NEON USER GUIDE TO DISCHARGE FIELD COLLECTION (DP1.20048.001)

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CHANGE RECORD

REVISION	DATE	DESCRIPTION OF CHANGE
A	07/20/2017	Initial Release
B	03/30/2018	Documentation added for river discharge measurements using acoustic Doppler current profilers
C	06/04/2020	Documentation added for wadable stream and river discharge measurements using acoustic Doppler current profilers. Included general statement about usage of neonUtilities R package and statement about possible location changes.

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1 DESCRIPTION

1.1 Purpose

This document provides an overview of the data included in this NEON Level 1 data product, the quality controlled product generated from raw Level 0 data, and associated metadata. In the NEON data products framework, the raw data collected in the field, for example, a single discharge measurement, are considered the lowest level (Level 0). Raw data that have been quality checked via the steps detailed herein, as well as simple metrics that emerge from the raw data are considered Level 1 data products.

The text herein provides a discussion of measurement theory and implementation, data product provenance, quality assurance and control methods used, and approximations and/or assumptions made during L1 data creation.

1.2 Scope

This document describes the steps needed to generate the L1 data product Discharge field collection, the process of measuring the instantaneous discharge of a stream or river at a unique point in time. This is achieved by multiplying velocity times depth of water times cross-sectional width, and associated metadata from input data. This document also provides details relevant to the publication of the data products via the NEON data portal, with additional detail available in the file, NEON Data Variables for Discharge Field Collection (DP1.20048.001) (AD[05]), provided in the download package for this data product.

This document describes the process for ingesting and performing automated quality assurance and control procedures on the data collected in the field pertaining to AOS Protocol and Procedure: Stream Discharge (AD[07]). The raw data that are processed in this document are detailed in the file, NEON Raw Data Validation for Discharge Field Collection (DP0.20048.001) (AD[04]), provided in the download package for this data product. Please note that raw data products (denoted by 'DP0') may not always have the same numbers as the corresponding L1 data product.

2 RELATED DOCUMENTS AND ACRONYMS

2.1 Associated Documents

AD[01]	NEON.DOC.000001	NEON Observatory Design (NOD) Requirements
AD[02]	NEON.DOC.000913	TOS Science Design for Spatial Sampling
AD[03]	NEON.DOC.002652	NEON Data Products Catalog
AD[04]	Available with data download	Validation csv
AD[05]	Available with data download	Variables csv
AD[06]	NEON.DOC.001152	Aquatic Sampling Strategy
AD[07]	NEON.DOC.001085	AOS Protocol and Procedure: Stream Discharge
AD[08]	NEON.DOC.000008	NEON Acronym List
AD[09]	NEON.DOC.000243	NEON Glossary of Terms
AD[10]	NEON.DOC.004825	NEON Algorithm Theoretical Basis Document: OS Generic Transitions
AD[11]	Available on NEON data portal	NEON Ingest Conversion Language Function Library
AD[12]	Available on NEON data portal	NEON Ingest Conversion Language
AD[13]	Available with data download	Categorical Codes csv

2.2 Acronyms

Acronym	**Definition**
AOS	Aquatic Observation System
ADCP	Acoustic Doppler Current Profiler
GPS	Global Positioning System
QAQC	Quality Assurance Quality Control
USGS	United States Geological Society

3 DATA PRODUCT DESCRIPTION

The Discharge field collection (DP1.20048.001) data product provides stage and discharge data for a site along with water depth and velocity measurements collected using AOS Protocol and Procedure: Stream Discharge (AD[07]). Individual discharge measurements are conducted by means of wading and acoustic Doppler current profiler (ADCP) surveys that occur in wadeable streams and ADCP surveys that occur in non-wadeable rivers within NEON aquatic sites. Both wading and ADCP surveys occur along permenantly benchmarked cross-sections at NEON aquatic sites.

At wadable stream sites, hydrologic conditions dictate the type of instrument and method used to measure discharge. When site conditions (stream depth, water velocity, and bed material) are within the measurement tolerance of the instrument, ADCP instrumentation is the primary means of discharge collection. When site conditions are outside measurement tolerance of the ADCP (i.e. during the ulta-low flow regime), handheld flowmeters are utilized via wading surveys.

ADCP surveys at wadable stream sites involve mounting an ADCP within the center of a trimaran floating boat and utilizing a tethered rope system to pull the boat back and forth across the channel so that the base of the ADCP is fixed beneath the water surface. Each pass from one bank to another is known as a measurement transect. A minimum of four transects must be measured during each ADCP survey. Each transect must last a minimum of 180 seconds and the total measurement duration must be >720 seconds.

The ADCP contains four beams pointed at 20 degrees from the vertical that continuously measure water depth, water velocity, and boat speed. Depth and velocity are measured continuously throughout each transect using the ADCP transducers (or beams), which divide the water column into depth cells (or bins). To measure velocity, the ADCP uses sound, applying the Doppler principal by reflecting an acoustic signal off small particles of sediment that are suspended in the water column. The velocity measured by the Doppler principal is parallel to the direction of the transducer within the ADCP emitting the signal and receiving the backscatter acoustic energy. The boat velocity is accounted for by either bottom tracking or through the use of GPS instrumentation (mounted to the boat above the ADCP). Bottom tracking determines the velocity of the boat by measuring the Doppler shift of acoustic signals reflected from the streambed, which serves as a fixed reference in non-moving bed conditions. The measured water velocity is then corrected using the measured boat velocity and a total velocity is reported for each bin.

The ADCP software integrates total bin velocity over the bin depth to obtain bin discharge. The resulting subsection discharges are then summed over the width of the cross-section to obtain total measured discharge for each transect. Certain areas within the channel cross-section profile cannot be measured by the ADCP (at the water surface due to draft and flow disturbance around the instrument, near the channel bed due to side-lobe interference, and near each bank due to shallow depths). These areas must be estimated by the ADCP software. Discharge in the unmeasured upper and lower portions of the cross-section are typically estimated using a one-sixth power-curve estimation scheme while discharge in the unmeasured portions of the cross-section near the bank edges are estimated using a ratio-interpolation method (Simpson, 2001). Total discharge is the sum of the total channel discharge (the sum of all discharge bin values calculated during the discharge measurement transect), the near-shore discharge measurement on the left side of the channel and the near-shore discharge estimate on the right side of the channel. The total discharge associated with the measurement is the mean discharge of all transects conducted during the sampling bout. Measured discharge in an individual transect is not to exceed 5% of the mean discharge measured in all transects. Every effort is made to collect reciprocal transects until all transect discharges are below 5% of the mean. Achieving this standard can be challenging during periods of low streamflow or while stage levels are changing.

A Moving Bed Test is conducted prior to ADCP surveys in order to assess whether or not the channel bed is in motion. A moving bed can occur when high streamflow produce downstream bed sediment movement. These conditions bias velocities and discharge to lower than actual values (Gartner and Ganju, 2007). If a moving bed is found to be present, the ADCP software calculates the velocity of the moving bed and applies a correction to the measured velocity. GPS integration is applied in order to bottom track during moving bed conditions. Other QAQC procedures prior to ADCP surveys include an instrument diagnostic test and compass calibration. During the ADCP survey a number of metrics are assessed in order to ensure a quality measurement is being collected. These include water velocity vs. boat speed, transect measurement duration, consistent edge distances, the percentage of discharge measured within each transect, and the total discharge measured in each transect relative the mean discharge measured across all transects.

During wading surveys at wadable stream sites a meter tape is extended across the channel, the line of which defines the cross-section. The meter tape, or tag line, serves to guide the line of measurement and to divide the stream into lateral subsections (of which there are typically 20-25 per cross-section). 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 discharge is then calculated by the flowmeter, which sums 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 AOS Protocol and Procedure: Stream Discharge follows USGS protocols (Rantz et al., 1982, Turnipseed and Sauer, 2010).

Discharge is measured in rivers following protocols set forth by the USGS (Mueller et al., 2013). ADCP survey methods at river sites are similiar to those employed at wadable stream sites with the exception of the ADCP model (ADCP models deployed at river sites are rated to measure velocity at greater depths and contain a fifth vertical beam and slightly different beam angles) and deployment methods. ADCPs are primarily deployed at river sites from the floodplain via remote controlled boats (where the ADCP sits in the center of the hull) and, as a secondary option, via piloted boats (where the ADCP is deployed off the side of the boat). In both instances the boats are driven back and forth across the channel with the base of the ADCP secured beneath the water surface. Discharge calculations and QAQC procedures are the same as those practiced at during ADCP surveys at wadable stream sites.

The height of water relative to a staff gauge is recorded prior to and following discharge measurements at wadeable stream and river sites to enable the development of a stage-discharge rating curve and calculation of continuous discharge from pressure transducers, which are reported as other data products.

3.1 Spatial Sampling Design

Discharge is measured at all wadeable stream sites in a run or riffle near the staff gauge and a pressure transducer and near the buoy at river sites (Figure 1). During wading surveys, point measurements of water depth and velocity are made along the transect from one bank to the other using a wading rod and attached velocity meter. For streams with a wetted width less than or equal to 2.00 m, as many point measurements are collected as possible at a **maximum** of 0.05 m increments. For streams with a wetted width greater than 2.00 m, 20 - 25 approximately evenly spaced points are measured. If the transect has a non-uniform flow with more concentrated areas of high flow, a higher number of stations are concentrated within the portion of the transect with greatest flow (Figure 2). During ADCP surveys velocity and depth are continuously calculated throughout the water column by the ADCP instrument as the boat moves across the channel (Figure 3). A minimum of four transects are conducted during each sampling bout from the same cross-section location with additional reciprocal transects collected if individual transect discharges are <5% of the mean.

As much as possible, sampling occurs in the same locations over the lifetime of the Observatory. However, over time some sampling locations may become impossible to sample, due to disturbance or other local changes. When this occurs, the location and its location ID are retired. A location may also shift to slightly different coordinates. Refer to the locations endpoint of the NEON API for details about locations that have been moved or retired: https://data.neonscience.org/data-api/endpoints/locations/

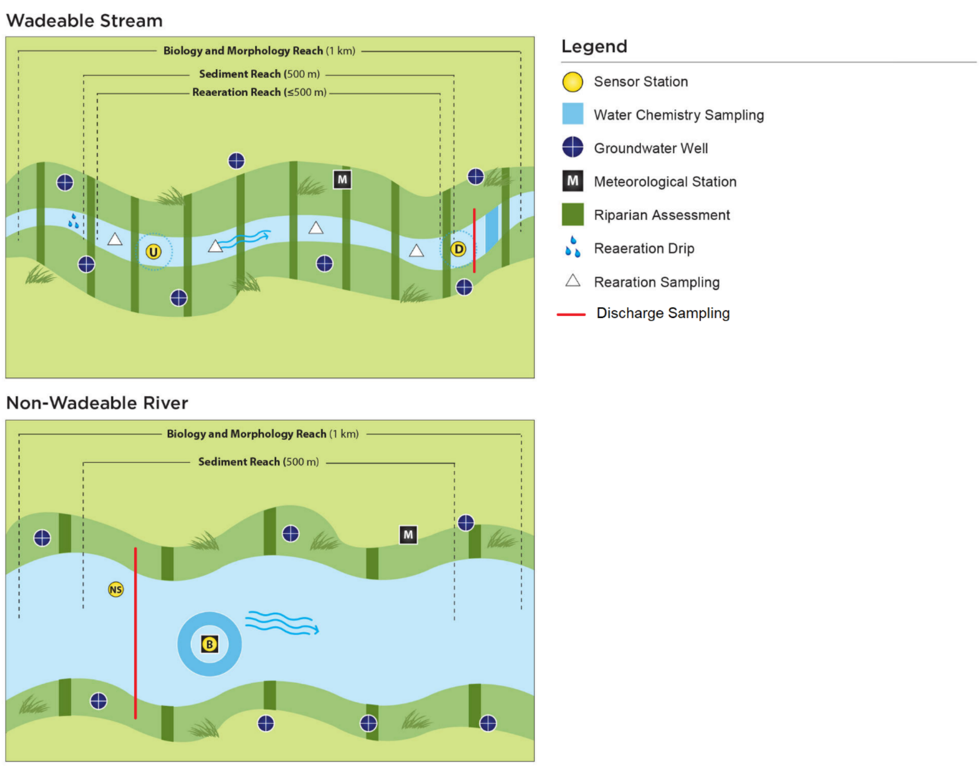

Figure 1: The discharge transect for wadeable streams is located on a run or riffle associated with the pool near the staff gauge and a pressure transducer (usually by the upstream sensor set, S1 or the downstream sensor set, S2).

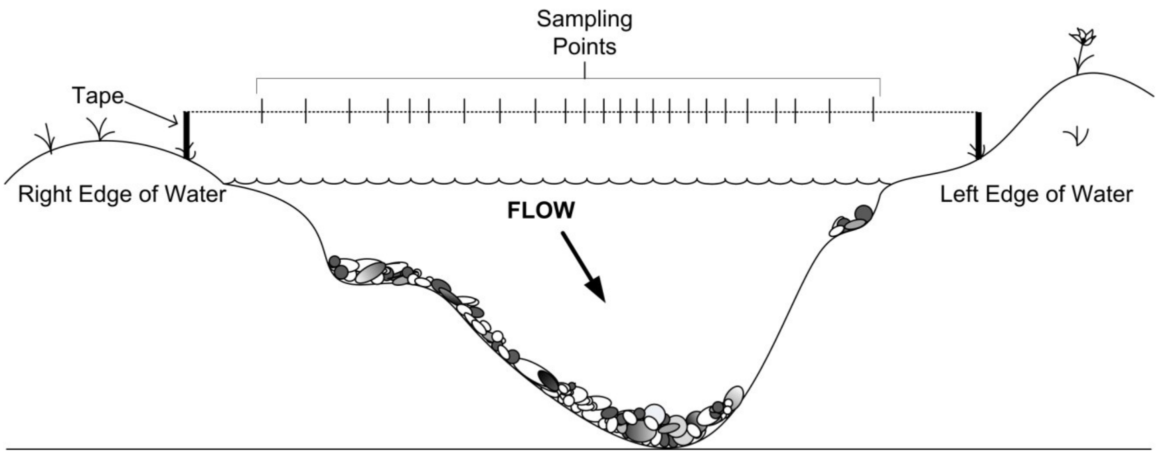

Figure 2: Uneven point measurement distribution across a wadeable stream sampling transect with concentrated areas of flow.

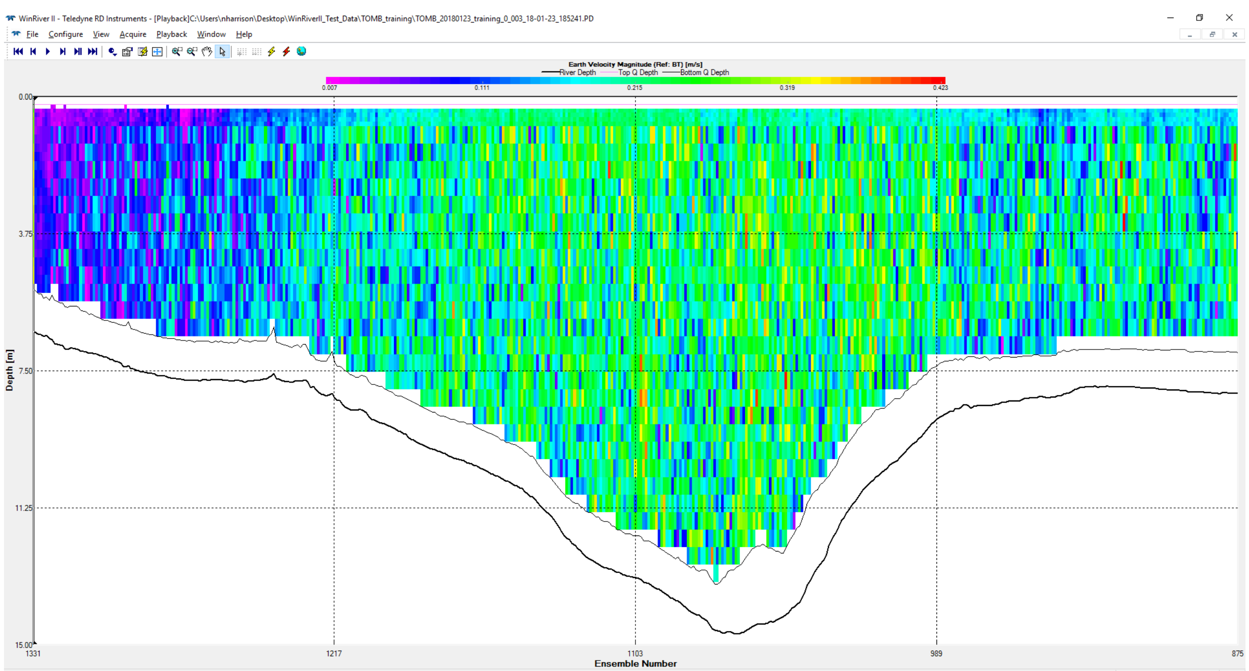

Figure 3: A velocity contour graph of the channel profile using an acoustic Doppler current profiler during a discharge measurement.

3.2 Temporal Sampling Design

Discharge field collection measurements are conducted 24 times per year until a valid stage-discharge relationship, i.e. rating curve, is developed. Once a relationship has been established, measurements will be made 12 times per year to verify the rating curve and identify when a new stage-discharge relationship may need to be developed. River discharge measurments are collected 12 times per year during pre and post-rating curve development periods.

Discharge field collections are planned to capture discharge over the full range of stages within a particular stream and river. For some streams or rivers this may mean relatively evenly timed surveys, e.g. every two weeks at wadeable streams during stage-discharge relationship development, while at in other systems the surveys may be concentrated during variable-flow times of year, e.g. spring snow-melt, with less frequenct surveys during the baseflow regime.

3.3 Variables Reported

All variables reported from the field or laboratory technician (L0 data) are listed in the file, NEON Raw Data Validation for Discharge Field Collection (DP0.20048.001) (AD[04]). All variables reported in the published data (L1 data) are also provided separately in the file, NEON Data Variables for Discharge Field Collection (DP1.20048.001) (AD[05]).

Field names have been standardized with Darwin Core terms (http://rs.tdwg.org/dwc/; accessed 16 February 2014), the Global Biodiversity Information Facility vocabularies (http://rs.gbif.org/vocabulary/gbif/; accessed 16 February 2014), the VegCore data dictionary (https://projects.nceas.ucsb.edu/nceas/projects/bien/wiki/VegCore; accessed 16 February 2014), where applicable. NEON TOS spatial data employs the World Geodetic System 1984 (WGS84) for its fundamental reference datum and GEOID 12A for its reference gravitational ellipsoid. Latitudes and longitudes are denoted in decimal notation to six decimal places, with longitudes indicated as negative west of the Greenwich meridian. Some variables described in this document may be for NEON internal use only and will not appear in downloaded data.

3.4 Spatial Resolution and Extent

The finest resolution at which discharge field collection data are reported is a single set of point measurements made at a discharge transect. Overall, this results in a spatial hierarchy of:

namedLocation (ID of the discharge transect location) → **siteID** (ID of NEON site) → **domainID** (ID of a NEON domain).

The discharge transect is predominantly stationary over time. However, if a disturbance event occurs that changes the stream morphology, the discharge transect may need to be be moved and a new stage-discharge relationship may need to be developed.

Shapefiles of all NEON Aquatic Observation System sampling locations can be found in the Document Library: http://data.neonscience.org/documents. If users are interested in the geospatial locations of the data relative to a global coordinate system, those can be retrieved using the NEON data API using the **namedLocation** and the following:

1. The def.extr.geo.os.R function from the geoNEON package, available here: https://github.com/NEONScience/NEON-geolocation
2. The NEON API: http://data.neonscience.org/api

3.5 Temporal Resolution and Extent

The finest resolution at which discharge field collection data are reported is the **collectDate**, a single date on which point measurements of depth and velocity are made along a discharge transect. The total number of sampling events per year is expected to be 12 - 24 per wadeable stream site and 12 per river site.

The NEON Data Portal currently provides data in monthly files for query and download efficiency. Queries including any part of a month will return data from the entire month. Code to stack files across months is available here: https://github.com/NEONScience/NEON-utilities

3.6 Associated Data Streams

The data from this L1 data product is used to develop two Level 4 (L4) data products: Stage-discharge rating curves (DP4.00133.001) and Continuous discharge (DP4.00130.001). These data products can be linked by **siteID**.

3.7 Product Instances

The NEON Observatory contains 24 wadeable streams, 3 large rivers, and 7 lakes. Discharge is measured at all NEON stream sites, river sites, and one lake site that contains measurable inflow and outflow.

For wadeable stream sites, discharge field collection yields approximately 576 discharge records per year during stage-discharge relationship development and 288 stage and discharge records per year once a relationship has been developed. Assuming that 20 point measurements are collected per transect, there will be 11,520 point records per year during stage-discharge relationship development and 5,760 point records per year once a relationship has been developed. For river sites and flow-through lake inflow and outflow locations, discharge field collection yields approximately 36 stage and discharge records per year.

3.8 Data Relationships

The protocol dictates that discharge field collection during wadable stream surveys (non-ADCP) will take place at each siteID per event (one record expected per siteID and collectDate combination in dsc_fieldData). All of the point measurements across the transect are records in dsc_individualFieldData, which are child records of dsc_fieldData. The number of records in dsc_individualFieldData per siteID per collectDate vary depending on the width of the stream and usually range from 10 to 25 records.

dsc_fieldData has one record per site per date when discharge field collection is performed.

dsc_individualFieldData has a variable number of child records (usually between 10 and 25 records) for each point measured along the transect record in dsc_fieldData.

For ADCP discharge measurements, field collection will take place at each siteID per event (one record expected per siteID and collectDate combination in dsc_fieldDataADCP).

Data downloaded from the NEON Data Portal are provided in separate data files for each site and month requested. The neonUtilities R package contains functions to merge these files across sites and months into a single file for each table described above. The neonUtilities package is available from the Comprehensive R Archive Network (CRAN; https://cran.r-project.org/web/packages/neonUtilities/index.html) and can be installed using the install.packages() function in R. For instructions on using neonUtilities to merge NEON data files, see the Download and Explore NEON Data tutorial on the NEON website: https://www.neonscience.org/download-explore-neon-data

4 DATA ENTRY CONSTRAINT AND VALIDATION

Many quality control measures are implemented at the point of data entry within a mobile data entry application or web user interface (UI). For example, data formats are constrained and data values controlled through the provision of dropdown options, which reduces the number of processing steps necessary to prepare the raw data for publication. An additional set of constraints are implemented during the process of ingest into the NEON database. The product-specific data constraint and validation requirements built into data entry applications and database ingest are described in the document NEON Raw Data Validation for Discharge Field Collection (DP0.20048.001), provided with every download of this data product. Contained within this file is a field named 'entryValidationRulesForm', which describes syntactically the validation rules for each field built into the data entry application.

For discharge data collected during wadable stream (non-ADCP) surveys, the following validation rules are checked via customized spreadsheet validation:

1. Velocity measurements contain valid location values. Horizontal distance measurements are to increase with each vertical along the transect.
2. Velocity measurements contain valid depth values. Beginning at the third vertical, measured depth is not to exceed 20 times that measured at the previous vertical.

For ADCP discharge measurements, WinRiver II software (TRDI) interfaces with the ADCP and provides real-time data monitoring during collection. This allows for measurement quality to be assessed in the field. The following criteria must be met in order for a discharge measurement to be finalized in the field:

Prior to the discharge measurement, the following quality assurance tests must be performed:

1. Moving bed test
2. Compass calibration
3. Instrument diagnostic test

Following the discharge measurement, the following criteria must be evaluated:

1. Transect discharge relative to mean discharge across all transects
2. Transect duration
3. Edge distances across each transect
4. Percent of measured discharge during each transect
5. Water speed vs. boat speed during each transect

Along with the WinRiver II program, Q-Rev software (USGS) is also utilized to post-process the river discharge measurement following field collection. Post-processing is a manual activity during which an HQ staff scientist reviews and finalizes the measurement.

Data entry constraints are described in Nicl syntax in the validation file provided with every data download, and the Nicl language is described in NEON's Ingest Conversion Language (NICL) specifications

([AD[11]).

5 DATA PROCESSING STEPS

Following data entry into a mobile application or web user interface, the steps used to process the discharge data through to publication on the NEON Data Portal are detailed in the NEON Algorithm Theoretical Basis Document: OS Generic Transitions (AD[10]).

ADCP discharge measurements are post-processed using WinRiver II and Q-Rev software. Once finalized, an output file (.mmt) produced by the software that contains all of the measurement data per collection is read into an R-script. The R-script parses the .mmt file and outputs a spreadsheet that contains the records found in the dsc_fieldDataADCP table in the document, NEON Raw Data Validation for Discharge Field Collection (DP0.20048.001). The spreadsheet is then uploaded onto the NEON Data Portal. The WinRiver II (.mmt), Q-Rev (.xml) data files, and all associated transect measurement files (.pdo) are stored on a cloud-based server and are available for users by request.

6 DATA QUALITY

6.1 QUALITY FLAGGING

Records of land management activities, disturbances, and other incidents of ecological note that may have a potential impact are found in the Site Management and Event Reporting data product (DP1.10111.001)

7 REFERENCES

Gartner, J.W., and Ganju, N.K., 2007. “Correcting acoustic Doppler current profiler discharge measurement bias from moving-bed conditions without global positioning during the 2004 Glen Canyon Dam controlled flood on the Colorado River,” Limnology and Oceanography: Methods, v. 5, pp. 156-162.

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