

<i>Title:</i> AOS Protocol and Procedure: Wadeable Stream Morphology		<i>Date:</i> 05/16/2017
<i>NEON Doc. #:</i> NEON.DOC.003162	<i>Author:</i> D. Monahan	<i>Revision:</i> B

AOS PROTOCOL AND PROCEDURE: WADEABLE STREAM MORPHOLOGY

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See configuration management system for approval history.

The National Ecological Observatory Network is a project solely funded by the National Science Foundation and managed under cooperative agreement by Battelle. Any opinions, findings, and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation.

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	02/29/2016	ECO-03668	Initial release, includes Rapid Habitat Assessment SOP
B	05/16/2017	ECO-04578	There is now only one type of survey implemented once every 5 years, or when a major channel altering event occurs. Added 13 cross-section (for a total of 15); Added a pebble count; Added a LWD tally; Set a maximum of 50 bankfull indicators collected; set a maximum of 50 floodprone width collected. With the exception of the 50 floodprone measurements collected at the transects, eliminated measuring any feature outside of the bankfull channel. Set minimum point amounts for features; wetted edge and thalweg. Changed the Total Station start of the project procedure; Changed the procedure for moving the Total Station; Updated Rapid Habitat to include gravelometer and detailed mapping survey. Changed the benchmark procedure to include – permeant benchmarks and trimble points.

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1 OVERVIEW

1.1 Background

Streams exhibit a massive degree of physical diversity and geomorphic character. The geomorphic character of a stream channel is driven by current and past geologic, climatic, and biological conditions present in the terrestrial environment immediately adjacent to the channel and in the upland contributing area of the watershed. The morphology of a stream is dynamic over time. Changes in water level and sediment supply play a major role in shaping the channel and dictate how the channel morphology will change in response to perturbation. Glacier-fed streams may shift from a braided, unstable channel to a single, stable channel as the glacier retreats up valley and sediment supply diminishes (Marren and Toomath 2014). In another example, if precipitation declines over time in an arid- or semi-arid region, stream channels will begin to incise and form deep canyons, leaving former floodplains perched high above the contemporary active stream channel (Leopold 1994). The collective physical attributes in a stream, including in-stream channel structures, sinuosity, density of wood, and channel morphometrics, is known as the geomorphic template.

The geomorphic templates strongly influence ecological processes in streams. Attributes related to geomorphic features significantly influence the quantity and quality of habitat for virtually all aquatic organisms at multiple spatial scales, from the frequency of small features such as pools to the sinuosity of the entire channel (Frissell et al. 1986). Sediment supply, transport, and stability, largely a reflection of the geomorphic template, may also directly affect the composition of biotic communities residing in the stream across spatiotemporal scales (Lamouroux et al. 2004). Although in-stream biota play a limited role in structuring the physical nature of stream channels, riparian and upland vegetation may strongly influence stream channel shapes by controlling erosive forces (Keeton et al. 2007). Woody debris within the stream channel plays an important role for aquatic organisms, as large woody debris (LWD) creates refugia and provides unique structural habitats on which many aquatic species depend (Lemly and Hilderbrand 2000).

Stream geomorphology is an important component of the ecological system and a metric for assessing biological and physical processes in streams. NEON will measure the geomorphic attributes of all NEON wadeable stream sites annually. Geomorphology surveys will be conducted using standard surveying equipment. A number of metrics will be drawn from data products derived from the surveys to quantitatively depict in-stream and riparian habitat in NEON wadeable stream sites.

1.2 Scope

This document provides a change-controlled version of Observatory protocols and procedures. 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.

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1.2.1 NEON Science Requirements and Data Products

This protocol fulfills Observatory science requirements that reside in NEON’s Dynamic Object-Oriented Requirements System (DOORS). Copies of approved science requirements have been exported from DOORS and are available in NEON’s document repository, or upon request.

Execution of this protocol procures samples and/or generates raw data satisfying NEON Observatory scientific requirements. These data and samples are used to create NEON data products, and are documented in the NEON Scientific Data Products Catalog (RD[03]).

1.3 Acknowledgments

CHaMP (Columbia Habitat Monitoring Program). 2014. Scientific protocol for salmonid habitat surveys within the Columbia Habitat Monitoring Program. Prepared by the Columbia Habitat Monitoring Program.

CHaMP Transformation tool, <http://ctt.ioewheaton.org/>

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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	EHSS 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 Performance QA/QC 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.005003	NEON Scientific Data Products Catalog
RD[04]	NEON.DOC.001271	NEON Protocol and Procedure: Manual Data Transcription
RD[05]	NEON.DOC.003224	Datasheets for AOS Protocol and Procedure: Wadeable Stream Morphology
RD[06]	NEON.DOC.001646	General AQU Field Metadata Sheet
RD[07]	NEON.DOC.001152	NEON Aquatic Sample Strategy Document
RD[08]	NEON.DOC.001717	TOS Protocol and Procedure: TruPulse Rangefinder Use and Calibration

2.3 Acronyms

Acronym	Definition
BFI	Bankfull Indicators
BM	Bench Marker
CP	Control Point
DEM	Digital Elevation Model
GIS	Geographic Information System
GPS	Geographic Positioning System
LWD	Large Woody Debris
POC	Rugged hand held unit to record Total Station data.
STD	Standard Deviation
TSOP	Total Station Operator
UTM	Universal Transverse Mercator Coordinate System
HD	Horizontal Differences
dH	Height Differences

2.4 Definitions

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Active channel: The natural waterway that contains all stream flow at and below bankfull stage

Assumed coordinate system: Localized coordinate system (i.e. not elevation, latitude, and longitude) of a survey established by attributing the first occupied point of a new site survey with the coordinates: 0 northing, 0 easting, 1000 elevation. All new surveys will be attributed an assumed coordinate system during the initial survey.

Bankfull Indicator: A physical marker created during the 1.5 to 2 year bankfull forming discharge used to identify the maximum channel height and width of the that discharge. Indicators used can be break in slope, change in soil type, the line where terrestrial vegetation starts, debris, and sand lines.

Bankfull Stage: the elevation of the water surface when rising water completely fills the channel and first begins to spill onto the floodplain.

Bankpin: Pins placed at bankfull locations on both sides of the stream

Benchmark: A geographic marker of a known location; elevation, latitude, and longitude.

Control point: A permanent or temporary location used to set up or orient the surveying instrument. Includes any station setup, benchmark, or backsight locations.

Cross-Section Profile: A transect running perpendicular to the channel where channel features are mapped.

Datum: A frame of reference for measuring locations on the surface of the Earth (i.e. lines of latitude and longitude).

Deposition zone: Area where sediments settle and accumulate on the stream bottom. Usually areas where the current is slow moving.

Established coordinate system: Spatially accurate coordinate system (UTM) established after the first survey of a site. All revisit site surveys must re-occupy the exact same established coordinate system as the first survey.

Floodplain: The relatively flat valley-floor surface that has been constructed during the present hydrologic regime.

Flood prone width: The valley floor outside of bankfull flood stage that is formed by floods two times the 1.5 to 2 year bankfull forming floods. Discharge level is defined as twice the bankfull depth.

Geographic coordinate system: Data defined by a 3-dimensional surface and measured in meters or feet (i.e. latitude and longitude). Used interchangeably with datum.

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Geographic Information System: A system designed to connect data to geography. The system is designed to capture, store, manipulate, analyze, manage, and present all types of spatial or geographical data.

Gradient: Is a value used to define the slope of a stream. This is expressed as the ratio of the amount a stream decreases in elevation over a selected horizontal unit length of stream. The resulting value is typically expressed as a number ranging from 0 – 1.0, or a percentage.

Habitat unit: A single habitat feature (e.g., a pool) within the stream reach.

Large woody debris (LWD): Woody debris a minimum of $\geq 0.15\text{m}$ in diameter and 1 meter in length.

Left bank: By standard convention, left bank is the left side of the channel from the perspective of an individual facing downstream.

LWD jam: Grouping of three or more pieces of wood that are touching and lie within bankfull channel. Logjams are important for stream complexity and are important components of aquatic habitat for many species.

Meander: A bend in a sinuous stream or river. Form when moving water erodes the outer banks and widens the channel, and the inner part with less energy deposits material. The result is a snaking pattern of the watercourse.

POC: Rugged handheld tablet for controlling the robotic Total Station used to capture features during the survey.

Pool: A river and stream aquatic habitat unit created by scour or impoundment and having a structural control. Pools are longer than they are wide and are 1.5 x deeper at their maximum depth than at their crest. Pools are deeper and have slower velocity than other stream habitat units. If all the running water in the stream was shut off, pools would still hold water. Fine sediments typically deposit in pools.

Prism: Mirrored flat surface that acts as a reflector to return the light pulse back to the Total Station to measure distance.

Prism pole: Graduated pole fixed with a prism on top used with the Total Station to measure the height of and mark survey points.

Projected coordinate system: Data defined by a flat 2-dimensional surface which is measured in meters or feet.

Riffle: A river and stream aquatic habitat unit comprised of shallow water flowing over rough bed material, such as boulders and cobbles, creating ripples, waves, and eddies on the water surface.

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Right bank: By standard convention, the right bank is the right side of the channel from the perspective of an individual facing downstream.

Run: A river and stream aquatic habitat with swiftly flowing water but no surface water agitation, with relatively laminar flow.

Sinuosity: A measure of the deviation of a line from the shortest path. Calculated by dividing the total length by the shortest possible path.

Step pool: High-gradient streams (steep) where water cascades over a rock or woody snag, dropping into small pools. Due to the gradient and surrounding geology, this pattern continues down the stream: step (drop)—pool—step—pool—etc.

Thalweg: The Deepest part of the active channel.

Total Station: (TS) The HILTI POS 180 Robotic Total Station is a high-resolution instrument used in surveying to measure distances and angles from horizontal points of interest. Total Stations utilize a laser pulse (light pulse) to determine distance. They are equipped with a positioning system to determine the angle of rotation of the Total Station from a known datum to the points of interest.

Trimble Point: A non-permanent marked point mapped with the total station and Trimble GPS with Tornado Antenna. If it is the first time a survey is done at a given location, then the survey needs at least three Trimble points. Trimble points need to cover as much of the surveyed reach as possible, form as close as possible an equilateral triangle, and collect 300-1000 Trimble seconds using the Tornado antenna for each point. They do not have to be permanently marked however.

3 METHOD

3.1 Overview

The NEON wadeable streams morphology protocol provides methods to conduct an engineering-grade survey of the topographical aspects of a stream channel and the adjacent floodprone area. The survey captures the geometry of the stream channel at NEON aquatic reach. Furthermore, it demarks the locations of biological habitats and stream channel features that are used for determining sample collection locations for other NEON aquatic protocols.

The survey covers the entire NEON aquatic reach, approximately ≤ 1000 m. The location, or spatial position of points along the channel bed, water surface, floodplain, and the boundaries of in-channel habitats are recorded as Cartesian (X, Y, Z) coordinates using a Total Station (TS). Northing and Easting positions of each point are measured as X and Y coordinates and elevation is recorded as Z coordinates. All coordinates are recorded as the distance from the origin of the survey (e.g. 0, 0, 0 m). The origin of the survey is the first station location.

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If it is the first survey at a site, the first station location is determined by using the survey technique “missing line” workflow, in which the missing line maps two points and establishes the TS location on the landscape. During “the missing” line workflow one of the two points needs to be a benchmark (known to the world location mapped using a Trimble GPS). This benchmark, along with the eventual mapping of at least two other benchmarks during the survey, will tie the data into the known world. TS data will be processed after the survey, and transformed into a geographic coordinate system. The product of TS data processing is a digital elevation model (DEM) map.

The survey captures the fluvial geomorphic template of the reach by capturing the topographic features of the stream channel and floodplain, water surface elevation, and the location of channel features/biological habitats. Geomorphology mapping, used in concert with NEON’s Aerial Observation Platform (AOP), precipitation, groundwater, and turbidity data, enables researchers to have a complete picture of the stream fluvial geomorphology in time and space. NEON’s geomorphology mapping is comprised of four components: cross-sectional profile mapping, longitudinal channel mapping, pebble count, and LWD tally.

Cross-sectional profile maps capture floodplain width, bankfull width and height, and stream channel depth. Longitudinal profile mapping captures in stream habitats, the location and position of in-channel LWD jams, mid-channel islands and bars, pool frequency and quality, dramatic changes in stream topography, and water level height. Pebble and LWD counts quantify the quality of substrate and the quantity of wood in the channel, two extremely important components of stream structure.

Geomorphology features are collected using a robotic TS. The use of the TS to complete the survey will take two highly skilled technicians, approximately eight days, assuming technicians work eight hours each day. In order to meet this schedule, mapping a minimum of 200 meters per day should be the goal. This time estimate includes the first day spent implementing the “missing line” workflow needed to orientate the TS in an X, Y, Z Cartesian grid.

Technicians mapping the stream will use a HILTI TS and prism pole with an attached 360° mirrored prism. The prism pole is placed on points representing geomorphology features (e.g., points of topography or elevation of water surface). Survey points capture major slope breaks in the channel and floodplain, edge of water (i.e., wetted edges) along channel banks, mid-channel features, position of thalweg, and location of habitat features. Data points are individually coded by specific feature when entered into the TS POC. The codes aid in post processing of the data and the creation of different GIS derived topographic layers of the surveyed area.

The methods described here provide a single, unified guide to surveying geomorphic features and biological habitats in wadeable stream channels at all sites within the NEON program. The data collected from the surveys will be used to generate a GIS-based digital elevation model (DEM) map for each site. The protocol and data products are designed to interface with other habitat and geomorphology monitoring programs currently operating in the United States and Canada.

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Standard Operating Procedures (SOPs), in Section 7 of this document, provide detailed step-by-step directions, contingency plans, sampling tips, and best practices for implementing this sampling procedure. To properly collect and process samples, field technicians **must** follow the protocol and associated SOPs, and use NEON’s problem reporting system to document and find resolution to any field issues associated with executing this protocol.

The value of NEON data hinges on consistent implementation of this protocol across all NEON Domains, for the life of the project. It is therefore essential that field personnel carry out this protocol as outlined in this document. In the event that local conditions create uncertainty about carrying out these steps, it is critical that technicians document the problem and enter it in a trouble ticket.

Quality assurance will be performed on data collected via these procedures according to the NEON Science Performance QA/QC Plan (AD[05]). The documentation of standard deviation (STD) for shooting COP during the TS moves. The acceptable sampling error between features needs to be < 0.25 m.

3.2 Survey Set-Up

Prior to mapping, it will take approximately .5 to 1 day to set up, which involves finding a location with a good, wide line of site for the “missing line” workflow. The “missing line” workflow will create one X,Y,Z point defined as 0,0,0. All other points will be mapped in relation to that 0,0,0 point. Because the survey will start at the bottom of the reach, the location chosen for the “missing line” workflow will be set up close to the bottom of the permitted reach. Technicians will need to know the locations of the following transects: 10 aquatic plant transects, discharge, S1, S2, the bottom and top of the reach. It is important that future mapping efforts be able to revisit the exact same transect locations every year, so technicians need to use the directions stamped on the permanent plot markers to set up transects.

The “missing line” workflow requires the mapping of two points, one of which is a permanently marked benchmark. The entire geomorphology survey requires the mapping of a minimum of three permanent benchmarks.

Benchmarks are point locations “known to the world” and are used to tie the TS survey points into a GIS map. Benchmarks require that technicians GPS survey benchmark points using a Trimble with Tornado antenna, and collect between 300 and 1000 GPS seconds. Benchmarks need to form as close as possible an equilateral triangle on the landscape, the benchmark used in the “missing-line” workflow should be one point in that triangle. Set the benchmark triangle up so that future surveys will have line of site to all three benchmarks from a number of different TS locations. If there has already been a geomorphology survey at the site, benchmarks will already exist, before installing benchmarks make sure that benchmarks do not already exist for the site.

3.3 Survey Workflow

To increase the “known world” accuracy of a map, non-permanently benchmarks called Trimble points will be measured during the first geomorphology mapping event at a site. If there has already been

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geomorphology mapping at the site, Trimble points are not necessary. For the first geomorphology mapping survey at a site, three Trimble points, forming as close to an equilateral triangle as possible, and spread out so they cover as much of the entire reach as possible, need to be mapped. Map Trimble points using the TS and Trimble with Tornado antenna. Collect between 300-1000 points for each Trimble point. Survey Workflow

1. If this is the first geomorphology survey at a site, complete the “missing line” workflow (SOP B), if there are no already established benchmarks, establish and map benchmark points.
2. If it is the first time a survey is done at a given location, map (and gps with the tornado) three Trimble points in as large a triangle as possible that cover the entire survey area.
3. Move the TS from the location of the “missing line” workflow to the location of the first cross-section at the bottom of the permitted reach (SOP D). The move will require mapping three Control Points (COP).
4. Map the bottom of the reach’s cross-sectional profile (SOP C. 3)
5. Collect a 40-count pebble count at 5 riffle or run or step-pool transects (SOP C. 5)
6. Map longitudinal features (SOP C. 4)
7. As longitudinal features are mapped, tally in bankfull LWD (SOP C. 6)
8. Map cross-sectional profiles at 14 additional locations (=15 total).
9. After the first day of TS set up mapping should proceed at a rate of 200 m per day, given an eight-hour working day.

4 SAMPLING SCHEDULE

4.1 Sampling Frequency and Timing

The wadeable streams morphology protocol is executed once every 5 years at NEON wadeable stream sites. Geomorphology survey bout dates, will be selected by November of the preceding year ahead of time and will coincide with periods of expected baseflow conditions. Baseflow is strongly recommended because it facilitates access to geomorphological features and provides repeatability in scheduling future mapping efforts. . However, it is understood that scheduling may not allow everyone to map at baseflow conditions. In those cases, try to schedule during hydrologic conditions that are not too deep or fast for technicians to access required features, or too dry that features during normal flow conditions would be absent. Future mapping efforts need to be scheduled at a time that matches the seasonal and hydrologic conditions similar to the initial geomorphology survey.

NEON has five Total Stations available for use across all Domains. Survey dates need to be coordinated between Domains and with availability of the survey equipment. After FOPS has scheduled a Domain’s geomorphology survey, the Domain needs to request the TS from the

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warehouse using an Internal Request in Maximo. The units will be shipped between Domains or from HQ to Domain offices.

Geomorphology Sampling Schedule:

Geomorphology mapping occurs every five years or scheduled earlier after a potential major channel altering event. In order to determine if a potential major channel altering event has occurred at a site, Domains will use the steps outlined in the NEON Discharge Protocol to determine if a site’s Staff Discharge Rating Curve (SDRC) has shifted, and assessments of the effects of high flow and bank failure events on AIS infrastructure and sampling transect locations. If following the steps outlined in the Discharge Protocol, discharge sampling indicates that the SDRC has shifted at a site then a new geomorphology mapping event will be scheduled prior to the five-year cycle. If a high flow event of causes damage or the removal of stream instrumentation, or the need to reestablish sampling locations, the Domains need to write a trouble ticket explaining the event and providing pictures of the event. Science will work with the Domains to determine if the event is significant enough to cause an earlier revisit for geomorphology mapping.

Geomorphology mapping is scheduled for eight days including set up and unforeseen circumstances. In order to complete the survey in this time frame technicians must map at a rate of 200 m a day. It is important to attempt to adhere to this schedule as closely as possible. If it is difficult to meet this schedule then it is possible that your mapping concentration is at too fine a scale, and fewer points should be mapped. If after 2 days of mapping you find that you are unable to meet the 200 m a day mapping requirement write a trouble ticket and science will help work with Domains to reduce the number of cross-sectional profiles required.

Rapid Habitat Assessment

The rapid habitat assessment SOP is done once during site characterization at each wadeable stream site during a period when the stream is safely wadeable. The Rapid Habitat Assessment should be scheduled at a time when the stream level is relatively close to baseflow, but not during an abnormally dry part of the year (e.g., similar conditions or time of year as a biological sampling bout) and when leaves are on the trees if working in a deciduous forest (e.g., between Bio Bout 1 and Bio Bout 2 at the site). The Rapid Habitat Assessment SOP requires 4-8 hours of work for two highly skilled technicians.

Following characterization, the Rapid Habitat Assessment SOP will be performed once per year around the same time of year, optimally between Bio Bout 1 and Bio Bout 2. Changes noted from the annual Rapid Habitat Assessment will trigger more frequent occurrences of the Stream Geomorphology SOPs.

4.2 Criteria for Determining Onset and Cessation of Sampling

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The protocol may be initiated at any time during daylight conditions and may be executed during mildly inclement weather, such as light rain. However, the protocol shall be temporarily ceased if hazardous conditions (e.g., lightning or flooding conditions) threaten personnel safety. The protocol may be resumed on a different day without compromising data quality. Geomorphology survey dates should also coincide with minimal planned biological or chemical sampling in the stream reach so as not to compromise other protocols' data. For instance, if personnel have been wading in the stream and disturbing sediments to conduct the geomorphology surveys, water quality samples cannot be collected for at least 12 hours.

4.3 Timing for Laboratory Processing and Analysis

All raw survey data points and associated data files shall be downloaded from the TS POC and Fulcrum STDs to an external drive (e.g., USB key supplied with the TS) and uploaded to a network drive at the Domain support facility within 12 hours of the completion of the survey.

4.4 Sampling Timing Contingencies

Table 1 Contingent Decisions

Delay/Situation	Action	Outcome for Data Products
Nightfall	Measure and record three control points (COP) or benchmarks (BM). Turn off instrument. Return to site and begin with a New Station (NewSta) setup using the COPs or BMs	No change to the outcome of data products if COP and BM points are shot correctly and the TS is level.
Heavy rainfall or rising water levels in the channel	Survey three COPs or BMs. Turn off instrument, cover with waterproof covering (e.g., heavy weight garbage bag), then move to higher ground. Once waters have receded, set up TS and shoot COPs, and continue surveying.	The re-orientation of the survey will not be impacted. However, there may be changes in wetted edge depths. The survey shall be continued when the stream has returned to ± 20 cm staff gauge reading of when the original survey started. If after a week the stream discharge never drops below > 20 cm of the discharge at the start of the survey, write a trouble ticket and reschedule the survey.
Dead batteries in Total Station	Survey two COP or BM's. Do not move or disturb the tripod or TS. Change the battery, turn on, check level, establish communication with the POC, and continue with the survey.	No expected change in data products. After changing batteries, the crew should re-shoot the nearest benchmark and verify that the instrument was not disturbed. If disturbed, see "Accidental movement of tripod and TS" below.
Accidental movement of tripod and TS	Reset Total Station into proper place. Ensure tripod and TS are level, establish communication with POC, shoot the three	Misaligned coordinate system and skewed survey points.

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	nearest COPs or BMs that have been previously surveyed. Continue with survey from the new station location. If the station was slightly bumped, check level, take a backsight shot to a COP or BM, and verify the measurements are within the error range.	
Wind	Keep prism pole at shortest height to avoid movement of the prism in wind. Halt survey if wind gusts are impacting the plumb line of the prism pole.	If the prism and the point of the prism pole are not plumb (i.e., the prism pole is offset from the normal line to the feature) results in an incorrect measurement of x, y, and z coordinates.

4.5 Criteria for Permanent Reallocation of Sampling within a Site

Stream morphology sampling will occur on the schedule described above. Ideally, sampling will occur at these sampling locations for the lifetime of the Observatory (core sites) or the duration of the site’s affiliation with the NEON project (relocatable sites). However, circumstances may arise requiring that sampling within a site be shifted from one particular location to another. In general, sampling is considered to be compromised when sampling at a location becomes so limited that data quality is significantly reduced. If sampling at a given site becomes compromised, a trouble ticket should be submitted.

There are two main pathways by which sampling can be compromised. Sampling locations can become inappropriately suited to answer meaningful biological questions (e.g., a terrestrial sampling plot becomes permanently flooded or a stream moves after a flood and the location is no longer within the stream channel). Alternatively, sampling locations may be located in areas that are logistically impossible to sample on a schedule that that is biologically meaningful.

5 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 Operations Field Safety and Security Plan (AD[02]) and EHS Safety Policy and Program Manual (AD[01]). Additional safety issues associated with this field procedure are outlined below. The Field Operations Manager and the Lead Field Technician have primary authority to stop work activities based on

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unsafe field conditions; however, all employees have the responsibility and right to stop their work in unsafe conditions.

Personnel should wear clothing appropriate for weather conditions at the site. Both team members are required to wear hip waders and wading boots with no-slip soles. Technicians should consider wearing NEON approved personal flotation devices in high velocity streams or streams with pools and runs deeper than one meter. Activities in streams should only be performed when flow conditions are safe. Do not attempt to wade a stream where velocity x depth is $\geq 10 \text{ ft}^2/\text{s}$ ($0.93 \text{ m}^2/\text{s}$).

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6 PERSONNEL AND EQUIPMENT

6.1 Equipment

Table 2 Equipment list – [Total Station Survey]

Item No.	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
Durable items						
MX109898	R	HILTI POS 180 Robotic Total Station and POC data collector	Measure and collect survey data	All	1	Y
MX107405	R	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	All	1	N
MX107406	R	HILTI POA 360° mirrored prism	Mirrored target for TS measurement shots	All	1	N
MX107407	R	Sokkia heavy duty fiberglass tripod	Supports and orients TS	All	1	N
MX102549	R	Trimble® GEO XH 6000 GPS receiver or equivalent model.	Locate and mark benchmarks	All	1	N

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Item No.	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
Part of MX109898	R	POA 84 Battery for the POS 180	Power for POS	All	2	N
Part of MX109898	R	POA 86 battery charger for the POC 180	Charge batteries for POC	All	2	N
Part of MX109898	R	Hilti application software USB key	Access HILTI updates	All	1	N
Part of MX109898	R	POC Controller with Stylus	Operate TS from pole	All	1	N
Part of MX109898	R	POA battery for the POC 100	Power for POC	All	2	N

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Item No.	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
Part of MX109898	R	POA 81 AC adapter for POC 100	Charge battery for POC	All	1	N
Part of MX109898	R	POA 100 Accessories case (tools)	Change battery on POC	All	1	N
Part of MX109898	R	POA 76 Frame clamp	Attach POC to prism pole	All	1	N
	S	Camera	Photo document the reach and associated features	All	1	N
	R	Pin flags	Used to mark locations of control points, benchmarks, and survey boundaries	All	25	N
MX100320	R	Compass	Verify orientation of the survey	All	1	N

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Item No.	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
MX104369	R	50m measuring tape	Measure and layout	ALL	1	N
MX100324	S	Radios	For communication between team members	All	1 per person	N
	R	Rain Cover (e.g., heavy duty plastic bag)	Protect TS from rain	Rain	1	N
Consumable items						
MX105556	R	Flagging tape, orange	Mark features	All	1 ROLL	N

R/S=Required/Suggested

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Table 3 Equipment – Rapid Habitat Assessment and Pebble Count

Item No.	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
Durable items						
	S	Clipboard	Recording data	All	1	N
MX100491 MX100494 MX107505	R	Waders (hip or chest) or knee boots	Wading	All	1 pair/ person	N
MX100703	R	Handheld GPS unit (recreational or Trimble)	Record waypoint	Habitat survey	1	N
	R	30 Meter tape	Measuring features	Habitat survey	1	N
MX105823	R	Meter stick or foldable meter stick	Measuring depth or pebble size	All	1	N
MX100322	S	Laser rangefinder	Measuring streams width	Habitat survey	1	N

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Item No.	R/S	Description	Purpose	Conditions Used	Quantity	Special Handling
MX110827	R	Gravelometer	Measuring pebble size	Pebble count	1	N
		Stake or Chaining Pins	To secure meter tape while measuring bankfull width	Cross-section	2	N
Consumable items						
	R	Field data sheets (all-weather copier paper, write in pencil)	Recording data	All	1 set	N

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6.2 Training Requirements

All technicians must complete protocol-specific training for safety and implementation of this protocol as required in Field Operations Job Instruction Training Plan (AD[04]). Field personnel shall be trained on how to: operate, troubleshoot, and retrieve data from robotic TS; proper use of a prism pole with prism; recognizing and how to properly survey in-channel and flood plain topographic points; fundamentals of basic surveying; QA/QC procedures for the survey; and safe working practices for stream field work.

All technicians must receive training in accordance with NEON EHSS Policy, Program and Management Plan (NEON. DOC.004300 AD[01]) and Field Operations Safety and Security Plan (NEON.DOC.004316 AD[02]). Technicians working in or near wadeable waterways shall be trained in Cold Water Safety Awareness and shall be competent in the use of waders.

The accurate identification of bankfull is extremely important in order to correctly map geomorphology. Use available training materials until bankfull can be accurately identified at the site.

6.3 Specialized Skills

Technicians must have the ability to accurate survey using the TS.

6.4 Estimated Time

Surveys should be completed in no more than eight days, assuming an eight-hour workday. Initial set up of the TS, recording benchmarks using a Trimble, and completing the “missing line” workflow will take at least two hours and in rare cases the entire first day. After the initial setup, it is expected that in-channel mapping will be completed at a rate of 200 m per day over an eight-hour workday. One factor that can reduce the speed of mapping is the inability to maintain line of sight between the TS prism (e.g., vegetation, water depth, foul weather, excessive rain and gradient/steepness of the channel).

If after the third day of mapping, Technicians are unable to meet the 200 m of mapping a day criteria, write a trouble ticket detailing survey rate and issues contributing to slower mapping rates. Science will work with the Domain to identify and solve problems. If it is determined that the sites conditions are such that the 200 m a day criteria is not possible then Science will reduce the number of aquatic plant cross-sectional profiles from 10 to 6. Science will work with the Domain to determine which of the 6 cross-sectional profiles to sample, so as to ensure spatial and habitat representation across the reach. If after the 5th day and the reduction of the cross-sectional plant transect from 10 to 6, technicians are still unable to meet sampling rate

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expectations, write a trouble ticket. Science will work with the Domain to reduce the number of cross-sectional profiles from 6 to 4.

7 STANDARD OPERATING PROCEDURES

SOP A Preparation for Sampling

A.1 Preparing for Data Capture

Make sure that all batteries are fully charged at the beginning of each field day.

In addition, given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets for pebble counts, LWD tallies, and TS moving STD, are always available to record data. Paper datasheets should be carried along with the mobile devices to sampling locations at all times.

A.2 Equipment and Supplies

1. Check all surveying equipment to ensure it is ready for field use.
 - a. Inspect prism mirror for cracks or scratches.
 - b. Check and tighten all bolts on prism and prism pole.
 - c. Check prism pole knob lock to ensure it works properly and when locked holds the measurement rod securely in place.
 - d. Remove the TS from its case and check for signs of damage.
 - e. Ensure that primary and backup batteries for the TS and GPS are fully charged.
2. Prepare a field kit with all equipment listed in Table .
3. Be sure to bring adequate water and food as the morphology surveys will require a full day in the field. Polarized sunglasses will allow technicians to see below the water surface. Wearing them will reduce the risk of a fall and potentially submerging equipment such as the POC.

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A.3 Total Station Components

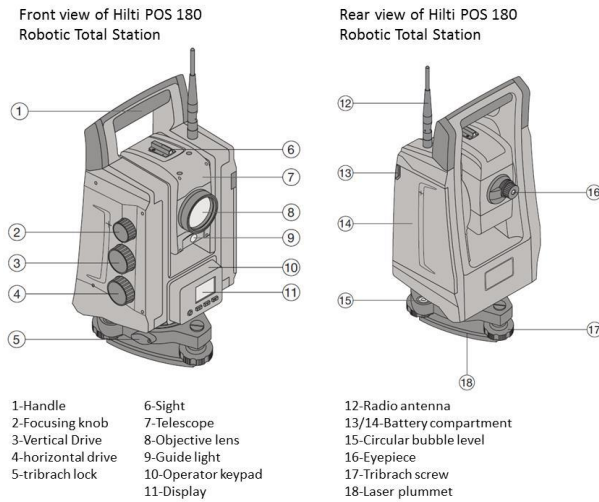


Figure 1. HILTI POS 180 Robotic Total Station. Photo from www.us.hilti.com

A.4 Total Station Operator Keypad

The operator keypad is located on the front of the TS (Figure). The keypad is used to turn the TS on/off, laser plummet on/off, and confirming the selection on the display. The keypad and display screen are also used for the fine tune leveling of the TS prior to beginning a survey (Figure).

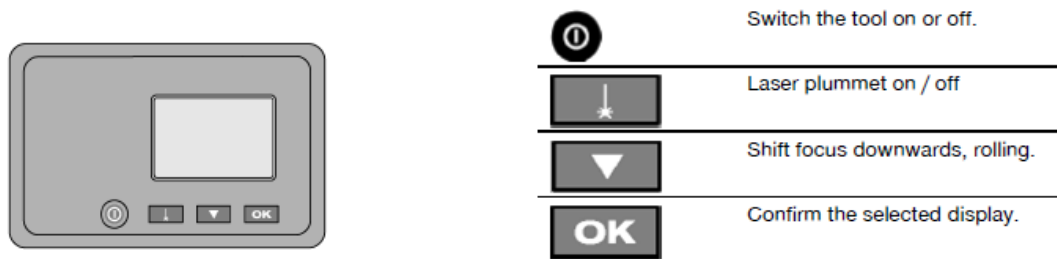


Figure 2. HILTI POS 180 keypad. Photo from www.us.hilti.com

A.5 POC Components

The POC is the data collection unit (Figure and 4) that can be either attached and operated from the prism pole or operated as a hand-held device when removed from the prism pole.

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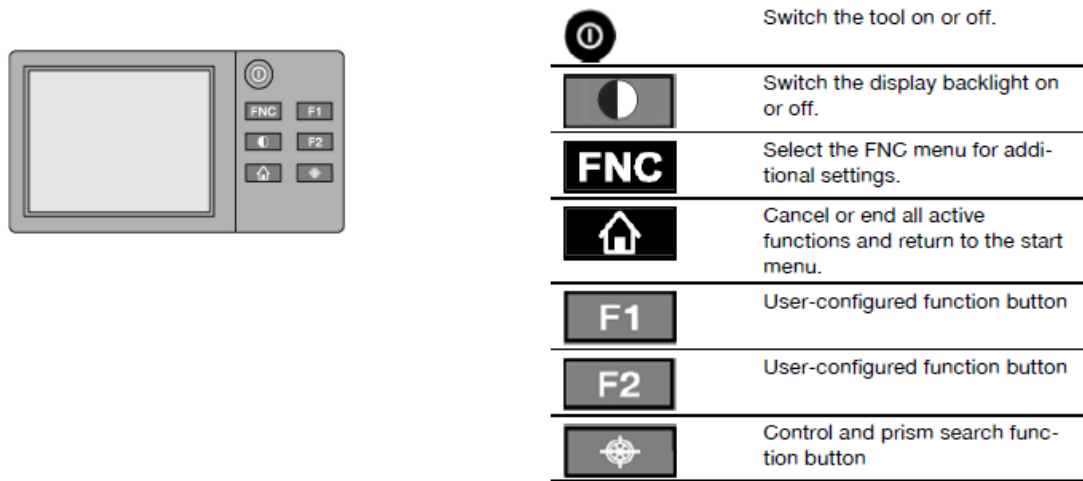


Figure 3. HILTI POC unit keypad. Photo from www.us.hilti.com

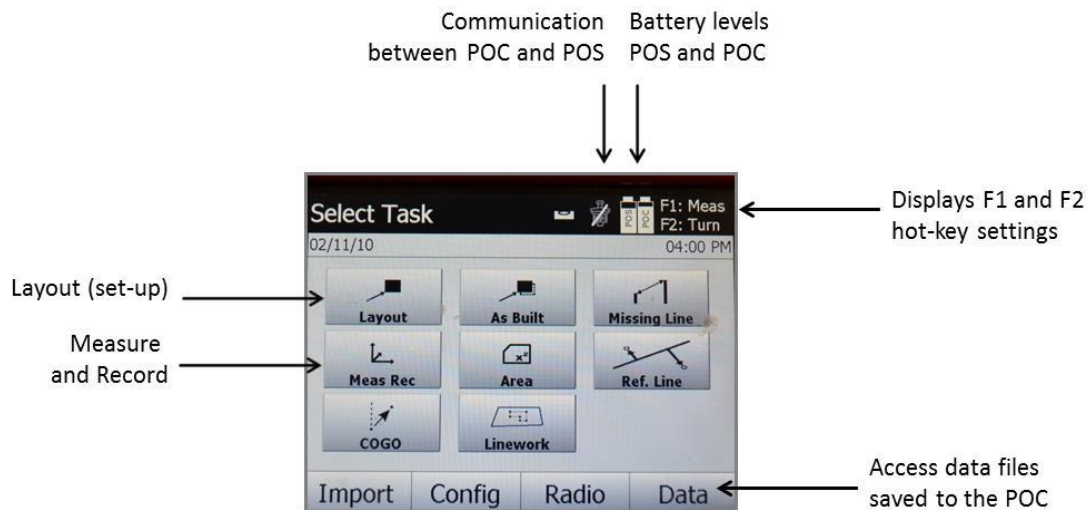



Figure 4. Home Screen on Hilti POC for the Total Station.

A.6 Transferring Relevant Data Files to the GPS Receiver

If Technicians desire data to help navigate in the field, such as coordinates for benchmark locations, they can be imported into the Trimble GPS unit so that they can be navigated to easily. Benchmarks may become covered with debris, rendering them difficult to locate in the field without navigation capabilities provided by a GPS unit, i.e. Trimble.

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1. Connect the Trimble GPS to the computer with the supplied USB cable and power on the unit. Tap on the Windows icon at the bottom left side of the GPS screen.
2. Find the TerraSync icon and tap twice with the stylus.
3. Use the Windows Mobile Device Center (Window 10 to connect the device to Windows. If this is the first time connecting the GPS to the computer, the Windows Mobile Device Center may install automatically. If it does not, download it online from the windows software website.
4. Set the coordinate system in the Trimble TerraSync software to the corresponding coordinate system used for the site.
 - a. In the TerraSync software on the GPS, from the MDD tap **Setup** then click the **Coordinate System** box.
 - b. Match to the coordinate system of downloaded data, select: **System** = UTM, **Zone** = [appropriate zone and datum], then click **OK**. From the MDD, return to the **Map** screen.
5. Once the GPS unit is connected to the computer, within Pathfinder Office, use the  **Data Transfer** utility to transfer all desired files to the GPS receiver. You should at least import the data files with benchmark locations, though data depicting other landmarks such as sensor, or well locations may help find a benchmark in the field. Importing a background image or pertinent data dictionary may also help.

A.7 Robotic Total Station Set-up

1. Set up tripod and TS at location decided upon for the “missing line” workflow in a manner that creates as large an equilateral triangle as possible between the two points and the station location, one of the points needs to be a benchmark. The benchmark for this needs to be permanently marked and must be one of three points in the established site benchmark network. Benchmarks need to be captured on the Trimble and submitted for data processing. The triangle need to be a close to an equilateral triangle as possible, given the challenge of field conditions.
2. Fully unfold the tripod so the legs are spaced at even intervals (Figure).
 - a. Make sure that the tripod shoes are firmly fixed into the ground by stepping on the foot pedals until they are flush with the ground.
 - b. Alternatively, the tripod may be set up on a large flat boulder, road or other fixed structure. Be sure that wind or a slippery surface will not compromise the TS when setting up the tripod. The unit is top heavy and may fall over on a smooth or uneven surface.

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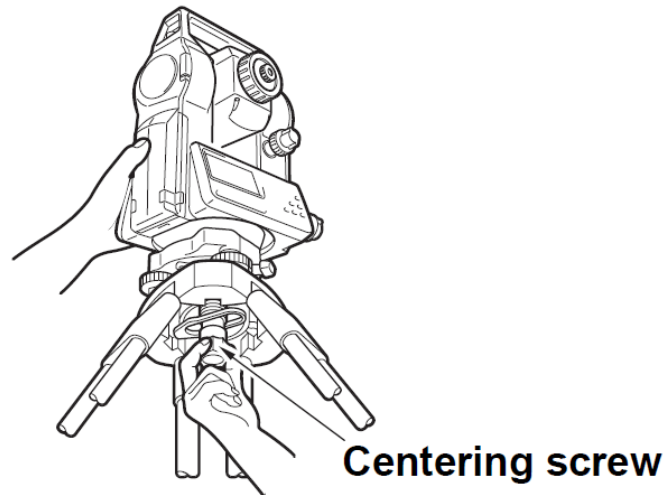


Figure 5. Attaching the Total Station to the tripod

3. Every time the TS is set up after relocation, the location must be determined by the line of sight between the TS, prism, COPs, and the features and point to be mapped. Place the HILTI POS 180 Robotic TS onto the tripod head by supporting the TS with one hand while tightening the centering screw on the bottom of the unit ensuring it is secured to the tripod.
4. Turn on laser plummet.
5. Level the TS by adjusting the tripod legs until the bubble is completely in the center area (Figure).
6. Turn on the TS
7. Use TS keypad and screen to view level of the TS (7A)
8. Fine adjust the level of the TS using the tribrach screw knobs (Figure) until the display screen indicates the TS is level (Figure 7b). This can be time consuming so be patient.
9. Press [OK]. The TS is now leveled and ready for use.
10. Establish communication (via Bluetooth wireless) between the TS and the prism pole/POC unit. This connection should happen automatically. See section A.8.

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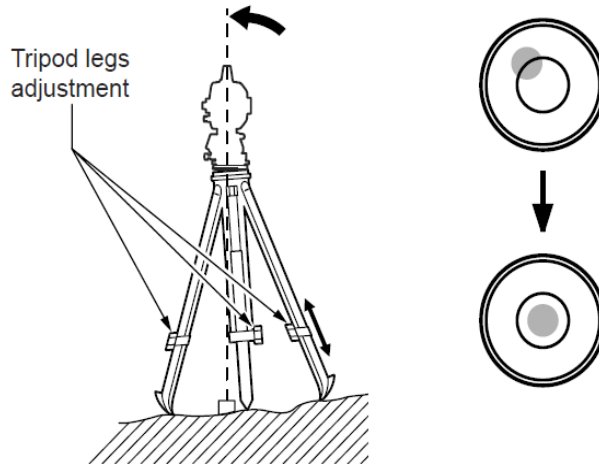


Figure 6. Leveling the tripod using the bubble level

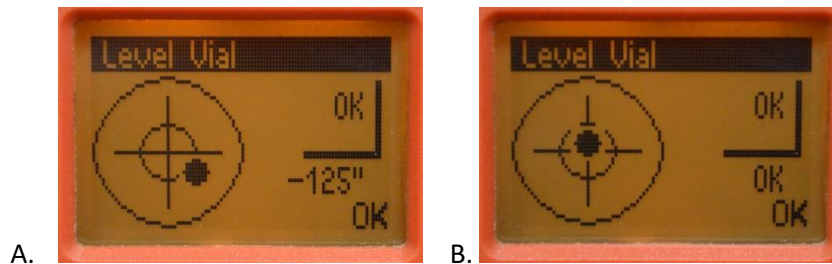

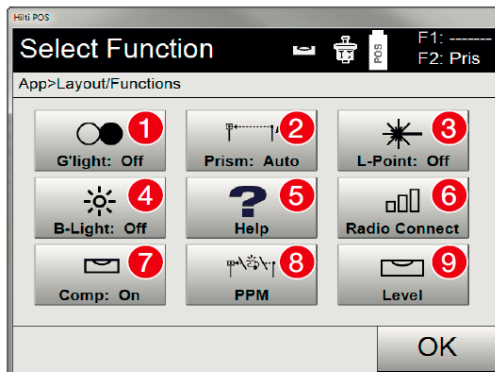


Figure 7. POS 180 display screen leveling application. A.) Total Station not level. B.) Total Station is level.

A.8 Establishing Connection between the Total Station and Prism


1. Press the search button  on the POC.
2. Press [G'light:ON] button (Figure)
 - a. Setting options for the guide light
 - 1) OFF
 - 2) Flashing frequency-slow
 - 3) Flashing frequency-fast
 - 4) **Flashing frequency-AUTO (with this setting, the light flashes only if there is a loss of connection to the prism pole.)**

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- ① Guide light: Normal, fast, automatic, switch off
- ② Set standard measuring target
- ③ Laser pointer on / off
- ④ Adjust backlight
- ⑤ Brief description of all functions (Help)
- ⑥ Wireless on / off, select wireless channel
- ⑦ Compensator on / off
- ⑧ PPM: Settings for atmospheric corrections
- ⑨ Level (bubble level): Bring up the electronic level and laser plummet

Figure 8. Layout applications functions screen on the HILTI POC

3. Set guide light option to “Flashing frequency-auto”
 - a. **If the flashing red/green light is in the activated state, a person can see either a green or red light depending on which side of the sighting line the person is located.**
 - b. **A person (i.e., the prism) is in the sighting line if both colors can be seen at the same time.**
4. Stand at least 5 m from the TS holding the prism pole upright with the prism in direct line of sight of the station.
5. Adjust your position until both colors (red/green) of the guide light are visible.
6. Hold prism pole in place and press the prism search button  on the POC.
7. Remain still until you hear a single three-bell ring, meaning the TS has connected with the POC controller and is in view of the prism.
8. If the prism and TS are NOT in contact, a red line will display through the prism icon on the POC. **When communication is lost the POC will beep a three-ring tone.**
NOTE: WHEN WALKING BETWEEN GEOMORPHOLOGY POINTS WITH PRISM POLE UPRIGHT (90° TO GROUND) WHEN MOVING. THIS WILL ALLOW THE TS TO FOLLOW THE PRISM AND MAINTAIN COMMUNICATION. Be mindful of overhead obstructions that could damage the prism.
 - a. If there is an obstruction in the line of the site and communication is lost, return to the point where the communication was lost, align with the red/green guide lights and press the prism search button on the POC.
9. Once communication between the TS and the prism is established and the ‘missing line’ workflow is completed, continue to SOP B (Survey layout and Benchmarks).

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SOP B SURVEY LAYOUT AND BENCHMARKS

The TS survey maps a northing (X), easting (Y), and elevation (Z) for each feature. Before mapping, the TS needs to be orientated to the landscape and eventually tied to the outside world. For the first geomorphology map surveyed at a site NEON uses the “missing line” workflow to orient the TS to the landscape and benchmarks to tie the map to the outside world. Before the mapping of geomorphology features can start, technicians will need to complete the “missing line” workflow.

The “missing line” workflow (Figure 9) will require that two points are surveyed at the start of mapping, one of those points needs to be a benchmark Point 1 (P1). Point 2 (P2) must be the second leg of an equilateral triangle. The TS is the third leg of the triangle, the more area on the landscape the triangle is able to cover on the more accurate the data will be. The location for completing the “missing line” survey should be close to the bottom of the reach, so that the TS can be moved a minimum distance to map the first transect at the bottom of the reach.

A minimum of three permanently marked benchmarks must be collected at each site. Some sites will already have established benchmarks, if the site has already established benchmarks, one of those established benchmarks needs to be P1 for the “missing line” workflow. For the best data the three benchmarks will be placed on the landscape in a shape representing as close as possible an equilateral triangle, benchmarks need to be set up in a way that allows for all three to be reshot regardless of where the TS is set up. Benchmarks also need to be surveyed using a Trimble GPS. Collect between 300-1000 GPS points with the Tornado antenna attached (denoted as seconds in the top right-hand of the Trimble’s screen).

Three Trimble points need to be established at some point during the survey. Trimble points should form as closely as possible an equilateral triangle, and cover as much of the reach as possible. Trimble points do **NOT** need to be permanently marked, but do need to be mapped with the TS and the Trimble GPS using the Tornado antenna. For each Trimble point, collect between 300-1000 GPS points. The three Trimble points can be collected over the course of the survey (i.e. they do not need to all be collected as the TS is moved upstream to cover as much area as possible).

1. Choose P1 and P2 so that they are 2 points in a large equilateral triangle with the third point being the TS. Temporarily mark P1 and P2.
2. Set up TS so that the TS is a point in as large a triangle between the Point 1 (P1) and Point 2 (P2) as possible.

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3. Turn on the hand held POC and name the project SITE.YYYYMMDD.geo.
(for example, ARIK.20170316.geo)
4. Press the prism search function button. Tap the prism option and choose the correct prism type you are working with. Return to the home screen.
5. Choose the “missing line” prompt.
6. Enter the rod height. Rod height is measured at the black line marked in meters.
7. Ensure the prism and the TS are connected.
8. Map P1. Make sure that the tip of the prism pole is on top of the ground, but not pushed into the ground. Make sure P1 is marked so that the point of the prism pole can be placed in the exact same location every time you map it.
9. **Measure P1** and the hit **next**.
10. Map P2 (change the rod height in the POC if the rod height differs from survey P1) the same as you did for P1.
11. **Measure P2**, click **Results**
12. In a notebook, record the **HD** (horizontal distance, e.g. 2000 m) and the **dH** (height difference, e.g. -1.00). There is no need to digitally save this information, however it may be needed for data processing
13. **DO NOT MOVE THE PRISM** from P2.
14. Return to the home screen. Press the **Measure and Record** option. Choose **New Station**. Leave the first screen as defaults and click “OK”. Choose **Target Points** and call the point PT2.
15. Leave **Easting** as 0, **Northing** as whatever was recorded for HD (e.g. Northing 2000), **Height** input add (if the dH was a positive number) or subtract (if dH was a negative number) dH from 1000 ± whatever was recorded for dH (e.g. 1000-1.00= 999.000). If the HD was a negative number subtract from 1000, if positive add to 1000.
16. Select **OK**, check your HR (height of rod) and select **Measure and Record**.
17. Go back to P1, **MAKE SURE TO PLACE PRISM ROD POINT IN THE EXACT SAME LOCATION THAT THE ORIGINAL POINT 1 WAS MAPPED AT DISTANCE AND HEIGHT**.
18. Name **PT1**. Leave easting and northing as 0, but input 1000 for height, choose **OK**, check your HR and select **Measure and Record**.
19. Select **Calculate**.
20. If the STD for distance and height is less than 1.0 cm go ahead and start collecting points or shoot a COP move the TS to *bottom of the reach transect* and start the survey.
21. If the STDs are >1.0 cm , repeat steps 8-19 If after five attempts a STD of 1.0 cm cannot be attained-start over using new points.

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22. Using Trimble GPS with a Tornado antenna collect 300-1000 points on top of the P1 benchmark.

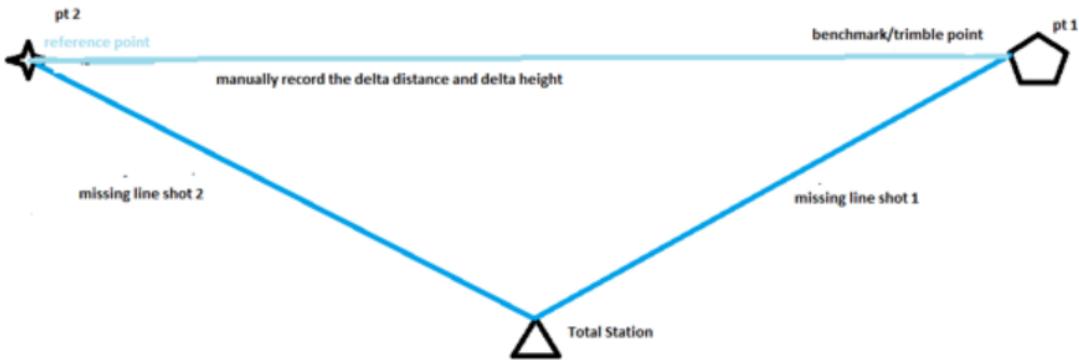


Figure 9. "Missing line" workflow example of idealized layout.

SOP C DATA COLLECTION METHODS

The collection methods for the geomorphic survey require precision and accuracy. In order to capture the status and trend of fluvial geomorphological conditions at NEON sites, data will be collected at fifteen cross-sectional transects and in a longitudinal survey. Substrate pebble counts and a LWD tally will also be collected. The geomorphic survey collects important topographical points along the reach to create a DEM map. A complete list of all features that need to be surveyed is found in the next section (Table 4). The complexity of stream channels varies at every site. For this reason, the amount and distribution of survey points will also vary, some parameters will have a minimum number of points, while other parameters will be mapped at a scale dictated by the complexity of the reach. Site surveys should cover an average of 200 m a survey day, if Technicians fail to map 200 m a day, write a trouble ticket.

The overarching goal of the protocol is to conduct a survey that is geometrically representative of the stream channel and floodplain. The survey data will generate morphology maps that capture changes in the geometry of the stream channel and floodplain over time.

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C.1 Survey Codes

Table 4. Survey codes for data input into Total Station

Feature Description	Code
MISSING LINE AND BENCHMARKS	
Point 1	P1
Point 2	P2
Benchmark	BM#
Trimble Point	TP#
Control Point	COP#
CROSS-SECTION PROFILE	
Flood Prone Width	FPW
Bankfull Indicator	BFI
Wetted Edge Left (looking downstream)	WEL
Wetted Edge Right (looking downstream)	WER
Depth 25%	25D
Depth 50%	50D
Depth 75%	75D
Thalweg	THL
Thalweg at the bottom of the reach	BOT
Thalweg at the top of the reach	TOP
LONGITUDE CODES	
Run Tail	RUT
Run Head	RUH
Riffle Tail	RIT
Riffle Head	RIH
Pool Head	POH
Pool Tail	POT
Pool Max Depth	MPD
Pool Crest	POC
Maximum Pool Wetted Width Left	MPL
Maximum Pool Wetted Width Right	MPR
Mid-channel Bar Top	MBT
Mid-channel Bar Bottom	MBB
Mid-channel Bar Left (looking downstream)	MBL
Mid-channel Bar Right	MBR
Mid-channel Bar Height	MBH
Island Left	ISL
Island Right	ISR
Island Bottom	ISB
Island top	IST
Island Height	ISH
Tributaries	TRI
Beaver Dam	BEA
Water Falls	WFS
LWD Jam Bottom	LWB
LWD Jam Top	LWT
LWD Jam Left	LWL
LWD Jam Right	LWR
LWD Jam Height	LWH

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C.2 Collecting Data Points using the Total Station-POC and Prism pole with 360° Mirrored Prism

1. Place the prism pole with mirrored prism on top of the point where you want to measure elevation and survey the position. **If the substrate is soft do not push the pole into the ground. This will give a false reading of the elevation. Gently rest the pole on the substrate, prevent it from sinking by holding it at the correct level.**
 - a) The prism pole must remain in the plumb position, meaning that the rod is held vertical and is not tipped to the side. Use the plumb level on the prism pole to ensure the rod is set correctly before shooting the point with the TS. **If the rod moves during the shot, reset the prism pole and re-shoot the point. If you believe there was an error, it is always better to re-shoot the point.**
2. When the rod is plumb (use bubble level on rod), press [Meas Rec] button on POC
 - a. Alternatively, The F1 hot key on the POC is set to the [Meas Rec] function.
3. Name point by selecting [Pt ID] and use the keypad to enter point identification. See Table for codes. Use format: FPW01...THA01...BFI01
4. Press [OK]
5. Select [HR] and enter in the rod height in metric (i.e., the height of the prism), which is read from the numeric graduations on the prism pole (Figure 10).
 - a. **All HRs are reported in meters (m) with two decimal places, e.g., 2.55, or 2.00. It is advised to set the rod height at a workable distance and do not adjust unless absolutely necessary (i.e., ...). When the HR changes it must be changed in the TS using the POC prior to taking the survey shot. If the HR changes and it is not changed on the POC then the shots must be retaken. The best advice is to change the HR as few times as possible. During windy conditions, chose a HR that is as low as possible to avoid wiggling of the prism during data collection.**

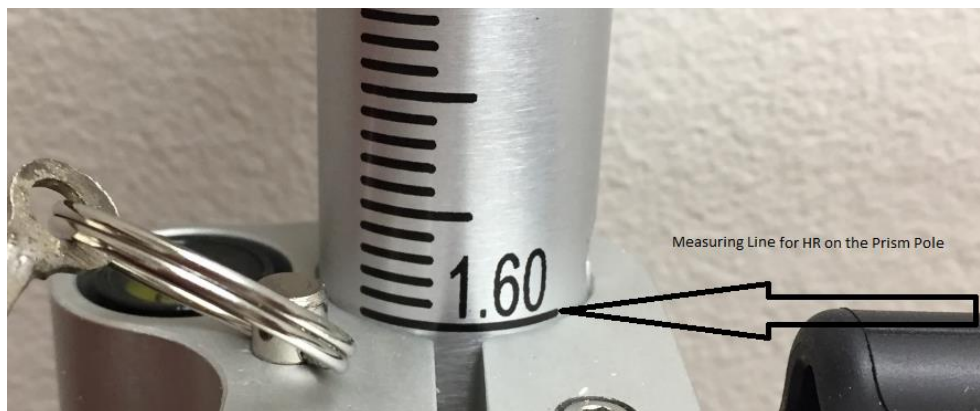


Figure 10. How to tell HR height on prism pole

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6. Press [OK] to return to the measure points screen.
7. On the Measure Points screen press [M&R] or hotkey F1
8. The POC screen will show “measuring distance” and when data collection is complete “Point ‘LEW01’ was saved”
 - a. To check if the data was collected return to the home screen on the POC (Figure 4) and select [Data]. All points will be available to view as a text or map file. Use the POC screen to navigate to the proper job name and data file.
9. Move the prism pole and prism to the next point.
10. If the next point is in the same code (e.g., LEW) then press F1. The point will be automatically named using the next numeric number in the series. Pay attention to this when recording different stream features in sequence.
 - a. The alpha code for each point will be entered in the POC. The POC will auto fill a numeric value (e.g., LEW01, LEW02, LEW03) during consecutive shots of points with the same code. **It is advised to take advantage of this feature by shooting points with the same code consecutively up or down the survey sub-section area to reduce time typing in new numbers. If you return to a feature code that was previously shot the numbering will pick up where it last left off.**
 - 1) Select OK. You can now continue to collect data in series for the same code by simply pressing the F1 hotkey (measure and record).
 - 2) When returning to a feature code type in the code identifier and default numeric value 01 (e.g., LEW01), a message on the POC screen will appear “LEW01 is already in use, Use LEW02”. This prevents accidental overwrites.

C.3 Collecting Cross-section Profile Data Points

Cross-section profile mapping starts by mapping the first cross-section, the first cross-section is the cross-section profile located at the permanently marked bottom of the reach. All other cross-section will be mapped working upstream. Map the next fourteen cross-section profiles (10 aquatic plant transects, S1, S2, discharge transect, top of the reach).

After completion of the TS set up, use the methods described in SOP C to move the TS to a place where the bottom of the reach’s cross-section profile transect can be mapped. It is vital that stream cross-sectional profile mapping occurs in a way that future mapping efforts capture the exact same fifteen cross-section profile locations. To ensure that the exact locations are visited every time a site is mapped, make sure to use the directions on the permanent markers to navigate and set up transects. For S1 and S2, transects should bisect the unistrut that the sensor sets are attached to. The most time-consuming element of the geomorphology protocol is moving the TS. In order to limit the amount of times the

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TS is moved choose a location where as many features as possible can be mapped. Collect cross-section profiles at the following permanently marked locations, ensuring that future mapping efforts can effectively map cross-sections at previously mapped locations. Use permanent markers to navigate to the following cross-section profile transects:

- a. Bottom of the reach
 - b. 10 permanently marked aquatic plant transects
 - c. Discharge transect
 - d. S2, transect should bisect the unistrut
 - e. S1, transect should bisect the unistrut
 - f. Top of the reach
2. After navigating to the cross-section profile transect, lay out the transect as follows.
- a. Along the line of the transect on each bank, identify the bankfull indicators by using physical indicators that mark the location where every 1.5 to 2 years the stream high flow creates the bank. Indicators of bankfull are break in slope, top of point bar, the line where substrate types change, scum lines, or the line where perennial vegetation grows . Use training materials provided by NEON identify and map bankfull at the transect (Figure).
 - b. Once the bankfull indicators on each bank are identified, use chaining pins or stakes to mark the bankfull width. Then run a tape from bankfull indicator to bankfull indicator, making sure that the tape runs along the transect line and is taut.
 - c. The **length of the tape is the bankfull width**. Divide bankfull width by four. Starting from the right bank, mark the location along the transect where 25%, 50%, and 75% of the bankfull width are located. These are the locations where transect depths will be collected.
 - d. Along the transect line identify the thalweg. Holding the tape tight so that it is strung across the stream and is running level from bankfull to bankfull, use the prism pole or meter tape to measure bankfull depth. **Bankfull depth is measured at the thalweg, from the bottom of the stream up to the bankfull height**. In order to calculate floodprone height **multiply bankfull depth by 2**.
 - e. Extend the meter stick or the prism pole to the height calculated for the floodprone height. Looking out into the valley, demarcate the area on the landscape where the floodprone height intercepts a slope (Figure).
 - f. Using a clinometer or laser level, mark the location where the flood prone height intercepts the slope. One technician should identify the flood prone

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location standing at the thalweg, and the other technician should place a pin flag at the intercept location.

- g. Do not move the TS to map the flood prone width. If the flood prone width is obscured by vegetation, or is > 50 m from the bankfull indicator, DO NOT MAP flood prone on the bank in question.

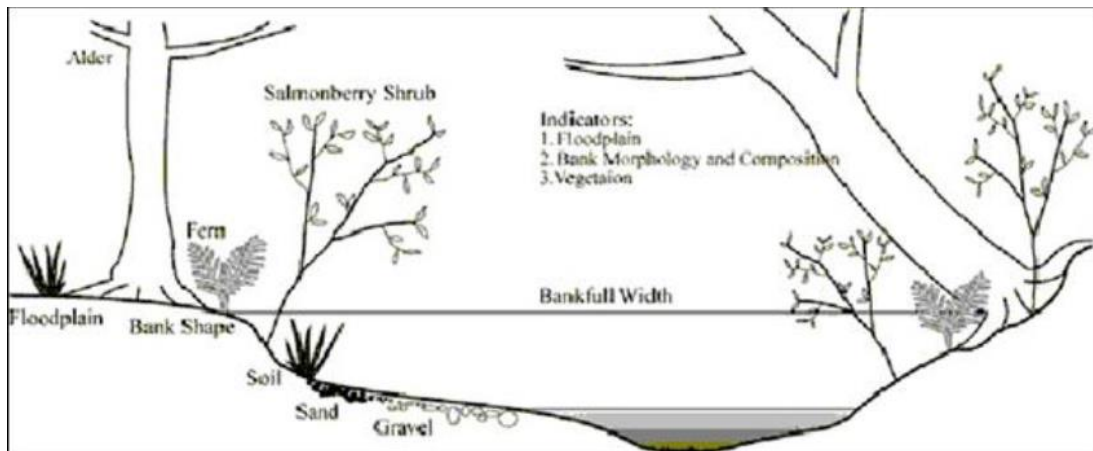


Figure 11. Bankfull indicator identification (Oregon Department of Health 2016)

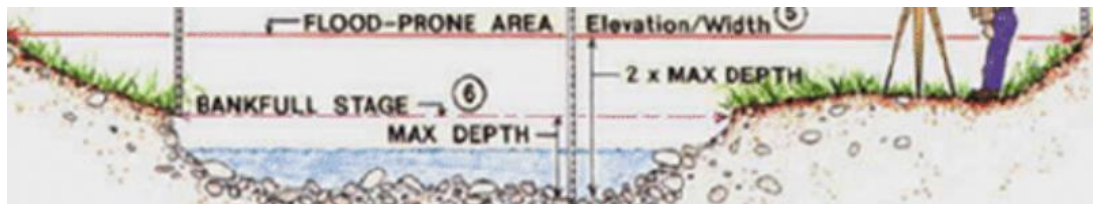


Figure 12. Example of floodprone height and width (Venkasten et al 2015)

3. Once the bankfull and floodprone have been established, at each cross-section transect, use the TS to map the following points. Using the appropriate three letter code to ingest the data into the POC, map the following features:
 - a. **Floodprone Width (FPW)** Both banks
 - b. **Bankfull Indicator (BFI)** Map on both banks the bankfull indicator (Figure 10).
 - c. **Wetted Edge Left and Right (WEL, WER)** Map the location where the water makes contact with the bank on both the left and right bank along the transect. If the channel is dry along the transect do not record this feature.
 - d. **Depths at 25%, 50%, and 75% of bankfull width (25D, 50D, and 75D).** At the 25%, 50%, and 75% percent of the bankfull width, starting at the right bank,

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map the depth. Map depth even if the spot is dry and/or falls on a large boulder.

- e. **Thalweg (THL)** Map the deepest part of the active channel falling on the transect. If the transect falls on a dry section of stream, map the most indented part of the channel and name the point Dry Thalweg (**DTH**). Name all wetted thalwegs **THL**, except the thalweg along the bottom and top of the reaches. Name that thalweg at the bottom of the reach **BOT**, and the thalweg at the cross-section along the top of the reach **TOP**.

C.4 Collecting Longitudinal Profile Data Points

The longitudinal profile consists of a series of important fluvial geomorphology features. Begin mapping features immediately upstream from the bottom of the reach’s cross-sectional profile transect and end by mapping at the cross-sectional transect at top of the reach.

1. Map the following features during the longitudinal survey. Use the appropriate three-letter code to ingest the data in to the POC. Note the minimum number of points for each feature needed to map each the entire reach, included in the description.
 - a. **Habitat Unit Run Tail (RUT), Habitat Unit Run Head (RUH), Riffle Tail (RIT), Riffle Head (RIH), Step-Pool Head (SPH), Step-Pool Tail (SPT), Pool Tail (POT), and Pool Head (POH)**). The entire length of the active channel from the bottom of the reach cross-section to the top of the reach cross-section must be included in a habitat unit. While mapping longitudinal features identify habitat unit types then map where the habitat unit starts and where it ends. Stream sections are complex and can contain more than one habitat unit. Mapped and identified habitat unit must be >50% of the wetted width and be longer than they are wide. When a habitat no longer meets that criteria, it has ended, that is where the habitat head should be mapped. When a habitat ends, a new one must begin, that is where you should map the tail. There may be times when a decision between two habitat types need to be made. When in doubt be a lumpers and not a splitter. Each habitat unit must have at least five measurements: tail, head, left wetted edge, right wetted edge, and thalweg. If part of the reach is **DRY** mark the extent of the dry channel and designate it (**DRY**). If there is a dry channel map the top and bottom of the dry section and name both DRY.
 - b. **Right and Left Wetted Edge (LWE, RWE)** Map where water makes contact with the bank on both the left and right edges. Collect at a minimum **50**

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points for each side, for the whole reach. Every defined habitat unit must have at least one wetted edge measurement for the left and right side of the habitat unit. Map the left and right so that they are roughly directly across from each other. Attempt to choose wetted edges that more closely represent the average rather than the maximum or minimum wetted edges. Wetted edge features. When measuring the wetted edge of pools, do not measure pool wetted edge at the narrow crest. Points collected for each habitat unit can count towards the minimum of 50 points needed for the entire 1 km reach.

- c. **Thalweg (THL)** The deepest part of the active channel. **A minimum of 20 thalweg points** for the reach must be collected. Each habitat unit must have at least one thalweg point. The deepest thalweg in the habitat unit should be one of the thalwegs collected. If only one thalweg is captured for a habitat unit, attempt to collect the point deepest thalweg for that unit.
- d. **Pool Crest (POC)** The spot where water first leaves a pool habitat, usually the start of a riffle or a run. Map the spot where water leaves the pool. If the pool crest and pool tail are in the same location collect both points in that location.
- e. **Maximum Pool Depth (MPD)** The deepest part of the pool. Measure the deepest part of every pool habitat mapped. This measurement also counts as that habitat's thalweg point.
- f. **Mid-channel Bar (MBL, MBR, MBB, MBT, MBH)** Mid-channel bars are a channel consolidated sand/silt/gravel/cobble surrounded by the stream protruding above flow, but below bankfull height. At least 4 measurements should be taken, 1 each at the downstream wetted edge (MBD), upstream wetted edge (MBT), and the left (MBL) and right (MBR) mid-channel bar wetted edges. If it is possible to collect without moving the TS, collect a point at the highest (MBH) part of the bar.
- g. **Island (ISL, ISR, IST, ISB, ISH)** Islands are in channel consolidated sand/silt/gravel/cobble surrounded by water and rising above the bankfull indicator. Map the following 4 points for every island; downstream bankfull edge (ISB), upstream bankfull edge (IST), and left (ISL) and right (ISR) side of the island's bankfull edge. When possible, without having to relocate the TS, map the highest point on the island (ISH).
- h. **Tributaries (TRI)** Tributaries are smaller order streams that join the main stem. Tributaries can either be active (flowing water) or inactive (dry). For

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- each tributary, collect 1 point 1 m upstream from the mouth of the tributary. If the tributary is active, take the point at the thalweg, if the tributary is inactive take the point in the middle of the dry channel.
- i. **Beaver Dams (BEA)** For every beaver dam encountered that actively alters the stream’s flow, collect 1 point **on the beaver dam** in the middle section of the dam **where the upstream water meets the dam**.
 - j. **Water Falls (WFS)** Collect 2 points at each waterfall, one at the waterfall’s base and the other at the top. The objective of these points is to identify the change in elevation of the stream caused by the waterfall.
 - k. **LWD Jam: (LWT, LWB, LWL, LWR, LWH)** LWD Jams are three pieces of qualifying LWD are connected (touching each other), and they all sit within the bankfull channel, collect the following 4 points: upstream terminus (**LWT**), downstream terminus (**LWB**), and left (**LWL**) and right (**LWH**) extent. If safely possible, map the height of the jam (**LWH**).
2. The scale at which longitudinal features are mapped can be difficult to estimate. Is it enough to map the bare minimum required points, or should more points get mapped? Keeping in mind the need to stay on schedule, the mapping tips below may help determine the appropriate frequency to map longitudinal features.
- a. Stream sinuosity, how much a stream meanders, is very important in understanding the geomorphology of a stream. Thalweg and wetted edges points are used to visualize sinuosity. Sites that are relatively straight need fewer points in order to capture stream sinuosity. In most cases a straight reach can be captured using the minimum required points needed for mapping wetted edge, thalweg, and habitat units. More complex channels with bends and meanders will require the mapping of additional thalweg and wetted edge points. Technicians should pay particular attention to capturing the bend of the channel, mapping extra wetted edge and thalweg points in the elbow of the channel bend. When and if the channel straightens again, then technicians can reduce the concentration of points mapped.
 - b. Human and natural watershed changes can alter the gradient of a streambed. Streambed gradient will have an effect on the biology and the chemistry of a stream. This protocol requires the mapping of beaver dams and waterfalls in order to capture areas where streambed elevation changes dramatically. It is important for technicians to recognize channel segments where gradient changes less rapidly. If while mapping upstream the reach starts to gain elevation at a rate that is not being captured with the minimum required

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mapping points, then start mapping extra wetted edge and thalweg measurements in order to capture this change.

C.5 Pebble Count

At five aquatic plant transects, collect a 40-count pebble count. If five of the sites dominate habitats are riffle habitats, collect pebble counts at the five aquatic plant transect riffle habitats. If there are no riffle habitats, then collect pebble counts at the five aquatic plant run habitats. If there are no run habitats, then collect pebble count at the five aquatic plant riffle-pool transects. If there are only pool habitats write a trouble ticket prior to sampling. Pebbles are measured on the b-axis, and binned by size using a gravelometer (SOP E.3). Counts start on the right bank, the first pebble sampled should be roughly 10 cm in towards the stream from the bankfull indicator. Space pebble selection so that samples are collected along the entire transect with the last pebble measured roughly 10 cm below the left bankfull indicator. It is less important that pebble count stations are separated exactly 1/40th across the transect. What is more important is that the entire transect is represented and samples are not concentrated along one specific area of the transect. Record each pebble using the Fulcrum App or paper datasheet.

1. Start pebble count 10 cm from the right bankfull indicator.
2. Close your eyes bend down and pick up the first pebble you touch next to the big toe of your boot (either foot).
 - a. If the substratum is too large to pick up, measure *in situ*.
 - b. If the transect falls in a pool that is too deep to pick up the selected pebble, use the viewing bucket to measure in-situ.
3. Use the gravelometer to measure the B-axis (intermediate axis) of the pebble (SOP E.3).
 - a. Use the gravelometer to bin and record pebble size in Fulcrum.
4. Space your pebble selection station equally across the transect.
5. Move to the next station and repeat Steps 2-4.

C.6 LWD

Tally each piece of LWD (≥0.15 m diameter and ≥1 m in length) observed in the bankfull margins. Tally a piece of LWD even if only a small piece of the LWD falls within the bankfull margins. Tally LWD during the survey while mapping from downstream to upstream. Tally each piece encountered and enter LWD using the Fulcrum App.

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SOP D MOVING THE TOTAL STATION TO A NEW LOCATION

In order to move the TS from the current location to a location where more features can be mapped, control points are used. Control points are three points on the landscape that are shot from the current location of the TS, AND can be shot from the location that the TS is being moved to. The TS will need to be moved during the survey, because it will not be possible to shoot all the points from one location. Try to set up the TS in a location where the line of sight allows a technician to map the greatest number of features without having to move the TS. The majority of the time the station has to be moved because of obstructions by vegetation or to accommodate dramatic changes in the direction or elevation of the channel. Care should be taken when moving the station since there is the potential for error in combining the data between multiple station locations. Each time the station is moved, errors are compounded as the survey continues. When the TS is moved be sure to double check and verify the TS is level, that new COPs and benchmarks are shot correctly and the prism pole/prism is in perfect plumb position, **and most importantly the rod height (HR) is entered into the POC correctly.** Use fulcrum to record the calculated height (HSTD) and distance (DSTD) standard deviation for each move. If the STD is < 1 cm then continue mapping. If STD is >1cm, reshoot the COPs and recalculate. If after five attempts, the STD is still >1cm, record the STD and move on with the survey. It is of vital importance that the COPs are marked in a way that allows the point of the prism pole to be placed on the exact same location every time a COP point is shot.

1. When contemplating a move, identify three locations that can be used as COP. The COPs selected will ideally make an equilateral triangle with the TS. Be sure that the triangle is as large as possible. In cases where it is not possible to create a large triangle, be sure to create a triangle that can be accurately shot from the new location.
2. COPs will not work unless you can place the point of the prism pole on the exact same location every time within a survey (height and distance), make sure to mark the location and number of the COP on the ground or locate a surface that can be marked for the point (i.e., use pin flag).
3. Survey the new COPs. **Each control point should be consecutively labeled beginning with COP01 as the first COP established.** Record the data for the COP on the data sheet.
4. Turn off the TS and remove it from the tripod.
 - a. Place lens cap on and secure TS in the carrying case. **Be sure the case is locked before moving it.**
 - b. Fold up the tripod legs. Lock them into place for easier transport.
5. Move the TS to the new location. This location is the third corner of the triangle.

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6. Set the station up (**See SOP A, A.7 for complete instructions on setting up the TS**).
7. Level the tripod.
8. Attach the TS.
9. Level the TS using the keypad and display.
10. Turn on optic plummet laser
11. Reestablish communication between the POC and the TS. Follow the steps below using the POC. [...] identifies what selection to make on the POC screen.
12. [HOME]
13. [MEAS REC]
14. [NEW STA]
15. Using the **Target** list Select the first control point (COP). **One of the points surveyed in Step 3 and the point you are currently on.**
16. [OK]
17. Place the prism on the point [MEAS]
18. Move the prism to the second control point.
19. Using the **Target** list Select the second COP point from the table.
20. [OK]
21. Measure distance to second COP.
22. Move the prism to the third control point.
23. Using the **Target** list Select the third COP point from the table.
24. [OK]
25. [CALC]
26. After hitting CALC the error screen will show the STD. It should be under 5 mm for the height (dH) and under 1 cm for distance. If it falls within these bounds, start measuring features, if it falls above then retry the above steps until this level of accuracy is achieved. If after 3 times the STDs are still >1.0 cm record the STD and continue.
27. To start the next day's survey, three COPs from the day before will need to be mapped using the steps above.

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SOP E RAPID HABITAT ASSESSMENT

The Rapid Habitat Assessment SOP is performed once during AOS site characterization to define which habitats and samplers to target for stream biological sampling efforts. During Operations, this SOP will be performed annually to document channel changes and trigger more frequent occurrences of the stream morphology SOPs. When the full Stream Morphology Protocol is performed, follow the Detailed Mapping Procedure in SOP **Error! Reference source not found.** Data must be entered using the Trimble data dictionary.

E.1 Habitat Survey: Annual

1. Navigate to the downstream permitted boundary of the site using reach boundary coordinates found in the Domain-specific Sampling Design.
2. Record the waypoint using the Trimble (latitude, longitude) and coordinate uncertainty (GPS accuracy) at the downstream boundary using the Trimble data dictionary.
3. Determine and record the habitat type of the habitat unit directly upstream of the boundary (Error! Reference source not found.).
 - a. Tips for determining discrete habitat units:
 - i. If the habitat is shorter than it is wide, do not consider it to be its own habitat unit. Consider it a part of the next habitat unit, or as part of a complex of the same unit.
 - ii. If there is a small, embedded habitat within the main habitat unit (e.g., a small pool to the side of a riffle), consider it a unique habitat unit only if it accounts for >50% of the stream width.
 - b. Habitat types
 - i. Riffle
 - ii. Run
 - iii. Pool
 - iv. Step pool
 - v. Other (define)

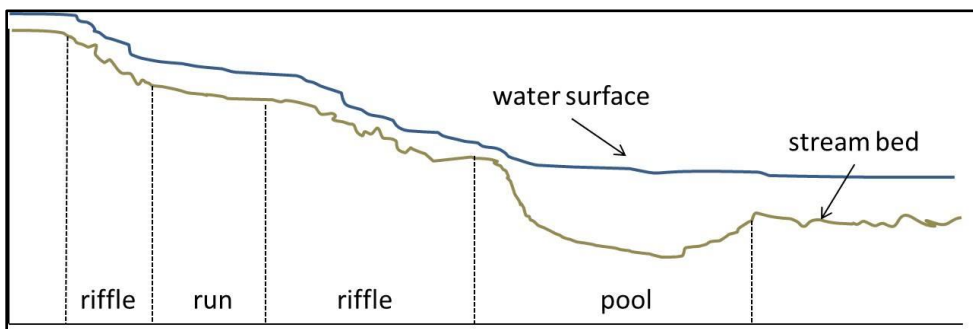


Figure 13. Example of habitat types in a wadeable stream.

4. Measure and record the length (to nearest 0.1 meter) of the habitat unit along the thalweg.

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- a. If a significant obstruction (e.g., deep pool, debris dam) exists so that you cannot follow the thalweg, estimate the length along the shore instead.
- b. If the stream branches, follow and measure the branch that appears to have the most flow. Note the existence of the branch in the remarks of the Trimble data dictionary.
5. Measure and record the maximum wetted width of the habitat unit. You may use either the laser rangefinder (RD[08]) or a meter tape.
6. Measure and record the depth of the habitat unit to nearest 0.01 meter.
 - a. Pools: measure depth at the deepest point
 - i. If too deep to wade, measure the deepest location that you can safely reach
 - b. Riffles, runs: measure depth in the thalweg
7. Estimate and record the percentage of submerged large woody debris (LWD%) for that habitat type to the nearest 5%. Think of this as debris that might be used as habitat for algae, macroinvertebrates, or fish.
 - a. This is a relatively subjective rating, so the same technician should make the final decision for each habitat unit during the survey.
 - b. Technicians should break the habitat into visual sections to estimate percent cover more easily (Figure).
 - c. Calibrate percent cover against other technicians, even though one technician will make the final decisions.



Figure 14. Example of habitat division

8. Estimate and record the size classes of the dominant substrata within the habitat unit. Substrata type classifications are used to determine sampling locations and sampler types for macroinvertebrate and periphyton sampling.
 - a. You may record one or multiple size classes per habitat unit.
 - b. Substratum size classes
 - i. Bedrock
 - ii. Boulder: >256 mm
 - iii. Cobble: 64.0 – 256 mm

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- iv. Pebble 2.0 – 64.0 mm
 - v. Sand: 0.062 – 2.0 mm
 - vi. Silt: 0.004 – 0.062 mm
 - vii. Clay: 0.001 - 0.004 mm
9. Estimate and record the percent riparian cover over the channel at the habitat unit. This is a coarse visual estimate (no densiometer) of how much of the water’s surface is shaded throughout the day, which has been shown to directly affects algal growth on the stream bed (Lowe et al. 2006).
 - a. This number may change dramatically depending on the time of year of the survey, but current conditions should be recorded. If the canopy is primarily deciduous and the survey is taking place when leaves are off the trees (due to scheduling during characterization), make a note on the field datasheet.
 - b. Use the same estimating techniques and calibration between technicians as presented for LWD% above. This is a relatively subjective rating, so the same technician should make the final decision for each habitat unit.
 10. When all measurements have been recorded for the present habitat unit, move upstream to the next habitat unit and repeat Steps **Error! Reference source not found.-Error! Reference source not found..**
 11. Record a waypoint and coordinate uncertainty at the downstream end of every 10-15 habitat units. There is no need to record a waypoint at each habitat feature.
 12. Habitat units may be linked together if they occur multiple times in a row.
 - a. For example, in streams where there are multiple short step pools, you may measure a series of step pools together rather than splitting them up to save time. Call this example a “step pool complex” provided there are no other habitat types in the middle.
 13. Long habitat units may be split apart to make measurements easier.
 - a. For example, a 100-m long riffle may be split into two units, each called “riffle” if it makes measurements easier.
 14. Continue until the entire permitted reach (up to 1 km) has been surveyed. Record a waypoint and coordinate uncertainty at the upstream end of the survey.

E.2 Habitat Survey: Detailed Mapping Procedure

During years when data for a detailed stream morphology map survey are not collected, collect additional Trimble GPS points so that the habitat survey map can be linked to the stream morphology map.

1. Follow the steps in SOP E.1 as usual.
2. Collect the waypoint (latitude, longitude) and coordinate uncertainty of the downstream end of the reach. This is the initial point.
3. Continue with remaining habitat unit measurements.

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4. Collect a waypoint (latitude, longitude) and coordinate uncertainty at the top of each habitat unit. This is the only addition to SOP **Error! Reference source not found.** and may take additional time depending on Trimble accuracy at each site.

E.3 Pebble Count

1. Start in the most common habitat type (as determined above). Choose a location that appears representative of the reach (i.e., did not appear to be an outlier in the habitat survey).
2. Step into the stream perpendicular to flow.
3. While averting your eyes from the substratum, bend down and pick up the first pebble you touch next to the big toe of your boot (either foot). If the substratum is too large to pick up, measure *in situ*.
 - a. This step removes bias from the measuring process.
4. Measure B-axis (intermediate axis) using a gravelometer to group particles to the nearest size bin (Error! Reference source not found.).
 - a. Measure B-axis by determining the closest size hole that the particle fits through in the gravelometer and record the bin size (size of gravelometer hole), record in mobile application or datasheet (Error! Reference source not found.).
 - b. Bin sizes are as follows:
 - i. silt/clay
 - ii. sand
 - iii. 2.8 mm
 - iv. 4.0 mm
 - v. 5.6 mm
 - vi. 8.0 mm
 - vii. 11.0 mm
 - viii. 16.0 mm
 - ix. 22.6 mm
 - x. 32.0 mm
 - xi. 45.0 mm
 - xii. 64.0 mm
 - xiii. 90.0 mm
 - xiv. 128 mm
 - xv. 180 mm
 - xvi. < 265 mm
 - xvii. > 256 mm
 - xviii. bedrock

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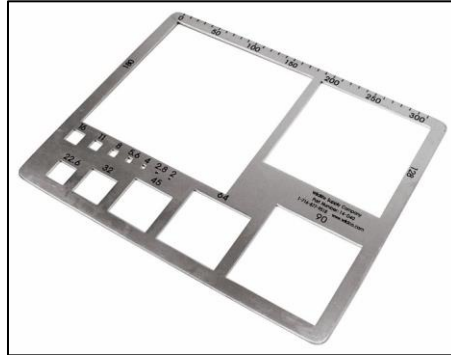


Figure 15. Use a gravelometer to determine which size bin/hole the particle fits through.

Site (4-letter code): HOPB		Recorded by: sparker@neoninc.org								
Date (YYYY-MM-DD): 2016-09-15		Collected by: critz@neoninc.org								
Local time (HH:MM): 14:00		Sampling protocol: NEON.DOC.003162 Rev: B								
Habitat types: riffle, run, pool		<i>Record length of B-axis in mm by size bin</i>								
	1	2	3	4	5	6	7	8	9	10
1-10	11	11	16	>256	5.6	32	>256	>256	16	22.6
11-20	sand	sand	22.6	4	>256	2.8	>256	16	45	90
21-30	>256	bedrock	3	18	>256	boulder	15	>256	>256	sand
31-40	8	>256	silt/clay	>256	11	11	bedrock	<256	8	22.6
41-50	sand	<256	2.8	22.6	5.6	8	sand	sand	<256	sand
51-60	sand	sand	8	>256	5.6	>256	22.6	11	8	>256
61-70	22.6	sand	32	45	16	2.8	sand	>256	2.8	4
71-80	sand	22.6	11	>256	32	sand	11	22.6	128	180
81-90	>256	90	4	22.6	16	32	45	180	22.6	sand
91-100	11	sand	>256	22.6	>256	>256	22.6	16	16	32

Figure 16. Example pebble count datasheet.

5. Take another step into the stream channel and repeat Steps **Error! Reference source not found.**-**Error! Reference source not found.**.
6. Move upstream systematically in a zigzag pattern (from bank to bank) until 100 measurements have been recorded (**Error! Reference source not found.**). Measurements are taken while passing through multiple habitat units as you move upstream, but at a minimum the most common habitat is captured. A very small portion of the entire sampling reach will be surveyed for pebble count.
7. Record all habitat types encountered across the 100 particles in the mobile application.

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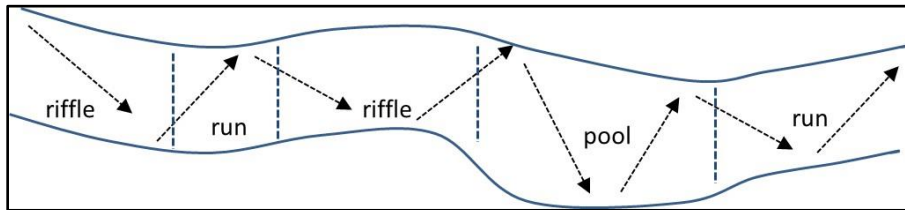


Figure 17. Zigzag pattern through multiple habitats for pebble count measurements.

SOP F Data Entry and Verification

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.

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 should be carried along with the mobile devices to sampling locations at all times. As a best practice, field data collected on paper datasheets should be digitally transcribed within 7 days of collection or the end of a sampling bout (where applicable). However, given logistical constraints, the maximum timeline for entering data is within 14 days of collection or the end of a sampling bout (where applicable). See RD[04] for complete instructions regarding manual data transcription.

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APPENDIX A QUICK REFERENCES

The following information can be printed and taken to the field for reference

B.1 Keys to Success

1. Plan out new station locations carefully. Get the most out of each location. Each time the Total Station is moved to a new location there is an opportunity for error.
2. When setting up COPs for a new station, be sure the angle between the new TS location and the two COPs is always 90° or greater. Take extra care to align the new station location in view of the two new COPs. Be aware of obstructions, such as large trees or banks. Once you move the station to the new location you **MUST** be able to shoot the two COPs.
3. Check the level of the tripod and TS regularly.
4. Only change the rod height when standing at a point to survey. Make it a habit to change the rod height (HR) immediately after tightening the knob to lock the pole. This ensures you will enter the new rod height into the POC immediately. Forgetting to change the rod height prior to collecting data results in poor measurements.
5. To reshoot a point due to an error. Place the rod back on the point, reshoot, and name with the same code and number and add the letter “R” to the end (e.g., a reshoot of point “THA02” would be entered into the POC as “THA02R”). **NEVER ATTEMPT TO DELETE DATA IN THE FIELD.**
6. Be aware of changing data collection times by the POC. During rain or snow, the signal time and quality between the POC and TS (Bluetooth™ enabled) and most importantly the laser path from the TS to the prism and back may be reduced. This generally causes delays in data transmission. If data transmission is reduced, consider halting the survey until conditions become more favorable.
7. Wetted edge points are a measurement of the location (X,Y) and elevation (Z) of the wetted edge/edge of water. Theoretically, the wetted edge at a specific location on the left bank should be at the same elevation (Z), as the coinciding point along the right bank. For this reason, be sure to capture the true elevation of the wetted edge. The wetted edge/edge of water is the point where the edge of the water contacts the bank (or other features of interest, such as wood or a log jam). In areas where there are “wetland” like edges (i.e., Arikaree River, D10) the wetted edge is not always obvious. For this reason, be consistent in the choice of location. If a wetted area exists such as a saturated soil or muddy bank, attempt to survey the actual stream channel wetted edge.
8. Be sure to hold the prism pole in the proper position when surveying wetted edges of channels with soft, muddy banks. Do not let the prism pole sink into

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the substrate giving a false reading of wetted edge elevation. If the TS and POC lose connection, try returning to the location that you were at when the equipment lost communication. Place prism pole point on the ground, hold plumb, and wait for unit to reconnect. If unit does not reconnect with five seconds, line up with the red/green lights on the station and press the search button on the POC.

9. When setting up or moving the TS to a new location, be sure to choose control points that form an equilateral triangle with the new station location. The three points (e.g. TS location, pt1, and pt2) and the triangle they form should be as large as possible and span the stream with points on both banks and/or floodplains. The better the layout the easier it is to transform the TS data into a fixed geographic coordinate system.
10. If a feature is not present, do not try to survey it. Bankfull indicators and other bank features fall into this category. The presence/absence of these features may change along the reach. You can only survey what is present.
11. The bank geometry points top and toe of bank provide the basic shape of the bank. However, when there are slope breaks present between these two points be sure to capture them using the code TOP for general topography. The TOP code can also be used in complex channels where there are numerous slope breaks in the wetted channel.
12. Remove the POC from the prism pole when taking thalweg measurements. One technician can work the POC from the bank while the other works as the rod person in the stream. This prevents the POC from being submersed in water. The POC can handle being dropped in water but should not be submerged for any period of time.
13. Set prism pole at the lowest possible height. This alleviates wiggle of the rod and deviation between the prism and the tip of the rod.
14. Walk with the prism pole perpendicular to the ground. This helps the prism and TS remain in contact, reducing the amount of time spent reestablishing communication between the two. Carrying the rod, this way also alleviates the chances of injury if you fall with the prism pole in your hand. The rod is equipped with a sharp point on the end.
15. When moving the station to a new location carry the tripod and TS separately. Detach the station from the tripod and stow in the carrying case. This will avoid the likelihood of damage to the station or injury to the technician while carrying the equipment. The tripod with the TS attached is top heavy and not safe to carry as one unit.
16. Abide by sub-survey area flags to avoid repeat or missed data collection after changing stations.

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17. If prism pole shifts during data acquisition, reshoot the point.
18. **If an incorrect data entry is made into the POC (feature code, rod height, etc.) correct it in the field by re-shooting the points. Take careful notes of ANY change made in the field in the field data sheet.**

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APPENDIX B CHECKLIST FOR FIELD DEPLOYMENT

Preparation for field work

- Batteries are present and not damaged
 - Total Station (TS), POC
 - GPS
- Batteries are fully charged:
 - Total Station (TS)
 - POC
 - GPS
- Total Station and carrying case are dry and free of dirt
- Total Station turns on and is in working condition
- The following Items are in working order and packed:
 - POC Controller
 - POC metal stylus
 - POC to prism pole attachment clamp and screw
 - POC charging plug
 - Graduated and adjustable prism pole
 - Locking knob and clamp are present and in working condition
 - 360° mirrored prism
 - Prism pole bubble level
 - Total Station unit
 - Total Station battery charging unit
 - Total Station battery charging unit cord
 - 2 Total Station batteries
 - 2 POC batteries
 - Tripod
 - 50 or 100m measuring tape
 - 25 pin flags
 - 1 roll of flagging
 - Field notebook
 - Morphology data sheet

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APPENDIX C ESTIMATED DATES FOR ONSET AND CESSATION OF SAMPLING

The dates in table 5 are based on historic records and are estimates for the start and stop dates of sampling. It is essential that Domain staff monitor real-time conditions to determine and plan survey bout dates that coincide with the guidelines in Section 4 of this protocol.

Table 5. Estimated dates for onset and cessation of data collection for NEON and NEON aquatic sites. Bars denote favorable conditions based on historic discharge data for streams in each Domain.

Geomorphology Survey Schedule for Wadeable Aquatic Sites

Domain	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
1												
2												
3												
4												
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9												
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Bars denote favorable conditions based on historic discharge data for streams in each domain