AOS PROTOCOL AND PROCEDURE: BATHYMETRY AND MORPHOLOGY OF LAKES AND NON-WADEABLE STREAMS

PREPARED BY	ORGANIZATION	DATE
Brandon Jensen	AQU	10/31/2018
Charlotte Roehm	AQU	04/14/2014

APPROVALS	ORGANIZATION	APPROVAL DATE
Kate Thibault	SCI	01/29/2019
Mike Stewart	PSE	01/23/2019

RELEASED BY	ORGANIZATION	RELEASE DATE
Anne Balsley	CM	01/29/2019

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.

Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	06/02/2014	ECO-01129	Initial release
B	01/26/2015	ECO-02636	Migration to new protocol template
C	08/27/2015	ECO-03158	Updates for clarification, added figures.
D	02/29/2016	ECO-03680	Updates for clarification, and edits based on FOPS review; added figures.
E	04/10/2017	ECO-04483	CM updated with new template and changes based on feedback from FOPS; Major changes include removal of the need to sketch field observations on datasheets, removal of measuring discharge and inlet/outlet locations at lakes, and clarification of equipment setups with more figures. Sampling dates now coincide with peak greenness.
F	04/27/2018	ECO-05697	Bathymetric surveys take place within the site-specific biological sampling bout 2 (summer), or +/- 2 weeks of the Aquatic Plant survey, and overlaps with the period of peak greenness. Removed GPS spot-checking. Will collect ground-truthing data using random and targeted locations. Shoreline and in-water features are collected with a Trimble handheld unit. Ground-truth points identified in the field are recorded with the Humminbird GPS. Updated figures. Updated FOPS data entry and verification steps using Humminbird PC and HumViewer programs; removed converting the sonar files to .csv. Included references to the use of the mobile application and device. Revised data entry and validation section. No longer recording many of the sonar settings. Updated mobile application and datasheets with these changes.
G	01/29/2019	ECO-05998	Clarified the sampling timing contingency data product impacts if a survey occurs 5 days beyond the scheduled date or is outside of the +/- 2 week plant sampling window. Updated the Sampling Timing Contingency Outcome for Data Products in the event that the survey cannot be completed. Included a reference to the Humminbird Helix sonar unit in use at Domain 08. Updated the guidance for collecting shoreline/in-water features with the GPS. Minor updates to clarify the ground-truthing procedures. No datasheet or mobile application updates.

TABLE OF CONTENTS

LIST OF TABLES AND FIGURES

1 OVERVIEW

1.1 Background

Bathymetry and morphology are key parameters for defining the hydrological, physical, chemical, and biological characteristics of lakes and non-wadeable streams. Water level, volume, area, and stage curve relationships provide spatial quantitative information. They also impart a governing role on hydrodynamics, chemical reactions and biotic distribution and productivity. Furthermore, temporal comparisons between bathymetries can be used as an indicator of environmental change by providing information on ecosystem functioning, changes in water turnover times and storage, and catchment erosion-sedimentation rates (Dost and Mannaerts, 2008). Obtaining baseline characteristics, hence, becomes imperative in light of future activities aimed at a better understanding of lake and non-wadeable stream (river) dynamics as well as health through time.

High accuracy depth (bathymetric) maps are obtained using a suite of hydroacoustic instrumentation interfaced with a differential global positioning system (DGPS) mounted on a vessel. The Wide Area Augmentation System (WAAS) is a form of DGPS that provides enhanced position accuracy (<3 m). Hydroacoustics are utilized to detect the depth of a water body, sediment characteristics as well as the presence or absence, approximate abundance, distribution, size, and behavior of underwater biota. Measurements of depth and morphology are undertaken using an echosounder transducer, and side scan sonar. Images of sediment and structures are obtained with Side Imaging® Sonar and Down™ Imaging offered as an integrated unit in the Humminbird 1198c Si Combo. High accuracy depth data can be obtained with a lower beam angle and higher frequency (>200 kHz) echosounder. The side and down imaging features enable the identification of water bottom sediment morphological features that can be used to better elucidate spatio-temporal hydrodynamics that may impact biological activity (Hofmann et al., 2008; Donohue and Molinos, 2009).

The sampling strategy involves bisecting the water body along its longest axis, then subsequent continuous transects are conducted parallel (lakes and non-wadeable streams) and perpendicular (lakes only) to this initial transect along the longest axis (Figure 1a lakes and Figure 1b non-wadeable streams). The instrumentation collects coordinate positions with an accuracy of less than 3 meters and depths simultaneously. The combined unit provides a high resolution and precision survey of the complex bathymetry and morphology of lakes and non-wadeable streams.

The data collected in the field is in x, y and z format – Eastings, Northings and Depth. Following quality assurance and quality control directives (RD[08]), data are spatially interpolated and clipped to the shoreline shapefile to produce 2D and 3D bathymetric maps. Bottom morphometric characteristics, such as vegetation extent, sediment characteristics, and sediment compaction are defined by converting the side-scan images into a master mosaic image of the waterbody bottom (Figure 2). Information about volume, surface area, and habitat features are calculated. The maps are used to calculate mean and maximum water depths along with shoreline and sediment morphometry. Additional information that the bathymetric maps can provide is an estimate of the depths and area that plants can colonize. Water surface morphometric characteristics (shape and shoreline development index) can be used to calculate fetch distances. This protocol describes the steps required to collect data for the creation of bathymetric and morphological maps utilizing an acoustic system.

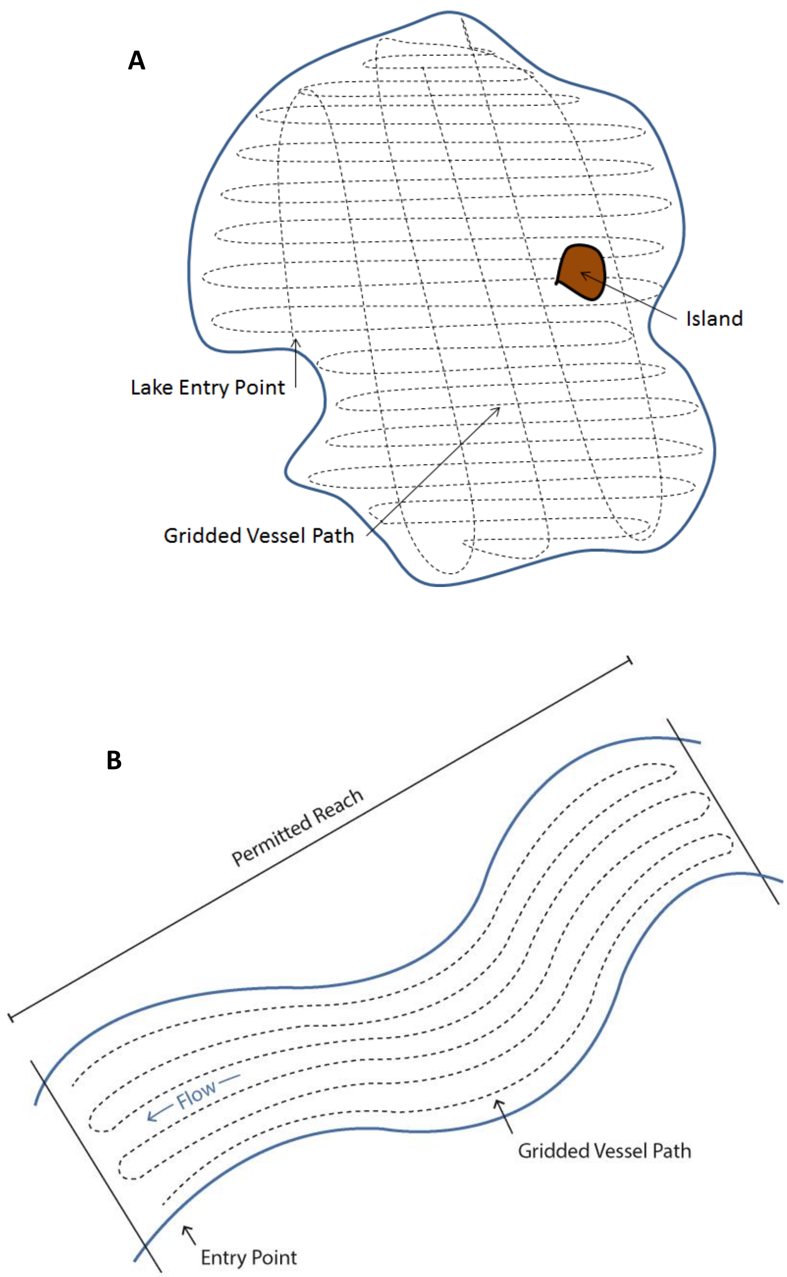


Figure 1. Grid pattern used for determining the (A) lake and (B) non-wadeable bathymetry and morphology

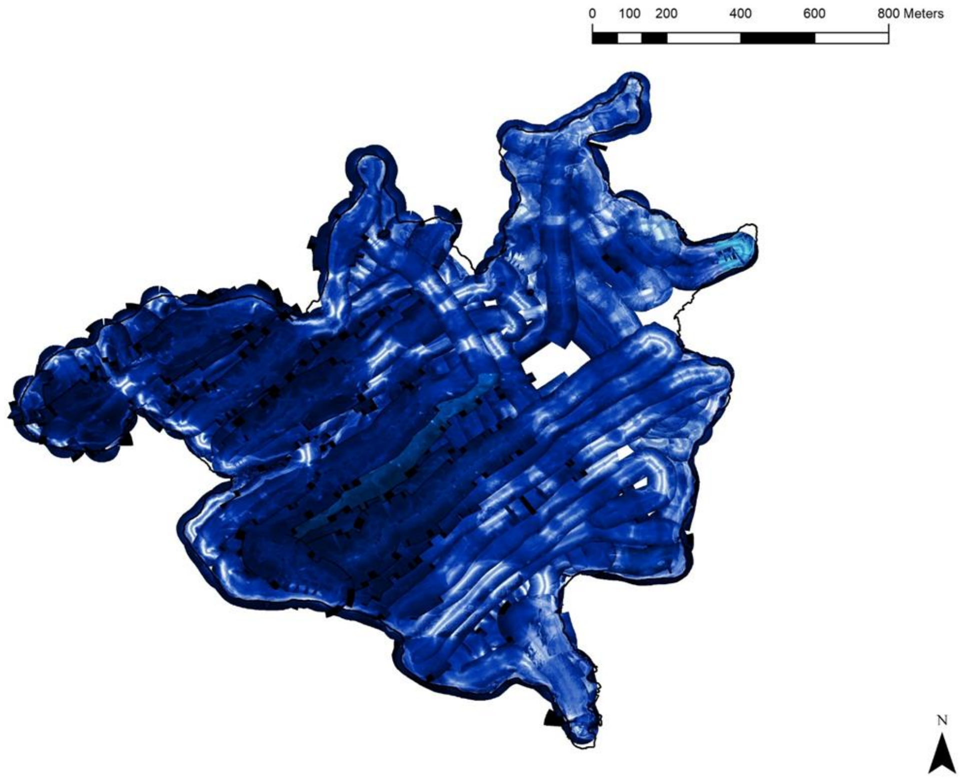


Figure 2. Example of side-scan mosaic (D18, Toolik Lake August 2016).

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.

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]).

Along with the echosounder used to collect bathymetric data, the side-scan and down imaging products are used to define bottom morphology of lake and non-wadeable streams. Since the side-scan images cover an approximate width of 20 meters, the images obtained from the linear transects across the water bodies are collated to produce a map of the bottom morphology using additional software

(SonarTRX). NEON will produce a bathymetric map and a classified habitat map using collected sonar data available through the NEON data portal. Additional data available through the NEON data portal includes volume and area calculations as well as the collected field data, survey tracks, and point locations.

1.3 Acknowledgments

The field protocol used by NEON for producing bathymetric and morphometric maps of the lakes and non-wadeable streams follows the general requirements set forth by the U.S. Army Corps of Engineers (2002) and Heyman et al. (2007; ED[01]).

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

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

AD[01]	NEON.DOC.004300	EHS Safety Policy and Program Manual
AD[02]	NEON.DOC.004316	Operations Field Safety and Security Plan
AD[03]	NEON.DOC.000724	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.002652	NEON Level 1, Level 2, and Level 3 Data Products Catalog
RD[04]	NEON.DOC.001271	AOS/TOS Protocol and Procedure: Data Management
RD[05]	NEON.DOC.001646	General AQU Field Metadata Sheet
RD[06]	NEON.DOC.001152	NEON Aquatic Sample Strategy Document
RD[07]	NEON.DOC.004257	All Systems Standard Operating Procedure: Decontamination of Sensors, Field Equipment, and Field Vehicles
RD[08]	NEON.DOC.004856	NEON Standard Operating Procedure: Post-Processing of Bathymetric and Side Scan Sonar Data from NEON Lakes and Non-Wadeable Streams
RD[09]	NEON.DOC.001085	AOS Protocol and Procedure: Stream Discharge
RD[10]	NEON.DOC.002494	Datasheets for AOS Sample Shipping Inventory
RD[11]	NEON.DOC.003104	Datasheets for Bathymetry and Morphology of Lakes and Non-Wadeable Streams

2.3 External References

ER[01]	Heyman, W.D., J-L. B. Ecochard, and F.B. Biasi. 2007. Low-cost bathymetric mapping for tropical marine conservation – A focus on reef fish spawning aggregation sites. Marine Geology, 30: 37-50
ER[02]	Humminbird Product Manual: Operations Manual. 2012. Humminbird 1198c SI Combo. Johnson Outdoor Marine Electronics. Racine, WI.

2.4 Acronyms

Acronym	Definition
DEM	Digital Elevation Model
DGPS	Differential Global Positioning System
LCD	Liquid Crystal Display
MMC	Multi-Media Card
NAD83	North American Datum of 1983
P&P	Procedure and Protocol
PVC	Polyvinyl Chloride
USGS	U.S. Geological Survey
UTM	Universal Transverse Mercator
WAAS	Wide Area Augmentation System
YSI	Yellow Springs Instrument Co.

2.5 Definitions

Bathymetry: Underwater depth of an aquatic ecosystem.

Morphology: Structure and arrangement of features within the lake watershed and lake bottom. It can include the shape of the surface of a lake and the arrangement of rocks and sediments.

Fathometer: Type of echosounding system ('sounding' is the measurement of water depth) using active sonar.

Sonar: Technique that uses sound propagation. The active sonar emits pulses of sounds and records echoing returns. When used in water it is more frequently known as hydroacoustic and involves the use of an echosounder.

Epilimnion: Top layer of water of a stratified lake, denoted by highest temperatures and least dense water in the summer.

Hypolimnion: The dense bottom layer of a stratified lake that sits below the thermocline. This layer is denoted by cooler summer temperatures and slightly warmer winter temperatures relative to the epilimnion.

Thermocline: A distinct layer in a body of water where the change in temperature is more rapid than the increase in depth. The denser and cooler layer below the thermocline is the hypolimnion. The warmer upper layer is termed the epilimnion.

3 METHOD

This protocol describes the steps required to collect data for creation of bathymetric and morphological maps utilizing an acoustic sonar system. Bathymetric and morphological data are collected to produce 2D and 3D bathymetric maps and to characterize the structure of the waterbody by creating morphological maps of the underwater environment. Bathymetric and morphometric data add another dimension to geographic mapping and modeling and can be used either as a background layer or as a 3D surface for draping thematic maps such as benthic habitats, organism habitats or geologic data.

A vessel is mounted with the DGPS and sounding equipment and driven across the lake or non-wadeable stream surface in a gridded pattern. Data points, including depth and GPS position, and side scan sonar images are recorded every second. The field protocol used by NEON for producing bathymetric and morphometric maps of the lakes and non-wadeable streams follows the general requirements set forth by the U.S. Army Corps of Engineers (2002) and Heyman et al. (2007; ER[01]). While the equipment is not the same, the assumptions remain valid. The U.S. Army Corps approach entails the use of a dual-beam echosounder that is mounted on a large research vessel and capable of mapping large areas. The equipment utilized here also uses an echosounder, but it is a dual beam high frequency system that is better able to accurately (<1 cm) detect bathymetry of shallow systems. It is combined with WAAS GPS technology, which increases the horizontal accuracy. The echosounder transmits at a dual frequency of 200/83 kilohertz at beam angles of 6^o and 19^o, respectively. Water depths are determined by the echosounder based on the speed of sound in water and compensated for temperature.

Recent advances in echo-sounding equipment and the possibility to combine echo-sounding with side-scan sonar results in acoustic returns that provide information regarding bathymetry (depth), as well as recording the strength of sound energy that bounces back (called "backscatter"). Backscatter is used to identify the composition of the underwater sediments. The side-scan and down-imaging sonar data allow for the identification of water bottom characteristics (biological and physical) otherwise not visible to the naked eye. This technology facilitates the identification of changes in the morphometry of water bodies over time that may result from high impact events or long-term changes in the environment. The shoreline and large in-water features are recorded at the time of sampling with a handheld GPS receiver with decimeter accuracy (e.g. Trimble) in continuous mode. The use of a handheld GPS receiver antenna is preferred if available but not necessary. Other in-water ground-truthing feature locations identified while surveying will be collected using the Humminbird GPS. **Do not use a recreational GPS (e.g. Garmin) for the mapping procedures associated with this protocol**. These data are imported into GIS and used for interpolation. Data collected in the field are formatted and downloaded into formats required for post-processing and data product creation (RD[08]).

Bathymetry data will be collected every 5 years (at minimum) during biological sampling bout 2 and during the period of peak greenness, defined as the range of dates where MODIS NDVI is within 90% of the site maximum. In the case of a major change in water level (e.g., significant event that changes morphology), erosion or accretion of the lake or non-wadeable stream banks, or other noticeable changes to subaquatic habitat or vegetation, an additional survey may be conducted to document bathymetric changes when safe conditions allow. Field Operations will notify the lead aquatic scientist of substantial morphological or submerged habitat changes through the NEON problem tracking system. The aquatic scientist will evaluate the need to schedule a bathymetric survey that is out of cycle (less than 5 years) and request support for the effort. Refer to the Site-Specific NEON Aquatic Site Sampling Design documents for the biological bout 2 schedule for determining the bathymetry and morphology schedule.

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 scientists **must** follow the protocol and associated SOPs. Use NEON's problem reporting system to resolve any field issues associated with implementing 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 the field scientist documents the problem and enters it in NEON's problem tracking system.

Quality assurance will be performed on data collected via these procedures according to the NEON Science Performance QA/QC Plan (AD[05]).

3.1 Sampling Frequency and Timing

Bathymetric surveys at lakes and non-wadeable streams are completed at a minimum of every 5 years except if an extreme event results in substantial physical change to the morphology or submerged habitat. In that case, an out-of-cycle survey may be requested. Bathymetric surveys take place within the site-specific biological sampling bout 2 (summer), or +/- 2 weeks of the Aquatic Plant survey, and overlaps with the period of peak greenness. Subsequent sampling events are scheduled to occur +/- 2 weeks of first sampling event. It is recommended that the sampling time during the day should remain the same for all sites and all years. The survey duration will vary for each site based on water body area (size) and seasonal conditions (wind, lightening, etc.). It is advised that surveys are started as early in the day as possible to complete the survey. Surveys that take longer than one day to complete will resume the following day. Typically, non-wadeable stream sites are surveyed in one day; however, lake sites can take up to five days.

3.2 Criteria for Determining Onset and Cessation of Sampling

A baseline lake or non-wadeable stream bathymetric and morphological map is generated during the first year of operations at each site during the period of peak greenness as defined by maximum cumulative growing degree days. The annual timing of such bathymetric surveys shall remain the same for each individual site (within the site-specific peak greenness window), to have seasonal comparison at sites sampled at the same time of year each year. The specific dates are determined using multivariate statistics and site-specific historical information (see RD[06]).

3.3 Sampling Timing Contingencies

Table 1. Contingent decisions

Delay/ Situation	Action	Outcome for Data Products
Hours	Should the bathymetric mapping be interrupted or stopped at any point during the sampling, make a note in the field metadata. Should the continuation of that sampling take place the following day, field science shall ensure that the set-up is identical to the previous day and that no major changes in the lake or non-wadeable stream have taken place (+/- 15 cm water height difference, weather change, or increased turbidity).	No adverse outcome.
	Do not undertake bathymetric sampling if wind speeds exceed 5 knots. Either wait for the weather to change and attempt a mapping session later in the day, or postpone to another day.	No adverse outcome.
	If equipment stops functioning during sampling, verify equipment and start sampling again as soon as possible. If you restart sampling the next day and sampling conditions are very different (turbidity of water, weather, etc.), start sampling from the beginning.	No adverse outcome.
	If weather becomes unsafe during sampling, stop and resume or restart as soon as possible. If you restart sampling the next day and sampling conditions are very different (turbidity of water, weather, etc.), start sampling from the beginning.	No adverse outcome.
5 Days or More	Should safety conditions change while on the water and in the middle of a mapping project, note this in the remarks section of the field datasheets and stop working. Save the data, turn off all equipment and start re-surveying as soon as conditions permit. If conditions have changed substantially so that more than 5 days have passed or the survey occurs outside of the +/- 2 week plant sampling window, file a trouble ticket and contact the lead aquatic scientist.	No adverse outcome if survey is completed. Surveys that cannot be completed will result in no data.

3.4 Sampling Specific Concerns

A bar check on the echosounder is performed at the beginning of each day of data collection by comparing the echosounder depth reading with that of a weighted measuring tape. Navigate the boat to up to five different areas and record the depths from the echosounder and the weighted line. Use the handheld depth finder if performing the bar check in deep or fast moving water. Adjust the offset (draft of transducer below the water surface) of the transducer in the on-board software until depth readings and the depth of the weighted line agree to within +/- 5 cm (Linhart and Lund, 2008).

Bathymetric mapping requires calm conditions in order to improve the accuracy and precision of the data acquired. Pitch, roll and heave can affect the angle at which the acoustic beams are delivered in the water column and received by the transducer on the boat. Should the boat be at an angle the apparent depth will differ substantially from the actual depth.

Data are post-corrected to account for the average water column speed of sound calculated from the water temperature profiles. Quality assurance and quality control is also performed on the data in the post-processing stage (AD[05]).

4 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 fieldwork 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 Scientist have primary authority to stop work activities based on unsafe field conditions; however, all employees have the responsibility and right to stop their work in unsafe conditions.

In addition, the following safety guidelines are provided:

1. Due to site-specific hazards, the safest approach may be for the field scientist to perform GPS positioning and measurements for inflow and outflow (where applicable) in the boat without dismounting.
2. When alligators inhabit waters, the field scientist should not place hands or feet in river, lake, or pond.
3. The field scientist must wear personal flotation device (PFD) prior to entering boat and during work operation.
4. The field scientist must have communication with team members such as a two-way radio, satellite phone/pager, or cellular.
5. Safety briefing should include known hazards and any specific requirements or procedures for the location. Examples are navigation rules, deep or shallow areas, etc.

5 PERSONNEL AND EQUIPMENT

5.1 Equipment

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

Table 2. Equipment list – Field equipment

Supplier	Supplier Number	R/S	Description	Purpose	Quantity	Special Handling
Durable items						
		R	Mobile field data recording device (Tablet)	Recording data	1	N
		R	Container with latch top	Transporting and storing the Humminbird	1	N
Compass Tools	88180-04 57972-10 58129	R	GPS receiver, decimeter accuracy (Trimble GEO XH 6000 or 7000), MGIS Tornado Antenna, and Range Pole	Mapping the shoreline and in-water features	1	N
		R	Humminbird 1198c SI Combo Echosounder and side imaging sonar with DGPS antenna (or similar, e.g. Helix 10 SI GPS)	Creating bathymetric imagery, marking locations, and monitoring speed	1	N
		R	SD Memory cards 8 GB minimum	Storing bathymetric imagery	2	N
		R	Mounting Brackets	Mounting the Humminbird on the boat	1	N

Supplier	Supplier Number	R/S	Description	Purpose	Quantity	Special Handling
		R	Mounting pole, ¾” EMT conduit	Mounting the Humminbird on the boat	1	N
		R	12V portable battery packs	Powering the Humminbird	2	N
		R	Marine antenna rail mount, 1”-14 thread	Mounting DGPS antenna to pole	1	N
		S	Measuring Tape with weight	Calibrating depth	1	N
		R	Camera	Photographing site locations	1	N
		R	Hip Waders (when necessary)/boots/	Safe wading	1	N
Consumable items						
		R	Rite in the rain notebooks	Taking notes	2	N
		R	Pencils	Recording data	2	N
		R	Multiple copies of data sheets for inflow, outflow, and lake stretch	Recording data	4	N
		R	Bleach	Decontaminating equipment	Ongoing	N

R/S=Required/Suggested

Table 3. Equipment list – General boating equipment

Supplier	Supplier Number	R/S	Description	Purpose	Quantity	Special Handling
Durable items						
		R	Boat		1	Y
		R	Anchor with rope		1	N
		R	Oars		2	N
		R	Boat motor (electric trolling motor for lakes and gas motor for non-wadeable streams)use		1	Y
		R	Battery (12 volt) for electric trolling motor		up to 3	Y
		R	Safety kit for boat (e.g., flares, bailer, float with rope)		1	Y
		R	First Aid Kit		1	N
		R	Personal Flotation Devices (PFDs)		1 per person	N
		R	Handheld depth meter	Measuring water depth for transducer calibration	1	N
		S	Weighted line with depth increments (m)	Measuring water depth for transducer calibration	1	N

Supplier	Supplier Number	R/S	Description	Purpose	Quantity	Special Handling
Forestry Suppliers	89183	R	Handheld wind meter	Measuring wind speed before operating boat	1	N
Consumable items						
			(none)			

R/S=Required/Suggested

5.2 Training Requirements

All field scientists must complete protocol-specific training for safety and implementation of this protocol as required in Field Operations Job Instruction Training Plan (AD[04]).

All personnel required to operate a boat shall be trained through a program approved by NEON Environmental, Health, and Safety. All others shall be aware of boating safety procedures.

Personnel are to be trained in lake and non-wadeable stream bathymetry and morphometry measurements and safe working practices for lake and non-wadeable stream work.

5.3 Specialized Skills

Where applicable, personnel will be licensed to operate a boat and able to safely handle an electric motor and drive a boat safely.

5.4 Estimated Time

The time required to implement a protocol will vary depending on a number of factors, such as skill level, system diversity, environmental conditions, and distance between sample plots. The timeframe provided below is an estimate based on completion of a task by a skilled two-person team (i.e., not the time it takes at the beginning of the field season). Use this estimate as framework for assessing progress. If a task is taking significantly longer than the estimated time, a problem ticket should be submitted. We estimate sampling for bathymetry and morphology in lakes requires two field scientists between 5 to 10 hours each sampling day (up to 5 days) plus travel to and from the site.

6 STANDARD OPERATING PROCEDURES

SOP A Preparing for Data Capture

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 error and improve data quality. For detailed instructions on protocol-specific data entry into mobile devices, see the NEON Internal Sampling Support Library (SSL). Mobile devices should be synced at the end of each field day, where possible; alternatively, devices should be synced immediately upon return to the Domain Support Facility. However, given the potential for mobile devices to fail under field conditions, it is imperative that paper datasheets are always available to record data. Paper datasheets should be carried along with the mobile devices to sampling locations at all times.

SOP B Preparing for Sampling

1. Ensure memory cards are blank. If files are present, confirm data and photos have been uploaded prior to deleting.
2. Verify all equipment is available.

3. Fully charge all batteries and electronic equipment the night before. DO NOT assume that batteries are functional or fully charged even if new.
4. Ensure all equipment is decontaminated with bleach (see NEON Decontamination Protocol RD[07]).
5. Print datasheets.

SOP C Field Sampling

Ensure the General AQU Field Metadata Sheet (RD[05]) is completed.

C.1 Bathymetry (Depth)

Transducer and DGPS Antenna Setup

1. Attach the DGPS antenna to the ¾” EMT conduit (pipe) using a marine antenna rail mount with 1”-14 thread. Ratchet the antenna rail mount so that the top of the antenna is facing toward the sky (Figure 3).
2. Run the cable through the conduit and attach the transducer to the bottom of the conduit using a hose clamp or U-bolt. There may be stress on the cable near the transducer, so include a service loop (Figure 4) and consider reinforcing with electric tape at points that may rub. Make sure that the DGPS antenna is mounted to the top of the conduit with the boat mount in the middle, and the transducer on the bottom (Figure 5).
3. The motor mount used to attach the bathymetry system to the front of the boat may not grip the ¾” conduit. If it is too thin, use PVC spacers.

Figure 3. DGPS antenna, boat mount, and transducer setup

Figure 4. Transducer set up with service loop to prevent over tensioning the wire coupling

Boat Setup

4. Ensure the boat plug is inserted.
5. Mount the motor on the boat (if not already mounted).
6. Once the boat and motor are in the water, immediately check the motor is working properly by lowering the motor into the water and turning it on.
7. Load all the equipment onto the boat making sure weight is evenly distributed.
8. Install and fix the mounting rod onto the bow of the boat (this will vary according to the type of boat; Figure 4 and Figure 5).
9. Mount the transducer and DGPS antenna system to the front of the boat (Figure 5). Adjust the depth in the water using the thumbscrew on the motor mount, being careful not to lose spacers if used.
   a. The transducers should NOT be placed where there is interference from wave action. (This will depend on the boat type).
   b. Place the transducer at 0.3 m below the surface of the water. If windy conditions create waves that expose the transducer, lower the depth of the transducer to 0.5 m. Should this not be possible due to the boat type, record the depth at which the transducer is installed for later data correction in the remarks section of the mobile device or Bathymetry Field Datasheet.
   c. Ensure the transducer is positioned horizontally to the lake or stream bottom, facing backwards and with a slight tilt (Figure 3 and Figure 4). Ensure that the transducer cord is not too tight to prevent the cord from breaking free from the transducer.

Figure 5. Bathymetric mapping system components.

d. The transducer should be placed directly under the DGPS antenna in order to reduce errors (Figure 3 and Figure 5).

Humminbird Connections

10. Ensure that all connectors between the instruments are securely attached to the Humminbird Unit (Figure 6). Ensure that there is no stress on the cable where it enters the transponder (may be helpful to zip tie a short loop in the cable; Figure 4).

Figure 6. Rear view of the Humminbird control head with connector details. 1) Video-Out (RS-232), 2) Power, 3) GPS/Communications, 4) Video Out, 5) Ethernet, 6) Temperature/speed, and 7) Transducer

11. Ensure 2 blank SD cards have been inserted into the card slot (Figure 8):
    a. Remove the SD memory card slot cover.
    b. Position the SD memory card with the label facing the left side of the unit. Press down until the card clicks into place.
    c. Close the slot cover and turn the knob ¼ of a turn to close. DO NOT over-tighten as this will decrease the water resistance and may damage the cover.

Figure 7. Insertion of SD cards in Humminbird card slot

12. Connect the main Humminbird unit to one of the 12V batteries, by first connecting the ground (black) then the hot (red). (*Ensure that the cover to the battery pack is shut securely in order to avoid potential spraying by water*). It is recommended by the manufacturer that the battery have at least 10V of power; signal transmission may be affected with low battery power. An optional low voltage alarm can be set to indicate a low battery while operating the sonar. Be sure to check battery power before leaving the Domain Support Facility.

Humminbird Initial Settings

13. Turn on the Humminbird control panel and GPS unit with the **POWER/LIGHT** key (Figure 9).
14. Verify that you have a good GPS signal and that the transducer is functioning. Upon turning the Humminbird on, the unit will perform a:
    a. **Self-Test**:
        1) Displays results from the internal diagnostic self-test.
            a) From start-up screen, select System Status.
    b. **Accessory Test**:
        1) Lists the accessories connected to the unit.
            a) Select view for Accessory Test.
    c. **GPS Diagnostic View**:
        1) Shows a sky chart and numerical data from the GPS receiver with locations of each visible GPS satellite, its number and its signal strength. Verify that the **Fix Type** is set on **Enhanced**, since this is the augmentation (more precise horizontal positioning) using 

information from WAAS and is required for navigation.
        2) To access the GPS diagnostic view, go to **Views** on the menu screen and turn on GPS diagnostics view from **Hidden** to **Visible**.

Press MENU to access the **Start-up Options menu** (Figure 9 and Figure 10).

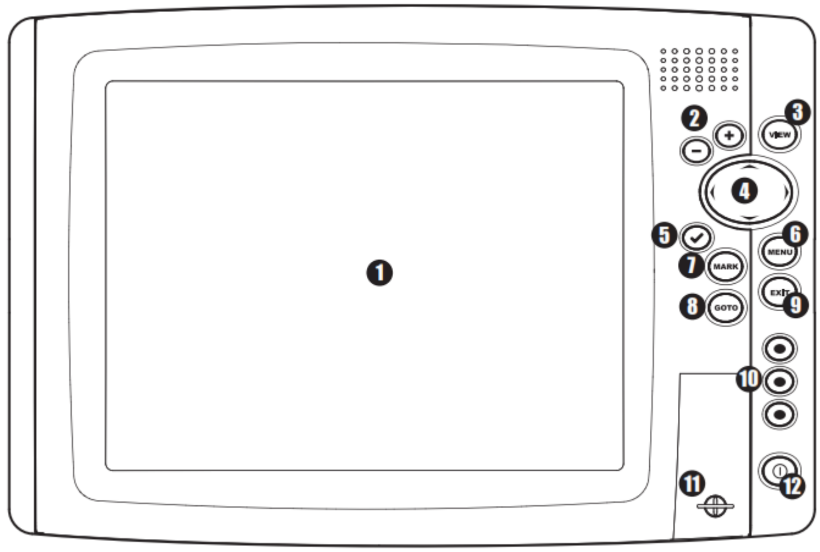


Figure 8. Humminbird 1198cSI control head key functions: 1) Screen, 2) ZOOM (+/-), 3) View, 4) 4-WAY Cursor Control, 5) INFO, 6) MENU, 7) MARK, 8) GOTO, 9) EXIT, 10) View Preset, 11) SD Card Slots, and 12) POWER/LIGHT.

Figure 9. Humminbird control head view example. Left screen - Side Imaging view. Right screen - Chart view.

15. Navigate to the location of the staff gauge. Take a reading of the water level at the beginning of the survey and at the end of the survey day; record on the mobile device or *Field Metadata Sheet* (Figure 11). Please make a note using the mobile device or the *Field Metadata* sheet if a staff gauge was not present at the time of the survey.

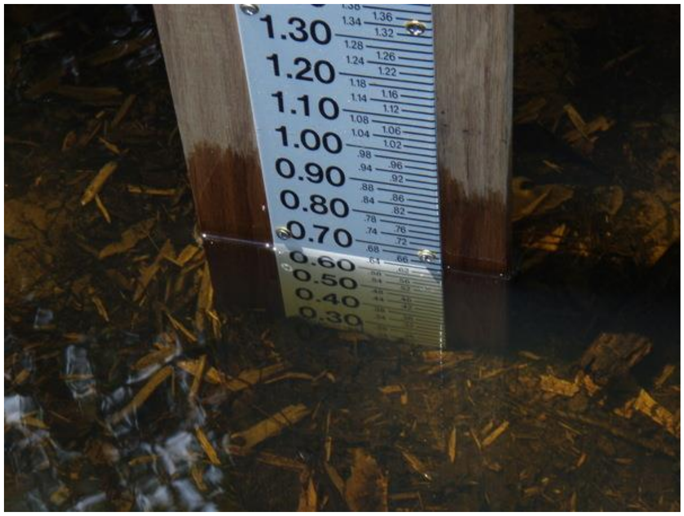


Figure 10. Example of a staff gauge. If conditions are wavy, note the mean height.

Humminbird Depth Calibration

16. Perform a bar check on the echosounder. First, set the adjusted depth (vertical measurement from the transducer to the keel). Navigate to a shallow depth and use the handheld depth sounder or a weighted line with depth increments to get a depth reading. Compare the hand-measured depth with the sonar depth in the upper portion of the screen (Figure 12).

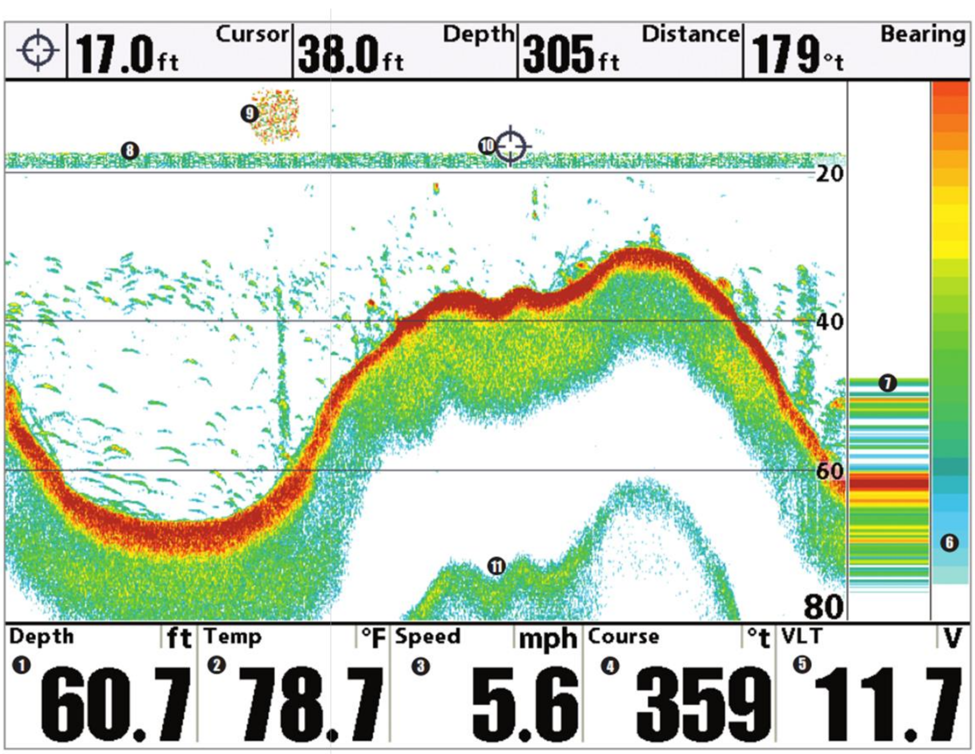


Figure 11. Example sonar display information from the Humminbird controller.

17. Make adjustments to offset (draft of transducer below the water surface) the transducer in the computer software until sonar depth readings and the depth of the handheld depth meter (or weighted line) agree to within approximately 5 cm (2 inches).
18. Adjust the Depth offset in the **Systems Set-up** menu by pressing the menu key twice (can be accessed from any view). Include the transducer depth to the water line (0.3 m; 1 foot) in the total depth when making the adjustment to reflect the true water depth.
    1) To adjust the depth offset, go to the menu screen, select **Setup** and change the user mode to **advanced**, the depth offset will then appear in the setup menu
19. A summary of the sonar settings can be found in the **Sonar Menu Advanced**.

Humminbird Sensitivity Settings

20. Use the **View** button to navigate between pages (Figure 9).
21. Only change settings of Sensitivity, Side Imaging (SI) and Down Imaging (DI) Sensitivity and SI Enhance – no other setting should be changed. These settings do not need to be recorded.
    a. **SI and DI Sensitivity** (all types): controls how much detail is shown on the display and will adjust the sensitivity of all sonar frequencies (Figure 13). Decrease the sensitivity to eliminate clutter particularly if in murky or muddy waters. Do not adjust too low since the unit may not display important sonar returns. Increase the sensitivity in clear waters in order to pick up weaker returns. If too high, the screen may become too cluttered. Generally set this lower for hard bottoms and higher for soft bottoms. Sensitivity settings may need to be adjusted multiple times during sampling events if water column and substrate conditions change.
    b. **SI Enhance**: adjust your Side Imaging View into three categories: Sensitivity, Contrast and Sharpness. Unless needed leave Sensitivity and Contrast at default values and change Sharpness to Medium.
    c. **SI Range:** sets the depth of the Side Imaging views on the display. Auto shows depths between 6 – 360 feet (2-120 m); default is set at 150 feet (50 m). The SI range must be set manually. Adjust the SI range based on the known maximum depth of the lake or non-wadeable stream that is being surveyed. The SI range can be changed in the field and only adjusts the deepest extent visible extent on the control display; this does not affect data being recorded.
    d. **Beam Select**: Ensure the **Beam Select** under the **Sonar** tab is set to 200/83 kHz. **Do not change the beam bandwidth setting.**
    e. **Imaging Frequency:** Ensure the **Imaging Frequency** under the **Sonar** tab is set to 455 kHz.

Figure 12. Sonar Menu Tab. Verify and alter these tabs accordingly to the text

Beginning Bathymetry Transects

22. Using a handheld weather meter, confirm wind speed is lower than 5 knots. If wind speed is higher than 5 knots, suspend sampling. Wind speeds at some aquatic sites may often not go lower than 5 knots (e.g., D09 lakes). At these sites, it is recommended to initiate the bathymetry protocol when conditions are perceived to be the most ideal (e.g., early morning).
23. Start recording on the Humminbird unit.
    a. Press the MENU key once in the **Snapshot and Recording View**.
    b. Highlight **Start Recording** and press the RIGHT Cursor key. A waypoint will be created at the boat location and the recording shares the same file name (.SON).
24. Record the recording number (example R00019) and start/stop times from the Humminbird on the mobile device or *Bathymetry Field Datasheet*.
25. Remember your point of departure and note the exact time of departure on the mobile device or on the *Bathymetry Field Datasheet* so that it can be used as a cut-off point for data processing.
26. **Combo views** provide one or more views on the screen (Figure 9). To change the settings for either side of the view, the individual view must be selected as the 'active side'. Ensure that the side-scan imaging sonar view is displayed as one of the views in order to use the information displayed to identify morphological characteristics of the water bottom.
    a. The GREEN ARROW points to the active side (Figure 14):
    b. **Active Side**: Press MENU key once and select ACTIVE SIDE from Menu. Choose RIGHT or LEFT to set the active side.
    c. **Menu**: after you set the Active Side, press MENU key once to access the Menu to provide settings for the active view and the updated display.

d. **Display Size**: Press MENU key once and select SPLIT POSITION from the Menu. Split Position allows you to adjust the size of the left side of the display. **All data are reported in English units.**

e. **Active Cursor**: Press any arrow on the 4-WAY Cursor Control key and the cursor will appear on the active side of the view.

Figure 13. Example of screen with green arrow pointing to the currently "active side' (referenced by the red circle)

27. Travel at no more than 5 kilometers (3.1 miles or 2.7 knots) per hour. Faster speeds will add errors to the readings by changing the rate of return of the sounder signal versus the GPS coordinate. Monitor your speed on the Humminbird unit.
28. Travel at a constant speed in an approximate grid pattern. Once you start in a direction across the lake or stream as part of a cross section, drive the boat in the same heading (follow this on the screen under the "COURSE" window. Given the beam angle for the instrumentation, the grids should be spaced approximately 20 meters apart (Figure 15). Stay as close to the shoreline as possible without damaging the instrumentation. Be cautious of submerged vegetation, rocks, or other hazards that could come into contact with the transducer.
    a. Create a scale bar using a small piece of paper and clear packing tape. Place the scale bar next to the boat icon in the center of the display with marks for 20 m on either side. This will aid in keeping the survey lines straight while underway.

NOTE:

- *While recording press the EXIT key to exit the Snapshot and Recording menu and scroll to a different view. Recording will continue*
- *The Slider Bar at the bottom of the Snapshot and Recording view shows the recording progress and remaining space on the SD card*
- *For maximum performance keep the Pings Per Second setting on Auto*

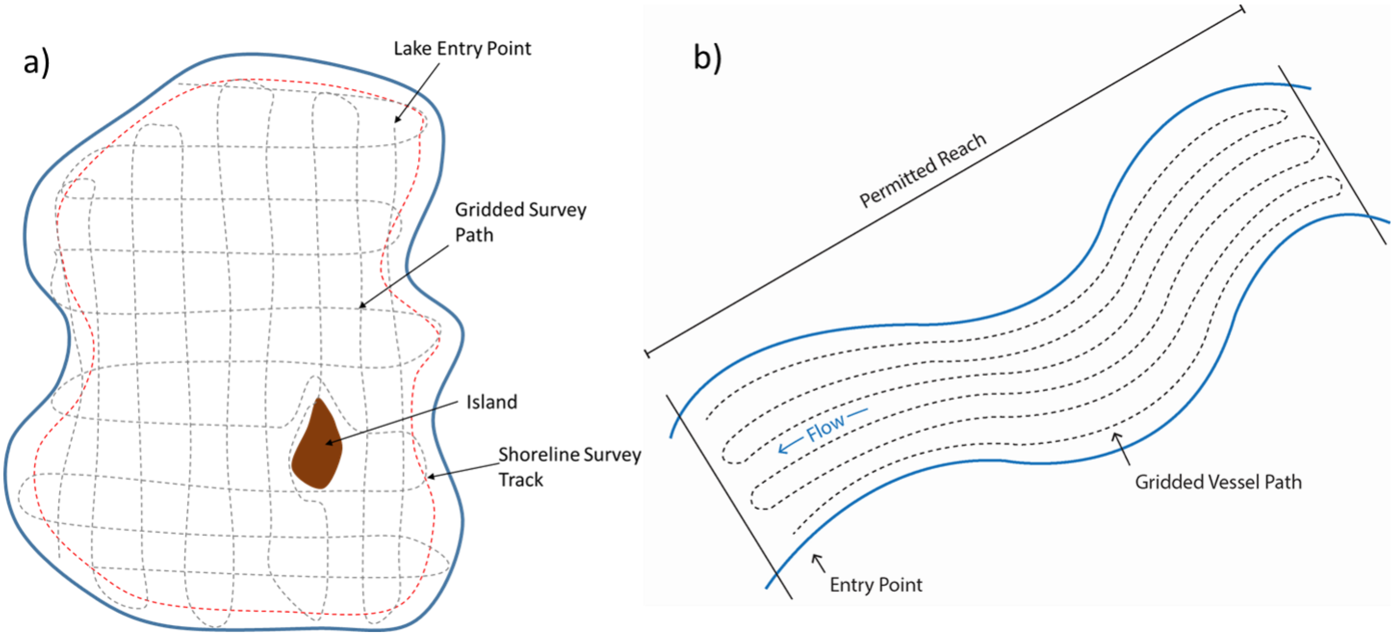


Figure 14. Schematic of survey pattern undertaken in the vessel for a) lake grid survey of shoreline and b) non-wadeable stream parallel to shoreline survey pattern. Note: lake grid lines should be approximately 20 m apart; figures are not to scale.

Ending Bathymetry Transect

29. Once the bathymetric mapping is finished, stop recording.
30. To stop recording data, in any view (Figure 9) press the **MENU** key once to open the Snapshot **and Recording Menu**.
31. Highlight **Stop Recording** and press the RIGHT Cursor key.
32. Check the lake or stream elevation again by taking a reading from the staff gauge then record on the mobile device or the *Field Metadata Sheet*.

NOTE:

- *For non-wadeable streams, follow the procedure above with the exception that the bathymetry will cover the full length of the stream section (1 km).*
- *Due to the currents in the* non-wadeable streams, *it is advisable to run the grid pattern in an upstream-downstream-upstream (Figure 15) manner to avoid potential sideway drifting caused by the currents.*

C.2 Lake /Non-wadeable Stream Shoreline and In-Water Features

1. Map shoreline and in-water features with a handheld GPS (Trimble) to create a shoreline/in-water feature bathymetry (0 meters depth) line file. This step must be done every time the bathymetric survey is conducted. If permitting or hazards prevent access to mapping the shoreline/in-water feature, follow the instructions in Step 10 below.
2. To maximize the accuracy of the handheld GPS (Trimble) unit use the following settings in the Setup menu:
   a. Select Settings (wrench icon) from the upper left dropdown (Figure 16).
   b. Uncheck the box next to the Productivity/Precision scale.
   c. DOP Type – select PDOP.
   d. Max PDOP – enter 6.0.
   e. Min SNR – enter 12.0.
   f. Min Elevation – enter 15°.

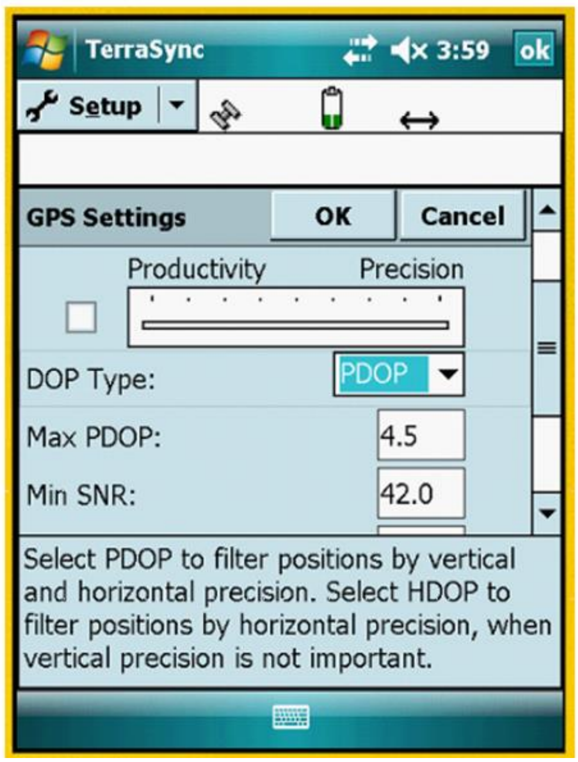


Figure 15. Trimble Setup menu to adjust settings for optimal location accuracy.

   g. Make sure four or more satellites are visible. Collect a single point with a minimum of 30 readings at each location where morphological or other in-water features are mapped with GPS. ,
   h. Click the "↔" icon in the upper right (Figure 16) and check that the minimum post-processing accuracy is ≤ 1.0 m.

i. Some sites will not fit these "ideal" settings due to canopy cover, lack of satellite coverage, or other obstructions. Therefore, the settings may have to be adjusted or offset just to collect a reading. In this case, check the box next to the Productivity/Precision scale and slide pointer incrementally toward Productivity until data point collection can resume (sufficient satellite coverage).

NOTE: *The position dilution of precision (PDOP) is indicative of the geometry of the satellite's location relative to others in the constellation and the receiver. Low PDOP indicates an even distribution of satellites throughout the sky and therefore indicates a higher probability of accuracy. The signal-to-noise ratio (SNR) is a measure of the signal strength of the satellite relative to the signal noise. As the ratio between the signal and the noise decreases, data is distorted by the noise therefor, a higher SNR value represents a stronger signal and less noise distortion. The elevation mask restricts the receiver to using satellites that are above 15° elevation. This ensures that both the hand held unit and a nearby base station (used in post-processing) can see the same satellites.*

3. Maximizing GPS accuracy is important for relating the bathymetry data to the edge (zero meter depth) of the lake or non-wadeable stream.
4. Select "Data" from the Main Menu.
5. Set File Type to "Rover" and Location to "Default."
6. Enter a unique file name. Example *D03_SUGG_Shore_20170616.* Record the GPS file name on the mobile device or the *Bathymetry Field Datasheet*. Also, include the waypoint name, feature type (e.g. shoreline), accuracy, accuracy units (meters or feet), start time, and description.
7. If applicable, select the data dictionary previously created.
8. Select "Create" on the upper right side of the page.
9. Select "Line_generic" to create a path around the lake edge.
10. Walk around the lake or stream edge or current water line at a normal pace, and hit "OK" to terminate data collection. **Note:** for larger lakes or where not permitted to walk the shore, it may be more efficient to map the shoreline via boat under low motor power or using a pole to maneuver. Keep the boat speed under 3.1 miles per hour (5 km/hour). Get as close to shore as safely possible and record the distance from shore as an offset as a remark on the mobile device or *Bathymetry Field Datasheet*.
11. Additionally, while undertaking the bathymetric survey, record any main morphologic features (such as an island, large submerged woody debris, objects on sediment floor, vegetation, or other; if other describe in the comments) seen on the SI images. Map the perimeter of the in-water feature with the handheld (Trimble) GPS (Figure 17). Record the file name(s) on the mobile device or *Bathymetry Field Datasheet*. Include the waypoint name, feature type, accuracy, start time, and description.

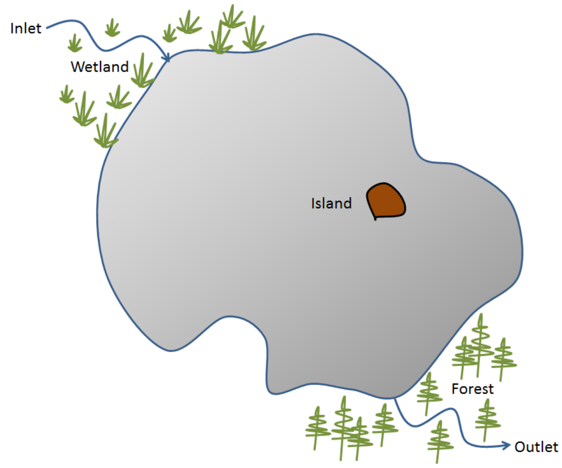


Figure 16. Detailing of morphometric features identified in the field

C.3 Ground-Truthing

The purpose of ground-truthing in conjunction with the bathymetric surveys is to collect visual (e.g. viewing bucket with a Plexiglas bottom) and/or sampled (e.g. ponar; rake) information about the benthic substrate and presence of aquatic vegetation at lake and non-wadeable stream sites. Ground-truthing measurements of lake and non-wadeable stream bottom types (e.g. plant, rock, silt) allow accurate classification and description of the benthos. In order to produce habitat maps, which are a component of Bathymetric and Morphological Maps data product (NEON.DP4.00132), ground-truthing will be required. This information will be collected during the bathymetric survey and following post processing to identify habitat patches derived from sonar data. These data will be used by NEON Science to classify habitat along with mapping software when creating maps.

1. While surveying, collect waypoints of substrate, habitat, and vegetation features such as sand fields, boulders, cobbles, large woody debris, or human structures (roads, fences, boats, etc.). Also, collect waypoints where patches of plants occur. Press the **MARK** button on the Humminbird control unit (Figure 9), collect and record the waypoint number, location accuracy, and a description on the mobile device or *Bathymetry Field Datasheet*.
2. Once the survey is complete, return the ground-truthing locations and follow the procedures described below.

Each ground-truthing technique requires the collection of field observations from random and targeted points. Equipment will be selected to optimize data collection for the substratum, depth, and visibility of the sampling location, similar to other AOS collection procedures (e.g., aquatic plant or sediment chemistry sampling). Equipment includes:

- Humminbird sonar system
- Petite ponar
- Rake
- Viewing bucket

- GPS
- Handheld depth finder
- Tablet with the bathymetry Fulcrum application
- Field Datasheets in the event that the tablet or application are not working

Low-impact observational ground-truthing techniques using a viewing bucket are preferred over the more invasive collection methods such as using the petite ponar or rake where possible. At lake or non-wadeable stream sites where plants occur, use the rake to collect and confirm the presence of aquatic vegetation. At deep lakes or where the water column is too turbid to view the bottom, the ponar is the best option for ground-truthing. General substrate descriptions and sub-aquatic vegetation presence/absences observations from each ground-truthing point are recorded.

Two ground-truthing techniques, random and targeted observations, will provide essential information to aid in the classification of subaquatic features (habitat and substrate) during the post-processing activities.

Random Observations

A proportional number of randomly selected ground-truthing points are generated prior to conducting the bathymetric survey. At the end of the survey day or during a suitable breaking point in the survey, navigate to the random survey points and follow the sampling steps below. Non-wadeable stream sites will have between 10-20 random points to collect ground-truthing information. Lake sites will survey 20-30 random ground-truthing points. TOOK which has an area of roughly 1,500,000 m^2 will survey 40-50 random ground-truthing points.

Targeted Observations

Targeted observation locations are collected from the previous bathymetric survey. There are two types of <u>targeted</u> ground-truthing procedures.

<u>Field Identified Targets</u>

The first includes 5-10 sampling locations identified by FOPS while conducting the bathymetric survey (see SOP C.3 Identify Ground-Truthing Locations, above). These observations may include unique features that appear on the sonar display or are visually observed that are different from the expected benthos (e.g. unusual habitat patches, large woody debris, or unique substrate features).

<u>Post-Processing Identified Targets</u>

The second targeted ground-truthing procedure includes 5-10 sampling locations identified from the post-processed bathymetric survey data. The targeted sampling effort is expected to take one day (up to three days) depending on the size of the non-wadeable stream or lake.

Collecting Ground-Truthing Data

The following ground-truthing survey procedures are applied to both Random and Targeted surveys. Therefore, there are two phases to the bathymetry survey, 1) the initial survey with random ground-truthing and 2) follow-up ground-truthing with targeted locations identified by field science and targeted locations based on post-processed data. These steps need to be conducted within one month from the time of the initial bathymetric survey in order to minimize seasonal changes to the benthic features being classified in the habitat map. The bathymetric survey as well as the random and targeted ground-truthing efforts need to occur within the one-month period. FOPS and the lead aquatics scientist will coordinate the timing of these activities to ensure that sufficient time is available to provide targeted ground-truthing locations.

1. Navigate to the first ground-truthing location. Set the boat anchor if needed to stay in place. Select the appropriate observation tool according to the following:
    a. In shallow, less turbid water, use the Plexiglas viewing bucket to observe and record observations of the bottom.
    b. In deeper and/or turbid water where the viewing bucket is not effective, use the aquatic plant survey rake to collect plant material and the petite ponar to collect soft sediments (silt or sand).
2. Record the header information and observations on the mobile device or on the *Bathymetry Ground-Truthing* field datasheet.
    a. Header information includes:
        i. Domain
        ii. Site ID
        iii. Measured By
        iv. Recorded by
        v. Start Date Collected
        vi. End Date Collected
        vii. Sonar System Model
        viii. Handheld (Trimble) GPS Unit Model
        ix. GPS File Name
        x. Remarks
        xi. Protocol Number and Revision Number
    b. Field ground-truthing data includes:
        i. Random or targeted sampling?
        ii. Waypoint Name
        iii. GPS accuracy (m)
        iv. Depth (m)
        v. Time of individual observation (24:00)
        vi. Sampler type (viewing bucket, rake, and petite ponar)
        vii. Substrate type
            1. Silt/clay
            2. Sand/gravel

3. Cobble/boulders/bedrock
4. Coarse woody debris
5. Human (e.g. trash, fence, boat)
6. Other

viii. Plants present? (Yes or no)
ix. Photo number (SITE.DATE.WAYPOINT_NAME)
x. Remarks (annotated description of observations)

3. Using the mobile device, take a photograph of the collected materials (plants, woody material, sediment) and record the photo ID using the format Site, Date, and Waypoint (example BLWA.20170825.007).
   a. **Photographs must be taken using the mobile device.** If the mobile device is unavailable, provide a concise description of the material on the datasheet.
4. Discard any collected ground-truthing material once the information has been recorded.
5. Take and record a depth measurement using the handheld depth finder (Vexilar).
6. Record the ground-truth location using the handheld (Trimble) GPS.
7. Navigate to the next ground-truthing location and repeat the steps described above.

3. When ground-truthing activities are completed, go to SOP D, Data Entry and Validation.

C.4 Ending the Sampling Day

1. Download survey data following the bathymetric survey and save to the appropriate location at the Domain Support Facility.
   a. Review the collected data using the HumViewer program. View the survey tracks in Google Earth by selecting “Tools” then Show in Google Earth.
   b. Once the completed survey tracks are projected in Google Earth, confirm that the survey was complete (i.e., no excessive gaps or missing sections). If the survey is not complete, reschedule a time to complete the survey as soon as possible.
   c. If the survey is complete, save a copy of the survey tracks Google Earth (.KML) file to the CI Dropbox.
2. Equipment Maintenance, Cleaning, and Storage
   a. Ensure all equipment is properly decontaminated and dry prior to storage as per NEON Aquatic Decontamination Protocol (RD[07]).
      1) Refer to the Humminbird 1198c SI Owner’s Manual for specific maintenance procedures and equipment troubleshooting (ER[02]).

SOP D Data Entry and Verification

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 are within 14 days of collection or the end of a sampling bout (where applicable). See RD[04] for complete instructions regarding manual data transcription.

1. Copy all data from the Humminbird unit SD cards into date and location folders on the designated computer at the Domain Support Facility. Upload files to the CI Dropbox in the appropriate file by Domain, Site, and Year.
2. Verify that the following folders are transferred from the SD cards:
   a. SD card 1:
      1) A folder RECORD with a subfolder "R000xx", where xx is the number displayed when you initiate the recording in the field. This should contain one ***.IDX*** and one ***.SON*** file for each recording.
      2) An R000xx.***DAT***; R000xx.***XML***; and an R000xx.***XML.BAK*** file
   b. SD card 2:
   c. Profile***.DOC***
3. All waypoints collected with the Humminbird need to be exported following these steps ***after*** downloading the SD card recordings as this will overwrite information on the SD card:
   a. Under menu: "Nav" tab: select "Waypoints, Routes, Tracks"
   b. Export waypoints: Select "Options", then "Select All" and "Export."
   c. Open the SD card files .HWR (Humminbird file type) in Humminbird PC.
      1) In Humminbird PC go to "Edit" and select "Preferences." Choose the Position format as decimal degrees (dd.ddddd°).
   d. Convert the .HWR file(s) to a GPX file. A message will appear asking to save a copy of the .HWR file as a .GPX file; select "Yes."
   e. All the "marked" waypoints and the starting waypoints will be provided in a list organized by date and time collected.
   f. Copy the waypoint table and paste into an Excel spreadsheet. Add the headers: Name, Icon, Shared, Latitude, Longitude, Depth (ft.), and Date. Save as a .CSV by Site, WAYPOINTS, and Date (example: PRLA_WAYPOINTS_20160728). Save to the CI Dropbox in a separate folder called "Waypoints."
4. Lastly, open all sonar records (R000xx.DAT) for each survey in HumViewer. Export each file and save as a .KML file by recording number (example R00017) and place into a file folder called "SonarTracks" in the CI Dropbox file for the survey data.
   a. Review the survey tracks in Google Earth to ensure that the survey was complete. If there are large areas that were missed file a trouble ticket identifying the root cause and the plan to complete the survey. Discuss the survey completion plan with your manager and the lead aquatic scientist.
5. Ensure that the following files are loaded to the CI Dropbox:
   a. Sonar Records (example R00001.DAT)
   b. Shoreline shape file (example PRLA_SHORLINE_20160728.SSF)
   c. In-water features shape files (example PRLA_ISLAND_20160728.SSF)
   d. Waypoints .CSV file (example PRLA_WAYPOINTS_20160728.CSV)
   e. Sonar tracks saved as .KML files in a separate folder called "SonarTracks."

6. Ensure that the field data are present and readable. Save field datasheets to the appropriate file in the AOS dropbox. Synchronize the mobile device at the end of each field day. Make sure any ground-truthing photos were downloaded with the mobile device sync.
7. All data and notes shall be transcribed into the database within 7 days.

SOP E Sample Shipment

There is no sample shipment for this protocol.

7 REFERENCES

Donohue, I., and J.G. Molinos. 2009. Impacts of increased sediment loads on the ecology of lakes. Biological Reviews, 84(4): 517-531.

Dost, R.J.J. and Mannaerts, C.M. (2008) Generation of lake bathymetry using sonar, satellite imagery and GIS. In*:* ESRI 2008: Proceedings of the 2008 ESRI international user conference: GIS, Geography in action*,* August 4-8, 2008, San Diego, Florida / ed. by J. Dangermond. Redmond: ESRI, 2008. 5 p.

Heyman, W.D., J-L. B. Ecochard, and F.B. Biasi. 2007. Low-cost bathymetric mapping for tropical marine conservation – A focus on reef fish spawning aggregation sites. Marine Geology, 30: 37-50.

Hofmann, H., A. Lorke, and F. Peeters. 2008. Temporal scales of water-level fluctuations in lakes and their ecological implications. Hydrobiologia, 613(1): 85-96.

Linhart, S.M., and K.D. Lund. 2008, Bathymetric contour maps for lakes surveyed in Iowa in 2006*:* U.S. Geological Survey Scientific Investigations Map 3051, 2 sheets.

U.S. Army Corps of Engineers. 2002. Engineering and Design-Hydrographic Surveying Manual No. 1110-2-1003: Washington, D.C., 510 p.

APPENDIX A DATASHEETS

The following datasheets are associated with this protocol:

Table 4. Datasheets associated with this protocol

NEON Doc. #	Title
NEON.DOC.003104	Datasheets for Bathymetry and Morphology of Lakes and Non-Wadeable Streams
NEON.DOC.001646	NEON General AQU Field Metadata Sheet
NEON.DOC.002494	Datasheets for AOS Sample Shipping Inventory

These datasheets can be found in the NEON Document Warehouse.

APPENDIX B QUICK REFERENCES

Step 1 – Check the bathymetry field sampling kit to make sure all supplies are packed.

Step 2 – Set-up and secure the sounder on the mounting rod.

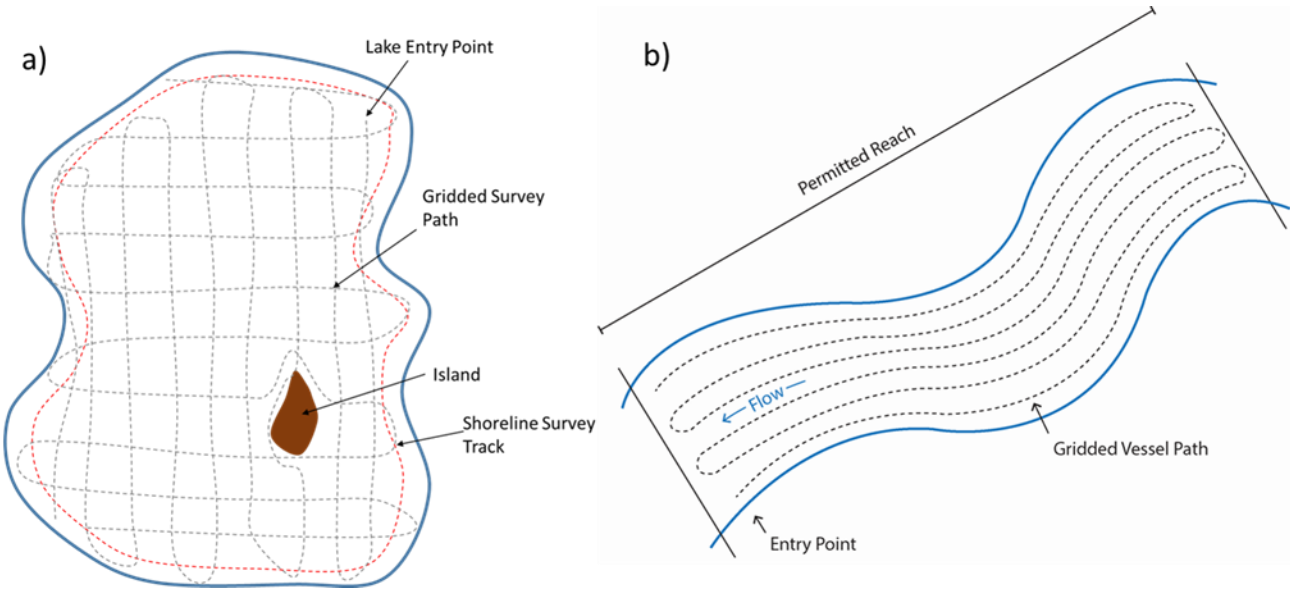
Step 3 – Take a reading of the water level and record on the mobile device or *Bathymetry Field Datasheet*.

Step 4 – Verify that the Humminbird and handheld GPS units have a good signal and that the transducer and control head are functioning.

Step 5 – Verify depth calibration and settings of the echosounder.

Step 6 – Record depth changes made to the echosounder and transducer.

Step 7 – Start recording on the Humminbird unit and create a gridded pattern around the lake or non-wadeable stream.



Step 8 – Record the shoreline and all morphological features encountered both within the lake or stream (i.e., islands, lake bottom biological and physical features) with the handheld (Trimble) GPS.

Step 9 – Record the location of unique substrate, habitat features, or vegetation with the Humminbird GPS for ground-truthing.

Step 10 – Once the transects are completed, stop recording on the Humminbird unit.

APPENDIX C REMINDERS

Before heading into the field: Make sure you…

- ☑ Collect and prepare all equipment.
- ☑ Fully charge all batteries and electronic equipment the night before.
- ☑ DO NOT assume that batteries are functional or fully charged even if new.

Bathymetric mapping: Be sure to…

- ☑ Travel at no more than 5 kilometers (3.1 miles) per hour. Faster speeds will add errors to the readings by changing the rate of return of the sounder signal versus the GPS coordinate.
- ☑ Travel at a constant speed in an approximate grid pattern.
- ☑ Given the beam angle for the instrumentation, the grids should be spaced approximately 20 meters apart.
- ☑ Stop and clear vegetation from transducer/rod after passing through aquatic vegetation
- ☑ **Do not change the beam bandwidth setting.**
- ☑ Monitor your speed on the Humminbird unit.
- ☑ For maximum performance, keep the Pings per Second setting on Auto.
- ☑ Use the same handheld GPS (Trimble) receiver for all data collection throughout the day.
- ☑ If wind speed is higher than 5 knots, suspend sampling.

APPENDIX D ESTIMATED DATES FOR ONSET AND CESSATION OF SAMPLING

See the Site Specific Sampling Strategy Documents.

APPENDIX E SITE-SPECIFIC INFORMATION

See the Site Specific Sampling Strategy Documents.