AOS PROTOCOL AND PROCEDURE: STREAM DISCHARGE

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See configuration management system for approval history.

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Change Record

REVISION	DATE	ECO #	DESCRIPTION OF CHANGE
A	02/06/2014	ECO-01092	Initial release
B	01/26/2015	ECO-02636	Migration to new protocol template
C	02/29/2016	ECO-03662	Baseline of protocol following FOPs review
D	04/04/2017	ECO-04480	Updated to new template; changes to sampling frequency, point of zero flow, removal of 3 depth sampling

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1 OVERVIEW

1.1 Background

The degree to which flow, or discharge, affects the structure of stream and river ecosystems cannot be overstated. Stream ecologists consider discharge a master variable, as varying rates of discharge directly affect the physical, chemical, and thermal attributes of the stream ecosystems. High flow events have the ability to entirely reshape the physical habitat of streams by repositioning large woody debris, sediments, and boulders within the active channel, or create new channels. Flow rates often directly affect water temperatures, particularly during flood and low-flow events (Poole and Berman 2001). Surface water discharge rates directly affect flow through the hyporheic zone (space between sediments in the benthic zones of streams) as well, where microbial activity is concentrated. Consequently, discharge can directly affect nutrient cycling in streams (Grimm and Fisher 1984). Because of these and other interactions between discharge and the physicochemical attributes of streams, flow regime characteristics have been found to be significantly correlated with life history attributes of stream-dwelling organisms such as fishes (Mims and Olden 2012).

Flow regimes in stream and rivers worldwide are rapidly changing due to environmental stressors, consequentially affecting the ecological services these systems support. Climate change impacts the timing, magnitude, and severity of flood and drought events with profound consequences for lotic ecosystems. For example, peak flows in western North American rivers are consistently occurring earlier in the spring (Clow 2010) and these changes may significantly alter the habitat suitability for species such as cutthroat trout (Zeiglar et al. 2012). Land use change from natural cover to human-dominated landscapes can also affect discharge. Impervious surfaces (such as roads and rooftops) in urban landscapes transfer water directly to stream channels, resulting in elevated flood frequencies and magnitudes (Schoonover et al. 2006). Agricultural lands may also impact flow regimes either by reducing flows directly through withdrawals or elevating flow when soils become compacted (Dodds et al. 2004). All flow regime changes associated with land use substantially impact the biological communities that reside in the receiving waters (Cuffney et al. 2010, Dodds et al. 2004).

Because discharge is fundamentally important to stream ecosystems, NEON will calculate discharge in all rivers and stream sites within the Observatory. The discharge data product will be a crucial input to a number of additional high-level NEON data products, such as stream metabolism and nutrient fluxes. Consequently, discharge represents a critical component in the NEON Aquatic Observation System.

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]).

1.3 Acknowledgments

NEON acknowledges the current definitive work on this topic, "Discharge Measurements at Gaging Stations", U.S. Geological Survey Techniques and Methods Book 3, Chapter A8, by D. Phil Turnipseed and Vernon B. Sauer (2010).

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Applicable Documents

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

AD[01]	NEON.DOC.004300	EHS Safety Policy and Program Manual
AD[02]	NEON.DOC.004316	Operations Field Safety and Security Plan
AD[03]	NEON.DOC.000724	Domain Chemical Hygiene Plan and Biosafety Manual
AD[04]	NEON.DOC.050005	Field Operations Job Instruction Training Plan
AD[05]	NEON.DOC.004104	NEON Science 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.001646	General AQU Field Metadata Sheet

2.3 Acronyms

Acronym	Definition
LEW	Left edge of water (looking downstream)
P&P	Procedure and Protocol
REW	Right edge of water (looking downstream)
USGS	U.S. Geological Survey
SDRC	Stage Discharge Rating Curve
PZF	Point of Zero Flow

2.4 Definitions

Area (A): The cross-sectional area of a stream or a subsection of a stream. For a rectangular subsection, it is the width times the depth. For an irregular cross-section, it is the summation of a series of subsection areas, or the width times the average depth.

Control: The first riffle or run, below the pool in which the staff gauge is placed.

Depth (D): The depth of the water column at a particular point, measured from the water surface to the stream bottom.

Discharge (Q): (A.K.A. Stream flow) The volume of water flowing through a cross-section during a given period of time, measured in units of volume per unit time, such as cubic feet per second, cubic meters per second, liters per second, gallons per minute, or acre-feet per year. Discharge is computed as velocity x area.

Left edge of water (LEW): The edge of the stream that is on the observer's left when looking downstream.

Right edge of water (REW): The edge of the stream that is on the observer's right when looking downstream.

Stage: (i.e. stream height, water level) Height of a stream or river relative to a fixed point. Stage can be measured at a single point in time by reading the water level on a calibrated staff gauge mounted in the stream channel, or by using a weighted measuring tape to measure down from a fixed point to the water surface. Stage can also be measured continuously with a pressure, optic or acoustic sensor, or a staff gauge.

Stage Discharge Rating Curve (SDRC): An empirical relationship (formula) between a stream stage and the associated discharge at given stage, which allows automated measurements of stage to be converted to discharge.

Thalweg: The deepest part of the active channel stream channel.

Transect: The stream cross-section under the measuring tape stretched across the measuring section, along which velocity measurements are made to compute discharge.

Velocity (V): The speed of water flowing past a point along the transect, measured in liters per second.

Wetted Width: Width of a stream channel that has actual water in it. As water levels fluctuate in streams, the wetted width may as well, depending on the cross-sectional shape of the channel.

3 METHOD

The NEON approach to obtaining a continuous record of stream discharge is via two complementary methods used to generate a **stage-discharge rating curve (SDRC)**. Stage-discharge rating curves relate the stage to a volumetric measurement of streamflow. To accomplish this, NEON field personnel establish the rating curve by collecting discharge data that corresponds with a range of stream stage levels. In this technique discharge is a calculated metric obtained from a series of stream velocity measurements, taken along a transect, and integrated into a single value of stream discharge (called wading surveys).

Once this rating curve is established, and barring significant changes in channel morphology, a single measurement of water column depth in the stream channel is sufficient to estimate the stream discharge magnitude. Hence, a pressure transducer located at a fixed location in the stream is able to yield a continuous estimate of stream discharge by measuring water depth.

NEON uses an in-stream staff gauge positioned near a pressure transducer to make automated measurements of stream-level and "wading surveys" to make manual measurements of stream discharge at all sites. Wading surveys involve positioning a velocity meter sensor attached to a rod in the flowing stream. The velocity meter is designed to measure the speed of water around the sensor tip, yielding an instantaneous velocity measurement of the region local to the sensor tip. To obtain a total stream discharge magnitude, the stream is divided laterally into subsections. Within each subsection, an instantaneous velocity magnitude is obtained and transformed to a volumetric discharge magnitude by applying the velocity across the full subsection area. Total stream discharge is then calculated by summing up the discrete volumetric discharges for each subsection. Should site-specific conditions become unfavorable for wading surveys, such as insufficient water levels or velocities, a second method may need to be used and staff at NEON HQ will make this decision based on site conditions and site constraints. The method detailed in this document follows the United States Geological Society (USGS) protocols (Rantz et al. 1982, Turnipseed and Sauer, 2010).

When the rating curve is under initial development, it is particularly important to perform wading surveys frequently in order to form the basis of the stage-discharge relationship. NEON's target is to conduct 26 discharge surveys over a wide range of stage levels until Science has approved a valid SDRC. Once the rating curve has undergone this initial development, it is important to check the rating periodically, as it may change because of scour, aggradation, or other changes in channel geometry. Channel morphology in streams with unconsolidated bed materials is expected to fluctuate (to varying degrees) on an annual and storm-event basis. As a result, rating curves for these channel types will require more frequent measurements than those for bedrock channels, which are more stable. NEON's target is to use wading surveys to verify the rating curve 12 times per year across a range of stages. Discharge surveys that occur during and following high-flow events (which may substantially alter channel geometry) are especially important for detecting shifts in the stage-discharge relationship.

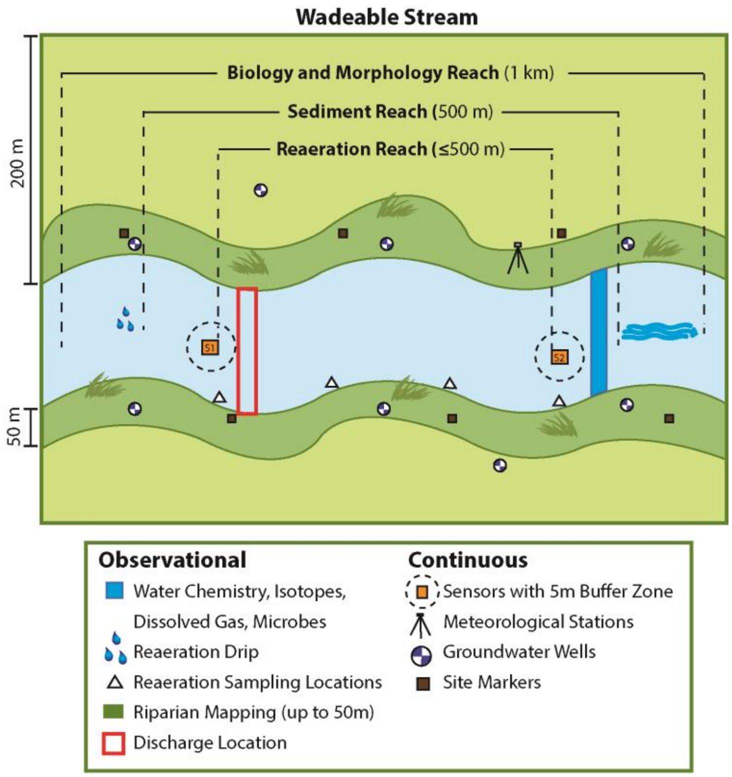

Figure 1. **Discharge station must be placed on a run or riffle associated with the pool that the staff gauge and pressure transducer is placed.**

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 collect an accurate discharge measurement, field technicians **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 technicians document the problem and enter 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]).

4 SAMPLING SCHEDULE

4.1 Sampling Frequency and Timing

The general plan for discharge frequency at a site is 26 times for the first year to establish an SRDC, followed by 12 times per year to validate and refine the SRDC. After the first year of sampling, the SRDC should be reviewed and approved by NEON Science. Once approved by Science, sites should reduce sample frequency to 12 times a year. If SRDC's are not approved by Science due to large scatter in the data, then Science will work with the Domain staff to schedule additional samples. Additional samples will be scheduled to fill in data gaps needed to improve the SDRC.

After the SRDC has been established, field technicians should compare discharge and stage measurements collected to the established rating curve. If three consecutive discharge sampling events yield discharge values that are outside the range of ± 10% of the discharge value calculated from the SDRC equation, the stream discharge may have shifted from that represented in the current SDRC equation. In that case, field technicians should increase the sampling frequency to re-establish the SDRC equation. If three consecutive discharge sampling events fall outside of the ± 10% expected value range, the field technician should write a trouble ticket informing Science and specify where in the hydrograph these events took place. In most cases, Science will follow up this trouble ticket with direction to increase discharge sampling frequency to 26 samples a year until a new SRDC has been approved by Science. However, there may be cases where science requires more data before increasing sampling. For example, if ± 10% readings occur at the extreme high or low of the hydrograph then Science may ask field technicians to collect more samples before determining if an increase in sampling is warranted.

Table 1. **The approximate sample dates for wading discharge measurements at all NEON sites**

	Date	**Frequency**
All domains (Until the development of an approved SDRC)	Year-round as feasible	26 times for the first year to establish an SRDC, followed by 12 times per year to validate and refine the SRDC. After the first year of sampling, the SRDC should be reviewed and approved by NEON Science. If SRDC's are not approved by Science, then Science will work with the Domain staff to schedule additional samples. Additional samples will be scheduled to fill in data gaps needed to improve the SDRC.
All domains (After an approved SRDC has been developed)	Year-round as feasible	12 times a year.

4.2 Criteria for Determining Onset and Cessation of Sampling

1. Data collection:
   a. Is there flowing water in the stream channel? If NO then STOP; If YES, proceed to (1b)
   b. Is >30% of the transect at a depth >0.06m? If NO then consider surveying the PZF ; f YES, proceed to (1c)
   c. Is there sufficient time to collect a discharge survey? If NO then STOP; if YES perform discharge survey

4.3 Timing for Laboratory Processing and Analysis

There is no domain lab processing for this protocol.

4.4 Sampling Specific Concerns

1. If technicians determine that logs, boulders, thick ice and or other submerged objects immediately upstream or downstream of the transect influence the stream flow at the specific measurement station, then do not sample but write a ticket and include pictures of the obstruction.

Results could be negatively impacted by:

1. Rapidly changing stage (rising and falling limbs of the hydrograph) and discharge
2. Dropping equipment into the stream
3. Heavy precipitation
4. Severe cold or wind
5. People or animals approaching the sampler while in the stream
6. Low or dead batteries in the current meter
7. Insufficient attention to the protocol
8. Errors in reading or entering data in the handheld velocity meter
9. Using the meter in the wrong mode, such as getting readings in English rather than metric units
10. Failure to read or set the depth on the wading rod in the correct manner
11. Failure to stretch the tape line perpendicular to the direction of flow
12. Improper site selection (too slow, too shallow, effects of backwater, too turbulent, too many rocks and eddies, undercut banks, bends, large woody debris, other obstructions)

4.5 Criteria for Permanent Reallocation of Sampling Within a Site

Discharge sampling will occur on the schedule described above at 1 location per site. 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 re-located 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 transect becomes compromised, a problem ticket should be submitted by Field Operations to Science.

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 channel migration occurs following a high-flow event 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.

Activities in streams should only be performed when flow conditions are safe. Do not attempt to wade a stream where (velocity x depth) is ≥ 10 ft2/s (0.93 m2/s)

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 Technician 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.

6 PERSONNEL AND EQUIPMENT

6.1 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**

Item No.	R/S	Description	Purpose	Quantity	Special Handling
Durable items					
	R	Survey Tape (15-100m, site specific lengths)	Establishing the transect	1	N
	R	Stakes	Anchoring survey tape	2	N
	S	Clamps	Attaching and securing tape to stakes	2	N
	R	5 Gallon Bucket	Zero Calibration of sensor	1	N
	R	Velocity Meter (Ex. Hach FH950.1)	Measuring velocity	1	N
	R	Top setting wading rod	Measuring velocity	1	N
	R	Waders (per person)	Safe wading	1	N
	R	Personal Flotation Device (at sites where required)	Safe wading	1	N

Item No.	R/S	Description	Purpose	Quantity	Special Handling
Consumable items					
		No Consumable Items			

R/S=Required/Suggested

6.2 Training Requirements

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

Personnel should be:

- Trained in Water Safety Awareness
- Trained in making wading discharge measurements
- Adept at wading in streams.

6.3 Specialized Skills

N/A

6.4 Estimated Time

Once at the discharge site, 1 discharge transect should take from setup to completion between .5 and 1.75 hours. If the technician needs to sample the transect more than once the time will increase.

7 STANDARD OPERATING PROCEDURES

SOP A Field Sampling

A.1 Preparation

1. Ensure flow meter is fully charged.
2. Gather and prepare equipment (See Table **2** for equipment list).
3. If site has an approved SDRC, be prepared to compare the current stage and measured discharge value with the SDRC in the field.

A.2 Determining Sampling Location

1. Navigate to the selected measurement location.
   a. The bounds for the discharge cross-section will be marked using permanent stakes (one on each side of the stream). If this is the first discharge measurement on the stream, see b1.
   b. Define the discharge transect.
      1. Look for a location in the stream, in the same location (pool or run) that one of the in-stream sensor sets is located (S1/S2 – request coordinates from AQU team if not known). This allows Science to link discharge with continuously monitoring pressure sensors. Determine which location will be more suitable for a stream discharge measurement and define a cross-section transect. When looking for the discharge transect, look for areas of the stream which have stable laminar flow, no (or very few) obstructions, average water depth at base flow approximated to be greater than 0.06 m across the whole channel (edges of the channel may have less than 0.06 m of water depth).
2. Examine the streamflow conditions to look for potential environmental issues that would inhibit measurements. Potential issues include, but are not limited to:
   a. Insufficient water in the channel to conduct velocity measurements. A minimum water level of 0.06 meters is required to conduct the discharge measurement at each point in the transect. Water levels shallower than 0.06 m may cause bias in the velocity reading. While sections of the channel, particularly the edges, may have water levels less than 0.06m. If the transect has >30% of the wetted width with a depth < 0.06 m then consider sampling the point of zero flow measurement SOP A9.
   b. Too much water in the channel to safely conduct the wading survey. Refer to NEON Operations Field Safety and Security Plan (AD[02]) for details. If the transect has too much water flowing to accurately measure discharge do not sample and write a trouble ticket upon return.
   c. Environmental issues that can affect sampling such as high potential for a thunderstorm (refer to NEON Operations Field Safety and Security Plan (AD[02] for details), or frozen

surface of stream (refer to NEON Operations Field Safety and Security Plan (AD[02] for details).

1. If the water surface is "lightly iced" over (< 1" of ice) and you can safely break through the ice to clear/open up the entire transect, collect a discharge measurement. On the General Field Metadata sheet RD[05] record ice conditions and indicate that surface ice was broken in order to collect the measurement.
2. If the surface ice thickness is > 1", do not measure stream discharge as it's probable that data won't match with the SDRC due to the influence of the ice on the stream cross-section.

d. Debris or large ice chunks are actively floating down from upstream of the cross-section area into the sampling transect.

e. Uneven substrate (e.g. cobble), that would lead to inaccuracies in discharge measurement especially at low flows.

3. From the selected measurement location, ensure:
   a. The measurement area lies within a straight reach of stream; flow lines are roughly parallel to each other and perpendicular to the full width of the measurement cross-section. Variances to this may be caused by flood events, which have the potential to rapidly change channel geometry.
   b. Flow is relatively uniform and free from eddies, slack water, and excessive turbulence.
   c. The streambed, in the near vicinity of the measurement location, is free from large obstructions, such as boulders, debris, and aquatic vegetation. Note: aquatic vegetation is ok to remove to facilitate velocity measurement, if the vegetation is small (thin tree branches, tumbleweeds, etc.) that were not present during previous discharge measurements. Should large debris fall in the discharge transect (trees or branches greater than 20 cm in diameter), do not remove it. Take a photo and submit a trouble ticket to document.
   d. Water velocity is >0.05 m/s in the thalweg (the deepest, swiftest part of the channel).
   e. Water depths >0.10 m are preferred, but a minimum depth of >0.06 m is required.
   f. If any of the above criteria are not met and no such area exists within 1 m upstream or downstream of the defined locations, submit a trouble ticket.

A.3 Dividing the Stream into Subsections

The following section defines how to set the spacing of the velocity measurement across the stream discharge transect. Spacing will differ with different stream flows, water surface elevation, and wetted width, so adjust accordingly.

1. Prior to each discharge measurement, measure the wetted width at the transect and determine if flow is relatively uniform (**Figure 2**) or non-uniform (**Figure 3**) across the channel.
   a. If the wetted width of the stream is >2 m divide the stream in 20-25 sampling stations.

b. If the wetted width is ≤ 2m, space station at a **maximum** of 0.1 m increments from wetted edge to wetted edge.

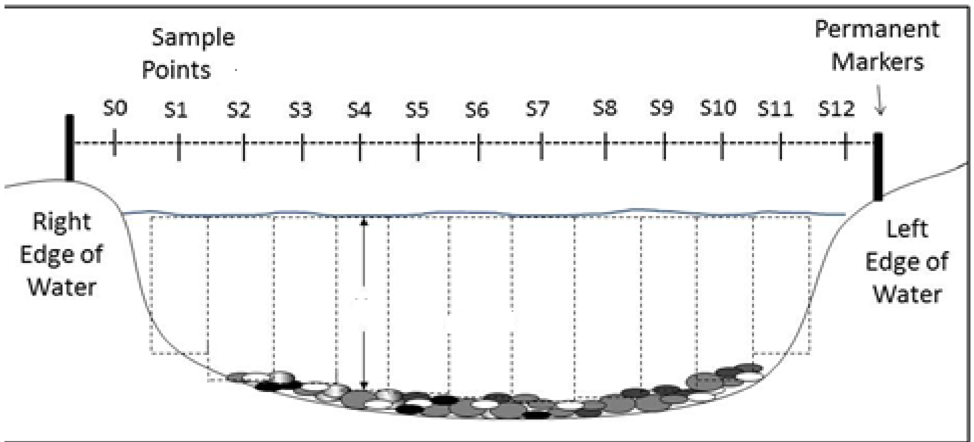

Figure 2**. Example of an excellent distribution of measurement section**

2. If the transect has a non-uniform flow with more concentrated areas of high flow, or 30% of depth < 0.06 meters, increase the number of sampling stations so that a higher number of stations are concentrated along the part of the transect with greatest flow (**Error! Reference source not found.**).
   a. Most natural stream cross-sections will have non-uniform flow or uneven channel structure (e.g. pools and shallow areas); sampling stations should be adjusted to represent the stream flow, with measurements more concentrated in areas with faster or deeper flow (**Error! Reference source not found.**).
   b. Sampling points within the transect should be selected for each survey based on the current stream stage and flow conditions, so that measurements are taken in the areas that best represent the current stream flow.

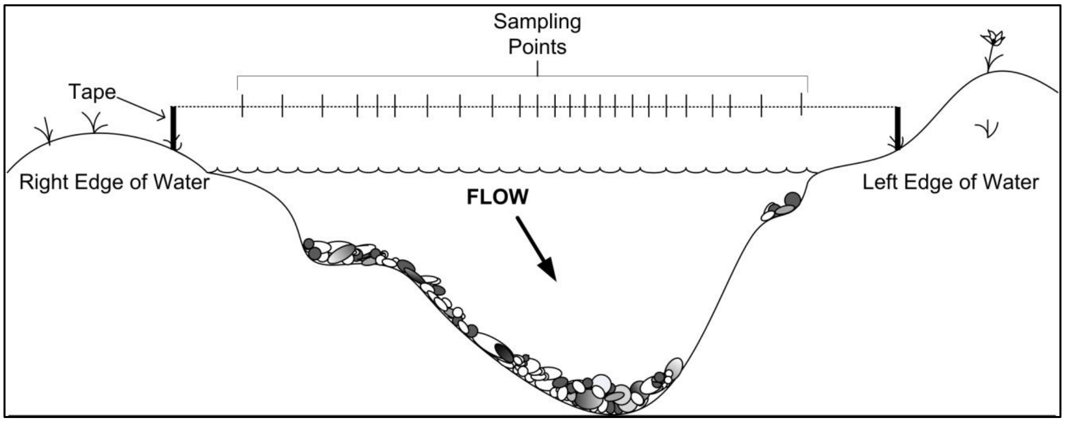

Figure 3. **Uneven subsections across sampling transect**

A.4 Discharge calculations based on selected station locations

1. While depth and velocity measurements are collected at each station, the discharge calculated encompasses a subsection. Subsections encompass the area starting at the mid-point along the transect from the last station measured, and ending at the mid-point along the transect from the station currently being measured (shown with dotted lines in **Error! Reference source not found.**). At the end of the discharge transect measurements; the meter will calculate the percentage of total flow represented by each subsection.
    a. **Ideally, no more than 5% of the discharge should be in one subsection**, but this can be difficult to achieve in small, irregular stream channels. If the 5% rule cannot be followed, document this issue in a trouble ticket.
    b. In general, **no more than 10%** of the discharge should be flowing through any one subsection. The distribution of subsections may be estimated by scanning the transect and looking for areas of high flow, and taking more measurements in the high-velocity zones than in the low-velocity zones (Error! Reference source not found.). In some NEON streams, this will be difficult if not impossible to accomplish. If the 10% rule cannot be followed at the current spacing, reduce the spacing distance by increasing the number of velocity measurements taken. If the original spacing for the velocity stations was set at .10, then set velocity-measuring stations at .05. If the original spacing was, 20-25 stations increase the number of sampling stations. Continue to reduce the velocity-measuring station spacing until there are no longer sub-sections with > 10% of the flow. If it is not possible to sample so that there are not subsections with > 10% flow, collect a discharge measurement and report that occurrence in a trouble ticket.
        1. If a clearly defined region of high flow exists, then measure stream depth and velocity at closer spacing in this region (Error! Reference source not found.).

2. When in doubt, select more sampling stations with each subsection sampling a smaller percentage of flow.

c. If a SRDC is already created, and discharge measurements fail to meet ± 10% of the SRDC values or if the technician suspects the discharge measurement to be incorrect, collect discharge again. If the value still does not meet the SRDC or is suspect after the second discharge sample, collect again and include more measurements at shorter intervals. If values still fail to meet the ± 10% of SDRC criteria after three attempts at collecting discharge, write a trouble ticket upon return from the field.

Table 3. Explanation of the number of stations needed depending on the width of the stream

Wetted-width of Stream	Suggested Sampling Points
≤ 2 m	Sample every 0.1 m unless any 1 sub-section has >10% of the flow, then space sample points every 0.05 m
> 2 m	20 – 25 sampling locations unless any 1 sub-section has >10% of the flow, then increase the number of sampling points.

A.5 Determining Depth of Sampling and Setting Wading Rod Depth

1. Determine the correct depth to collect velocity measurement.

a. To obtain the stream depth at each measurement point, position the base of the rod on the streambed and read the water level from the rod. The base of the rod should be as flat as possible on the bottom of the stream.

1. The wading rod is designed to allow for directly reading stream depth from the hexagonal rod. The hexagonal stationary rod is delineated into 2 cm (one band), 10 cm (represented by two bands on the rod, 10 cm mark is the bottom double-band), and 50 cm (represented by three bands on the rod) intervals as shown in **Error! Reference source not found.**.

a) Round water depth readings from the wading rod and the staff gauge to the nearest 1 cm.

b) Practice this step prior to putting the rod in the water to become familiar with the markings and how to read them.

b. Once total depth at a sampling point is measured use the depth to determine if a one-point (60%), or two-point (20% and 80%) measurement is required to represent the average velocity for each subsection (

c.

d. **Table 4).**

1. If stream depth is <0.45 m, collect a one-point measurement at 60% depth. See A.5.2 for instructions on setting the appropriate depth.
2. If stream depth is >0.45 m, collect a two-point measurements at 80% and 20% of the total depth. See A.5.2 for instructions on setting the appropriate depth.
3. These height percentages are always measured from top to bottom with the stream surface at 0 m. For example, if a sampling point has a depth of 0.30 m, then 60% depth would be 0.18 cm below the stream surface and 12 cm above the stream bottom.
4. If the depth of the sampling point is 0.50, then 80% of the depth is 40 cm, and 20% of the depth is 10 cm above the stream bottom.
5. At **each** sampling point along the transect, decided if a one-point or two-point measurement is required.

Table 4. Determine measurement depth based on stream depth.

Stream Depth at Measurement Location	Measurement Depth
< 0.45 meters	1 point - 60% of Depth
≥ 0.45 meters	2 point - 20% and 80% of Depth

2. Set the depth on the wading rod
   a. The top of the depth gauge rod and the sliding rod are used for setting the velocity meter at the correct depth on the wading rod (Figure 5). The round sliding rod is used to set the measurement depth and is scaled with graduations representing tenths of a meter, with 0 at the top. A smaller scale on the handle of the hexagonal fixed rod (**Error! Reference source not found.**) is used to fine-tune the depth, and is graduated (0 to 10) representing centimeter increments.
   b. Listed below are 3 examples on how to set velocity measurements at desired depths on the wading rod. A single depth of 0.72, is used to illustrate all three (40, 60, and 80) percentages, for the sake of simplicity. Refer to section A.5.2 to determine the amount and locations of velocity measurements required for various water depths in the field.

      1. **60% Depth** – Line up the 7 on the sliding rod (represents 0.70m total stream depth) with the 2 on the handle of the fixed hexagonal rod (represents 0.02m total stream depth) as shown. Coupled, these two settings define the depth of sensor to be at 60% of the depth of a 0.72m deep stream section. This is the simplest depth to set the rod to and requires no calculations by the user.

2. **80% Depth** – Divide the stream depth by 2, and round to the nearest hundredths place. Using this value set the two positions on the wading rod following the procedure for the 60% depth. If the stream is 0.72m deep, then half of 0.72 m is 0.36 m. Thus the 3 on the sliding rod will line up with the 6 on the handle of the hexagonal rod.

3. **20% Depth** – Multiply the stream depth by 2 (equal to 1.44 m). Using this value, set the sliding rod to 14 and the handle to 4.

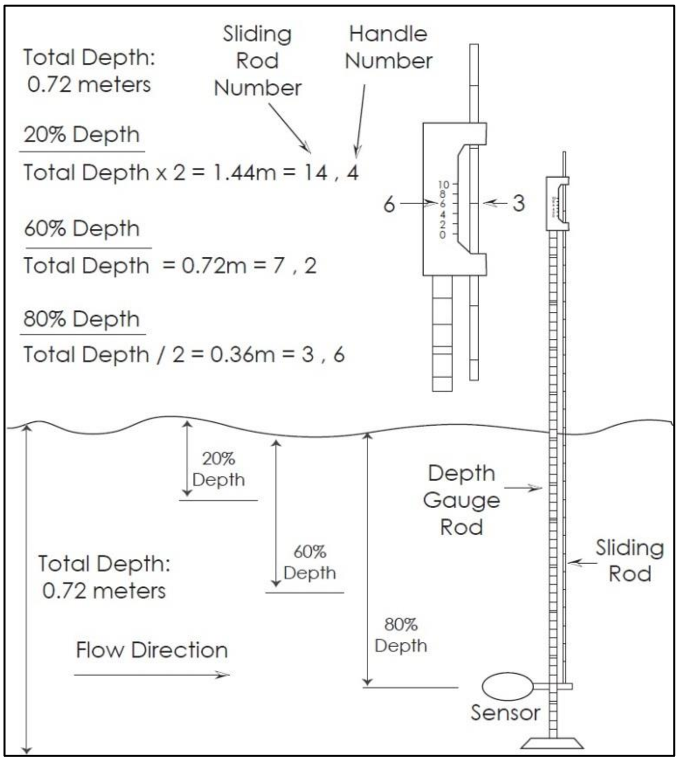

Figure 4. Correctly, assembled wading rod adjusted to 20, 60, and 80%

A.6 Setting up the transect

When setting up the survey tape it is important to follow the convention that the **stream banks are designated right and left based on the perspective of looking directly downstream** (see **Error! Reference source not found.** and **Error! Reference source not found.**).

1. Starting at the Right Edge of Water (REW), extend the measuring tape across the stream perpendicular to stream flow (Figure 2 and Figure 3).
2. Anchor measuring tape from right bank permanent marker to left bank permanent marker in order to measure the wetted width at the transect measuring location.

3. Calculate the stream wetted-width by calculating the difference between left edge of water (LEW) and right edge of water (REW).
4. Attempt to select measurement locations across the transect so that no more than 5% of the discharge is flowing through any one segment, as best as possible.

A.7 Zeroing the Velocity Meter

THE FOLLOWING SECTION DIRECTS TECHNICANS ON HOW TO ZERO OUT THE DOMAINS VELOCITY METER BEFORE MEAURING DISCHARGE-BECAUSE NEON DOMAINS USE MORE THAN ONE MODEL***CHECK THE USER MANUAL FOR THE MODEL USED BY THE DOMAIN***. BELOW IS AN EXAMPLE OF HOW TO USE THE HACH FH 950, THE MOST COMMON MODEL USED AT NEON.

1. Ensure the top-setting wading rod is attached properly to the wading rod base. The base and rod screw together, tighten if loose.
2. Attach velocity meter to the mounting shaft of the wading rod, using the thumbscrew. (**Figure 5**). Try not to get any residue from hands on the sensor bulb

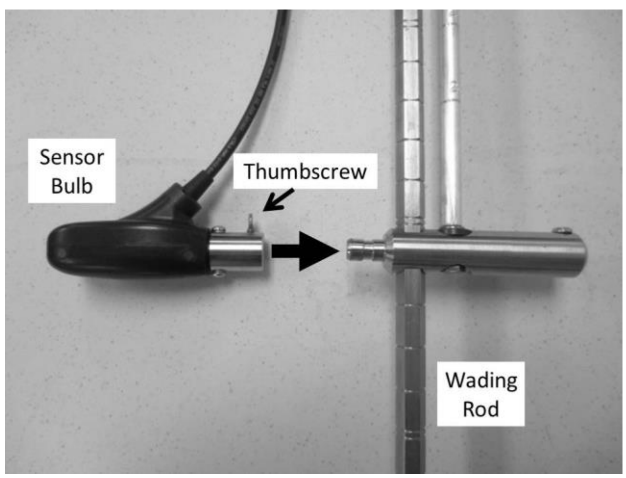

Figure 5. **Velocity meter and the thumbscrew that attaches it to the wading rod**

3. Turn the velocity meter on by pressing and holding the "ON/OFF" button, the meter may first run a diagnostic check to ensure it is connected to the sensor. When complete, a "Start" menu will appear as shown in **Figure 6**.

Figure 6. **Hach FH950 velocity meter showing the "Start" menu**

4. Set the measurement units**. Refer to the velocity meter manual to check or adjust the following measurement settings: Units = metric, Velocity = m/s, Discharge= l/s, Depth = m, 10 second averaging.**
5. Fill a 5-gallon bucket **with stream water**, this will ensure that the ionic strength of the "zeroing water" is the same as the water being measured. This step is required prior to starting each discharge wading survey each day since the conductivity of the stream water can change on a daily basis. This step helps to reduce the uncertainty of the measurements.
6. Put the velocity meter in the water. Keep the sensor bulb positioned the center of the bucket (or as close to it as possible). It should be a minimum of 3-inches from the sides and bottom of the bucket. The black sensor bulb should also be a minimum of 3-inches beneath the surface of the water.
7. After positioning the sensor bulb of the velocity meter in the bucket, let the water settle for 1-2 minutes to stabilize.
8. On the handheld display, follow the velocity meter's manual to calibrate velocity
   a. Water in the bucket must remain still during this calibration step.
   b. Allow the meter to cycle through a calibration reading, then zero (or calibrate) velocity.
   c. Cycle the meter again to ensure the calibrated value is still zero. Note: a negative zero reading (-0.00) is acceptable.
9. If the unit does not read zero (0.00, or -0.00) then repeat the above step.
10. Once the velocity meter is calibrated, return to the main menu.

A.8 Taking a Reading at Each Point Within the Transect

1. When standing in the stream, the wading rod is held upstream of the operator, with the sensor bulb pointed directly upstream, preferably into the flow, and perpendicular to the transect. Always point sensor upstream to the transect tape, regardless of where the flow comes from at that particular station. At stations where the flow does not flow vertically downstream, do not adjust the positioning of the sensor bulb. Take the measurement with the sensor pointing upstream in regards to the transect.
2. Hold the wading rod perpendicular to the water surface.
3. **DO NOT** stand upstream of the velocity meter; this would interfere with the flow of water past the meter and will cause an error in the readings.
4. **DO NOT** stand directly downstream of the velocity meter.
5. **DO** stand to the side and at arm's length from the velocity meter.
6. **DO** remember that the Velocity Meter does not save data until data is saved manually at the end. If the unit malfunctions or the power must be cycled, start the transect again.
7. Enter Operator and Site Information. The below example is based of the most common NEON velocity meter, the FH950.1. Please defer to the methods described in the user manual of the velocity meter used by the domain.
   a. Following the velocity meter's user's manual, enter the operator's name (e.g., in the FH950.1 steps from the start menu are; select "Profiler" > "Enter Operator Name" > type surveyors name here using the number/letter keys).
   b. Enter the 4 letter site code for the stream name (e.g., in the FH950.1 steps from the start menu are; select "Stream" > "Enter name for Stream" > enter the 4 letter code for the site name. (e.g. Arikaree = ARIK).
   c. Enter Stage Reference (m). Enter the reading from the staff gauge in meters; round to the nearest 1cm (Figure 7).

Figure 7. **Example of staff gauge installed in a pool**

d. Begin taking velocity measurements at the RIGHT BANK (lowest values on the survey tape).
e. Station 1 (REW). Refer to the velocity meter's manual to input the following information:
   1. Edge/Obstruction = Right
   2. Edge Factor = 0.75. 0.75 should always be the edge factor for every NEON wadeable stream
   3. Dist. To Vertical = the value on the survey tape which corresponds to the water's edge. This will be the value on the survey tape directly over the soil/water interface between the stream and the bank. This value will not be 0.00.
   4. Set Depth = depth of the water (at each transect station) as read from the wading rod (see SOP A.3 for how to read the wading rod). This value could be 0.00 if the angle of the stream bank is low, or > 0.00 if the stream bank is cut and has a drop off.
   5. Measure Velocity = the meter may display "Velocity is zero at edge". This will always be the case at the stream edge or at the boundary of an obstruction.
   6. Continue to the next station (Station 2) for additional measurements
f. Station 2+ (Intra-Transect stations)
   1. Move to the next transect location. Station measurements are to be taken at the interval calculated by dividing the wetted width by the number of velocity measurements intended, or if the wetted width is ≤ 2m set the measurement points every 0.10 or if ≥ 10% in any one subsection set measurement points every 0.05 m. Do not take measurements at the half way point of calculated station distances. All input depths should be measured at the station point.
   2. Repeat steps E.3 and E.4 above for setting "Dist. to Vertical" and "Set Depth" for each subsequent Station.

3. Measure Velocity = Based on the stream depth at the transect station select a "One point" (60% if measurement depth is < 0.45m) or "Two point" (20, 80% if stream depth is ≥ 0.45m) velocity measurement. The next screen will confirm the % value that the velocity survey will be conducted (i.e., 0.2, 0.6, or 0.8); select this value. Depending on model of your velocity meter, there may be a prompt with the recommended depth to set the sensor, ignore this prompt and set depth at the value you have already calculated for 20, 60, or 80% depth and proceed to capture The following screen will tell you at what value to set the velocity meter depth to. See SOP A.3.3 for details on how to set the depth of the wading rod.
4. Capture = This begins the velocity survey for this location and is a time average of instantaneous velocity measurements taken over a 10 second interval. Be sure to set meter to 10 second averaging.
5. The screen will display a graph showing the instantaneous values and the progress of the reading.
   a) If the velocity reading is not accurate or questionable, repeat the reading.
   b) If velocity values fluctuate within roughly 5% then accept the reading and move to the next station.
6. If the repeated velocity values are > than a 5% difference, this may be a result of turbulent streamflow. Increase the length of time average the survey is conducted for at this transect location by navigating to Setup within the same measurement screen (this should be an option at the bottom of the screen). Set this number to 20 s and repeat the test. If velocity values are still not within 5% between repeat surveys, then increase to a longer time and repeat. If 60 s for time averaging is reached and the values are still greater than 5% difference between repeat tests, submit a trouble ticket.
7. Repeat the steps for Station 2 for all locations in the transect that are "open water" and not a boundary location (i.e. edge of water or next to an obstruction). If an obstruction develops on the discharge transect take pictures and create a trouble ticket.

g. Last Station (Left Edge of Water LEW)
   1. Repeat steps for "Station 1" and for "Edge/Obstruction" select = Left
h. Summarize Collection and Save Data
   1. Channel Summary = this will display the stream discharge in Liters per second. Note this value as it will be needed shortly.
   2. Save Data and Exit = ***All data will be erased without this step.*** Enter Name of File: following the format for each event XXXX_YYYYMMDD or XXXX_YYYYMMDD_DSC, where XXXX is the site when uploading discharge files to the File Uploader in CI. The name format is flexible, but we need unique file names. For example: a discharge survey conducted at Posey Creek in D02 on September 30, 2015 will have the filename POSE_20150930

A.9 Calculate the Point of Zero Flow

The point of zero flow (PZF) is the depth as measured on the staff gauge where water has seasonally stopped flowing at the discharge transect. This can be envisioned as a portion of the streambed where the water level becomes too shallow to measure, or the surface water in the stream is not flowing (Figure 8). Technically groundwater seepage is still occurring, but not in a considerable enough amount to measure.

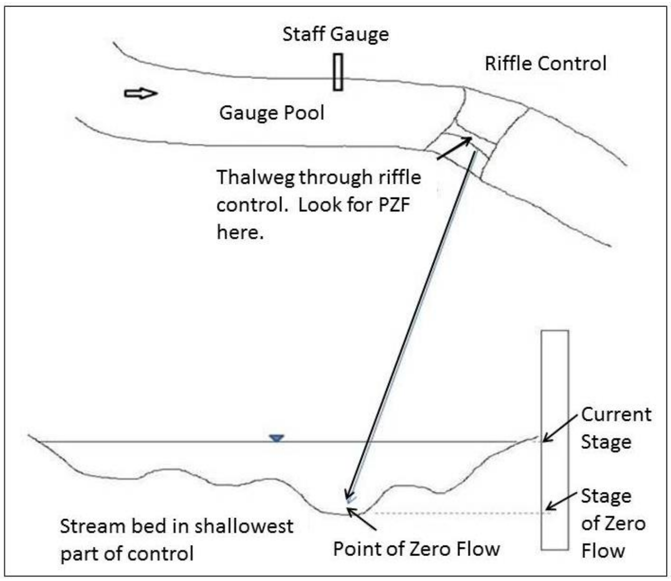

Figure 8. **Diagram showing point of zero flow and stage of zero flow**

The point of zero flow does not occur at every stream or in every year. If point of zero flow does not occur at the site during the calendar year, write a trouble ticket noting that the point of zero flow did not occur on site this year and therefore was not measured. If the PZF occurs at the site, implement the following methods.

1. Collect point of zero flow (PZF) if flow conditions have reached a point where there is no longer flow at the site, these conditions are often reached during times of summer low flow.
   a. Ensure the pool where the staff gauge is located has water. Document or note the stage height upon arrival at the staff gauge. If the staff gauge is in a dry pool, the point of zero flow cannot be determined and this should be documented in a trouble ticket.
   b. At the discharge transect measure and make note of the deepest point along the transect. The transect may be dry and therefore the deepest point will be zero.

c. Calculate the PZF by subtracting the deepest part of the control from the stage height. If there is no water in the control, subtract zero from the stage height. (i.e. If the staff gauge is 0.02 and the deepest point along the transect is 0.01, the PZF will be 0.01)

2. Create a record of zero flow in the velocity meter
   a. Use similar methods as collecting discharge data with the following exceptions:
      1. Enter PZF flow height in place of stage height.
      2. Collect velocity measurements at 10 points along the discharge transect. Because the discharge calculation should be zero, collect the velocity measurements with the sensor held out of the water. Make sure for every station you enter that the measurement is in fact zero.
      3. Calculate the zero discharge and save the file.
   b. If it is difficult to determining the PZF, do not collect this information, but rather submit a trouble ticket for assistance.

A.10 Red Bars

If red error bars are created, in the channel summary, increase the number of sample points so that the subsection with > 10% of the flow, has < 10% flow. Increase sample points again and redo discharge sample. If after adjusting sample points red errors bars still exist write a trouble ticket and do not download the data transect

A.11 Calculating Discharge

The velocity meter automatically calculates discharge based on the station and velocity data obtained during the wading survey detailed above. In general: A = Area, D = Depth, W = Width, Discharge = Q, V = Velocity. A = D x W. Q = A x V (Figure 2). Unless otherwise determined discharge values should be in L/s.

A.12 Field Data Verification

1. If a stage-discharge rating curve is available for this station, plot a point representing the collected stage and discharge on the current stage-discharge rating curve while still at the field site.
   a. The new point should fall within ± 10% of the curve (i.e. the discharge that was just obtained for the current stage should be within 10% of the discharge value indicated for that stage on the SDRC).
      1. If the point does not fall on or near the discharge curve, conduct another discharge survey immediately, if time and conditions permit.
      2. If three surveys point still does not match the curve, this may indicate that the stage-discharge curve is shifting. Record this value and write a trouble ticket upon return from the field.

b. This quality check will ensure the measured discharge appears reasonable in comparison to the rating curve.

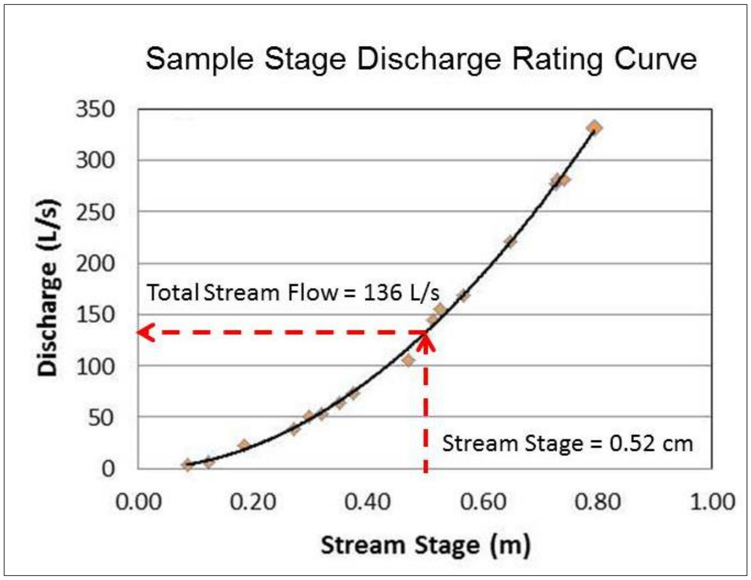

Figure 9. **Example of stage-discharge rating curve. Dots represent simultaneous measurements of stage and discharge**

A.13 Ending the Sampling Day

After each discharge survey the velocity meter, wading rod, and waders shall be cleaned following standard operating procedures for cleaning field equipment used in aquatic systems. Batteries for the velocity meter shall be charged or replaced as applicable.

SOP B Data Entry and Verification

There are no field data sheets for this protocol. Electronic data should be uploaded to the appropriate location within 7 days of collection. 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.

Extract stream discharge data from the digital meter to a local computer using the correct cable type (e.g., a USB to micro-USB cord).

1. Refer to the velocity meter's manual to locate the USB connection port. Plug the correct ends of the connection cord into the display unit and the computer.
2. Turn the velocity meter on.
    a. A "PVM Drive" should appear on computer, OR
    b. Locate the utility via *My Computer*. Two folders should be present: *P* and *RT*. Select the "P" folder.
    c. Note: if a dialog box appears asking to format the drive, close the window. DO NOT format the drive.
3. Select the appropriate file to transfer (e.g., POSE20150930.TSV).
4. Copy the file to the computer
5. Rename the file if needed
6. Upload or copy the (renamed) file to the appropriate final location (i.e., AOS Dropbox or WebUI)

8 REFERENCES

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APPENDIX A QUICK REFERENCES

Step 1 – Check and make sure that all supplies necessary gear is packed.

Step 2 – Ensure the General AQU Field Metadata Sheet (RD[06]) is completed per field site visit.

Step 3 – Navigate to the sampling location and divide the stream up into subsections according the width and uniformity of the streambed:

1. Ideally, no more than 5% of the discharge should be in one subsection, but this can be difficult to achieve in small, irregular stream channels.
2. No more than 10% of the discharge should be in one subsection

Step 4 – Explanation of the number of subsections needed depending on the width of the stream:

Width of Stream	Sampling Points
≤ 2 m	Sample every 0.1 m, or 0.05 m if there is >10% of the flow in any one subsection
> 2 m	20 – 25 sampling locations, or increase the number of sampling stations if > 10% flow, flows through any one subsection.

Step 5 – Determine if a one point (60%) or a two point (80% and 20%) measurement is required:

Stream Depth at Measurement Location	Measurement Depth
< 0.45 meters	1 point - 60% of Depth
≥ 0.45 meters	2 point - 20% and 80% of Depth

Step 6 – Set up the transect.

Step 7 – Turn on and zero the velocity meter using a bucket of water.

Step 8 – Take a reading at each sampling point within the transect.

Step 9 – Collect point of zero flow if flow conditions if the technicians determine that this is appropriate

Step 10 –Calculate discharge.

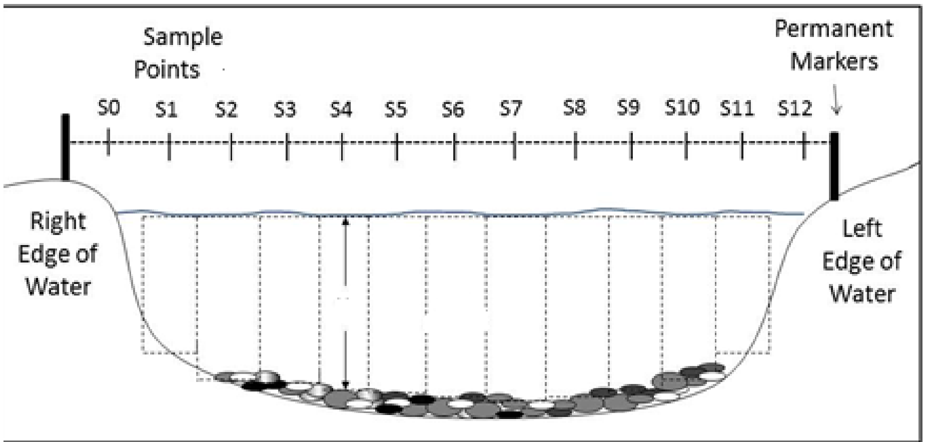
Step 11 – Save data.

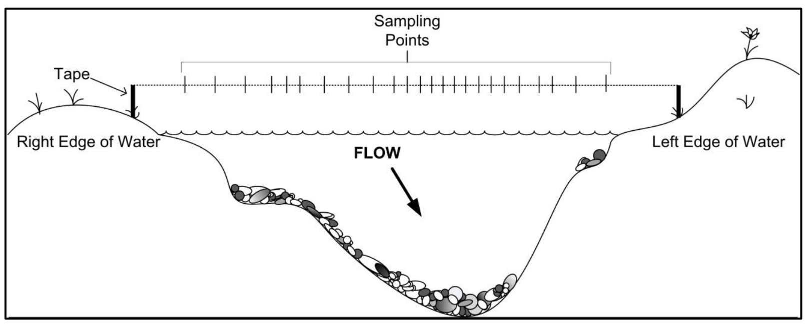
Step 12 – Verify data. If a stage-discharge rating curve is available for this station, plot a point representing the collected stage and discharge on the current stage-discharge rating curve.

Step 13 – Decontaminate equipment.

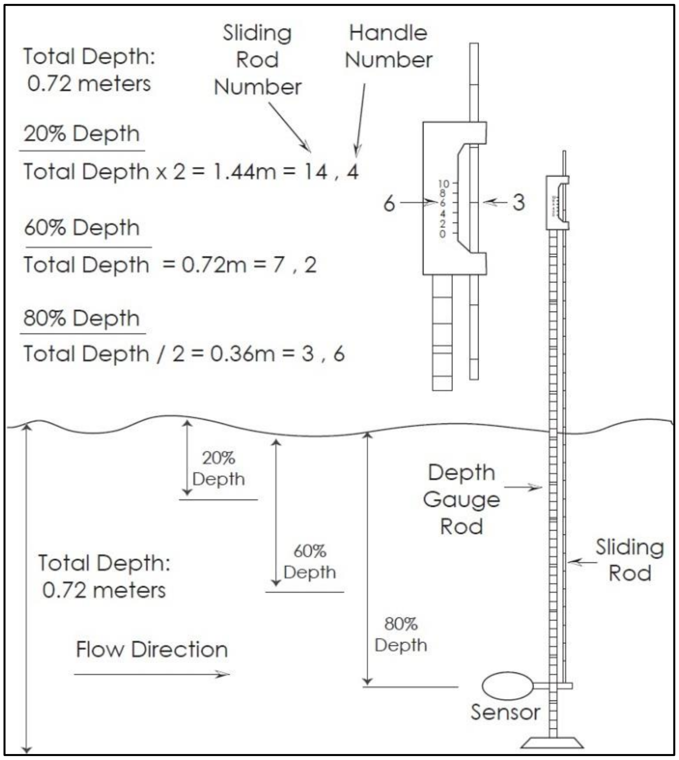
Step 14 – Recharge or replace batteries in the velocity meter.

A.1 Schematic for Dividing the Stream into Subsections





A.2 Schematic for Setting Depth on the Wading Rod



APPENDIX B REMINDERS

Before heading into the field: Make sure to

- Collect and prepare all equipment including labels.
- Ensure batteries are charged.

Sample collection: Be sure to…

- Aquatic vegetation can be removed to facilitate the discharge measurement.
- Fewer, wider subsections should be measured in areas of little or no flow, while more, narrower subsections should be made in deeper and faster flowing areas.
- If a sampling area cannot be found according to the criteria, **do not sample** and submit a trouble ticket.
- Stream banks are designated right and left based on the perspective of looking directly downstream. (If the permanent markers are missing and the transect cannot be set-up on the fixed points, then)
- Divide the wetted stream into 20-25 increments (Table 3); or, if the stream is less than 2 m wide, into 0.1-m increments. Increase the number of sampling stations if any one subsection has >10% of the flow in it.
- During calibration, stream water in bucket must remain still.
- Ensure the top-setting wading rod is attached properly to the wading rod base. The base and rod screw together, tighten if loose.
- **DO NOT** stand upstream of the velocity meter; this would interfere with the flow of water past the meter and will cause an error in the readings.
- **DO NOT** stand immediately downstream of the velocity meter; this would interfere with the free flow of water past the meter and will cause an error in the readings.
- **DO** stand to the side and at arm's length from the velocity meter.