benchmark ID and lift the monument lid up to access the benchmark that lies a few inches below the surface.

c. For permanent benchmarks installed in bedrock, no monument lid is present; a labeled cap is present that denotes the benchmark ID.

3. Use the bi-pod to level the prism rod on the divot in the center of the datum point or at exactly the center of the monument cap (see X- mark).
4. Sight the TS on the prism.
5. Select "Meas Rec".
6. Select "New Sta" tab.
   a. In the "Select Station Type" screen, ensure the following settings are selected:
   b. Heights: on
   c. Point System: Coord/Graph
   d. Setup Location: Anywhere
7. Select "OK".
8. Click on the rectangle next to 'Stat Pt ID' and enter "TS1", the code to be used for the first TS location.
   a. Subsequent "Stat Pt ID" codes will be sequential ("TS2", "TS3", etc.).
9. Set "HI" to equal 0.00m.
10. Select the "Targets" tab.
11. Select the button to the right of "Pt ID" and choose the benchmark point ID at which the prism is located (i.e. "BM1") and select "OK".
12. Select the numbers to the right of "HR" to enter the height of the prism rod.
    a. Enter this value to two decimal places (i.e. 1.60).
    b. Ensure that the TS and the prism rod are perfectly level.
13. Select the "Meas" tab to shoot in the first benchmark.
14. With the TS remaining level in the same location, use the bi-pod to level the prism rod on the divot in the center of the datum point or at exactly the center of the monument cap (**Figure 8**)
15. Select the button to the right of "Pt ID" and choose the new benchmark point ID at which the prism is now located (i.e. "BM2") and select "OK".
16. Select the numbers to the right of "HR" to enter the height of the prism rod.
    a. Enter this value to two decimal places (i.e. 1.60).

   b. Ensure that the TS and the prism rod are perfectly level.

17. Select the "Meas" tab to shoot in the second benchmark.
18. With the TS remaining level in the same location, use the bi-pod to level the prism rod on the divot in the center of the datum point or at exactly the center of the monument cap (see X-mark).
19. Select the button to the right of "Pt ID" and choose the new benchmark point ID at which the prism is now located (i.e. "BM3") and select "OK".
20. Select the numbers to the right of "HR" to enter the height of the prism rod.
    a. Enter this value to two decimal places (i.e. 1.60).
    b. Ensure that the TS and the prism rod are perfectly level.
21. Select the "Meas" tab to shoot in the third benchmark.
22. After each of the three permanent benchmark points have been measured, select "OK".
23. Leave the bi-pod leveled on the third benchmark.
24. On the 'Set Station' screen, select "Calc".
25. The error screen will display the station deviations calculated between the known BM coordinates and those just measured from TS1.
26. The following station deviation values will be listed:
    a. StDev(Pos): station deviation of the location of head unit of the TS.
    b. StDev(HA): station deviation of the horizontal angle.
    c. StDev(H): station deviation of the height.
27. Check that StDev(Pos) ≤ 0.01m and StDev(H) ≤ 0.005m.
    a. If station deviation values are within this threshold record StDev(Pos), StDev(HA), and StDev(H) values in the app and proceed to the next step.
    b. If StDev(Pos) is > 0.01m and/or StDev(H) is > 0.005m:
        i. Click "Back" two times to return to the Set Station screen.
        ii. Return to the beginning of **SOP B.2** and repeat the set station process up to five times.
        iii. See **Table 2** for potential causes of high station deviation and troubleshooting suggestions.
28. Select "Set" to set station (**very important step**).
29. Select "OK" and the "Measure Points" screen will appear.

a. If station is not set correctly, the survey will contain critical errors from this point forward without warning. It is thus critical to ensure the station is set properly before continuing with the survey.

30. Verify you are at the correct station (TS1).
    a. Hit the “Home” button on the outside of the POC.
    b. Select the “Meas Rec” icon.
    c. The “Meas Rec” screen appears that displays the job, current station, backsight point ID, and Height of Instrument.
    d. Verify each of these values are correct.
        i. “Job” should be the current job file.
        ii. “Current Station” should be the station you just set (i.e. “TS1”).
            1) “Bks Pt ID” should be one of the backsight points or targets you used to set the station (i.e. “BM1”).
            2) “Height of Instrument” should be 0.000m.
        iii. If all values are correct, hit “OK” and proceed to the next section to begin mapping points.
        iv. If all values are not correct, return to the beginning of **SOP B.2** and repeat the set station process.

Table 2. Potential causes of high station deviation values and suggestions for troubleshooting.

Potential Causes of High Station Deviation Values	Troubleshooting Suggestions
One or more benchmarks are not stable in the substrate.	Check that each benchmark is stable in the substrate. Any movement since the initial survey will result in increased station deviation. If one or more benchmarks are not stable, create a SN ticket for a discussion with Science staff.
The total station and/or prism rod were not level and or well-aligned prior to or while taking shots on one or more of the benchmarks.	Check and communicate the level of the total station and prism rod prior to each shot. If a shot was taken while either instrument was out of level, repeat the station setup process. Always use the bi-pod when leveling the prism rod over a benchmark. Avoid walking around the legs of the total station during station setup, particularly if the substrate is soft. Ensure that the total station is locked onto the prism prior to collecting the shot.
A mismatch occurred between the benchmark identified on the "Targets" screen of the POC and the benchmark the prism rod is levelled on.	Communicate between staff holding the rod and staff operating the TS to ensure that the prism rod is leveled on the benchmark that is being identified in the POC "Targets" screen.
The benchmark coordinate file contains errors or is being read into the POC incorrectly.	Ensure that the POC settings are correct in terms of the benchmark coordinate file column headers (See **SOP A.3**). If these settings are correct and the station deviations are significantly high (i.e. StDev(POS) values > 1 meter), check with Science to ensure the benchmark coordinate file is correct for the site being surveyed.
Site conditions such as poor line of site, high wind, heavy rain, and/or an unstable ground surface.	Deviations from threshold values should be discussed with Science during the pre-survey meeting given historic survey data and site conditions. Surveying should not be conducted during periods of heavy rain or extreme winds.

B.3 Mapping Points From a Total Station Location

To map points from a given TS location:

1. Select "Measure and Record" from the Home screen.
2. Verify that the station name is correct.
3. Place the prism rod on the point to be mapped and ensure both the rod and the TS are level.
   a. Reference the site-specific SOW for the required locations to be mapped during the survey. See **Appendix A** for details on point locations and shot codes.
   b. The Sliding Mini Prism can be used to map points in tight spaces or when the longer rod + 360° prism head are difficult to level. See **Appendix E** for details on using the Sliding Mini Prism.
4. Ensure that the correct prism type is selected in the POC.

   a. Hit the "Prism Search" button  on the outside of the POC.
   b. Select "Prism".
      i. Most shots will be taken with the 360 Standard Prism + rod. Select "360° Stand Prism" for this prism type.
      ii. If the Sliding Mini Prism is used, select "Sliding Prism".
   c. Hit "OK".
5. Select the "ABC" button to the right of "Pt ID" to label each point (see **Appendix A** or the survey-specific SOW for information on how to label individual points).
6. Enter HR, the height of the prism rod (in meters).
   a. See **Appendix E** for details on determining the HR for the Sliding Mini Prism. assembly.
7. Sight in the prism through the scope of TS.
8. Communicate to the staff member operating the rod that you are about to take the shot.
9. Select the "M&R" tab to shoot in the point.
10. If necessary, use a compass and meter tape to record any offsets (the angle and distance between where the tip of the prism rod sits and the location the point should be mapped at) associated with a given mapped point. Record this information in the Fulcrum app.
    a. When possible, avoid offsets to get the most direct and accurate measurements.
    b. Be wary of using the compass near ferrous material. Move the compass back and forth next to the instrument or infrastructure you are measuring to understand the degree of which the reading is being affected.
    c. Ensure that the declination of the compass is set correctly for the site location.
11. Ensure that all required points are mapped from TS1 before moving to TS2 (if more total station moves are required) or closing the survey (advance to **SOP B.5** if no further total station moves are required).

B.4 Moving the Total Station to the Next Location

If additional TS setups are not required, advance to **SOP B.5** to close the loop and finalize the survey. If multiple TS setups are required, TS locations must be laid out so that all required AIS infrastructure can be mapped in as few TS setups as possible. Complete the following steps to move the TS to the next location.

1. Before physically moving the TS from the current TS1 location, the next location (TS2) must first be identified.

a. TS2 should be located in an area that either (1) has a line of site to additional locations to be mapped or (2) is in a location along the route to the remaining locations.

b. A line of sight between TS1 and TS2 is not required. Rather, TS2 must have a line of site to a set of 3 or more control points that are installed between TS1 and TS2 (described in next step).

2. Once the location of TS2 has been established, a set of 3 or more magnetic nails (referred to herein as control points, or COP's) must be installed flush in the ground to form an equilateral triangle between TS1 and TS2 (**Figure 7**). COP requirements are listed below.

   a. Utilizing 3 or more COP's is critical in minimizing the amount of vertical and horizontal error introduced into the survey during each TS move.

   b. Maximizing the angles between the total station locations and the COPs is key in allowing the new position of the TS to be more easily triangulated and reducing survey error. Ideally, an angle of >45 degrees exists between each TS location and the two COP's that form the base of the triangle.

   c. If forming an equilateral tringle is impossible, placing the COP's in a line perpendicular to both TS locations will suffice. Note that COP's <u>cannot</u> be arranged vertically relative to lines of sight from each TS location.

   d. More than 3 COP's can and should be used whenever possible to minimize survey error. The new TS location can be placed in the middle of one or more COP's (**Figure 7**). This is a useful technique that maximizes the distance and angles between COP's in tight spaces.

   e. Ensure that a clear line of sight exists from each of the COP to both TS1 (the current TS location) <u>and</u> TS2 (the next TS location).

   f. Shorter foresights (the shots taken from TS1 to the COP's) and longer backsights (the shots taken from TS2 to the COP's) are preferred. Foresight shots should never be longer than backsight shots.

   g. Ensure that adequate spacing exists between each COP.

      i. Ideally, COP's are spaced >5m apart but this is not always possible in some locations.

      ii. Maintain a minimum of 2m spacing between COPS's in locations where lines of site are difficult to establish.

   h. When surveying in cold weather be aware that freezing/thawing can move COP's overnight. Address this by installing additional COP's in stable ground to serve as backups if others move.

i. Each COP must be consecutively labeled beginning with COP1 as the first COP established during the survey using flagging tape and a Sharpie.

j. Each COP must be installed flush and securely in the ground. Avoid installing COPs in locations with soft substrate or unstable substrate.

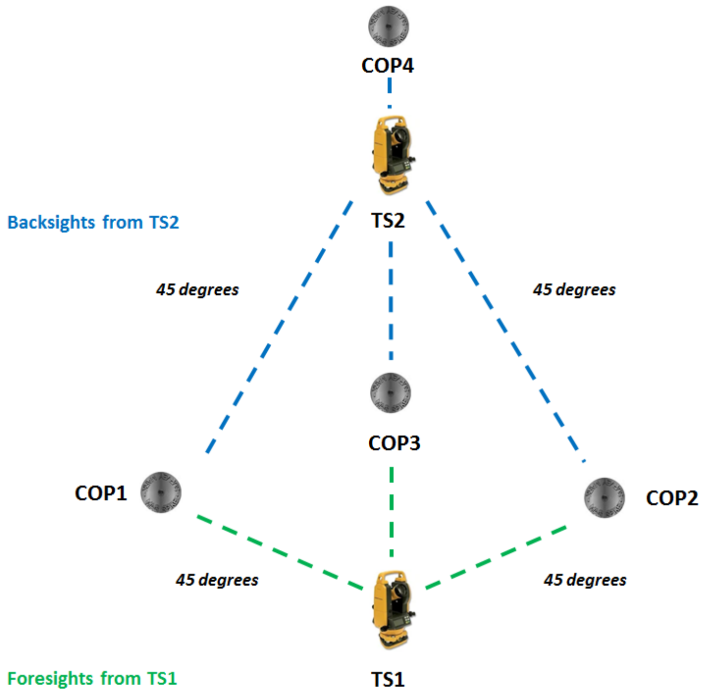


Figure 7. Ideal total station-control point setup using an optional fourth control point to set a second total station location (TS2). Note the wide 45-degree angles between COP1 and COP2, how COP4 is beyond TS2 and how the foresight is shorter than the backsight.

3. Once the COP's have been installed, ensure that the TS at TS1 has remained level. Adjust level accordingly if needed before collecting foresight COP shots.
4. From TS1, shoot in each of the COP's.
    a. Use the bi-pod to level the prism rod on the center of COP1.
    b. Select the button to the right of "Pt ID" to name this point "COP1".
    c. Enter HR, the height of the prism rod.
    d. Select "M&R" tab to shoot in COP1.
    e. Repeat above steps for COP2, COP3, and all others used to setup the next TS move.
    f. Make sure the TS is not disturbed between the COP shots and that it remains perfectly level.
        i. If the TS comes out of level between COP shots, re-level the TS and re-shoot each COP's (note – you will need to re-name these COP's with new point names. Make

sure this is well documented in the Fulcrum app remarks and that the flagging on each mag nail is correct).

5. After all COP's have been shot in, physically move the TS from TS1 and level it at the TS2 location.
6. Using the POC, identify each of the COP's that were just shot in as new targets (foresights):
    a. Navigate to the Home Screen.
    b. Select "Meas Rec" button.
    c. Select "NewSta" tab.
    d. Do not change any data listed in the "Select Station Type" screen, leave these values as defaults and select "OK".
    e. Under "Set Station" screen, select the ABC button to the right of "Stat Pt ID" to enter Stat Pt ID as "TS2" (for the second total station location).
    f. Set HI = 0.000m.
    g. Select "Targets" tab.
    h. Under "Meas Target Pt 1" screen, select the button next to Pt ID.
    i. Scroll down to select "COP1".
    j. Select "OK".
    k. Use the bi- pod to level the prism rod on COP1.
    l. Enter HR, the height of the prism rod.
    m. Check that the TS is level. If it has come out of level, re-level the TS prior to shooting in COP1.
    n. Select "Meas Rec" to shoot in COP1.
    o. Repeat above steps to shoot in COP2, COP3, and any others that were shot in as foresights from TS1.
        i. Make sure the TS is not disturbed between the COP shots and that it remains perfectly level. If the TS comes out of level between COP shots, re-level the TS and start this step over.
7. Once all COP's have been shot in as backsights select "OK" and "CALC". A screen will display station deviations (error values) calculated between the foresight and backsight COP shots. The following station deviation values will be listed:
    a. STDev(Pos): station deviation of the location of head unit of the total station.
        i. Only provided when at least 3 COP's were used.
    b. STDev(HA): station deviation of the horizontal angle.

i. Only provided when at least 3 COP's were used.

c. STDev(H): station deviation of the height.

8. Evaluate the station deviation values associated with the new TS setup (**Table 3**).

   a. The range of station deviations will vary by site with values being higher at sites where topography, vegetation, or substrate conditions force narrow angles between TS and COP locations, reduce sight lines, and/or result in an unstable ground surface. Keep these conditions in mind when evaluating station deviations.

   b. If station deviation values are significantly (and unexpectedly) high (e.g. > 0.02m), consider physically returning the TS to the previous location (e.g. TS1) and re-shooting the COPs as new foresights. Errors contained in the original COP shots (the foresights) may be leading to the high station deviation values contained in the backsights (these errors would be impossible to resolve with repeated backsight setups).

      i. Once the TS is leveled at the previous location, bring up the points used to originally set this station as targets (for TS1 this will likely be the benchmarks, for subsequent stations this will likely be other control points). Complete steps beginning at **Step 6** to finalize the new setup.

      ii. When setting up new foresights in this situation, evaluate the angles between the each of the COP's that were previously used. Can they be spaced wider? Can additional control points be installed? At this point it is OK to move these COP's if necessary. However, never re-locate COP's you may need to reset a station.

      iii. When shooting in new foresights in this situation, new point names are required for each COP (i.e. the new shot on COP1 could be labeled "COP1A", etc.). Rename the COP ID on the flagging to avoid confusion.

      iv. Once the COP's have been re-shot as new foresights with unique ID's, level the TS at the TS2 location, shoot in the COP's as backsights (using the new point names) and evaluate the standard deviation values.

Table 3. Interpreting station deviations collected while moving the total station to a new location.

Range of station deviation	Preference	Field Action
STDev(Pos) ≤ 0.01m STDev(H) ≤ 0.005m	Ideal	Record all station deviations in Fulcrum app and set station.
STDev(Pos) > 0.01m STDev(H) > 0.005m	Acceptable after 2 re-attempts	Consider environmental conditions that could be leading to high station deviation. Repeat backsight shot workflow up to two more times and ensure that the both the TS and bi-pod remain level. If STDev values exceed the ideal range listed in Row 1, the station can be set using the high values but consider wider COP angles and/or more COP's for future setups.

9. Once acceptable station deviation values have been achieved, select “Set” to set the station.
    a. This is a highly important step. If the station is not set correctly, the survey will contain critical errors from this point forward and there are no real warnings to alert you that this is happening.
10. Verify you are at the expected station.
    a. This must be done each time a new station is set.
    b. Hit the “Home” button on the outside of the POC.
    c. Select the “Measure and Record” workflow.
    d. A screen will appear that displays your station and associated backsight points. Verify both of these values are correct (note: the backsight value should be one of the COP’s that was just used to set the station).
    e. Once verified, begin measuring points from this TS location.
        i. If the station is not set correctly, repeat steps starting on **Step 6**.
11. Repeat this workflow, mapping all required points from each TS location, until all required AIS infrastructure has been surveyed.
    a. If required in the survey-specific SOW, collect and map Trimble points as specified (see **Appendix D** for details on collecting GPS data during the survey).
12. Leave all COP’s labeled and in place until the survey is complete so that they can be re-used if TS locations need to be re-established.
13. If the survey is not complete by the end of the day, the most recent set of COP’s will be used to continue the survey the following day.
    a. At the end of the day, install and shoot in new foresight COP’s from the day’s final TS location. At the beginning of the next day, set up the TS at the new location using these COP’s as backsights.
    b. For surveys that span multiple days, Hilti job files should be exported and saved after each field day to reduce the risk of data loss.

B.5 Closing the Survey

Once all required locations have been mapped, traverse back to an area where a clear line of site exists to one or all of the benchmarks that were used to orient TS1. Closing the survey by re-shooting the original benchmarks is a technique known as “closing the loop” and is performed to assess the total amount of spatial error accumulated during the survey. Complete the following steps to close the loop and complete the survey.

1. Traverse to either the benchmarks used to establish TS1 or to (if present) one of the permanent benchmarks installed at the upstream or downstream reach boundary.

a. No additional AIS infrastructure needs to be mapped while traversing the TS back to original benchmarks.

b. As you traverse back, setup TS locations using the methods described in **SOP B.4**.

   i. It is OK to use the same magnetic nails that were installed for previous TS setups, but these markers must be re-shot **using unique point ID's**.

   ii. For example, if COP29 was used for a previous TS location, this control point can be re-shot as a foresight with a new and unique point ID e.g., COP29A, or COP290) and then used as a backsight target (point ID = COP29A) to set up a new station while traversing back to the permanent benchmarks.

2. You do not need to take the same route back to the permanent benchmarks that was previously used. Roads, clearings, or other paths between the final AIS infrastructure locations and the permanent benchmarks may result in less overall TS setups.

3. Once the TS has a line of sight to the permanent benchmarks used to setup TS1, re-shoot (at minimum) one of them using a new and unique survey code.

   a. This is a critical shot that will be used to assess the overall error associated with the survey. Double check that the TS and bi-pod are completely level and that the point of the rod is at the correct survey location on the benchmark.

4. Code closure shots “BM#_CLOSE” substituting “#” in for the unique benchmark number (i.e. “BM1_CLOSE”).

   a. Enter the coordinates for the BM#_CLOSE shot into the Fulcrum app to obtain misclosure values. Misclosure values will vary depending on site and number of total station setups. If misclosure values are high, take additional shots on this closure benchmark and map additional closure benchmarks if necessary.

5. The field component of the survey is now complete.

6. All materials must be cleaned following standard operating procedures for cleaning field equipment used in aquatic systems. Batteries for the total station, handheld datalogger, and/or GPS antenna must be charged or replaced as needed.

SOP C Data Entry, Data Verification, and Post-Fieldwork Tasks

C.1 Data Entry

Mobile applications are the preferred mechanism for data entry. Data should be entered into the protocol-specific application as they are being collected, whenever possible, to minimize data transcription and improve data quality. Mobile devices should be synced at the end of each field day, where possible. Alternatively, devices should be synced immediately upon return to the Domain Support Facility.

However, given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets (RD[04]) should be carried along with the mobile devices to sampling locations at all times. Data collected on paper data sheets must be transcribed within 14 days of collection.

C.2 Data Verification

Data entered in Fulcrum must be reviewed upon completion of the survey. Be sure to include information in all applicable tables, particularly the "mapped points that contain errors" table, which documents mapped points that need to be edited or deleted during post-processing. Once reviewed, the "Survey Compete" button must be selected for the Fulcrum record to load.

C.3 Post Fieldwork Tasks

The following tasks must be completed following data verification:

- Complete Survey Notes using the template contained in **Appendix G.**
- Export Hilti Jobs file (raw data collected during survey).
- Export Trimble Data (if required).
- Notify the GIS Support Service in the relevant ServiceNow request ticket that the survey is complete and that Fulcrum data have been reviewed. Attach all relevant survey material (raw survey data file, GPS data if collected, survey notes) to the ticket for post-processing.
- If required, export Trimble files referencing details provided in RD[05]).

<u>To export the Hilti job file:</u>

1. Insert a USB flash drive into the POC (ensure that there is a folder on the drive called "Hilti Jobs".
2. Select the "Home" button on the outside of the POC.
3. Select "File".
4. Select "Export" to upload the appropriate job file (.CSV) onto the flash drive.

APPENDIX A MAPPING LOCATIONS DURING AIS SURVEYS

Table 4. Common locations mapped during NEON AIS surveys. Refer to the survey-specific SOW for explicit details on what is required for each AIS survey.

AIS Infrastructure Type	Shot Location	Shot Code
Permanent benchmarks (**Figure 8**)	Designs vary across sites but points should always be mapped at center of the benchmark. This includes the divot in datum point style and round monument style benchmarks, or the "O" in "NEON" on round monument style benchmarks	BM# (Designate benchmark number)
Temporary benchmarks (if used)	Permanent benchmarks are not available at some NEON AIS Sites. For these sites map a point on the top of each temporary benchmark and the label the point with the year the temporary benchmark is being surveyed.	BM#_YYYY (Designate benchmark number and survey year)
Groundwater wells (**Figure 9**)	• Base: Base of the metal outer casing on the southern-most corner • Top (no snorkel): Top of the PVC collar inside the groundwater well with PVC cap removed; with a ruler measure distance from the top of the PVC casing to the top of the metal docking ring and record offset in app • Top (with snorkel): Southern-most of the top of the PVC with entire coupler and cap removed; with a ruler measure distance from the top of the PVC casing to the top of the metal docking ring and record offset in app	• GWW#_BOT • GWW#_TOP_REG • GWW#_TOP_SNORKEL (Designate groundwater well number)
Aquatic Portal (**Figure 10**)	Base of the southern-most corner	PORTAL
Staff gauge (**Figure 11**)	Meter mark of your choosing, use a clamp to create a level surface for the prism rod and identify the meter mark at which the point was taken in the Shot Code	SP_X.XXM (Designate meter mark on gauge)
Discharge XS (**Figure 12**)	• ~30 points along XS, including floodplain • Top of left and right bank pins • Left and right edge of water • Left and right bankfull	• DSC_XS • DSC_LB/RB_PIN, • DSC_LEW/REW, • DSC_LBF/RBF
In-stream Level and Aqua TROLLs (**Figure 13**)	• Vertical install: remove the PVC cap and map point on PVC lip of the housing • Horizontal install: map point on divot in the housing above the sensor	• S1/S2_TROLL_VERT • S1/S2_TROLL_HORIZ (Designate S1 or S2 location)

AIS Infrastructure Type	Shot Location	Shot Code
Littoral Stations (**Figure 14**)	Low-profile designs (cinder block and under-ice): • TROLL: divot of the horizontal housing • uPAR: surface of the sensor • Primary Unistrut: the top of the pipe attached to the lakebed • Surface water elevation: the water surface	• LIT1/2_LOWP _TROLL • LIT1/2_LOWP _PAR • LIT1/2_LOWP _UNI • LIT1/2_LOWP _SWE (Designate littoral station number)
	Standard designs: • TROLL: remove the PVC cap and map point on PVC lip of the vertically installed housing • uPAR: the surface of the sensor • Primary Unistrut: the top of the pipe attached to the lakebed • Surface water elevation: water surface	• LIT1/2 _TROLL • LIT1/2 _PAR • LIT1/2 _UNI • LIT1/2 _SWE (Designate littoral station number)
MET Station (**Figure 15**)	Center of the MET Station at the base of the mast of the tripod	MET
DFIR (**Figure 15**)	• Top of the inlet of the rain gauge • Where concrete base meets the ground	• DFIR_INLET • DFIR_BASE
Tipping Bucket (**Figure 15**)	• Top of the inlet of the rain gauge • Where concrete base meets the ground	• TIPPING_INLET • TIPPING_BASE
NADP (**Figure 15**)	• Center of the top plate • Where concrete base meets the ground	• NADP_TOP • NADP_BASE

Figure 8. Examples of different permanent benchmark installations at NEON Aquatic sites. From left to right: round monument style benchmark with a triangle divot within a hinged access cap; datum point style benchmark within a hinged access cap; round monument style benchmark installed directly in bedrock.

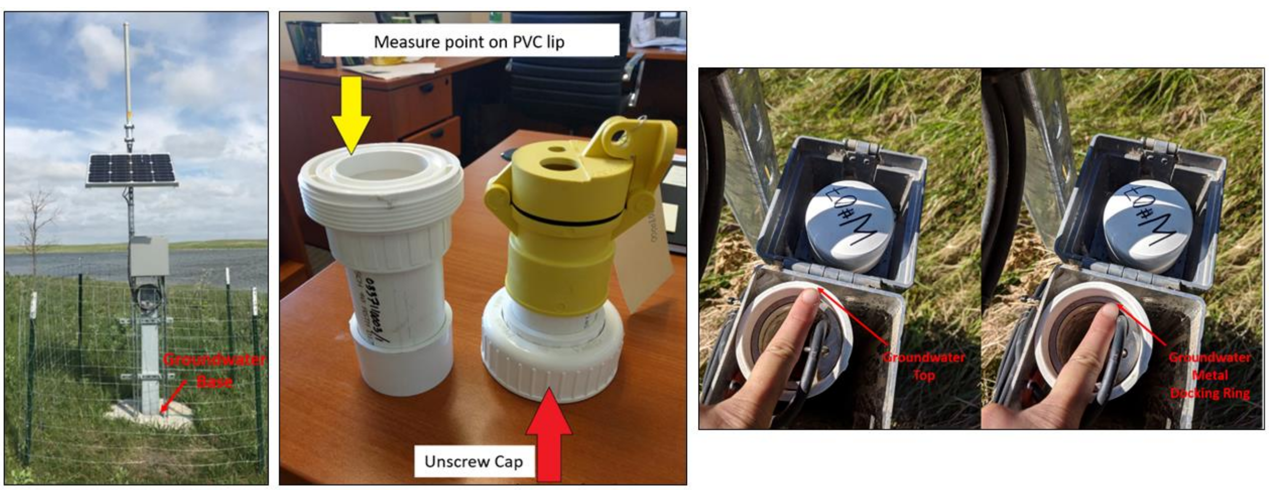


Figure 9. From left to right: NEON groundwater well with arrow indicating the base, where points shall be mapped on the southern-most corner; groundwater well snorkel caps, where points shall be mapped on the south side of the top of the PVC with the entire coupler and cap removed; the top of a NEON groundwater well without a snorkel cap, where points shall be mapped at the top of the PVC collar inside the well with the PVC cap removed.

Figure 10. NEON Data Portal, where points shall be mapped at the southern-most corner.

Figure 11. Left: NEON staff gauge where a clamp is placed to level the prism rod at the 1.20 meter mark, the red arrow indicates where the prism rod point is to be placed. Right: the staff gauge asset tag.

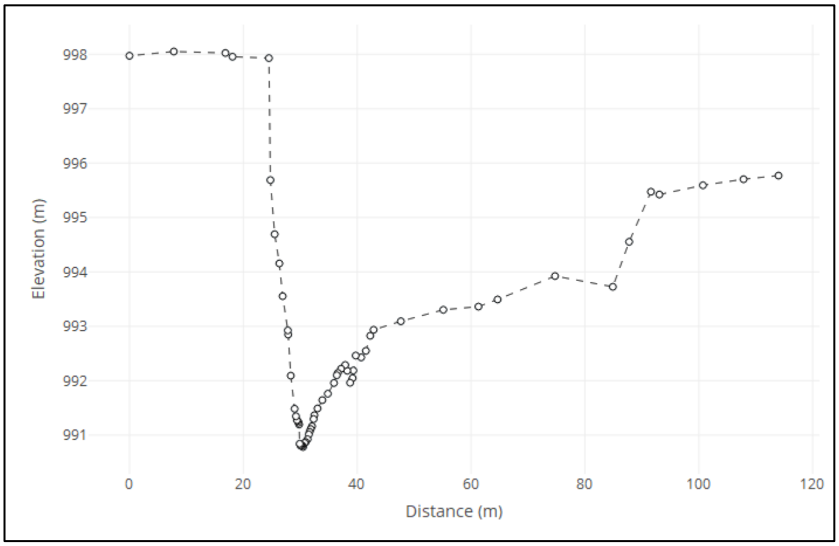


Figure 12. Example of high-resolution cross-section survey data where the floodplains, banks, and active channel are well-characterized by properly spaced points (each dot represents a mapped shot).

Figure 13. Left: Horizontally-installed Level TROLL with the yellow arrow indicating the divot where the point shall be mapped; Right: vertically-installed Level TROLL with the yellow arrow indicating the PVC cap, which is to be removed so that the point is mapped on the lip of the PVC

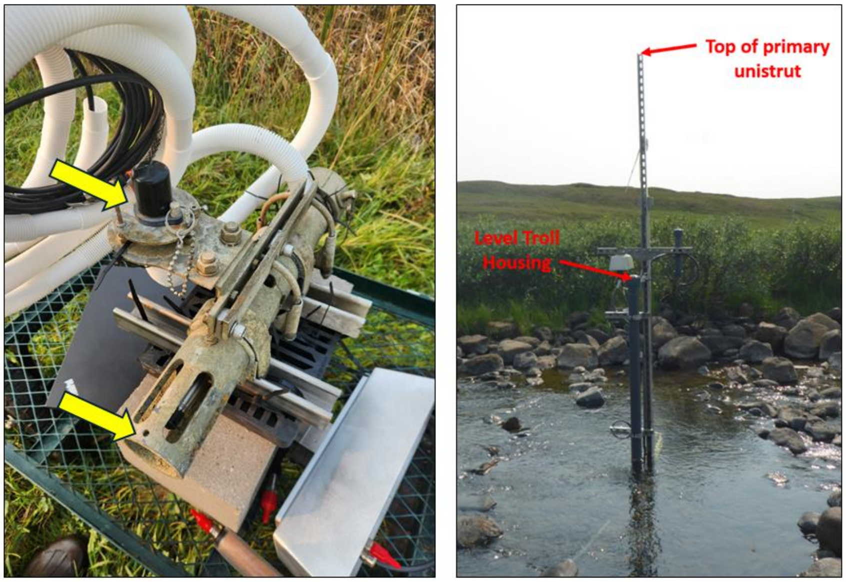


Figure 14. Left: Cinder block littoral station design with the yellow arrows indicating the locations on the TROLL housing and PAR sensor where points are to be mapped (the vertical pipe is not shown but this location also requires a mapped point); Right: standard littoral station design with the red arrows indicating the top of the primary unistrut and the top of the PVC cap, the latter of which is to be removed so that point is mapped on the lip of the PVC.

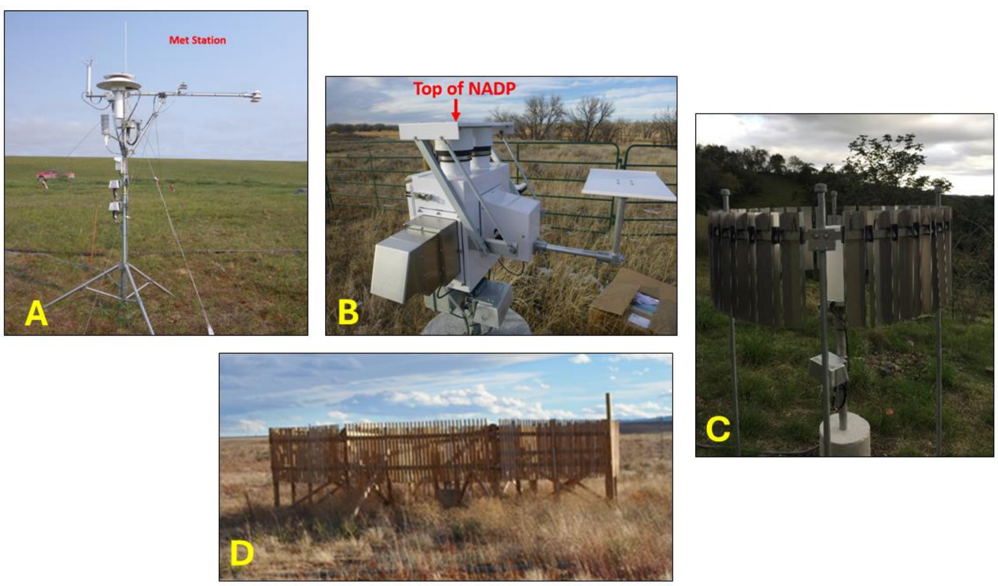


Figure 15. NEON meteorological infrastructure. A: MET station where a point shall be mapped at base of the mast of the tripod; B: NADP where points shall be mapped at the top of the center plate (red arrow) and where the concrete base meets the ground; C: Tipping bucket where points shall be mapped at the top of the inlet of the rain gauge and where the concrete base meets the ground; D: DFIT where points shall be mapped at the top of the inlet of the rain gauge and where the concrete base meets the ground.

APPENDIX B EQUIPMENT

The following equipment is needed to implement the procedures in this document. Equipment lists are organized by task. They do not include standard field and laboratory supplies such as charging stations, first aid kits, drying ovens, ultra-low refrigerators, etc.

Table 5. Equipment list for AIS surveys.

Supplier/ Item No.	Exact Brand	Description	Purpose	Quan-tity
MX109898	Y	HILTI POS 180 Robotic Total Station and POC data collector	Measure and collect survey data	1
MX107405	Y	Sokkia knob lock prism pole	Graduated pole that is attached to prism assembly and used for marking points and recording height of prism during surveys	1
MX107406	Y	HILTI POA 360° mirrored prism	Mirrored target for total station measurement shots	1
	Y	HILTI POA 53 Sliding Mini Prism	Measure target for total station measurement shots in tight scenarios	1
MX107407	Y	Sokkia heavy duty fiberglass tripod	Supports and orients total station	1
MX102549	Y	Trimble© GEO XH 6000 GPS receiver or equivalent model.	Locate and mark benchmarks and Trimble Points	1
MX109898	Y	POA 84 Battery for the POS 180	Power for POS	2
MX109898	Y	POA 86 battery charger for the POC 180	Charge batteries for POC	2
MX109898	Y	POC Controller with Stylus	Operate total station from prism pole	1
MX109898	Y	POA battery for the POC 100	Power for POC	2
MX109898	Y	POA 81 AC adapter for POC 100	Charge battery for POC	1
MX107144	N	Waterproof camera	Photo document the reach and associated features	1
	N	Magnetic nails	Used to mark locations of control points	25
MX104363	N	Pin flags	Used to mark locations of survey boundaries, bankfull delineation, etc.	25

Supplier/ Item No.	Exact Brand	Description	Purpose	Quan-tity
MX100320	N	Compass	Verify orientation of the survey	1
MX104369	N	50m measuring tape	Measuring and laying out of transects	1
MX100324	N	Radios (preferably waterproof)	For communication between team members	1 per person
	N	Rain Cover (e.g., heavy duty plastic bag)	Protect total station from rain	1
	N	Telescoping stadia rod	Measuring depth	1
MX106043 MX106199 MX104361	N	Stakes (wooden hubs), Clamps, & Chaining Pins	Secure meter tape during transect surveys, help secure TS during setups on un-solid ground.	2 sets
MX111388	Y	Tablet with AIS Survey app	Recording data	1
MX103220	N	Hammer or mini-sledge	Monument installation	1
	N	Map of site (Google Earth, AIS AS-BUILT)	Monument installation, periodic QAQC	1
	N	Torpedo level with clamp	To assist in staff gauge survey shot	1
	N	Cleaning wipes or towel	Clean/wipe the total station optics and rod prism.	1
MX102002	N	Permanent marker	Recording data	3
MX103940	N	Flagging tape, orange	Mark features and survey boundaries	1 roll per person

APPENDIX C FACTORY CALIBRATION OF THE TOTAL STATION

Factory calibration of the total station will typically occur on a less frequent basis than field calibration. The frequency of factory calibration depends on the NEON aquatic sites where the instrument is being used, the following guidelines are provided below.

When to factory calibrate the total station:

- **All Aquatic sites:**
  - Factory calibration is required any time the total station fails the field calibration laser point alignment test.
  - For total station kits that are still under the initial 2-year warranty include one free factory calibration per year, factory calibration should be performed the month before the warranty expires.
  - Field staff should work with their manager to coordinate calibration schedule needs and planned costs.
- **Stream sites:**
  - Factory calibration must be performed within 1 year leading up to the stream morphology survey.
  - This results in a factory calibration every five years, at minimum.
- **Lake and River sites:**
  - Factory calibration must be performed every 5 years, at minimum, regardless of field calibration.

APPENDIX D COLLECTING TRIMBLE DATA

The collection of GPS data may be required for surveys that occur at AIS sites without permanent benchmarks or during surveys where permanent benchmarks are being re-established. The collection of GPS data required during these types of surveys is described in the steps below.

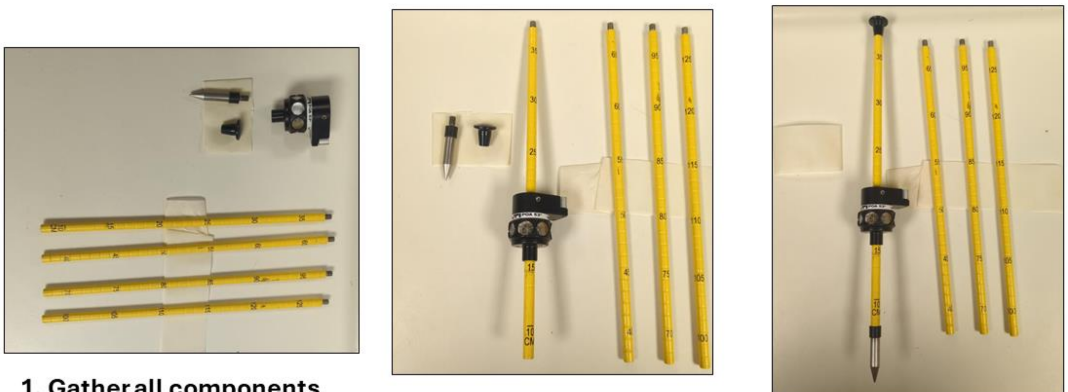
1. A minimum of three points must be mapped with the total station that will be used as GPS reference points.
    a. These survey points, referred to as Trimble Points, transform local coordinates into real-world values.
    b. The range of the three points must adequately represent the breadth of the survey.
    c. Reference the survey-specific SOW for details and consult with Science during the pre-bout meeting for information on this point spacing.
    d. One Trimble Point is typically a shot mapped on one of the benchmarks used to establish the first total station location.
2. In addition to mapping each Trimble Point with the total station, setup the Trimble GPS receiver and collect GPS data at each of the Trimble Points.
    a. See RD[05] for instructions on how to operate the Trimble GPS receiver.
    b. 10-30cm accuracy is required for the Trimble points.
    c. When using Trimble Geo xh 6000 or Trimble Geo 7x handheld receivers, reference **Table 6** for the required number of data points to achieve this accuracy at each AIS site.

Table 6. Minimum time for the Trimble GPS Receiver (with antenna) to log on each Trimble Point mapped during the AIS survey.

Domain	Site	Minimum GPS Time (min)	Minimum GPS Logs
1	HOPB	15	900
2	LEWI	15	900
2	POSE	15	900
3	BARC	15	900
3	SUGG	15	900
3	FLNT	75	4500
4	GUIL	15	900
4	CUPE	15	900
5	LIRO	15	900
5	CRAM	15	900
6	MCDI	225	13,500
6	KING	225	13,500
7	WALK	15	900
7	LECO	15	900
8	MAYF	15	900
8	TOMB	15	900
8	BLWA	15	900
9	PRPO	15	900
9	PRLA	15	900
10	ARIK	75	4500
11	PRIN	75	4500
11	BLUE	15	900
12	BLDE	75	4500
13	COMO	15	900
13	WLOU	15	900
14	SYCA	75	4500
15	REDB	225	13,500
16	MART	15	900
16	MCRA	225	13,500
17	TECR	225	13,500
17	BIGC	225	13,500
18	OKSR	15	900
18	TOOK	15	900
19	CARI	15	900

APPENDIX E USING THE SLIDING MINI PRISM

While conducting total station surveys, the Sliding Mini Prism (Hilti POA 53) can be used to map points that are hard to reach with the standard prism rod, which is much longer and can be difficult to keep level in tight spaces. Use cases for the Sliding Mini Prism can include, but are not limited to, mapping groundwater wells, Level TROLLs, staff gauges, or general points located in areas of dense vegetation. Assemble the Sliding Mini Prism using steps shown in **Figure 16**.



1. Gather all components

2. Slide the prism head through the 10-35cm rod length (add sequential rod lengths as needed)

3. Attach the top cap to the top of the rod length and the rod tip to the bottom

Figure 16. Steps to assemble the Sliding Mini Prism.

When switching prism rods **<u>it is critical</u>** that the settings are updated in the POC data logger. The survey data will contain errors if settings are not updated each time a new prism rod is used.

To switch prism types:

1. Select the “Prism” tab on the POC home screen.
2. Select the appropriate Prism Type.
    a. “360° Stand Prism” = the longer, standard prism
    b. “Sliding Prism” = the shorter, Sliding Mini Prism
3. Sight the total station on the new prism and select “OK”.
4. A ding will sound to confirm that the total station is linked up with the new prism type. An image of the new prism type will also be shown on the top of the screen (**Figure 17**).

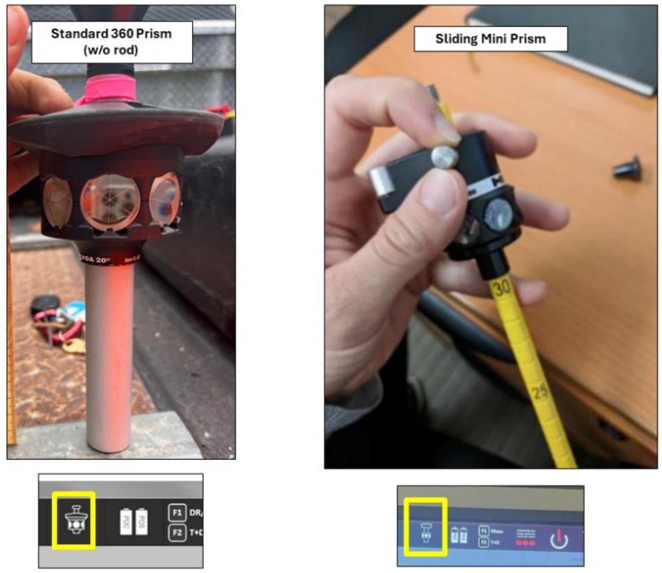


Figure 17. The two different prism types used for NEON total station surveys with images below that indicate which prism is selected on the POC screen.

Accurately recording the height of rod when using the Sliding Mini Prism is critical to maintaining high survey data quality. The base of the prism head rests at the height of rod to be recorded, as delineated by the numbers and markings on the rod length. The numbers are labeled below the cm marks they represent (**Figure 18**). Add rod lengths as the need for total prism height increases. Level the prism using the bubble level on the top of the prism head (**Figure 19**). Always remember to switch back to the "360° Stand Prism" in the POC settings when you have completed all shots with the Sliding Mini Prism.

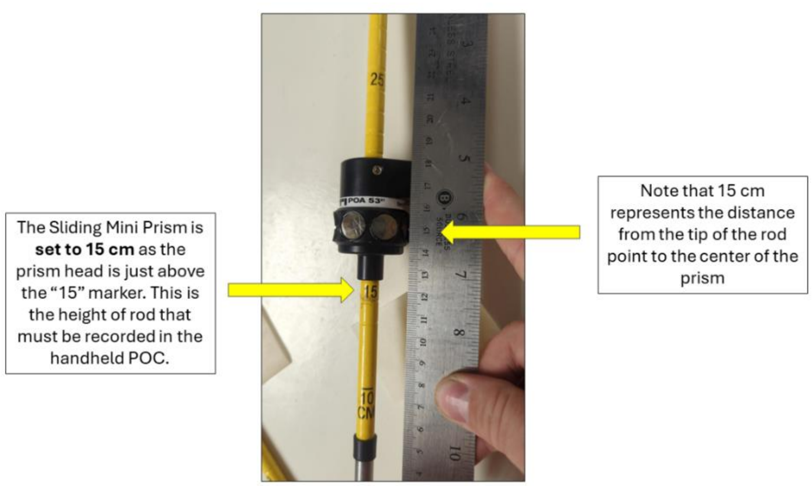


Figure 18. Assessing the height of rod on the Sliding Mini Prism.

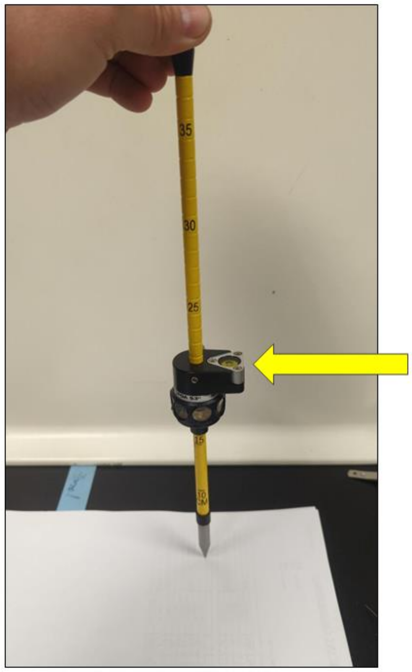


Figure 19. Arrow indicating the bubble level on the Sliding Mini Prism head.

APPENDIX F MISSING LINE WORKFLOW

The Missing Line Workflow is used to setup the initial total station location (TS1) when permanent benchmarks are not available at the AIS site. Complete the following steps to implement the Missing Line Workflow:

1. The (AIS) Site Survey [PROD] Fulcrum app should be used for all data entry pertaining to the Missing Line Workflow.
2. This workflow requires two points in addition to TS1.
    a. Benchmark #1 (BM1) will serve as the first point.
    b. If the benchmark has a different name (i.e. BM16) use that number instead of 1.
3. Install one temporary point using a mag nail (spike driven securely into the ground so it will not move) to serve as the second point (label this point "PT2").
    a. Try to place PT2 roughly the same distance as is between TS1 and BM1.
    b. Attach flagging to this temporary point and label it with Sharpie so it can be easily found and identified.
    c. Attempt to form an equilateral triangle between BM1, PT2, and TS1.
4. On the POC Home Screen:
    a. Select "Applications".
    b. Select "Missing Line".
    c. Verify that the job listed is current job and select "OK".
    d. The "Measure 1st Pt" screen will appear.
5. Use the bi-pod to level the prism rod on the BM1 divot.
6. Sight TS on the prism and ensure that prism and POC are linked up.
7. Select the numbers to the right of "HR" to enter the height of the prism rod.
    a. Check total station to ensure it is level.
8. Select "Meas" to shoot in BM1.
9. Select 'Next". The "Measure 2nd Pt." screen will appear.
10. Use the bi-pod to level prism rod on the center of PT2.
11. Sight TS on the prism and ensure that prism and POC are linked up.
12. Select the numbers to the right of "HR" to enter the height of the prism rod.
13. Select "Meas" to shoot in PT2.

14. Select the "Results" tab.
15. Record HD (horizontal distance) and dH (vertical distance) values calculated by POC in the Fulcrum app ("Missing Line Results HD (m)/dh (m)" tables).
    a. Note that dH may be a positive or negative number depending on the gradient between the points and TS1.
    b. Record all significant figures for these values.
16. Select "Save" to save results.
17. Leave the prism rod level on PT2 and proceed to the next step.
18. On the POC, hit the "Home" button to return to the home screen.
19. Select "Meas Rec".
20. Select "New Sta" tab.
    a. Don't change any data listed in the "Select Station Type" screen, leave these values as defaults and select "OK".
21. Under "Set Station" screen, select the ABC button to the right of "Stat Pt ID".
22. Enter Stat Pt ID as "TS1" (the name of the first total station location).
23. Set HI = 0.000m.
24. Select "Targets" tab.
25. The "Meas Target Pt. 1" screen will appear.
26. Ensure that the prism rod is still level on PT2.
27. Select the button to the right of "Pt ID".
28. Select the "Man" tab.
29. Select the ABC button to the right of Pt ID to name this point "PT2" (the name of the point the prism rod is currently on).
30. Select the 123 button to the right of "E" (Easting).
31. Set Easting to equal to 0m.
32. Select the 123 button to the right of "N" (Northing).
33. Set Northing to equal the HD value recorded in the Fulcrum app during **Step 15**.
34. Select the 123 button to the right of "H".
35. Set Height to equal 1000 + the dH value recorded in your notebook during **Step 15**.
    a. Keep in mind that the dH can be a negative number, which means you would be adding a negative number or subtracting from 1000.

   b. Example 1: dH = -0.007; H = 999.993
   c. Example 2: dH = 0.008; H = 1000.008

36. Select "OK" to save PT2.
37. Enter HR, the height of the prism rod.
38. Select the "Meas" tab to shoot in PT2.
39. The "Meas Target Pt. 2" screen will appear.
40. Use the bi-pod to level the prism rod on the BM1 divot.
41. Select the button to the right of "Pt ID".
42. Select the "Man" tab.
43. Select the ABC button to the right of Pt ID to name this point "BM1" (the name of the point the prism rod is currently on).
44. Select the 123 button to the right of "E".
45. Set Easting to equal to 0m.
46. Select the 123 button to the right of "N".
47. Set Northing to equal 0m.
48. Select the 123 button to the right of "H".
49. Set Height to equal 1000m.
50. Select "OK".
51. Enter HR, the height of the prism rod.
52. Select "Meas" to shoot in BM1.
53. Select "OK" to save BM1.
54. Select "CALC".
55. Check that StDev (H) is < 0.005m (standard deviation for height).
    a. If value is within error threshold, record it in the field datasheet and proceed to the next step.
    b. If StDev (H) is >0.005m, repeat the process starting on **Step 4** (install a new temporary point if necessary).
56. Select "Set" to set station.
57. Select "OK". The "Measure Points" screen will appear.

   a. **VERY IMPORTANT**: If station is not set correctly, the survey will contain critical errors from this point forward and there are no real warnings to alert you that this is happening. Therefore it's extremely important to make sure the station is set before you continue with the survey.

58. Verify you are at the correct station (TS1).
59. Hit the "Home" button on the outside of the POC.
60. Select the "Measure and Record" workflow.
61. A screen appears that displays your station and backsight point. Verify both of these values are correct (note: the backsight value should be one of the points used in the missing line workflow, i.e. BM1).
   a. If OK, leave the prism rod setup on the benchmark and proceed with the survey.
   b. If station is not set correctly, you must go back to **Step 4** and repeat the process.

APPENDIX G SURVEY NOTES TEMPLATE

Name/Date:

1. List the Domain, Site, Survey Start Date and Survey End Date.
2. List the names of the staff that conducted the survey.
3. What was the staff gauge height during the survey?
4. Why was the survey conducted?
    a. Post-repair infrastructure survey?
        i. If yes, what was repaired, what incident led to the repair?
    b. Infrastructure re-survey?
        i. If yes, why is the infrastructure being re-surveyed?
5. Was the total station field calibrated prior to the survey?
    a. If yes: Did the Laser point alignment test pass?
    b. If yes: Did the Prism track (PTrack) test pass?
6. Were benchmarks installed prior to the survey?
    a. If yes: how many were installed, what type, and where were they installed?
7. Was the first total station location (TS1) setup using benchmarks?
    a. If yes: what type of benchmarks (permanent/temporary) were used?
8. Was the first total station location (TS1) setup using the Missing Line Workflow?
    a. If yes: what was the horizontal distance between the two points?
9. Were GPS/Trimble data collected during the survey?
    a. If yes: how many points were collected, where was the data collected, how long was each point logged?
10. Did you close a survey loop?
11. How did the survey go overall? What challenges did you encounter during the survey? How did you deal with them?
12. Were there any unique calls you had to make during the survey? Please describe as this will help aid the next survey crew and lead to better data comparability.