# AOS PROTOCOL AND PROCEDURE: STREAM DISCHARGE

| PREPARED BY | ORGANIZATION | DATE |
|---|---|---|
| Michael Fitzgerald | AQU | 05/17/2013 |
| Ryan Utz | AQU | 01/22/2013 |
| Heather Powell | AQU | 05/20/2011 |
| Glenn Patterson | AQU | 05/18/2011 |
| Keli Goodman | AQU | 03/30/2011 |

| APPROVALS | ORGANIZATION | APPROVAL DATE |
|---|---|---|
| Charlotte Roehm | AQU | 1/26/2015 |
| Dave Tazik | SCI | 1/25/2016 |
| Kirsten Ruiz | OPS | 1/22/2015 |
| Mike Stewart | SE | 1/22/2015 |

| RELEASED BY | ORGANIZATION | RELEASE DATE |
|---|---|---|
| Jennifer DeNicholas | CM | 01/26/2015 |

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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 monitor stage to calculate discharge continuously in all river 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. Discharge will also inform the nutrient injection rate in the STREON experimental program. 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.001155 | NEON Training Plan |
| AD[05] | NEON.DOC.050005 | Field Operations Job Instruction Training Plan |
| AD[06] | NEON.DOC.014051 | Field Audit Plan |
| AD[07] | NEON.DOC.000824 | Data and Data Product Quality Assurance and Control 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 |
| SRDC | Stage Discharge Rating Curve |

### 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.

**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.

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

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

**Measuring section:** The stream transect where a velocity measurement is made.

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

**Stage:** (i.e. stream height, water level, or gauge height) 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.

**Thalweg:** The deepest part of the 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:** The speed of water flowing past a point, measured in feet per second or meters per second.

## 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, or water-level in the stream, to a volumetric measurement of stream flow. To accomplish this, NEON field personnel establish the rating curve by making several concurrent measurements of stream-level and discharge over a range of stream-levels and flow rates. 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 record 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 (e.g. first year or when a pressure transducer needs to be reset due to flooding/drying/etc.), it is particularly important to perform wading surveys frequently, to form the basis of the stage-discharge relation. NEON's target is to conduct 18-24 wading surveys over as wide a range of stages possible during the first year. Once the rating curve has undergone this initial development, it is important to check the rating periodically, as it may change as a result of erosion, deposition, or other changes in channel geometry. Channels that are more prone to erosion and deposition require more frequent rating checks than bedrock channels. NEON's target is to use wading surveys to verify the rating curve 8-12 times per year across a range of discharges. Discharge surveys following shortly after significant floods or other events that may change the geometry of the channel cross-section are especially important for detecting shifts in the stage-discharge relation.

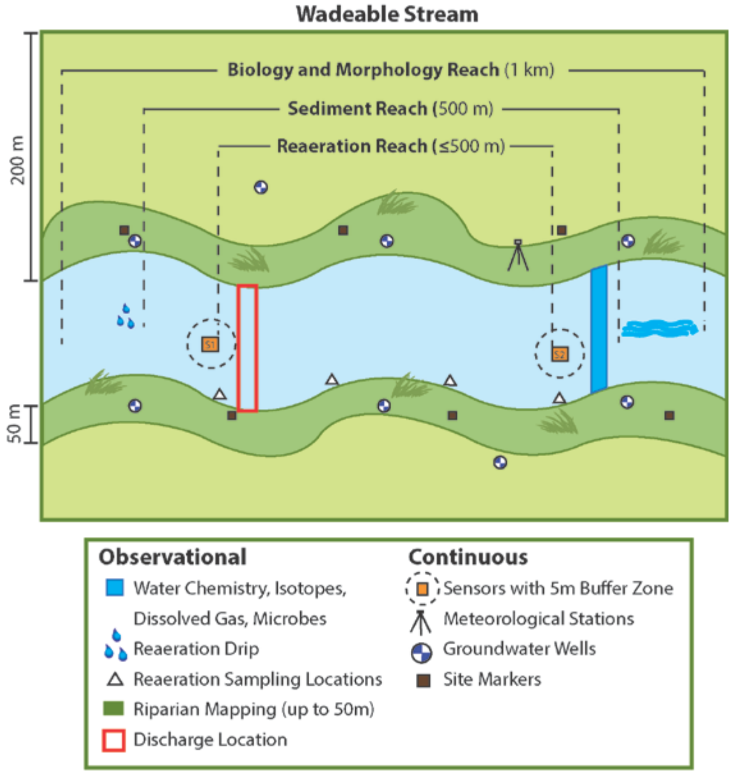


**Figure 1.** A generic wadeable stream site with the discharge sampling location

Standard Operating Procedures (SOPs), in Section 7 of this document, provide detailed step-by-step directions, contingency plans, sampling tips, and best practices for implementing this sampling procedure. To properly collect and process samples, field technicians **must** follow the protocol and associated SOPs. 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.

The procedures described in this protocol will be audited according to the Field Audit Plan (AD[06]). Additional quality assurance will be performed on data collected via these procedures according to the NEON Data and Data Product Quality Assurance and Control Plan (AD[07]).

# 4 SAMPLING SCHEDULE

## 4.1 Sampling Frequency and Timing

Stream discharge shall be measured at two different frequencies. During the 1st year stream discharge shall be collected at a minimum frequency of once every two weeks during the period of time which the stream is flowing. If time permits, Field Technicians should collect additional wading surveys during the period of time when the stream stage is changing the most rapidly (i.e. during the rising and falling limbs of the hydrograph).

Following the 1st year of stream discharge data collection, the frequency shall be reduced to a minimum of one wading survey per month with sample times selected to catch portions of the SRDC which have not been tested for before. For example if wading surveys have been collected at stream stages of 0.55m and 0.65m, then Field Technicians shall attempt, if the timing is reasonable, to collect a wading survey at a stream stage of 0.60m, and the same for either high or low stream stages that have not previously been examined.

Sample timing shall stay at the minimum of 1 wading survey per month, for all subsequent years following the development of the SRDC (i.e. 1st year of stream discharge data collection), unless 3 consecutive wading surveys yield discharge values that are outside the range of +/-5% of the discharge value calculated from the SRDC equation. This scenario indicates that the stream discharge has shifted from that of the SRDC equation and the equation requires a higher sampling frequency to reestablish the SRDC equation. In this scenario wading surveys shall be conducted following the sampling frequency of twice per month.

Stream discharge surveys shall be conducted at as many different hydrologic states (stream stages) that the stream experiences during the year, while maintaining safe practices for wading in a stream.

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

| | Date | Frequency |
|---|---|---|
| All domains, first year | Year-round as feasible | Minimum of twice per month, with greater emphasis on periods when flow varies significantly. |
| All domains, subsequent years | Year-round as feasible | Minimum of 12 times per year |

### 4.2 Criteria for Determining Onset and Cessation of Sampling

1. First Year of Discharge Data Collection (High Frequency Data Collection):
   a. Is there flowing water in the stream channel? If NO then STOP; elsewise proceed to (1b)
   b. Is the water depth in the thalweg greater than 0.08m? If NO then STOP; elsewise proceed to (1c)
   c. Is the current stream stage at a level (+/- 2cm) that has been previously examined with a wading survey? If YES then STOP; elsewise proceed to (1d)
   d. Has a stream discharge survey been conducted within the past 12 days? If YES proceed to (1e), elsewise proceed to (1f).
   e. Do you have sufficient time to collect a discharge survey? If NO then STOP; elsewise proceed to (1f).
   f. Perform discharge survey.
2. Subsequent Years of Discharge Data Collection (Reduced Frequency Data Collection):
   a. Does the stream channel appear to have been altered in terms of structure or compositional layout (i.e. are there new debris jams, channels, etc.) since the latest stream discharge survey? If NO then proceed to (2b); if YES proceed to (2b) and submit a trouble ticket to NEON HQ Aquatic Team with data obtained from current discharge survey.
   b. Is there flowing water in the stream channel? If NO then STOP; elsewise proceed to (2c)
   c. Is the water depth in the thalweg greater than 0.08m? If NO then STOP; elsewise proceed to (2d)
   d. Is the current stream stage at a level (+/- 2cm) that has been previously examined with a wading survey in the past 12 months? If YES then STOP; elsewise proceed to (2e)
   e. Has a stream discharge survey been conducted within the past 30 days? If YES proceed to (2e), elsewise proceed to (2f).
   f. Do you have sufficient time to collect a discharge survey? If NO then STOP; elsewise proceed to (2g).
   g. 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 logs, boulders, and or other submerged objects influence the stream flow, then either:
   a. Measure flow at 20, 60 and 80% of the depth from the stream surface and average the velocities at that increment as

$$V = 0.25(V_{20} + V_{80} + 2V_{60})$$

b. Or move the transect to another location as long as there are no intervening tributaries or significant water withdrawals that would change the flow. If this action is considered, a trouble ticket must be submitted prior to establishing a new permanent transect location. Though a temporary survey should be conducted at the desired location and the collected information sent to the NEON HQ Hydrologist along with the trouble ticket.

2. If the stream flow lines do not appear to be roughly perpendicular to the transect, then the individual velocity measurements will require an adjustment for the offset of the angle from perpendicular. Appendix F provides the method for adjusting the individual velocity measurement as a function of the angle of flow in relation to the transect orientation.

**Results could be negatively impacted by:**

1. Rapidly changing stage and discharge
2. Dropping equipment into the stream
3. Heavy precipitation, severe cold or wind
4. People or animals approaching the sampler while in the stream
5. Low or dead batteries in the current meter
6. Insufficient attention to the protocol
7. Errors in reading, entering, or transcribing data, or in computing sums and products using the calculator
8. Using the meter in the wrong mode, such as getting readings in English rather than metric units
9. Failure to read or set the depth on the wading rod in the correct manner
10. Failure to stretch the tape line perpendicular to the direction of flow
11. 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).

## 5 SAFETY

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

Personnel working at a NEON site must be compliant with safe field work practices as outlined in the Operations Field Safety and Security Plan (AD[02]) and EHS Safety Policy and Program Manual (AD[01]). Additional safety issues associated with this field procedure are outlined below. The Field Operations Manager and the Lead Field Technician have primary authority to stop work activities based on 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 (50-100m) | Establishing the transect | 1 | N |
| | R | Stakes | Anchoring survey tape | 2 | 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 |
| **Consumable items** | | | | | |
| | R | Discharge Data Sheet or PDA | Recording data | 1 | N |

R/S=Required/Suggested

### 6.2 Training Requirements

All technicians must complete required safety training as defined in the NEON Training Plan (AD[04]). Additionally, technicians must complete protocol-specific training for safety and implementation of this protocol as required in Field Operations Job Instruction Training Plan (AD[05]).

Personnel should be:

- Trained in making wading discharge measurements
- Adept at wading in streams.

### 6.3 Specialized Skills

N/A

### 6.4 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.

# 7 STANDARD OPERATING PROCEDURES

## SOP A Field Sampling

### A.1 Preparation

1. Gather and prepare equipment.

### A.2 Determining Sampling Location

1. Navigate to the selected measurement location.
   a. The bounds for the cross-section area will be marked using permanent stakes (one on each side of the stream).
2. Examine the stream flow 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 0.08 meters (~4 inches) is required to conduct the discharge measurement at each point in the transect. Water levels shallower than 0.08 meters may cause bias in the velocity reading.
   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.
   c. High potential for a thunderstorm.
   d. Debris or large ice chunks upstream of the cross section area that may transit downstream during the test.
   e. Uneven substrate (e.g. when cobble), that would lead to inaccuracies in discharge measurement especially at low flows.
3. From the defined 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. In general this should always be the case since the cross-section areas will be selected by the NEON HQ Aquatic team. 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 SHOULD NOT be removed to facilitate the discharge measurement.
   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 >0.08 m is required.
4. If any of the above criteria are not met and no such area exists within 1 m upstream or downstream of the defined locations, **do not sample** and submit a trouble ticket.

## A.3 Dividing the Stream into Subsections

The following section defines how to select velocity measurement spacing in the stream.

1. The number and size of the stream subsections in which measurements are taken depends on the width of the stream and how uniform the flow is across the cross-section (Table 3). 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.
   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.
   b. In general, **no more than 10%** of the discharge should be flowing through any one subsection. The distribution of subsections may also be estimated by scanning the transect and looking for areas of high flow.
   c. If a clearly defined region of high flow exists, then measure stream velocity at closer spacing in this region.
   d. When in doubt, select a closer sampling spacing.

**Table 3.** 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 |
| > 2 m | 20 – 25 sampling locations |

   e. In a stream with uniform flow across the width of the stream, sampling points will be evenly spaced across the stream width (Figure 1).
   f. Conversely, in streams with non-uniform flow or uneven channel structure (e.g. pools and shallow areas), sampling points shall be adjusted to best represent the stream flow, with measurements more concentrated in areas with faster or deeper flow (Figure 2).

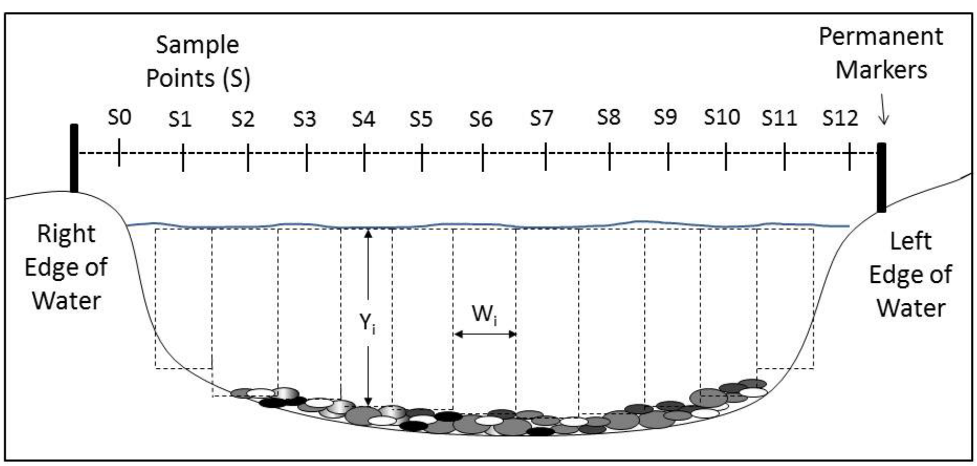


**Figure 2**. Example of an excellent distribution of measurement sections

Sampling points can be evenly placed due to streambed uniformity. W= Width, D= Depth. Area = Depth x Width. Discharge = Area x Velocity.

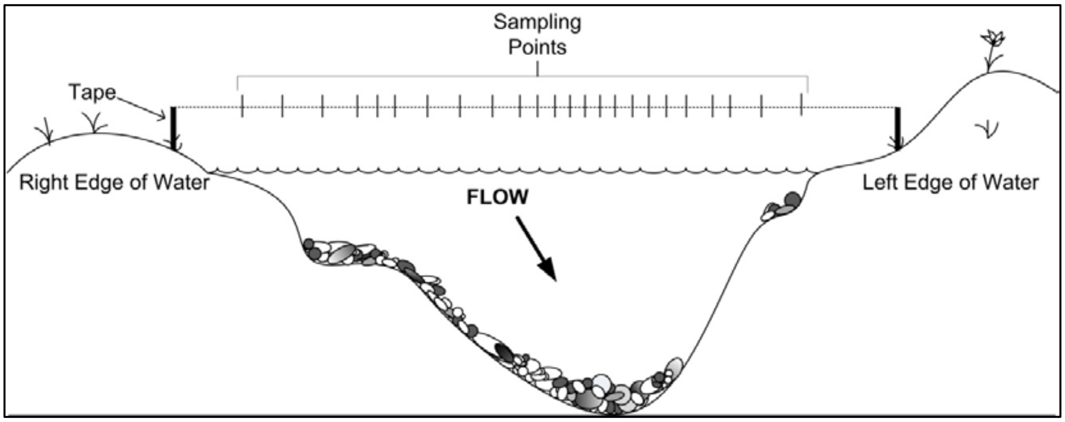


**Figure 3.** Uneven subsections across sampling transect

2. Determine depth of velocity measurement
   a. To get the stream depth at the measurement point, position the base of the rod on the stream bed and read the water level from the rod.
      1) The wading rod is designed to allow for directly reading stream depth from the hexagonal rod. The hexagonal stationary rod is delineated into 2cm (one band), 10cm (two bands), and 50cm (three bands) intervals as shown in Figure 4.
      2) Practice this step prior to putting the rod in the water to become familiar with the markings and how to read them.
   b. Velocity is measured at either one or two specified depths that represent the average velocity in the subsection. Three depth options are standard for measuring velocity in streams, 20%, 60%, and 80% of the depth of the stream at the measurement point. These heights are always measured downwards with the stream surface at 0. As an example: if the stream is 1m deep at the point of measurement, then 60% depth would be 60cm from the stream surface and 40cm from the stream bottom.
   c. Determine if a one point (60%) or a two point (80% and 20%) measurement is required (see Table 4). It is important to note that each measurement within the transect must undergo this decision as to sample at one depth or at two depths.

**Table 4**. Determining 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 |

3. Set the depth on the wading rod
   a. The wading rod has three scales, one for measuring stream depth and two for setting the depth on the rod. 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. On the handle of the hexagonal, fixed rod (depth gauge rod in Figure 4) is a smaller scale used to fine tune the depth, and is graduated (0 to 10) representing centimeter increments.
   b. The following examples will help with practicing setting the depth on the wading rod, and are constructed with an assumed water depth of 0.72 meters. You should practice these three depth options and also using different total water depths before beginning the discharge survey.
      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. As an example, if the stream is 0.72m deep, then half of 0.72m is 0.36m, so the 7 on the sliding rod will line up with the 2 on the handle of the hexagonal rod.
      3) **20% Depth** – multiply the stream depth by 2, again round to the nearest hundredths place and set using this value as above for the 60 and 80% scenarios.

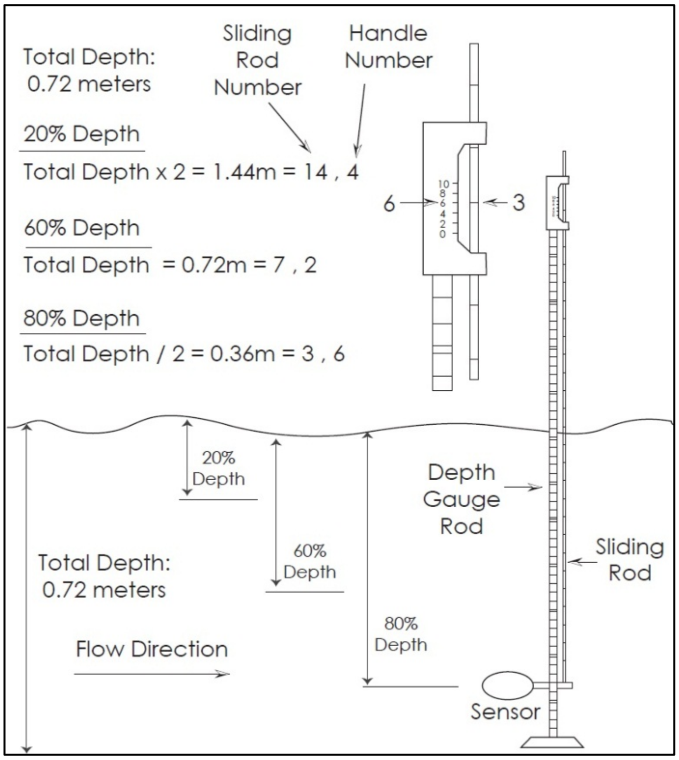


**Figure 4.** Correctly-assembled wading rod adjusted to 80%

## A.4 Setting up the transect

1. 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 Figure 2 and Figure 3)**.**
2. Starting at the Right Edge of Water (REW), extend the measuring tape across the stream perpendicular to stream flow (Figure 2 and Figure 3). Anchor measuring tape to the permanent markers for the measuring location (i.e. the 0m-mark will be located at the permanent marker).
3. Note the survey tape readings at the left edge of water (LEW) and right edge of water (REW). The difference is the stream width.
4. The stream shall be divided into the measurement increments prior to the site going into operations, based on the locations of the permanent markers.
5. Note: 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. Increments can be evenly spaced (if the channel is uniform; Figure 2) or aggregated in the areas of the most flow (Figure 3). Ideally no more than 5% of the discharge should be flowing through any one segment.

**Example 1)** In a uniform 3-m wide stream, measurements should be taken every 0.15 m (Figure 2)

**Example 2)** In a 3-m wide stream with most of its flow occurring in only half of the stream, the majority of measurements should be taken in that area, with fewer measurements taken in the region of the stream with less flow (Figure 3).

### A.5 Zeroing the Velocity Meter

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).

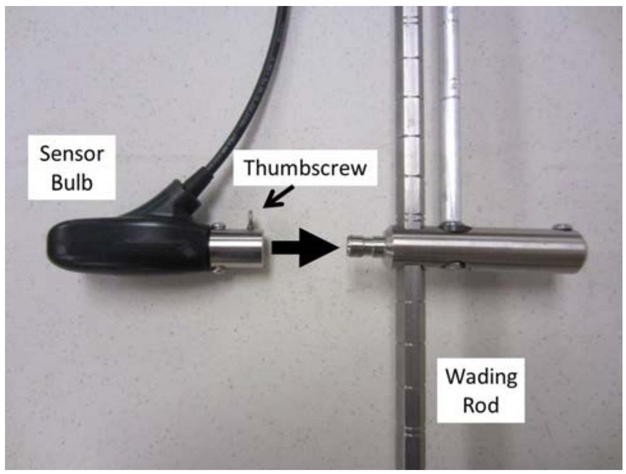


**Figure 5.** Velocity-meter and the thumbscrew that attaches it to the wading rod

3. Turn the velocity-meter on by pressing the “ON/OFF” button, the meter will first run a diagnostic check to ensure it is connected to the sensor, which takes about 20 seconds. When complete, a “Start” menu will appear as shown in Figure 6.
   a. Note: Appendix H provides a quick reference for the velocity meters keypad operations.


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

4. Set the measurement units: To check or adjust this setting, press "Setup" → "More" → "Units" → "Metric" then set "Velocity" = "m/s", "Flow" = "$m^3$/s", and "Depth" = "m".
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.
6. Put the velocity-meter in the water. Keep it 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 velocity-meter in the bucket, let the water settle for 1-2 minutes to stabilize.
8. On the handheld display,
   a. press "On" button,
   b. select "Set-Up"
   c. select "Velocity Calibration".
9. Choose "Ok" to start calibration. NOTE: water in bucket must remain still during this calibration step.
10. During the calibration step, allow "Progress bar" to go through 2 cycles and ensure the value is zero. Then choose "OK". NOTE: a reading of -0.00 is ok.
11. The unit is now zeroed. Return to the "Start" menu.

### A.6 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 flow meter bulb pointed directly into the flow and perpendicular to the transect.
2. The wading rod is to be held 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 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.
5. **DO** stand to the side and at arm's length from the velocity-meter.
6. Enter Operator and Site Information
    a. From the "Start" menu, select "Profiler" → "Enter Operator Name" → type your name here using the number/letter keys.
    b. Select "Stream" → "Enter name for Stream" → Put in the stream or lake name, using the first 4 letters of the site name. (Ex. Arikaree = ARIK).
    c. Enter Stage Reference (m): Type in the reading from the staff gauge in meters (Ex. 0.38).

**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. Keep this orientation during subsequent measurements at later dates for consistency.
    e. Station 1 (Right Edge of Water):
        1) Choose "Edge/Obstruction" and select "Right".
        2) Navigate down one entry to "Dist. To Vertical" and enter 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.

3) Navigate down one more entry and enter the “Set Depth” value. This is the depth of the water at this interface 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.
4) “Measure Velocity” → Screen will display “Velocity is zero at edge”. Press enter to OK this as this will always be the case at the stream edge or at the boundary of an obstruction.
5) Navigate to the bottom of the screen and select “Next”, the screen will now say “Station 2” at the top.

f. Station 2 (Intra-Transect stations)
   1) Move to the next transect location to collect a velocity measurement.
   2) Repeat the above steps for setting “Dist. to Vertical” and “Set Depth” for Station 2
   3) Select “Measure Velocity” and now based on the stream depth select a “One point” (60% - if measurement depth is less than 0.45m) or “Two point” (20, 80% - if stream depth is greater than or equal to 0.45m) velocity measurement. The next screen will read the % value that the velocity survey will be conducted. Select this value. The next screen will tell you at what value to set the velocity-meter depth to. See SOP A.3 for details on how to set the depth of the wading rod.
   4) Select “Capture” at the bottom of the screen. This begins the velocity survey for this location and is a time average of instantaneous velocity measurements taken over a 10 second interval. The screen will display a graph showing the instantaneous values and the progress of the reading. Repeat this step a second time by selecting “Repeat” at the bottom of the screen. If the values are fluctuating within roughly 5% then select “Ok” and move on. Choose “Main” then choose “Next” to move to Station 3.
   5) If the repeated velocity values are > 5.0% difference, then the stream flow is likely a little turbulent and it may be necessary to increase the length of time average the survey is conducted for. To do this select “Setup” from the bottom menu and then “Fixed Period Averaging”. Set this number to 20sec. and repeat the test again. If velocities values are still not within 5% between repeat surveys, then increase to a longer time and repeat. If you reach 60sec for time averaging and the values are still greater than 5% difference between repeat tests, submit a trouble ticket as the velocity-meter may be malfunctioning, if the flow does not appear to be turbulent.
   6) 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).

g. Last Station (Left Edge of Water)
   1) Repeat steps for “Station 1” and for “Edge/Obstruction” this time select “Left”.
   2) Summarize Collection and Save Data

h. Select “Channel Summary” from the current Station menu. This will display the stream discharge in $m^3/s$. Note this value as it will be needed shortly.

i. Select "Save Data and Exit"
j. Enter Name of File: use the date as yyyymmdd as the file name (Ex. January 1, 2013 = 20130101). Under the "Profiler" menu, select "Done" at the bottom of the screen.

## A.7 Calculating Discharge

1. The selected velocity meter (currently the Hach FH950) automatically calculates discharge based on the station and velocity data obtained during the wading survey detailed above.
2. Calculate discharge manually if automatic calculation is not available.
   a. Figure 8 shows a typical uniform stream subdivided into the measurement areas (denoted by S0 – S12). Here, each "S" interval equates to a point on the survey tape (i.e. S1 = 0.80m, S2 = 1.20m, etc.) where a velocity measurement is made. Each subsection area is defined by a width and height which when multiplied, yield an area of each subsection. The width of each subsection is calculated by solving for the difference between the two end points of each subsection found from:

$X_i$ = (S3 +S4)/2, and $X_{i+1}$ = (S4+S5)/2, as detailed in Figure 8.

3. In each subsection, velocity is obtained as either one point (60%) or two points (20%, 80%) of the stream depth. The velocity measured for each subsection is applied (multiplied by subsection area) over the full subsection to yield the discharge for that subsection. Totaling (adding) the discharges for all subsections yields the total discharge for the transect.

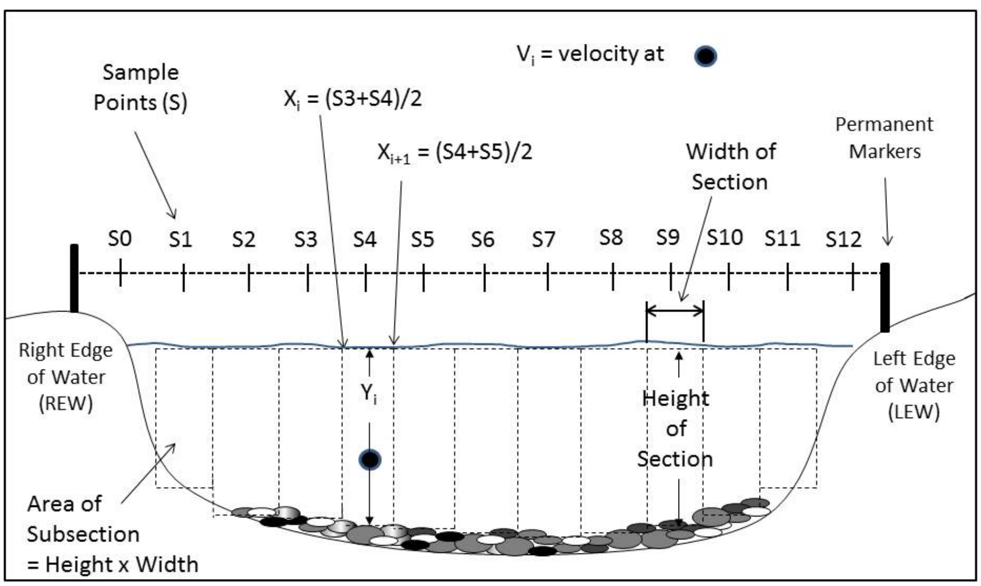


**Figure 8.** Components for manual discharge calculation

## A.8 Field Data Verification

1. If a stage-discharge rating curve (Figure 9) is available for this station, while still in the field, plot a point representing the present stage and discharge that was just obtained on the current stage-discharge rating curve.
   a. The new point should fall within +/-5 % of the curve (i.e. the discharge that was just obtained for the current stage should be within 5% of the discharge value indicated for that stage on the SRDC).
      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 the new survey point still does not match the curve this indicates that the stage-discharge curve is shifting and future sampling events should occur at a higher frequency to reestablish the curve.
   b. If 3 consecutive discharge surveys yield discharge magnitudes outside of the +/- 5% range then there is indication that stage-discharge relationship has shifted from the established curve and the sampling frequency should be increased to that of the 1st year sampling frequency.
   c. This quality check will ensure the measured discharge appears reasonable in comparison to the rating curve.

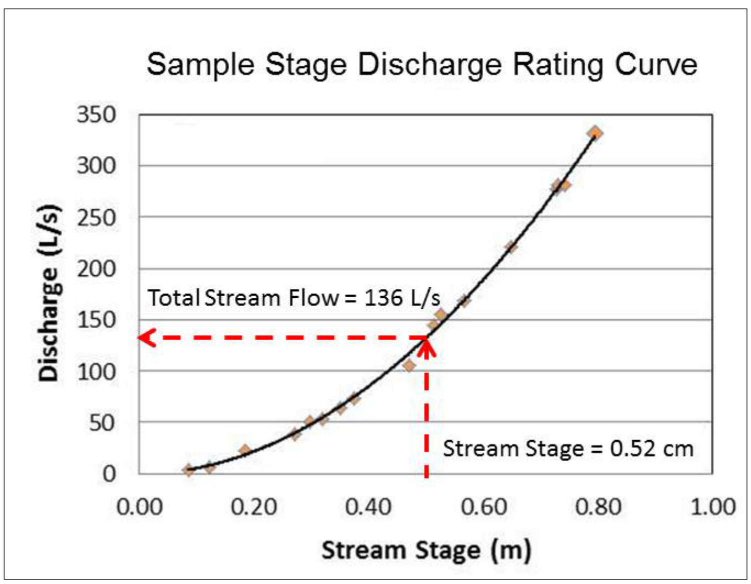


**Figure 9.** Example of stage-discharge rating curve. Dots represent simultaneous measurements of stage and discharge

2. Collect point of zero flow if flow conditions are low
   a. The point of zero flow (PZF) is an important part of the stage-discharge rating curve and should be collected a few times per year. This refers to when water may be found in the channel in isolated locations but the stream is not flowing. PZF happens when the staff

gauge is located upstream of an obstacle, such as a step-up in the stream bed or a beaver dam, which creates a small pool (Figure 10). This should only occur during low flow conditions. The measurement is relatively simple and adds another discharge measurement—the zero-discharge point on the stage-discharge rating curve.

b. Take the wading rod and wade across the control section, noting the water depths of the deepest points along the section.

c. When you find the deepest point along the hydrologic control, you subtract that depth from the current stage. The resulting stage, equivalent to the deepest point along the section, is the stage of zero flow.

d. When you determine the stage of zero flow, report that value in your field notes in the header section on stage of zero flow. Enter the current stage, the maximum depth along the control section, and make the subtraction to get the stage of zero flow.

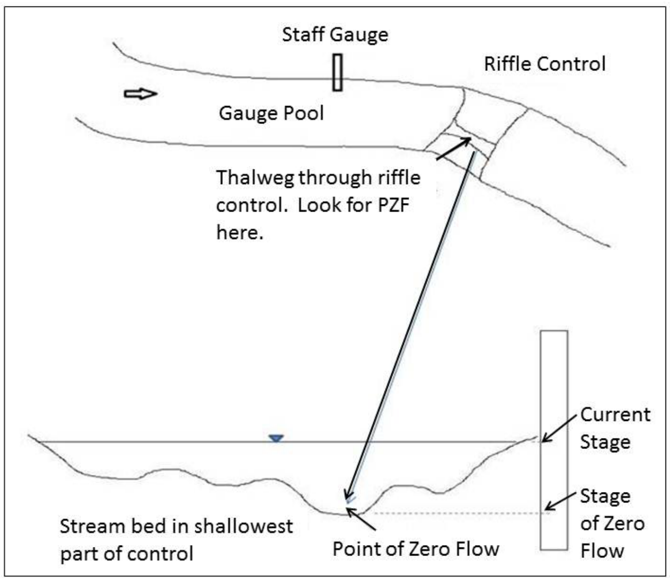


**Figure 10.** Diagram showing point of zero flow and stage of zero flow

## A.9 Ending the Sampling Day

1. Equipment maintenance, cleaning and storage
   a. 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 (if necessary).

## SOP B 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 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.

After collecting the stream velocity data, it needs to be extracted from the handheld device. To download the data from the handheld unit you need the USB to micro-USB cord and a computer.

NOTE: Before starting this step make sure the computer you are using has the application "PVM Utility" installed on it. If it does not then obtain a copy from: \\nas2fs\apps\field techs\.

1. Plug the micro USB cord into the handheld unit in the right hand side of the unit by pulling the lower of the two black "doors" open. Then connect the USB end to your computer.
2. The PVM Drive should appear on your computer. If it does not appear, go to "My Computer" and search for it. Two folders should be present "P" and "RT". Select "P" and then select the file "PVM.TSV".
3. Copy the file to: **TBD** (need to define location where file goes to be ingested in to the DAS or to CI).

## SOP C Sample Shipment

There is no sample shipment for this protocol.

## 8 REFERENCES

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## APPENDIX A DATASHEETS

The following datasheets are associated with this protocol:

**Table 5.** Datasheets associated with this protocol

| NEON Doc. # | Title |
|---|---|
| NEON.DOC.001646 | General AQU Field Metadata Sheet |

These datasheets can be found in Agile or the NEON Document Warehouse.

## APPENDIX B QUICK REFERENCES

**Step 1** – Check the discharge field sampling kit to make sure all supplies are 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. In general, 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 |
| > 2 m | 20 – 25 sampling locations |

**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 the stream depth on the wading rod and 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 point within the transect.

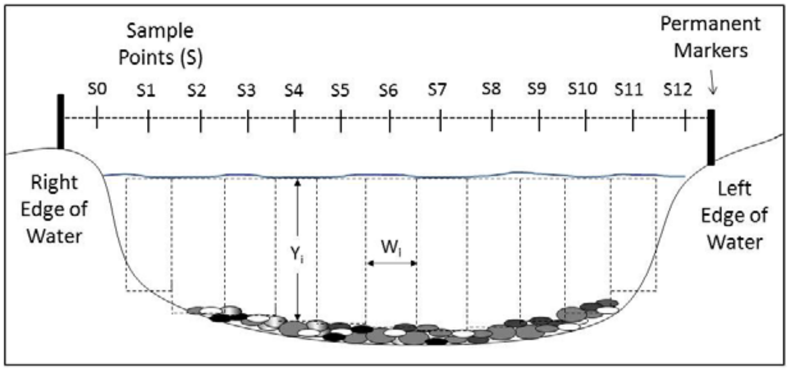
**Step 9** – Calculate discharge.

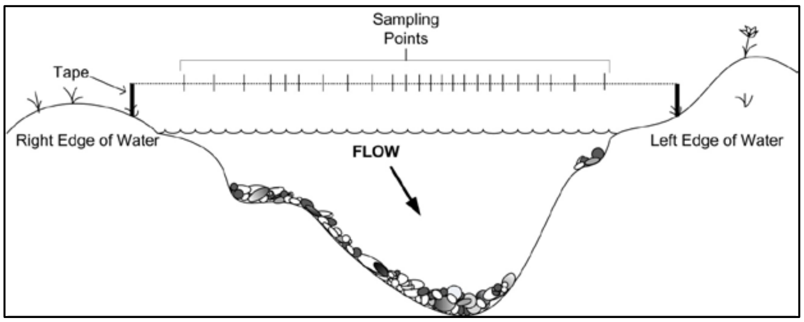
**Step 10** – If a stage-discharge rating curve is available for this station, while still in the field, plot a point representing the present stage and discharge that was just obtained on the current stage-discharge rating curve in order to verify data.

**Step 11** – Collect point of zero flow if flow conditions are low.

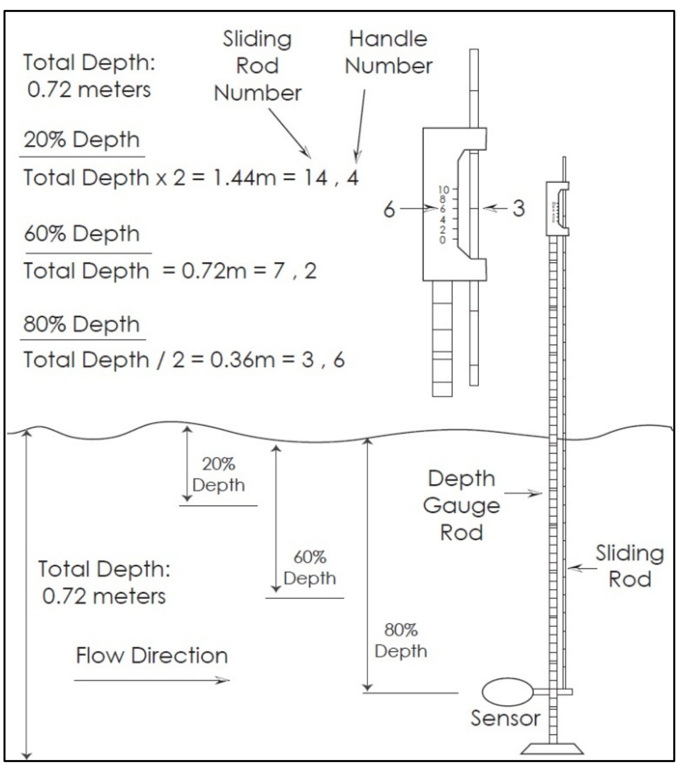
**Step 12** – Decontaminate equipment and charge batteries for the velocity meter.

## B.1 Schematic for Dividing the Stream into Subsections




## B.2 Schematic for Setting Depth on the Wading Rod



## APPENDIX C REMINDERS

**Before heading into the field:** Make sure you…

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

**Sample collection:** Be sure to…

- ☑ Aquatic vegetation SHOULD NOT 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.
- ☑ During calibration, 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.

**Data processing:** Be sure to…

- ☑ Before starting this step make sure the computer you are using has the application "PVM Utility" installed on it. If it does not then obtain a copy from: \\nas2fs\apps\field techs\.

## APPENDIX D ESTIMATED DATES FOR ONSET AND CESSATION OF SAMPLING

See the Site Specific Sampling Strategy Document on AQU's NEON intranet site.

## APPENDIX E SITE-SPECIFIC INFORMATION

See the Site Specific Sampling Strategy Document on AQU's NEON intranet site.

## APPENDIX F CORRECTION FOR NON-PERPENDICULAR FLOW

If the direction of flow in any subsection is not perpendicular to the tape stretched across the stream, the velocity for that subsection should be adjusted for the horizontal flow angle. In most cases this should not be required as the discharge measurement locations should be selected in areas where the flow lines are perpendicular to the survey tape. However, if an adjustment is necessary the adjustment is made by measuring the horizontal flow angle (the angular difference between the actual flow direction and the flow direction that would be perpendicular to the tape), noting the corresponding horizontal angle correction factor in the margin of the note sheet, and multiplying the subsection velocity by the correction factor.

$$Adjusted\ Velocity = Measured\ Velocity\ x\ \theta$$

If this step is required the extracted data will need to be adjusted in a spreadsheet program such as Excel prior to uploading the data to the NEON system, and a Jira ticket should be submitted to notify that this correction has occurred.

To check for flow angle:

- Hold the **Stream Discharge Measurement Notes Sheet (Appendix G)** horizontally above the stream, with the left margin facing upstream and the long edge of the sheet parallel to the measuring tape (Figure 11).
- If the flow line is parallel to the short edge of the sheet, then the flow is perpendicular. If the flow is not roughly perpendicular, then an angle adjustment is required.

To correct for flow angle:

If an adjustment is necessary, then the note sheet is used as the measuring guide (acts as a protractor).

- Orient the note sheet horizontally, with the $\Theta$ in the middle of the first column facing upstream, and the long edge of the sheet parallel to the measuring tape. Imagine a line across the note sheet matching the actual flow direction.
- Where this actual flow direction line crosses the top, right, or bottom margin of the note sheet, read the correction factor from the margin, or interpolate between the two nearest correction factors.
- Multiply the subsection velocity by this factor, and enter the result in the column labeled “Adjusted for any horizontal angle”. Use this adjusted value as the velocity for the subsection.

An example is shown in Figure 11 using floor cracks to represent the stream flow direction, which is not perpendicular to the measuring section, as shown by the tape. For this flow angle, the velocity must be multiplied by a correction factor of 0.95 to obtain the corrected velocity.

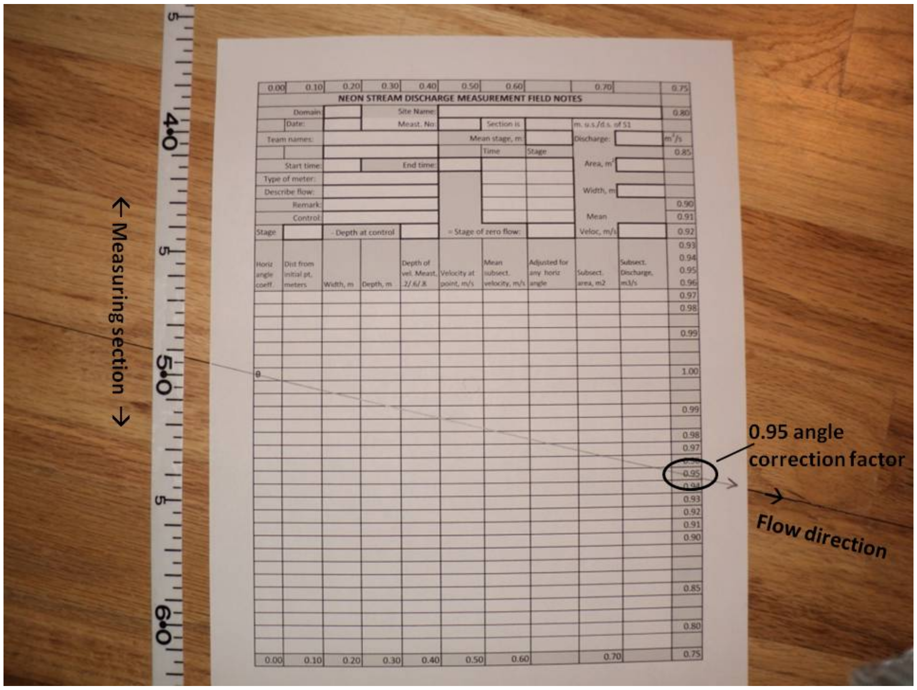



**Figure 11.** Example of correction for non-perpendicular flow using the data sheet in Appendix G

## APPENDIX G STREAM DISCHARGE FIELD DATA SHEET

The stream discharge field data sheet on the following pages serves as a backup procedure for times when electronic data collection devices (PDA) are not available. The following two pages provide blank field sheets.

(Intentionally Left Blank)

0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.75

## NEON STREAM DISCHARGE MEASUREMENT FIELD NOTES

| | | | | | |
|---|---|---|---|---|---|
| Domain: | | Site Name: | | | 0.80 |
| Date: | | Meast. No: | | Section is: | m. u.s./d.s. of S1 |
| Team names: | | Mean stage, m: | | Discharge: | $m^3/s$ |
| | | | Time | Stage | 0.85 |
| Start time: | | End time: | | | Area, $m^2$ |
| Type of meter: | | | | | |
| Describe flow: | | | | | Width, m |
| Remark: | | | | | 0.90 |
| Control: | | | | | Mean 0.91 |
| Stage | - Depth at control | | = Stage of zero flow: | | Veloc, m/s 0.92 |

0.93 0.94 0.95 0.96

| Horiz angle coeff. | Dist from initial pt, meters | Width, m | Depth, m | Depth of vel. Meast, .2/.6/.8 | Velocity at point, m/s | Mean subsect. velocity, m/s | Adjusted for any horiz angle | Subsect. area, m2 | Subsect. Discharge, m3/s | |
|---|---|---|---|---|---|---|---|---|---|---|
| | | | | | | | | | | 0.97 |
| | | | | | | | | | | 0.98 |
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| | | | | | | | | | | 0.80 |
| | | | | | | | | | | |

0.00 0.10 0.20 0.30 0.40 0.50 0.60 0.70 0.75

| 0.00 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | | | 0.75 |
|---|---|---|---|---|---|---|---|---|---|---|
| | Domain: | | | Site Name: | | | | | | |
| | Date: | | | Meast. No: | | | | | | 0.80 |
| Horiz angle coeff. | Dist from initial pt, meters | Width, m | Depth, m | Depth of vel. Meast, .2/.6/.8 | Velocity at point, m/s | Mean subsect. velocity, m/s | Adjusted for any horiz angle | Subsect. area, m2 | Subsect. Discharge, m3/s | 0.85 |
| | | | | | | | | | | |
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| | | | | | | | | | | 0.96 |
| | | | | | | | | | | 0.95 |
| | | | | | | | | | | 0.94 |
| | | | | | | | | | | 0.93 |
| | | | | | | | | | | 0.92 |
| | | | | | | | | | | 0.91 |
| | | | | | | | | | | 0.90 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | 0.85 |
| | | | | | | | | | | |
| | | | | | | | | | | |
| | | | | | | | | | | 0.80 |
| | | | | | | | | | | |
| 0.00 | 0.10 | 0.20 | 0.30 | 0.40 | 0.50 | 0.60 | 0.70 | | | 0.75 |

## APPENDIX H KEYPAD OPERATIONS QUICK REFERENCE


**Figure 12.** Keypad layout for the Hach FH950 portable flowmeter

| | |
|---|---|
| **1 Power On/Off** – Energizes and de-energizes the meter | **6 Main Menu** – Moves to the Main Menu from any submenu or screen. |
| **2 OK** – Confirms an entry or highlighted menu option | **7 Underscore or Decimal** – Puts in an underscore or decimal character. In numeric-only fields, this key automatically puts a decimal in the cursor position. |
| **3 Up and Down Arrows** – Moves up or down in the display. If the cursor is at the top or bottom of the display, the cursor wraps to the bottom or top when the UP or DOWN arrow is pushed. | **8 Backspace** – Moves the cursor back one space. |
| **4 Quick Jump** – In normal operation, this key jumps to the Selected Conduit shape screen. If the auto-zero feature is disabled, hold this key for five seconds to do a manual zero of the depth sensor. In Real-Time mode, the Quick Jump key toggles between the digital and graph views. | **9 Alpha-Numeric** – Puts in the key alpha or numeric values. Values are put in the order shown on the key. After 2 seconds, the value shown in the display is stored and the cursor advances. |
| **5 Right and Left Arrows** – Moves to the right or left in the display. | **10 Previous Menu** – Moves to the previous screen. |