



<i>Title:</i> AOS Protocol and Procedure: Stream Discharge		<i>Date:</i> 06/19/2020
<i>NEON Doc. #:</i> NEON.DOC.001085	<i>Author:</i> N. Harrison	<i>Revision:</i> G

AOS PROTOCOL AND PROCEDURE: DSC - STREAM DISCHARGE

PREPARED BY	ORGANIZATION	DATE
Nick Harrison	AQU	03/13/2020
Dylan Monahan	AQU	02/03/2017
Michael Fitzgerald	AQU	10/07/2016
Ryan Utz	AQU	01/22/2013
Glenn Patterson	AQU	05/18/2011
Keli Goodman	AQU	03/30/2011

APPROVALS	ORGANIZATION	APPROVAL DATE
Kate Thibault	SCI	06/19/2020

RELEASED BY	ORGANIZATION	RELEASE DATE
Anne Balsley	CM	06/19/2020

See configuration management system for approval history.

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



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

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	02/03/2017	ECO-04480	Updated to new template; changes to sampling frequency, point of zero flow, removal of 3 depth sampling
E	09/28/2017	ECO-05292	Baseline update of protocol sent to FOPS for review. Made slight revisions to Sections 1.1, 4.1, 4.2, 4.4, 4.5. Added definitions to Section 2.4. Included language on continuous discharge calculation to Section 3. Section 7: re-organized content throughout; added instrument-specific steps to flowmeter setup and measurement procedures; refined calibration procedures (did not change); added list of common data entry errors to post-measurement review section based on NEON-9064; replaced Figure 7 with one that shows equations and natural control segments; revised PZF procedure based on NEON-8821; added additional language on natural control types and how they affect ratings; added additional steps to data entry and verification based on NEON-9064. Added Appendix A which introduces plan for measuring river discharge. Added additional citations into References section. Made slight revisions to Appendix B. Removed Appendix C.
F	09/19/2018	ECO-05687	Section A.2: removed the requirement that >30% of velocity measurement stations within a discharge transect must contain velocity values >0.01 m/s in order for a discharge measurement to be conducted. Parser validation code now flags measurements that contain such low-velocity values. Section A.3: increased minimum filter parameter settings to 40 seconds based on standards set forth by the USGS. Section A.5: clarified station spacing requirements given wetted widths of channel. Section A6: updated equipment list for wadable discharge measurements; Section A7: provided



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

			<p>instructions on how to setup first and last measurement stations given undercut left and right banks within the discharge transect; clarified the example that illustrate one and two-point velocity measurement techniques. Removed point of zero flow calculation requirement and instructions- this offset is now calculated within the stage-discharge rating curve code for each aquatic site. Point of zero flow calculations are no longer required to be measured by field ecologists. Added Appendix B: measuring discharge at NEON large river sites using acoustic Doppler current profilers from a piloted boat; cross-referenced all Tables and Figures Moved Appendix B to Appendix D (Measuring Discharge with Acoustic Doppler Current Profiles via a Piloted Boat Deployments); added a new Appendix B (Measuring Discharge with Acoustic Doppler Current Profilers via Tethered Float Deployments) and Appendix C (Measuring Discharge with Acoustic Doppler Current Profilers via Remote Controlled ARC-Boat Deployments)</p>
G	06/19/2020	ECO-06449	<p>Protocol now includes all discharge measurement collection methods to date; updated Section 4.2 and 4.4 – added stipulations for ADCP methods at wadable streams and rivers; added SOP overview figures; made minor edits to SOP A station spacing and 10% discharge per station text; added SOP’s E-H in Appendix A – measuring discharge at wadable stream sites using the ADCP Method; added SOP’s I-L – measuring discharge at river sites using the Remote Controlled Boat Method; added SOP’s M-P – measuring discharge at river sites using the Piloted Boat Method; added reminders for ARC-Boat repair, viewing laptops in direct sun, and rating curve supplementary information in Appendix D; added site-specific information regarding the required number of annual bouts per site and site-specific sampling documentation references in Appendix E; revised and added new equipment tables in Appendix F.</p>



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

TABLE OF CONTENTS

1 OVERVIEW1

1.1 Background 1

1.2 Scope..... 1

1.2.1 NEON Science Requirements and Data Products 2

1.3 Acknowledgments..... 2

2 RELATED DOCUMENTS AND ACRONYMS2

2.1 Applicable Documents 2

2.2 Reference Documents..... 2

2.3 Acronyms 3

2.4 Definitions..... 3

3 METHOD4

4 SAMPLING SCHEDULE7

4.1 Sampling Frequency and Timing 7

4.2 Criteria for Determining Onset and Cessation of Sampling..... 7

4.2.1 Sampling Cessation – Discharge Measurements at Wadable Stream Sites Using the Flowmeter Method 8

4.2.2 Sampling Cessation – Discharge Measurements at Wadable Stream Sites Using the ADCP Method... 9

4.2.3 Sampling Cessation – Discharge Measurements at River Sites Using the Piloted and Remoted Controlled Boat Method 11

4.3 Missed or Incomplete Sampling..... 12

4.4 Estimated Time 14

4.4.1 Estimated Time – Discharge Measurements at Wadable Stream Sites Using the Flowmeter Method..... 14

4.4.2 Estimated Time – Discharge Measurements at Wadable Stream Sites Using the ADCP Method.....15

4.4.3 Estimated Time – Discharge Measurements at River Sites Using the Remote Controlled Boat Method 15

4.4.4 Estimated Time – Discharge Measurements at River Sites Using the Piloted Boat Method.....16

5 SAFETY16



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

6 PERSONNEL18

6.1 Training Requirements..... 18

7 STANDARD OPERATING PROCEDURES19

SOP A PREPARING FOR SAMPLING: WADABLE STREAM SITES USING THE FLOWMETER METHOD ..23

SOP B FIELD SAMPLING: WADABLE STREAM SITES USING THE FLOWMETER METHOD.....30

SOP C POST-FIELD SAMPLING TASKS: WADABLE STREAM SITES USING THE ADCP METHOD.....42

SOP D DATA ENTRY AND VERIFICATION: WADABLE STREAMS USING THE FLOWMETER METHOD ..43

8 REFERENCES45

APPENDIX A DISCHARGE MEASUREMENTS AT WADEABLE STREAM SITES USING THE ADCP METHOD.....47

SOP E PREPARING FOR SAMPLING: WADABLE STREAM SITES USING THE ADCP METHOD.....48

SOP F FIELD SAMPLING: WADABLE STREAM SITES USING THE ADCP METHOD61

SOP G POST-FIELD SAMPLING TASKS: WADABLE STREAM SITES USING THE ADCP METHOD..... 106

SOP H DATA ENTRY AND VERIFICATION: WADABLE STREAM SITES USING THE ADCP METHOD 107

APPENDIX B DISCHARGE MEASUREMENTS AT RIVER SITES USING THE REMOTE CONTROLLED BOAT METHOD.....108

SOP I PREPARING FOR SAMPLING: RIVER SITES USING THE REMOTE CONTROLLED BOAT METHOD.....109

SOP J FIELD SAMPLING: RIVER SITES USING THE REMOTE CONTROLLED BOAT METHOD..... 124

SOP K POST-FIELD SAMPLING TASKS: RIVER SITES USING THE REMOTE CONTROLLED BOAT METHOD.....170

SOP L DATA ENTRY AND VERIFICATION: RIVER SITES USING THE REMOTE CONTROLLED BOAT METHOD.....171

APPENDIX C DISCHARGE MEASUREMENTS AT RIVER SITES USING THE PILOTED BOAT METHOD 172

SOP M PREPARING FOR SAMPLING: RIVER SITES USING THE PILOTED BOAT METHOD..... 172

SOP N FIELD SAMPLING: RIVER SITES USING THE PILOTED BOAT METHOD 179

SOP O POST-FIELD SAMPLING TASKS: RIVER SITES USING THE PILOTED BOAT METHOD..... 217

SOP P DATA ENTRY AND VERIFICATION: RIVER SITES USING THE PILOTED BOAT METHOD 218

APPENDIX D REMINDERS220

APPENDIX E SITE-SPECIFIC INFORMATION 224

APPENDIX F EQUIPMENT 226



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

LIST OF TABLES AND FIGURES

Table 1. Required sampling frequency for discharge surveys at NEON aquatic sites containing wadeable streams and rivers..... 7

Table 2. Estimated staff and labor hours required for implementation of the Stream Discharge protocol using the Flowmeter Method at wadable stream sites. 14

Table 3. Estimated staff and labor hours required for implementation of the Stream Discharge protocol using the ADCP Method at wadable stream sites..... 15

Table 4. Estimated staff and labor hours required for implementation of the Stream Discharge protocol using the ADCP Method at river sites. 15

Table 5. Estimated staff and labor hours required for implementation of the Stream Discharge protocol using the Piloted Boat Method at river sites. 16

Table 6. Station spacing of the discharge transect relative to wetted width using the Flowmeter Method at wadable stream sites. 31

Table 7. Velocity point methods based on station depth using the Flowmeter Method at wadable stream sites..... 38

Table 8. Troubleshooting errors encountered while uploading wadable stream discharge files collected with the Flowmeter Method onto the NEON SOM Data Portal. 44

Table 9. ARC-Boat controller tips during a variety of operation settings..... 136

Table 10. Site-specific bout number, start dates, end dates and additional site-specific sampling guidance..... 224

Table 11. Equipment list for measuring discharge at wadable stream sites using the Flowmeter Method. 226

Table 12. Equipment list for measuring discharge at wadable stream sites using the ADCP Method. ... 227

Table 13. Equipment list for measuring discharge at river sites using the Remote Controlled Boat Method. 229

Table 14. Equipment list for measuring discharge at river sites using the Piloted Boat Method. 231

Figure 1. Sampling locations at NEON wadable stream and non-wadable river aquatic sites..... 6

Figure 2. Missed sampling workflow for the NEON discharge protocol..... 13

Figure 3. A high level workflow diagram that visually shows how the separate SOPs are sequentially connected. 19

Figure 4. A high level workflow diagram that visually shows the workflow for wadable stream sites..... 19

Figure 5. A detailed workflow diagram that visually shows the workflow for wadable stream sites using the Flowmeter Method..... 20

Figure 6. A detailed workflow diagram that visually shows the workflow for wadable stream sites using the ADCP Method. 20

Figure 7. A high level workflow diagram that visually shows the workflow for river sites. 21

Figure 8. A detailed workflow diagram that visually shows the workflow for river sites using the Remote Controlled Boat Method. 21



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

Figure 9. A detailed workflow diagram that visually shows the workflow for river sites using the Piloted Boat Method. 22

Figure 10. Velocity meter and the thumbscrew that attaches it to the wading rod. 25

Figure 11. HACH FH950 flowmeter with displayed Start menu. 25

Figure 12. Example of well-distributed stations across a discharge transect at a wadable stream site using the Flowmeter Method. Note that laminar flow is assumed in this example. S0-S12 represent stations and dashed rectangles represent sub-sections. 32

Figure 13. Example of uneven station spacing across a discharge transect at a wadable stream site using the Flowmeter Method. Note that non-laminar flow is assumed in this example. 32

Figure 14. Wading rod adjustments at 60% (one-point), and 20% and 80% (two-point) depths. Station depth = 0.72m. 38

Figure 15. Above: Trimaran float, StreamPro ADCP, and SX Blue II GPS antenna components; Below: Illustrated workflow (top left to bottom right) detailing how to configure the StreamPro ADCP unit and SX Blue II GPS antenna to the trimaran float. 50

Figure 16. Illustrated workflow (top left to bottom right) detailing how to configure the RiverPro ADCP unit and the Hemisphere GPS antenna to the trimaran float. 52

Figure 17. Top: Parani-SD1000U USB Bluetooth Adapter with default settings. Bottom: Correct settings for ADCP and GPS Bluetooth configuration. 54

Figure 18. ADCP Test Port Dialog indicating that StreamPro ADCP data is streaming from the ADCP to the laptop. 59

Figure 19. GPS Test Port Dialog indicating that GPS data is streaming from the GPS antenna to the laptop. 59

Figure 20. Parts included with the Temporary High Line Assembly. 63

Figure 21. Assembling the Temporary High Line. 65

Figure 22. Required settings in the WinRiver II Output Filename Options dialogue box within the Measurement Wizard. 72

Figure 23. Above: GPS Tabular window that confirms GPS data is available and is being collected; Below: GPS Time Series window that indicates GPS data is streaming. 73

Figure 24. Set the PC used for the discharge measurement to (UTC) Coordinated Universal Time and match the ADCP clock to this setting. 74

Figure 25. WinRiver II compass calibration dialog box. Upon initializing the compass calibration, all bars begin as bright red as shown above. Perform the compass calibration until all bars are the dark green color indicated in the far right side of the color scale. 77

Figure 26. The WinRiver II Ship Track window observed during a loop moving bed test. The green box indicates the boat starting position, the line shows the boat path as it is navigating across the channel and turned back around toward the starting bank, and the red box indicates the boat ending position. 79

Figure 27. Illustration of the Loop Moving Bed Test procedure. 80

Figure 28. Left: A moving bed is likely present (not open loop); Right: a moving bed is not likely present (note closed loop). 81



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

Figure 29. Moving Bed Loop Test Result window. In this example the required conditions were met to in order to evaluate a moving bed (Loop time, water velocity) and a moving bed was not detected (the moving bed velocity < the moving bed velocity criteria), thus no correction was recommended. 82

Figure 30. Above: Bottom Track and GPS data are in good agreement, indicating proper compass calibration, an accurate Magnetic Variation value, and low GPS latency; Below: Bottom Track and GPS data are in poor agreement, indicating poor compass calibration, an inaccurate Magnetic Variation value, and/or high GPS latency. 86

Figure 31. Composite Tabular window in WinRiver II, green box: Number of Ensembles (hold until 10 at transect start/end points); red box: Number of Good Bins (must be >2 to begin transect); purple box: Total Discharge; blue boxes: Water and Boat speed; orange box: Distance made good (MG = total transect length); brown box: Duration (total transect duration must be ≥180 seconds). 90

Figure 32. Unmeasured areas in the ADCP profile where velocity is extrapolated. Top left: ADCP blanking distance and cell size distribution (credit: SonTek); top right: unmeasured areas of the profile relative to ADCP beams (credit: SonTek); below: the WinRiver II velocity contour with unmeasured areas delineated. 90

Figure 33. Water Speed vs. Boat Speed graph. Above: Improper technique. The boat speed (purple line) is erratic and higher than the water velocity (red line). Below: Proper technique. Maintain an even boat speed so that the purple and red lines are more in line and boat speed remains generally lower than water speed. 95

Figure 34. Discharge summary window in WinRiver II. The red box highlights Delta Q values. In this example all are < 5%, an indication that no additional transect measurements are required. 98

Figure 35. Defining transect locations In WinRiver II. 99

Figure 36. RiverPro ADCP. Left: base of the ADCP showing the five beam lenses; Right: top of the ADCP with indicator lights and power cord. 110

Figure 37. The ARC-Boat is the preferred deployment method to measure discharge at NEON river sites. 111

Figure 38. The ARC-Boat setup with the RiverPro ADCP adapter. A: connect the long set screws to the top of the ADCP; B: connect a fully charged 12V battery inside the ADCP adapter; C: connect the long set screws to the circular base plate of the adapter with the wingnuts, connect the ADCP cable coming out of the adapter to the ADCP, and flip the adapter switch to “Power On” (ADCP light should be green); D: the RiverPro ADCP and ARC-Boat ADCP adapter fully integrated; E: set the ADCP adapter with the ADCP into the ADCP compartment of the ARC-Boat and connect the circular base of the adapter to the boat using small set screws. Not shown: GPS mounting plate on top of the ADCP adapter. 113

Figure 39. Installing the Hemisphere V102 GPS antenna onto the ARC-Boat GPS mount. 114

Figure 40. Hemisphere V102 GPS antenna schematics. Top: the back of the unit with cable port show; Middle: the side of the unit showing one of two set screw locations; Bottom: the base of the unit, the red circle to the right of the unit indicates the location that must be centered over the ADCP, the white arrow to the left of the unit indicates the direction the unit must face so that it is oriented toward Beam 3 of the ADCP. 115

Figure 41. Applying External Heading offsets to align GPS and Bottom Track Ship Tracks. 116



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

Figure 42. Top: Parani-SD1000U USB Bluetooth Adapter with default settings. Bottom: Correct settings for ADCP and GPS Bluetooth configuration. 118

Figure 43. RiverPro ADCP Test Port Dialog indicating that ADCP data is streaming from the ADCP to the laptop. 122

Figure 44. Required settings in the WinRiver II Output Filename Options dialogue box within the Measurement Wizard. 130

Figure 45. Above: GPS Tabular window that confirms GPS data is available and is being collected; Below: GPS Time Series window that indicates GPS data is streaming. 130

Figure 46. Set the PC used for the discharge measurement to (UTC) Coordinated Universal Time and match the ADCP clock to this setting. 132

Figure 47. Above: Top of the ARC-Boat (not pictured: ADCP Adapter with GPS mount); Below: Stern of the ARC-Boat. 134

Figure 48. When surface water velocity is sufficient operate the ARC-Boat in such a way that the bow is pointed into the velocity vectors and the boat is crabbed across the channel. 136

Figure 49. Illustration on different ways to control the ARC-Boat in a variety of streamflow levels. 136

Figure 50. ADCP Compass Calibration dialog box. The entirety of the horizontal bar is red upon initiating the test. Rotate the boat slowly and steadily so that bar is colored dark green throughout. 139

Figure 51. The WinRiver II Ship Track window observed during a loop moving bed test. The green box indicates the boat starting position, the line shows the boat path as it is navigating across the channel and turned back around toward the starting bank, and the red box indicates the boat ending position. 142

Figure 52. Illustration of the Loop Moving Bed Test procedure. 143

Figure 53. Left: A moving bed is likely present as indicated by the open loop; Right: a moving bed is not likely present as indicated by the closed loop. 144

Figure 54. Moving Bed Loop Test Result window. In this example the required conditions were met in order to evaluate a moving bed (Loop time, water velocity) and a moving bed was not detected (the moving bed velocity < the moving bed velocity criteria), thus no correction was recommended. 145

Figure 55. Above: Ship Track graphs to evaluate Bottom Track vs GPS data. Above: Track and GPS data are in good agreement, indicating proper compass calibration, an accurate Magnetic Variation value, and low GPS latency; Below: Bottom Track and GPS data are in poor agreement, indicating poor compass calibration, an inaccurate Magnetic Variation value, and/or high GPS latency. 149

Figure 56. Composite Tabular window in WinRiver II, green box: number of ensembles (hold until 10 at transect start/end points); red box: Number of Good Bins (must be >2 to begin transect); purple box: total discharge; blue boxes: water and boat speed; orange box: distance made good (total transect length); brown box: duration (total transect duration must be ≥180 seconds). 153

Figure 57. Unmeasured areas in the ADCP profile where velocity is extrapolated. Top left: ADCP blanking distance and cell size distribution (credit: SonTek); top right: unmeasured areas of the profile relative to ADCP beams (credit: SonTek); below: the WinRiver II velocity contour with unmeasured areas delineated. 153



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

Figure 58. Water Speed vs. Boat Speed graph. Above: Improper technique. The boat speed (purple line) is erratic and higher than the water velocity (red line). Below: Proper technique. Maintain an even boat speed so that the purple and red lines are more in line and boat speed remains generally lower than water speed. 158

Figure 59. Discharge summary window in WinRiver II. The red box highlights Delta Q values. In this example all are < 5%, an indication that no additional transect measurements are required. 161

Figure 60. Defining transect locations in WinRiver II..... 163

Figure 61. RiverPro ADCP. Left: base of the ADCP showing the five beam lenses; Right: top of the ADCP with indicator lights and power cord..... 173

Figure 62. The Kentucky II mount (USGS) is used to deploy the ADCP when measuring discharge at NEON river sites using the piloted boat method..... 174

Figure 63. Serial cables that connect the ADCP to the 12V battery and the laptop PC. Note the white RS-232 USB adapter that must be included in the set..... 175

Figure 64. RiverPro ADCP Test Port Dialog indicating that ADCP data is streaming from the ADCP to the laptop..... 177

Figure 65. Assembly of the ADCP mount on a piloted boat..... 182

Figure 66. Required settings in the WinRiver Output Filename Options dialogue box within the Measurement Wizard..... 188

Figure 67. Set the PC used for the discharge measurement to (UTC) Coordinated Universal Time and match the ADCP clock to this setting..... 189

Figure 68. ADCP Compass Calibration dialog box. The entirety of the horizontal bar is red upon initiating the test. Rotate the boat slowly and steadily so that bar is colored dark green throughout..... 192

Figure 69. The WinRiver II Ship Track window observed during a loop moving bed test. The green box indicates the boat starting position, the line shows the boat path as it is navigating across the channel and turned back around toward the starting bank, and the red box indicates the boat ending position. 194

Figure 70. Illustration of the Loop Moving Bed Test procedure..... 195

Figure 71. Left: A moving bed is likely present as indicated by the open loop; Right: a moving bed is not likely present as indicated by the closed loop..... 196

Figure 72. Moving Bed Loop Test Result window. In this example the required conditions were met in order to evaluate a moving bed (Loop time, water velocity) and a moving bed was not detected (the moving bed velocity < the moving bed velocity criteria), thus no correction was recommended. 198

Figure 73. Composite Tabular window in WinRiver II, green box: number of ensembles (hold until 10 at transect start/end points); red box: Number of Good Bins (must be >2 to begin transect); purple box: total discharge; blue boxes: water and boat speed; orange box: distance made good (total transect length); brown box: duration (total transect duration must be ≥180 seconds)..... 202

Figure 74. Unmeasured areas in the ADCP profile where velocity is extrapolated. Top left: ADCP blanking distance and cell size distribution (credit: SonTek); top right: unmeasured areas of the profile relative to ADCP beams (credit: SonTek); below: the WinRiver II velocity contour with unmeasured areas delineated..... 202



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

Figure 75. Water Speed vs. Boat Speed graph. Above: Improper technique. The boat speed (purple line) is erratic and higher than the water velocity (red line). Below: Proper technique. Maintain an even boat speed so that the purple and red lines are more in line and boat speed remains generally lower than water speed. 207

Figure 76. Discharge summary window in WinRiver II. The red box highlights Delta Q values. In this example all are < 5%, an indication that no additional transect measurements are required. 210

Figure 77. Repairing a disconnected tiller on the ARC-Boat..... 221

Figure 78. Example of stage-discharge rating curve. Circles indicate discharge measurements collected across a wide range of gauge heights. Rating equations for each of the three distinct segments are shown representing low, medium, and high flow regimes. In this example, a section control governs the stage-discharge relationship during the low-flow regime and the main channel control becomes deactivated at higher stages when as the streamflow tops the banks. Once flow exceeds the channel capacity the stage-discharge relationship is governed by floodplain channel control. 222

Figure 79. Schematic representation of control range in a rating curve. (Illustration: Braca 2008). 223



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

1 OVERVIEW

1.1 Background

The degree to which streamflow, 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, sediment, and boulders within the active channel, or the active channel itself. 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.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

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 works 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) and Mueller, D.S., Wagner, C.R., Rehmel, M.S., Oberg, K.A., and Rainville, Francois, 2013, Measuring discharge with acoustic Doppler current profilers from a moving boat (ver. 2.0, December 2013): U.S. Geological Survey Techniques and Methods, book 3, chap. A22, 95 p.

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
AD[01]	NEON.DOC.004300	EHS Safety Policy and Program Manual

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
RD[01]	NEON.DOC.000008	NEON Acronym List



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

2.3 Acronyms

Acronym	Definition
ADCP	Acoustic Doppler Current Profiler
GPS	Global Positioning System
LEW	Left edge of water (looking downstream)
MBT	Moving Bed Test
P&P	Procedure and Protocol
REW	Right edge of water (looking downstream)
USGS	United States Geological Survey
SDRC	Stage Discharge Rating Curve

2.4 Definitions

Acoustic Doppler Current Profiler (ADCP): a hydroacoustic current meter used to measure water velocity over a depth range using the Doppler effect of sound waves scattered back from particles within the water column.

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: A specific section of a stream channel, located downstream from the staff gauge that controls the relation between gauge height and discharge at the staff gauge.

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

Discharge (Q): (streamflow) 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.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

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.

Station: A location along the stream discharge measurement transect where velocity and depth are measured and area and streamflow are calculated. Station, or vertical, spacing is dependent on the wetted width of the channel and velocity distribution throughout the transect.

Thalweg: The line that connects the deepest part of the active 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 units of rate, such as liters/meters per second.

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

3 METHOD

A continuous record of stream discharge is derived using discharge measurement and observed gauge height data collected by field technicians and pressure data (converted to stage) collected by *in-situ* pressure transducers at each NEON aquatic site that contain a wadable stream or river. One component in building a stage-discharge rating curve involves the measurement of discharge across a wide range of stage levels by NEON field ecologists. These sampling events are known as discharge surveys. Discharge is a calculated metric obtained from a series of velocity and area measurements collected along a fixed cross-section in the stream or river (**Figure 1**). Velocity and area measurements are then integrated into a single value of stream discharge that is associated with the gauge height (or stage) during the measurement.

Once the 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 streamflow. Hence, a pressure transducer is located at a fixed location near the discharge cross-section and staff gauge is able to yield a continuous estimate of stream discharge by measuring surface water pressure.

Each NEON aquatic site contains an in-stream staff gauge that is located in a fixed position near a pressure transducer which automatically measures and logs absolute pressure values *in-situ* at one-minute intervals throughout the year (or while water is present within the hydrologic unit). Absolute pressure data is converted to raw depth using unique calibration coefficients. During each discharge survey field ecologists record gauge height. The raw depth values derived from the pressure transducer are regressed against gauge height measurements collected throughout the water year to derive an



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

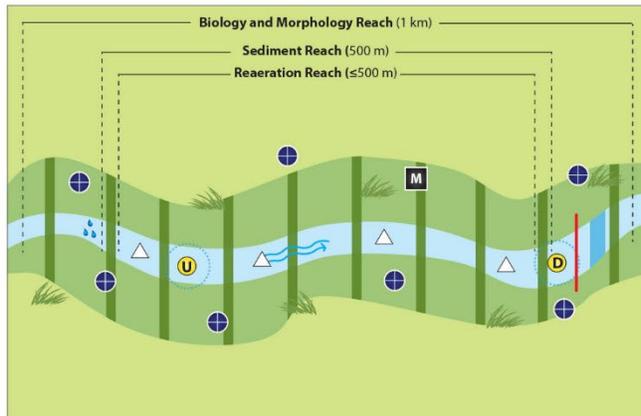
equation that transforms raw depth to stage. A continuous record of stream discharge is derived by applying stage-discharge rating equations to continuous stage data.

The purpose of this protocol is to provide detailed instructions on how to successfully implement a discharge survey in wadable streams and rivers. This involves pre-deployment and post-measurement review, step-by-step field methods, data entry procedures, troubleshooting, instrument quality assurance plans, and safety guidelines specific to NEON sites and personnel.

Two methods are presented for discharge surveys in wadable stream sites: (1) using a handheld flowmeter to measure discharge in the stream and (2) using an acoustic Doppler current profiler (ADCP) to measure discharge from the streambank. The flowmeter method utilizes a velocity meter that is designed to measure the speed of water around the sensor tip, yielding an instantaneous localized velocity measurement. To obtain an estimate of total stream discharge within the cross-section, the stream is divided laterally into sub-sections. Within each sub-section, an instantaneous velocity magnitude is obtained and transformed to a volumetric discharge magnitude by applying the velocity across the full sub-section area. Total stream discharge is then calculated by summing up the discrete volumetric discharges for each sub-section. The ADCP method utilizes an instrument (ADCP) that uses sounds to measure water velocity based on the Doppler Effect. The ADCP is mounted to a trimaran float which is pulled across the discharge cross-section while velocity and area are continuously measured and total discharge is calculated. The conditions of use relating to each wadable discharge survey method are described in detail later in the document. ADCP's are utilized as the sole means to conduct discharge surveys in rivers. Two ADCP deployment methods are presented to meet sampling goals at sites: (1) deploying ADCP instrumentation from a piloted boat and (2) deploying ADCP instrumentation from a remote-controlled boat.



Wadeable Stream



Legend

- Sensor Station
- Water Chemistry Sampling
- Groundwater Well
- Meteorological Station
- Riparian Assessment
- Reaeration Drip
- Reaeration Sampling
- Discharge Sampling

Non-Wadeable River

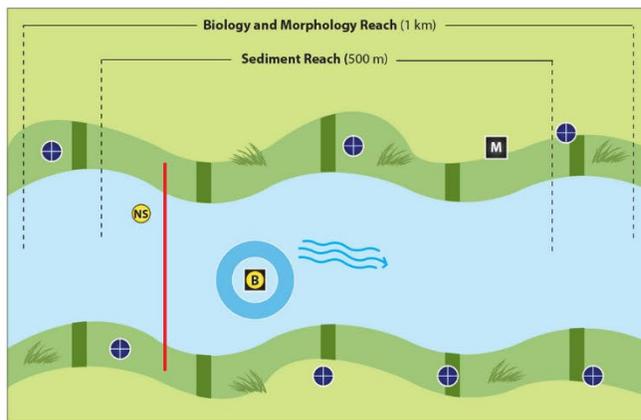


Figure 1. Sampling locations at NEON wadeable stream and non-wadeable river aquatic sites.

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.

Quality assurance is performed on data collected via these procedures according to the NEON Science Data Quality Plan (AD[06]).



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

4 SAMPLING SCHEDULE

4.1 Sampling Frequency and Timing

While the rating curve is under initial development, it is particularly important to perform discharge surveys frequently in order to form the basis of the stage-discharge relationship. At wadable stream sites NEON’s target is to conduct twenty-four (24) discharge surveys annually over a wide range of stage levels until Science has validated the stage-discharge rating curve for a given site. Once the rating curve is validated, NEON’s target is to use discharge surveys to verify the rating curve twelve (12) times per year across a range of stages. At river sites, twelve (12) discharge surveys are to be completed annually prior to and following rating curve establishment (**Table 1**). If necessary, the discharge sampling schedule may deviate in order to conduct measurements at certain flow levels. In these cases Field Science staff should work with Science through the appropriate channels that address scheduling changes.

Once the rating curve has undergone initial development and validation, the stage-discharge relationship must be verified over time, as ratings may shift due to bed scour, aggradation, or other changes in channel geometry. Following each discharge survey, staff must compare the measured discharge value to the predicted value derived from the rating equation. Consecutive discharge sampling bouts that yield discharge values greater than $\pm 10\%$ of the predicted value may be an indication that the stage-discharge relationship at a given site has changed, or shifted. If Science has determined that a rating shift is present, discharge sampling frequency at the site may need to be increased for purposes of validation, and, if necessary, the creation of new rating equations. Channel morphology in streams with unconsolidated bed materials are 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. Sampling frequency details for each site will be provided in Domain Specific Sampling Design documentation (**Appendix E**).

Table 1. Required sampling frequency for discharge surveys at NEON aquatic sites containing wadeable streams and rivers.

Aquatic Site Types	Sampling Dates	Sampling Bouts per Year
Wadable Streams: pre-rating curve establishment	Year-round (as feasible)	24
Wadable Streams: post-rating curve establishment	Year-round (as feasible)	12
Rivers: pre- and post-rating curve establishment	Year-round (as feasible)	12

4.2 Criteria for Determining Onset and Cessation of Sampling

Certain criteria for determining the onset and cessation of sampling is dependent on the discharge survey method. These details are presented below.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

4.2.1 Sampling Cessation – Discharge Measurements at Wadable Stream Sites Using the Flowmeter Method

At wadable stream sites, discharge sampling should be conducted according to the site-specific interval (24 times per year pre-rating curve validation, 12 times per year post-rating curve validation) using the Flowmeter Method under the following conditions:

1. Water is present in the stream channel.
 - a. If water is not present in the stream channel then a discharge measurement cannot be conducted using any available method. Submit an incident ticket to Science documenting that the reach has gone dry.
2. It is safe to enter the stream channel.
 - a. Reference AD[02] and any other Domain-specific safety plans that detail thresholds for working in the stream.
3. The staff gauge is present and un-disrupted.
 - a. If the staff gauge is not present, or has been disrupted/damaged, do not collect a discharge measurement using any available method.
 - b. Submit an incident ticket to Science documenting this occurrence.
 - c. Note that if a discharge survey is associated with a reaeration sampling event, discharge should still be measured regardless of staff gauge presence.
4. Surface water to bed depth is between 0.04 and ~0.17 m in > 90% of the channel wetted width.
 - a. The ADCP is the preferred method to measure discharge at wadable stream sites due to the high level of data quality the instrument provides. However, the handheld flowmeter can measure velocity at lower depths than the ADCP, making the Flowmeter method a suitable option to measure discharge during the ultra-low flow regime.
 - b. The minimum depth for the ADCP will be determined on a site-by-site basis as environmental conditions affect the instrument's measurement ability. At sites with rough streambeds (i.e. large boulders or cobble) the minimum ADCP depth will likely be greater than at sites with smooth beds (i.e. sand or small gravel). Consult with Science if there is a question as to when to utilize the Flowmeter vs. ADCP method.
 - c. There is no requirement for a minimum wetted channel width.
 - d. Discharge measurement quality is dependent on the continuous profile of water that maintains a minimum depth and laminar throughout the majority of the discharge transect (this should not include the shallow edge sections).
 - e. If needed, move smaller substrate and/or cobbles within the discharge transect to (1) maintain hydrologic connection within the channel, (2) maintain the minimum depth



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

requirements of the flowmeter, and (3) decrease the roughness of the streambed to improve data quality (reduce uncertainty in depth measurements).

- f. If larger debris is located in the discharge transect and cannot be moved, an alternative discharge measurement location should be considered. Submit an incident ticket to Science to document this occurrence and discuss a path forward.
 - g. If water depth is below this threshold and the discharge transect is dry, very nearly dry, or hydrologically disconnected, submit an incident ticket to Science to document this occurrence.
 - h. At higher stage levels (water depth is $\geq \sim 0.17\text{m}$ in $\geq 90\%$ of the channel wetted width), the ADCP method is to be used. Environmental conditions specific to the site will likely dictate when the transition from the flowmeter to the ADCP method can occur (see **Step 4a** above). Consult with Science if there is a question as to when to utilize the Flowmeter vs. ADCP method.
5. Minimal ice cover is present.
- a. If the water surface is “lightly iced” over ($< 1''$ of ice) and you can safely break through the ice to clear/open up a 1m width along the entire discharge transect, collect a discharge measurement.
 - b. Record ice presence and temporary hydrologic conditions in the app and indicate that surface ice was broken in order to collect the measurement.
 - c. If the surface ice thickness is $> 1''$, do not collect a stream discharge measurement.

4.2.2 Sampling Cessation – Discharge Measurements at Wadable Stream Sites Using the ADCP Method

At wadable stream sites, discharge sampling should be conducted according to the site-specific interval (24 times per year pre-rating curve validation, 12 times per year post-rating curve validation) using the ADCP method under the following conditions:

1. Water is present in the stream channel.
 - a. If water is not present in the stream channel then a discharge measurement cannot be conducted using any available method.
 - b. Submit an incident ticket to Science documenting that the reach has gone dry.
2. The staff gauge is present and un-disrupted.
 - a. If the staff gauge is not present, or has been disrupted/damaged, do not collect a discharge measurement using any available method.
 - b. Submit an incident ticket to Science documenting this occurrence.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- c. If the staff gauge is topped during high flows and a discharge measurement can be safely collected, attempt to mark or in some way reference the elevation of the edge of water (only do so if this can be accomplished in a safe manner). A future survey of this location (relative to the staff gauge) can provide an estimate of gauge height during the measurement.
 - d. Note that if a discharge survey is associated with a reaeration sampling event, discharge should still be measured regardless of staff gauge presence.
3. Surface water to bed depth is $\geq \sim 0.17\text{m}$ in $\geq 90\%$ of the channel wetted width.
 - a. The ADCP is the preferred method to measure discharge at wadable stream sites due to the high level of data quality the instrument provides. However, the handheld flowmeter can measure velocity at lower depths than the ADCP, making the Flowmeter method a suitable option to measure discharge during the ultra-low flow regime.
 - b. The minimum depth for the ADCP will be determined on a site-by-site basis as environmental conditions affect the instrument's measurement ability. At sites with rough streambeds (i.e. large boulders or cobble) the minimum ADCP depth will likely be greater than at sites with smooth beds (i.e. sand or small gravel). Consult with Science if there is a question as to when to utilize the Flowmeter vs. ADCP method.
 - c. There is no requirement for a minimum wetted channel width.
 - d. Discharge measurement quality is dependent on the continuous and laminar profile of water that maintains a minimum depth throughout the majority of the discharge transect (this should not include the shallow edge sections).
 - e. If needed (and it is safe to enter the channel), move smaller substrate and/or cobbles within the discharge transect to (1) maintain hydrologic connection within the channel, (2) maintain the minimum depth requirements specific to the ADCP at a given location, (3) decrease the roughness of the streambed to improve data quality (improve bottom tracking), and (4) minimize the unmeasured area at the bottom of the velocity profile.
 - f. If larger debris is located in the discharge transect and cannot be moved, an alternative discharge measurement location should be considered. Submit an incident ticket to Science to document this occurrence and discuss a path forward.
 - g. At lower stage levels (water depth is $\leq \sim 0.17\text{m}$ in $\geq 90\%$ of the channel wetted width), the Flowmeter method is to be used. Environmental conditions specific to the site will likely dictate when the transition from the flowmeter to the ADCP method can occur (see **Step 3a** above). Consult with Science if there is a question as to when to utilize the Flowmeter vs. ADCP method.
4. Minimal ice cover is present.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- a. If the water surface is “lightly iced” over (< 1” of ice) and you can safely break through the ice to clear/open up a 1m width along the entire discharge transect, collect a discharge measurement.
- b. Record ice presence and temporary hydrologic conditions in the app and indicate that surface ice was broken in order to collect the measurement.
- c. If the surface ice thickness is > 1”, do not collect a stream discharge measurement.
5. The ADCP passes diagnostics tests prior to the measurement.
 - a. If the instrument does not pass diagnostic tests prior to measurement, do not collect a measurement and submit a trouble ticket to Science.
6. See **Appendix E.2** for site-specific details on maximum depth thresholds which are dependent on ADCP model type and individual instrumentation configurations.

4.2.3 Sampling Cessation – Discharge Measurements at River Sites Using the Piloted and Remoted Controlled Boat Method

At river sites, discharge sampling should be conducted according to the site-specific interval (12 times per year) using the ADCP Piloted Boat or Remote Controlled Boat methods under the following conditions:

1. Water is present in the river channel.
 - a. If water is not present in the stream channel then a discharge measurement cannot be conducted using any available method. Submit an incident ticket to Science documenting that the reach has gone dry.
2. The staff gauge is present and un-disrupted.
 - a. If the staff gauge is not present, or has been disrupted/damaged, do not collect a discharge measurement using any available method.
 - b. Submit an incident ticket to Science documenting this occurrence.
 - c. If the staff gauge is topped during high flows and a discharge measurement can be safely collected, attempt to mark or in some way reference the elevation of the edge of water (only do so if this can be accomplished in a safe manner). A future survey of this location (relative to the staff gauge) can provide an estimate of gauge height during the measurement.
 - d. Note that if a discharge survey is associated with a reaeration sampling event, discharge should still be measured regardless of staff gauge presence.
3. The discharge transect can be safely accessed using the Remote Controlled Boat Method:
 - a. Reference AD[02] and any other Domain-specific safety plans that detail thresholds for working on the near shore of the river.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

4. The discharge transect can be safely accessed using the Piloted Boat Method:
 - a. Reference AD[02] and any other Domain-specific safety plans that detail thresholds for operating a vessel in the river.
5. The ADCP passes diagnostics tests prior to the measurement.
 - a. If the instrument does not pass diagnostic tests prior to measurement, do not collect a measurement and submit a trouble ticket to Science.
6. Surface water to bed depth is between 0.15 and 25.0 m in $\geq 90\%$ of the channel wetted width.
 - a. There is no requirement for a minimum wetted channel width.
 - b. Discharge measurement quality is dependent on the continuous profile of water that maintains a minimum depth throughout the majority of the discharge transect (this should not include the shallow edge sections).
 - c. If water depth is outside this threshold submit an incident ticket to Science that documents this occurrence.

4.3 Missed or Incomplete Sampling

Sampling according to the schedule is not always possible, and multiple factors may impede work in the field at one or more plots or sampling locations for a given bout. For example:

- Logistics – e.g., insufficient staff or equipment.
- Environment – e.g., deep snow/ice cover, excessive flooding, dangerous weather.
- Management activities – e.g., controlled burns, pesticide application.

Instances such as those listed above must be documented for scheduling, tracking long-term site suitability, and informing end users of NEON data availability. Some types of missed sampling are due to events that should be recorded in the Site Management App; refer to the Site Management and Event Reporting Protocol for more detail (RD[06]).

Missed or Incomplete Sampling Terms

Terms that inform Missed or Incomplete Sampling include:

- **Protocol Sampling Dates:** Bout-specific sampling dates.
- **Scheduled Sampling Dates:** Bout-specific sampling dates scheduled by Field Science and approved by Science. These dates coincide with or are a subset of the Protocol Sampling Dates.
- **Missed Sampling:** Incidence of *scheduled sampling* that did not occur. Missed Sampling is recorded at the same resolution as data that are ordinarily recorded.
- **Sampling Impractical:** The field name associated with a controlled list of values that is included in the data product to explain a Missed Sampling event – i.e., why sampling did not occur.



- **Rescheduled:** Missed Sampling is rescheduled for another time within the *protocol sampling dates*, resulting in no change to the total number of sampling events per year.

The documentation that must accompany missed sampling depends on the timing, subsequent action, and the audience appropriate for numerous scenarios (**Figure 2**).

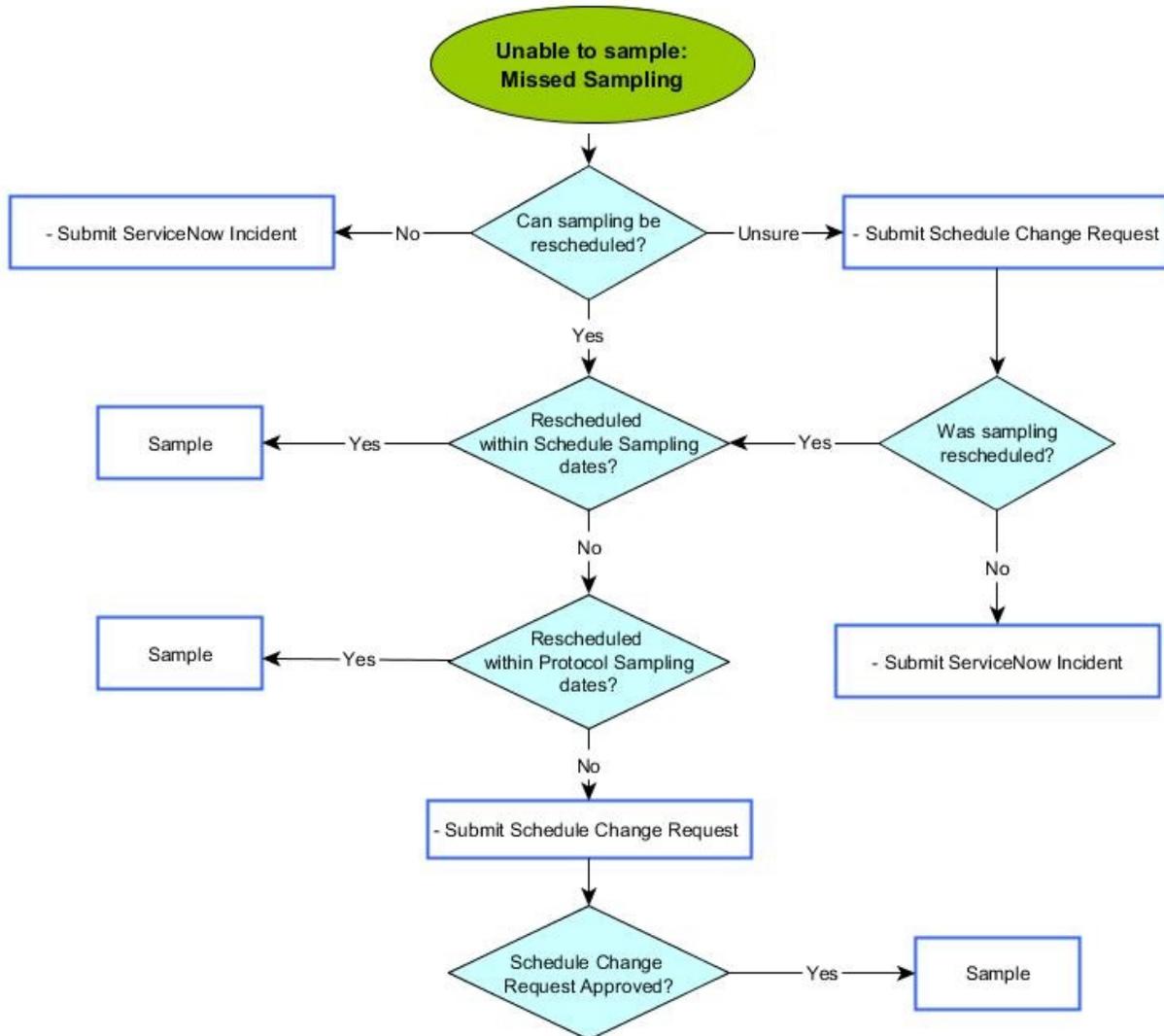


Figure 2. Missed sampling workflow for the NEON discharge protocol.

To Report Missed or Incomplete Sampling:



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

1. Missed or Incomplete Sampling must be communicated to Science by a Service Now Incident ticket.
 - a. For Missed Sampling that is Rescheduled, there are some cases that require approval by Science and Operations (**Figure 2**).
 - b. The lead Field Ecologist should consult the [Delayed or Cancelled Activities table](#) to best determine when reporting is required.

4.4 Estimated Time

Estimated time to complete the protocol is dependent on the type discharge survey method. Estimates for each method are presented below.

4.4.1 Estimated Time – Discharge Measurements at Wadable Stream Sites Using the Flowmeter Method

The time required to implement the protocol using the Flowmeter method at wadable stream sites will vary depending on a variety 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 single skilled Field Scientist (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, an incident ticket should be submitted to Science. Please note that if sampling at particular locations requires significantly more time than expected, Science may propose to move these sampling locations.

Table 2. Estimated staff and labor hours required for implementation of the Stream Discharge protocol using the Flowmeter Method at wadable stream sites.

SOP	Estimated time	Suggested staff	Total person hours
SOP A: Preparing for Sampling: Wadable Stream Sites Using the Flowmeter Method	10 minutes	1	0.2 h
SOP B: Field Sampling: Wadable Stream Sites Using the Flowmeter Method	30 minutes	1	0.5 h
SOP C: Post-Field Sampling Tasks: Wadable Stream Sites Using the Flowmeter Method	10 minutes (if necessary)	1	0.2 h
SOP D: Data Entry and Verification: Wadable Stream Sites Using the Flowmeter Method	10 minutes	1	0.2 h



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

4.4.2 Estimated Time – Discharge Measurements at Wadable Stream Sites Using the ADCP Method

The time required to implement the protocol using the ADCP method at wadable stream sites will vary depending on a variety 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 2-3 person team (i.e., not the time it takes at the beginning of the field season). Note that many of the pre-measurement tasks listed can be completed in parallel with one another. Use this estimate as framework for assessing progress. If a task is taking significantly longer than the estimated time, an incident ticket should be submitted to Science. Please note that if sampling at particular locations requires significantly more time than expected, Science may propose to move these sampling locations.

Table 3. Estimated staff and labor hours required for implementation of the Stream Discharge protocol using the ADCP Method at wadable stream sites.

SOP	Estimated time	Suggested staff	Total person hours
SOP E: Preparing for Sampling: Wadable Stream Sites Using the ADCP Method	10-30 minutes	1	0.2 – 0.5 h
SOP F: Field Sampling: Wadable Stream Sites Using the ADCP Method	30-60 minutes	2-3	0.5 – 1.5 h
SOP G: Post-Field Sampling Tasks: Wadable Stream Sites Using the ADCP Method	10 minutes (if necessary)	1	0.2 h
SOP H: Data Entry and Verification: Wadable Stream Sites Using the ADCP Method	10 minutes	1	0.2 h

4.4.3 Estimated Time – Discharge Measurements at River Sites Using the Remote Controlled Boat Method

The time required to implement the protocol using the remote controlled boat method at river sites will vary depending on a variety 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, an incident ticket should be submitted to Science. Please note that if sampling at particular locations requires significantly more time than expected, Science may propose to move these sampling locations.

Table 4. Estimated staff and labor hours required for implementation of the Stream Discharge protocol using the ADCP Method at river sites.

SOP	Estimated time	Suggested staff	Total person hours
-----	----------------	-----------------	--------------------



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

SOP I: Preparing for Sampling: River Stream Sites Using the Remote Controlled Boat Method	10-30 minutes	1	0.2 – 0.5 h
SOP J: Field Sampling: River Stream Sites Using the Remote Controlled Boat Method	30-60 minutes	2	0.5 – 1.5 h
SOP K: Post-Field Sampling Tasks: River Stream Sites Using the Remote Controlled Boat Method	10 minutes (if necessary)	1	0.2 h
SOP L: Data Entry and Verification: River Stream Sites Using the Remote Controlled Boat Method	10 minutes	1	0.2 h

4.4.4 Estimated Time – Discharge Measurements at River Sites Using the Piloted Boat Method

The time required to implement the protocol using the piloted boat method at river sites will vary depending on a variety 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, an incident ticket should be submitted to Science. Please note that if sampling at particular locations requires significantly more time than expected, Science may propose to move these sampling locations.

Table 5. Estimated staff and labor hours required for implementation of the Stream Discharge protocol using the Piloted Boat Method at river sites.

SOP	Estimated time	Suggested staff	Total person hours
SOP M: Preparing for Sampling: River Stream Sites Using the Piloted Boat Method	10-30 minutes	1	0.2 – 0.5 h
SOP N: Field Sampling: River Stream Sites Using the Piloted Boat Method	30-60 minutes	2	0.5 – 1.0 h
SOP O: Post-Field Sampling Tasks: River Stream Sites Using the Piloted Boat Method	10 minutes (if necessary)	1	0.2 h
SOP P: Data Entry and Verification: River Stream Sites Using the Piloted Boat Method	10 minutes	1	0.2 h

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.



<i>Title:</i> AOS Protocol and Procedure: Stream Discharge		<i>Date:</i> 06/19/2020
<i>NEON Doc. #:</i> NEON.DOC.001085	<i>Author:</i> N. Harrison	<i>Revision:</i> G

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.

- Activities in streams should only be performed when flow conditions are safe.
- Never enter the channel when it is unsafe to do so.
- Be aware of the potential for downstream debris transport as stage increases.
- Logs, debris, cobble, and boulders can be very slippery and unsafe to walk on.



<i>Title:</i> AOS Protocol and Procedure: Stream Discharge		<i>Date:</i> 06/19/2020
<i>NEON Doc. #:</i> NEON.DOC.001085	<i>Author:</i> N. Harrison	<i>Revision:</i> G

6 PERSONNEL

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



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

7 STANDARD OPERATING PROCEDURES

SOP Overview

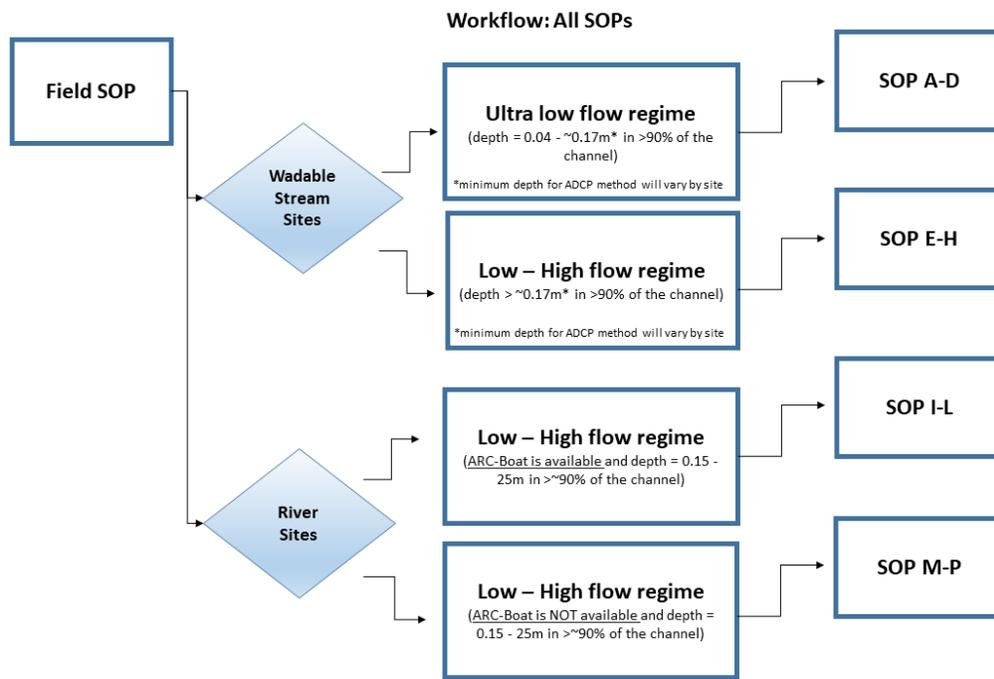


Figure 3. A high level workflow diagram that visually shows how the separate SOPs are sequentially connected.

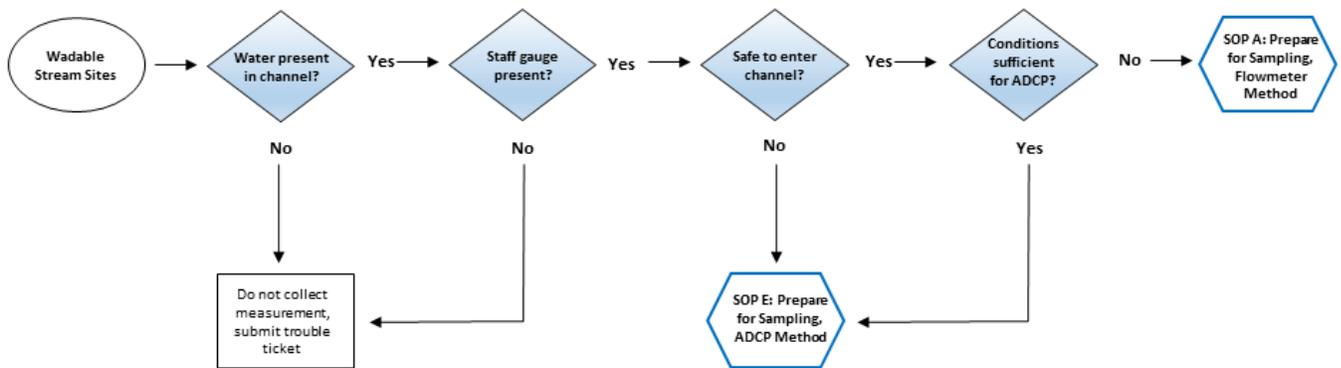


Figure 4. A high level workflow diagram that visually shows the workflow for wadable stream sites.

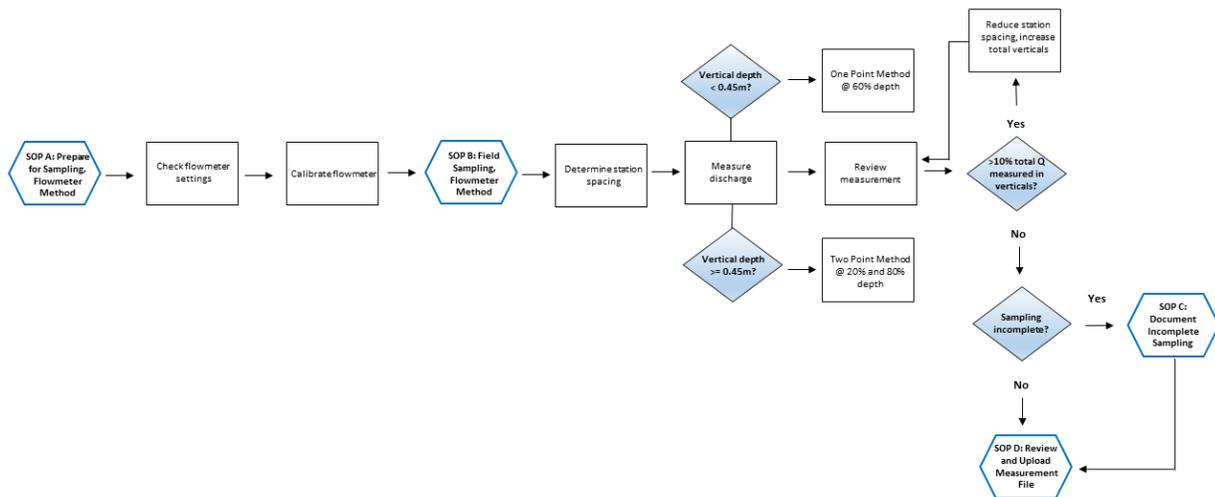


Figure 5. A detailed workflow diagram that visually shows the workflow for wadable stream sites using the Flowmeter Method.

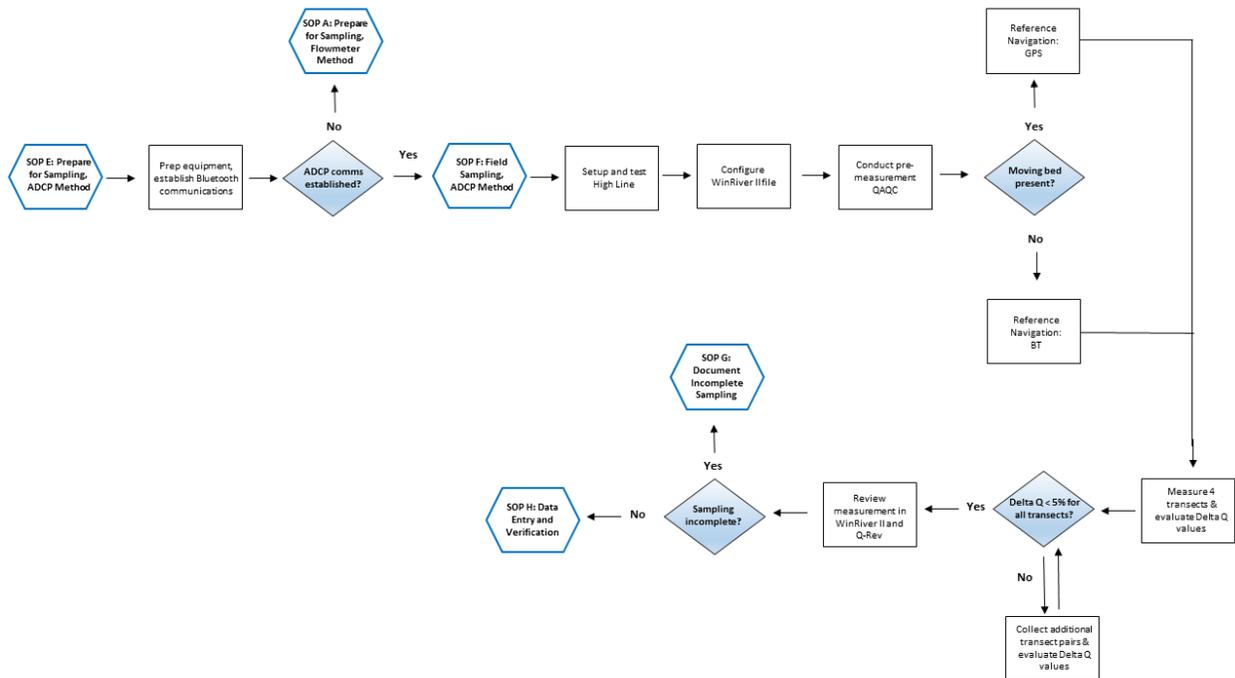


Figure 6. A detailed workflow diagram that visually shows the workflow for wadable stream sites using the ADCP Method.

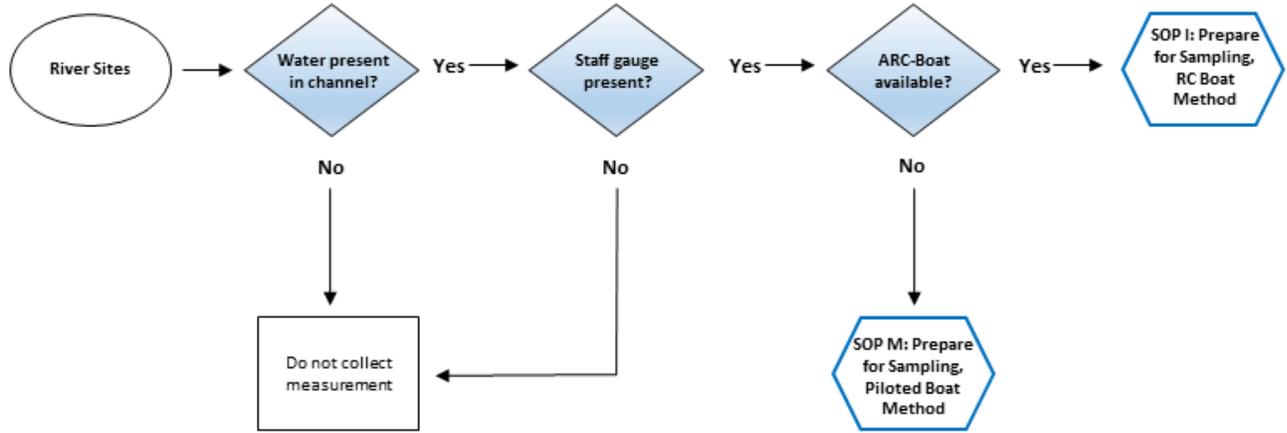


Figure 7. A high level workflow diagram that visually shows the workflow for river sites.

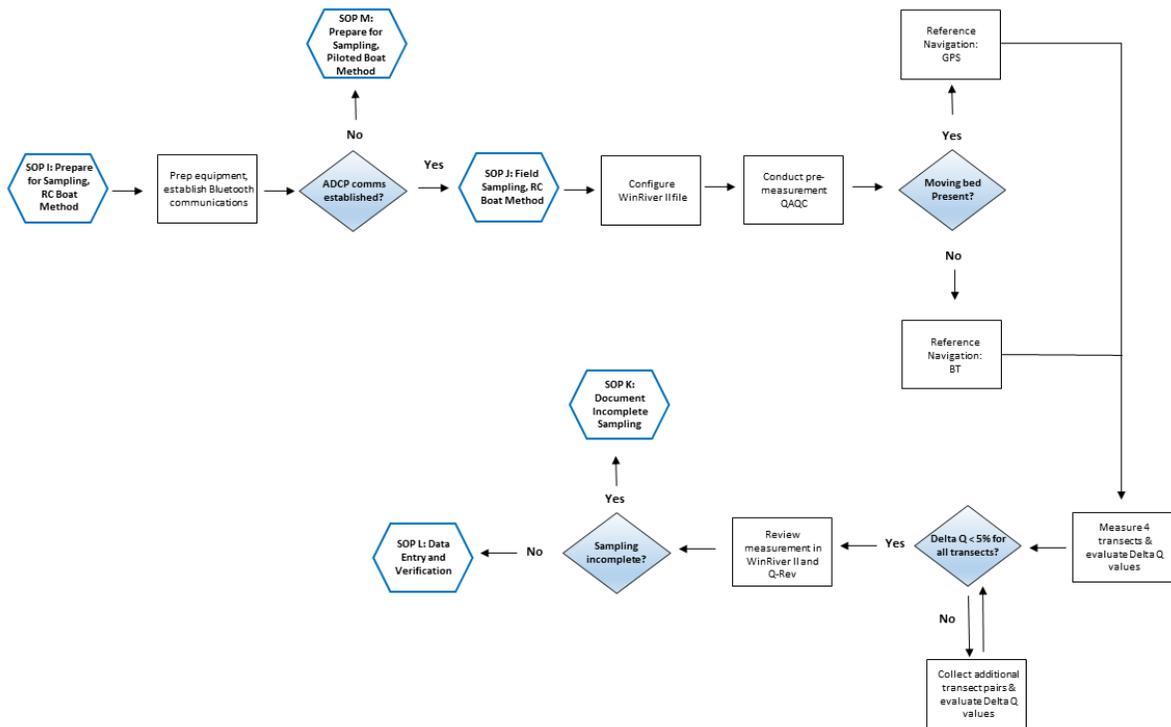


Figure 8. A detailed workflow diagram that visually shows the workflow for river sites using the Remote Controlled Boat Method.

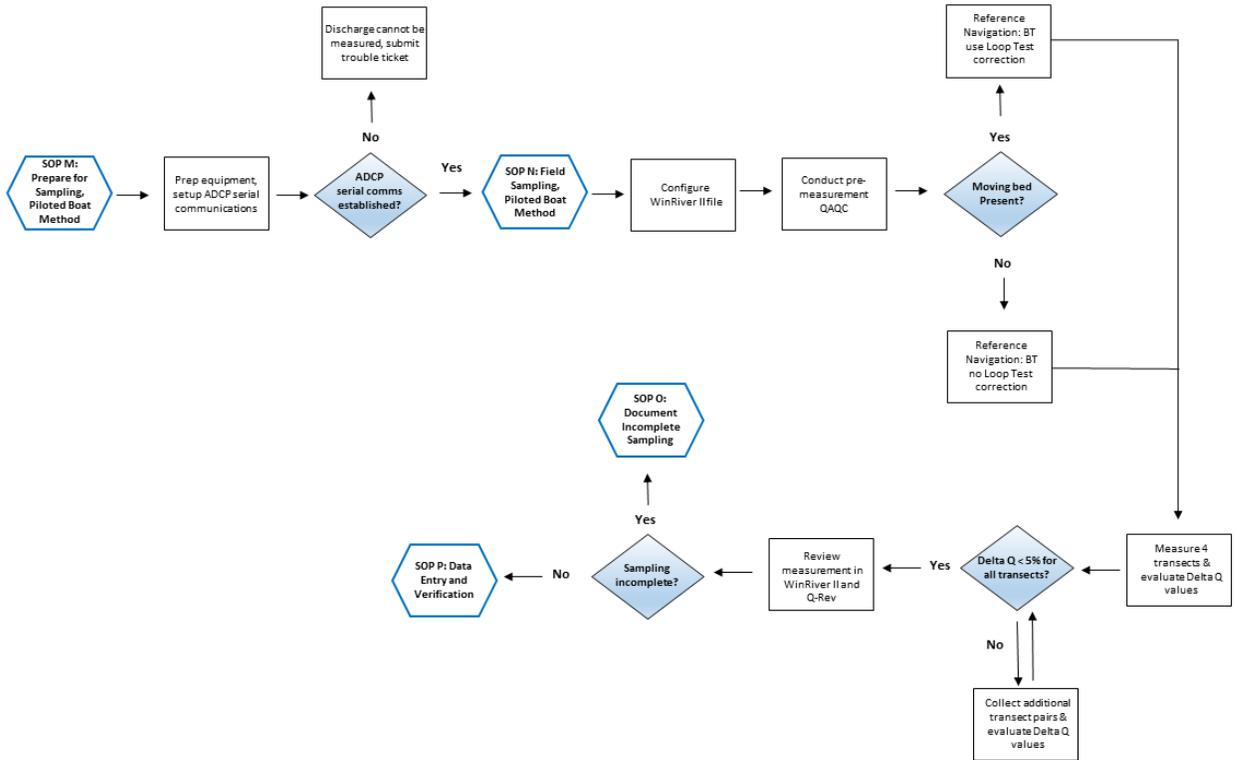


Figure 9. A detailed workflow diagram that visually shows the workflow for river sites using the Piloted Boat Method.



SOP A Preparing for Sampling: Wadable Stream Sites Using the Flowmeter Method

A.1 Preparing for Data Capture

Prior to leaving the office ensure that the following is met:

- The flowmeter is fully charged.
- All necessary equipment is gathered and prepared (**Table 11**).
- If the site has an approved stage-discharge rating curve, the current rating equation is available for measurement comparison/validation.

A.2 Navigate to the Discharge Transect

If a discharge transect, or cross-section, has already been established, the bounds should be permanently marked using stakes or plot markers (one on each side of the stream). Navigate to this location and proceed to **Section A.3**.

If a discharge transect has not been established at the site proceed with the following steps:

1. Determine an appropriate location to establish a discharge transect.
 - a. At wadable stream sites the transect location must be located in the riffle habitat unit in close proximity (just downstream) of the pool where the staff gauge and sensor set are installed. Consult with Science if the sensor set location is unknown or has not yet been established.
 - b. An ideal discharge transect will:
 - 1) Be located in a reasonably straight channel with velocity lines that are more or less parallel to each other.
 - 2) Contain velocities that are, for the most part, > 0.15 m/s, and depths that are, for the most part, > 0.15 m.
 - 3) Contain a stable streambed free of obstructions that would create eddies, slack water, and turbulence.
 - 4) Contain measurement sections that are roughly parabolic, trapezoidal, or rectangular.
 - 5) Contain a stable downstream control feature.
 - c. Take pictures of the transect location that best meets this criteria as well as the downstream control feature and send to Science for consultation.

A.3 Assess the Discharge Transect

Prior to collecting the discharge measurement identify any instrumentation or environmental issues that would negatively affect data quality. Document any temporary hydrologic conditions in the (AOS) Field



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

Metadata and Gauge Height [PROD] app in Fulcrum. If conditions are unfavorable to discharge measurement collection, submit a trouble ticket and consult with Science.

Unfavorable conditions include, but are not limited to:

1. The staff gauge is either not present or has been displaced in some way.
 - a. A discharge measurement should not be collected if a staff gauge is not present at the site or the gauge has been displaced in any way. Submit a trouble ticket to Science that includes photos of the gauge.
2. A pressure transducer is either not present or has been displaced in some way.
 - a. A discharge measurement **may be collected** in the event that the pressure transducer is missing or has been displaced. However the absence of this instrument prevents continuous discharge from being estimated. Submit a trouble ticket to Science immediately if the Pressure transducer is missing or has become displaced.
3. Too much water is present in the channel to safely conduct the wading survey.
 - a. Refer to NEON Operations Field Safety and Security Plan (AD[02]) for details.
 - b. Consider using the ADCP method (see **Section 4.2**).
4. There is an insufficient amount of water in the channel to conduct velocity measurements.
 - a. See **Section 4.2.1**.
5. Refer to NEON Operations Field Safety and Security Plan (AD[02]) and NEON Operations Field Safety and Security Plan (AD[02]) for further details.

A.4 Setup Flowmeter and Configure Flowmeter Settings

It is critical that the flowmeter settings are configured correctly in the handheld units. Incorrect settings will negatively affect data quality and, in some instances, prevent data entry. Follow the steps below to setup the flowmeter and ensure that flowmeter settings are correct prior to measuring discharge.

The most common flowmeter currently at use at NEON aquatic sites with wadeable streams is the HACH FH-950. The following steps detail calibration procedures for this model. If another flowmeter is used for discharge, consult with Science regarding configuration.

1. Attach the flowmeter to the wading rod.
 - a. Ensure the hexagonal wading rod is attached properly to the rod base. The base and rod screw together, tighten if the parts appear loose.
2. Attach the velocity flowmeter to the mounting shaft of the wading rod, using the thumbscrew (**Figure 9**).



- a. Do not touch the tip of the sensor bulb, residue from oil on your fingers and hands can negatively affect the calibration procedures.

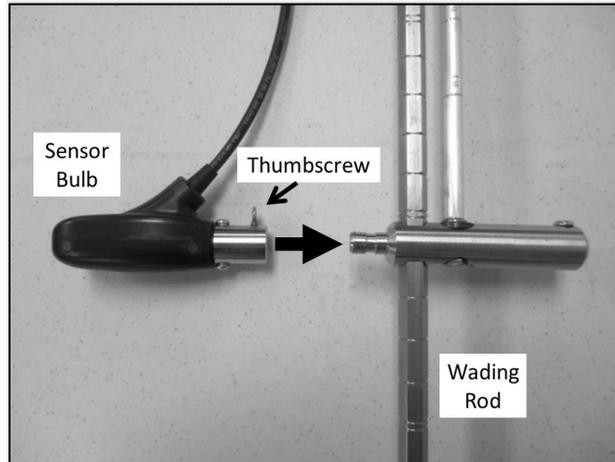


Figure 10. Velocity meter and the thumbscrew that attaches it to the wading rod.

3. Turn the flowmeter on by pressing and holding the “ON/OFF” button on the outside of the handheld instrument. Note that the meter may first run a diagnostic check to ensure it is connected to the sensor. Once complete, the Start Menu will appear on the screen (Figure 10).

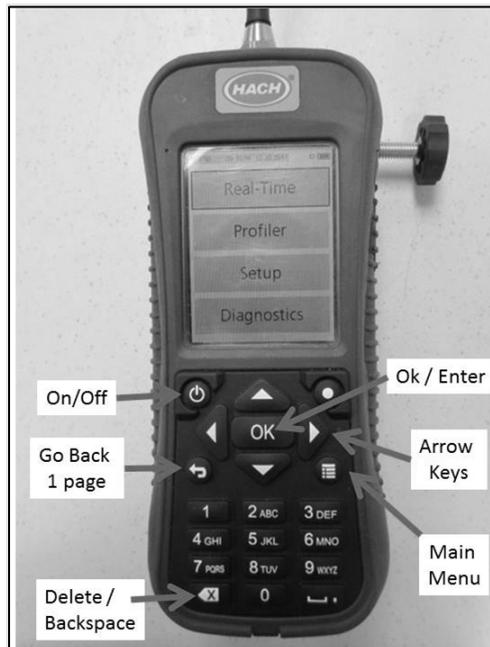


Figure 11. HACH FH950 flowmeter with displayed Start menu.



4. Set Measurement Units.
 - a. From the Start Menu, select “Setup” and press OK.
 - b. Select “More” at the bottom of the screen.
 - c. Select “Units” and press OK.
 - d. Select “Metric” and press OK.
 - e. Under the “Select function” screen, select “Velocity” and press OK.
 - f. Select “m/s” and press OK.
 - g. The “Parameters successfully saved” screen will appear. Press OK.
 - h. Select “flow” and press OK.
 - i. Select “liters/s” and press OK.
 - j. The “Parameters successfully saved” screen will appear. Press OK.
 - k. Select “depth” and press OK.
 - l. Select “m” and press OK.
 - m. The “Parameters successfully saved” screen will appear. Press OK.
 - n. Select “area” and press OK.
 - o. Select “m²” and press OK.
 - p. The “Parameters successfully saved” screen will appear. Press OK.
 - q. Once all units have been set correct, press OK.
5. Set Filter Parameters.
 - a. From the Start Menu, select “Setup” and press OK.
 - b. Select “Filter Parameters” and press OK.
 - c. Select “Main filter” and press OK.
 - d. Select “Fixed Period Averaging” and press OK.
 - e. In averaging time box, enter a value of “40” (seconds) and press OK.
 - 1) This is the amount of time the flowmeter will spend averaging the velocity measurements.
 - f. The “Parameters successfully saved” screen will appear. Press OK.
 - g. Check that “Pre-filter” is enabled and the data acquisition pre-filter rank is set to “5”.
 - 1) These are default values and should not be changed.



6. Set Flow Calculation Method.
 - a. From the Start Menu, select “Setup” and press OK.
 - b. Select “More” at the bottom of the screen.
 - c. Select “Flow Calculation” and press OK.
 - d. Select “Mid-section” and press OK.
 - e. The “Parameters successfully saved” screen will appear. Press OK.
7. Set Station Entry Method.
 - a. From the Start Menu, select “Setup” and press OK.
 - b. Select “More” at the bottom of the screen.
 - c. Select “Station Entry” and press OK.
 - d. Select “Non-Fixed” and press OK.
 - e. The “Parameters successfully saved” screen will appear. Press OK.
8. Set Measurement Resolution.
 - a. From the Start Menu, select “Setup” and press OK.
 - b. Select “More” at the bottom of the screen.
 - c. Select “Measurement Resolution” and press OK.
 - d. Select “0.001” and press OK.
 - e. The “Parameters successfully saved” screen will appear. Press OK.
9. Set Auto-Zero Mode.
 - a. From the Start Menu, select “Setup” and press OK.
 - b. Select “Auto Zero Depth” and press OK.
 - c. Select “On” and press OK.
 - d. The “Parameters successfully saved” screen will appear. Press OK.
10. Set EMI.
 - a. From the Start Menu, select “Setup” and press OK.
 - b. Select “EMI” and press OK.
 - c. Select “60Hz.” and press OK.
 - d. The “Parameters successfully saved” screen will appear. Press OK.
11. Set Wet/Dry Threshold.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- a. This is the trigger point for the meter to know when the sensor is out of the water.
- b. This is important because if the meter does not know that the sensor is under the surface of the water, the meter sets the velocity value to zero.
- c. From the Start Menu, select “Setup” and press OK.
- d. Select “Wet/Dry Threshold” and press OK.
- e. Select “Default” (value = 20) and press OK.
- f. If the specific conductivity of the water is very low (i.e. < 15 us/cm, although specific conditions may vary by site) the flowmeter may not function properly and this value will need to be adjusted.
 - 1) An indication of this problem is when the flowmeter measures 0.00 velocity rates in flowing water.
 - 2) To troubleshoot:
 - a) Obtain a “dry conductivity reading” with the flowmeter out of the water.
 - b) Obtain a “wet conductivity reading” with the flowmeter submerged in a bucket stream water.
 - c) Set the Wet/Dry threshold value to midpoint, or average of the “dry” and “wet” conductivity reading values.
 - d) Conductivity fluctuates with stream stage. If you change this value be sure to update it again during the next discharge measurement based on current conditions.
 - 3) If problems persist:
 - a) Document out of the ordinary conductivity conditions in the Fulcrum metadata app.
 - b) Submit a trouble ticket to Science.
- g. The “Parameters successfully saved” screen will appear. Press OK.

12. Set Clock.

- a. From the Start Menu, select “Setup” and press OK.
- b. Select “Clock” and press OK.
- c. Follow the instructions to set local time and current date and press OK.
- d. The “Parameters successfully saved” screen will appear. Press OK.
- e. Update Clock settings to reflect periods of daylight savings time.



A.5 Calibrating the Flowmeter

All flowmeters must be “zero-calibrated” prior to measuring discharge. The most common flowmeter currently at use at NEON aquatic sites is the HACH FH-950. The following steps detail calibration procedures for this model. If another flowmeter is used for discharge, consult with Science regarding calibration instructions.

To calibrate the HACH FH-950 flowmeter:

1. Fill a 5-gallon bucket with water from the stream you will be measuring discharge. Using the local water will ensure that the ionic strength of the “zeroing water” is the same as the water being measured.
2. Place the velocity meter in the water. Keep the sensor bulb positioned in the center of the bucket (or as close to it as possible). The sensor bulb must be kept a minimum of 3-inches from the sides and bottom of the bucket as well as the surface of the water.
3. Allow water settle for 1-2 minutes to stabilize. Water in the bucket must remain still throughout the calibration process.
4. Turn on the handheld flowmeter and select “Setup”.
5. Select “Velocity Calibration”.
6. Select “Zero Calibration”.
7. Allow the flowmeter to cycle through a calibration reading and, once complete, verify that the unit reads a velocity of 0.00 m/s. Note that -0.00 m/s is acceptable.
8. If the calibration velocity is 0.00 m/s, return to the main menu on the handheld flowmeter.
9. If the final calibration velocity does not equal 0.00 or -0.00 m/s at the end of the calibration cycle (100%), repeat previous calibration steps.
 - a. Reasons for calibration errors may include:
 - 1) The sensor bulb tip was touched or is dirty and needs to be wiped off with a dry cloth.
 - 2) Flowmeter batteries are low.
 - 3) The water in the 5-gallon bucket was shifted during the calibration procedures.
 - 4) The sensor bulb tip was too close to the bucket edges or the water surface during calibration procedures.
 - b. If, after five attempts, the flowmeter cannot be zero-calibrated, the flowmeter should not be used and discharge should not be measured.
 - 1) Submit a trouble ticket and consult with Science.
 - 2) If possible use another flowmeter to measure discharge that can be zero-calibrated.



SOP B Field Sampling: Wadable Stream Sites using the Flowmeter Method

B.1 Setting up the Discharge Transect and Delineating Station Spacing for Depth and Velocity Measurements

Discharge surveys at NEON wadeable stream sites are to be measured from the right to left bank, looking downstream. Velocity measurement stations are to begin at the right edge of water (REW) and extend to the left edge of water (LEW).

To ensure high data quality is collected, velocity measurement stations must be spaced correctly across the stream discharge transect. To determine proper station spacing across a transect, field ecologists must first assess the relevant hydrologic conditions present at the time of the discharge measurement; specifically, streamflow magnitude, water surface elevation, and wetted width. The overall goal is to establish as many velocity measurement stations as possible to obtain a complete and well-distributed velocity profile throughout the cross-section. However, stations must not be set so close so that subsequent stations measure the same velocity profile. The location of velocity measurement stations do not need to be equally spaced across the transect. Rather, the locations should be more closely spaced where water velocity and depth are changing most rapidly (this is often at the center of the channel and/or near the banks) to ensure that no more than 10% of the total discharge occurs within a single velocity measurement station.

Use the following steps to consider how to best space stations across the discharge transect given the dynamic nature of stream conditions within the monitoring location.

1. Attach the measuring tape to the permanent stake on the right bank and extend it across the stream so that is perpendicular to the flow. Attach the opposite end to the permanent stake on the left bank.
2. Assess whether streamflow appears to be relatively uniform across the channel. Note the location of any non-laminar (water is flowing in non-parallel vertical layers) streamflow conditions.
3. Measure the wetted width within the transect (the distance between the REW and the LEW) and determine station spacing (**Table 6**).
 - a. If the wetted width is $>2.00\text{m}$:
 - 1) Divide the transect into roughly 20-25 sampling stations.
 - 2) Space stations evenly and at wider intervals where flow conditions are homogenous and more closely together where flow conditions are non-laminar (**Figure 11**).
 - 3) Maintain a minimum 0.05m station spacing to avoid duplicate measurements between stations.
 - b. If the wetted width is $\leq 2.00\text{m}$:



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 1) Divide the transect into as many stations as possible without duplicating measurements between stations
 - a) Maintain a minimum 0.05m station spacing.
 - b) Obtaining 20-25 stations may not be possible in very narrow streams so less sampling stations are permitted.
 - c) The goal is to obtain a well-distributed velocity profile while avoiding duplicate measurements between stations.

4. Discharge measured at a single station should not exceed 10% of the total measured discharge across the transect.
 - a. If non-uniform flow conditions are present (more concentrated areas of high flow within the transect):
 - 1) Increase the number of sampling stations so that a higher number of stations are concentrated along the part of the transect with greatest flow (**Figure 12**).
 - a) This will aid in distributing discharge measurements across a greater number of stations.

5. Proceed with discharge measurement collection once station widths have been properly set.

Table 6. Station spacing of the discharge transect relative to wetted width using the Flowmeter Method at wadable stream sites.

Wetted Width (m)	Station Spacing
≤ 2.00	Divide the transect into as many stations as possible without measuring duplicate velocity profiles between stations. Maintain a minimum 0.05m station spacing. Obtaining 20-25 stations may not be possible in very narrow streams. A single station is not to account for >10% of the overall total measured discharge
> 2.00	Divide the transect into roughly 20-25 sampling stations. Space stations evenly and at wider intervals where flow conditions are homogenous and more closely together where flow conditions are non-laminar. Maintain a minimum 0.05m station spacing to avoid duplicate velocity measurements between stations. A single station is not to account for >10% of the overall total measured discharge.

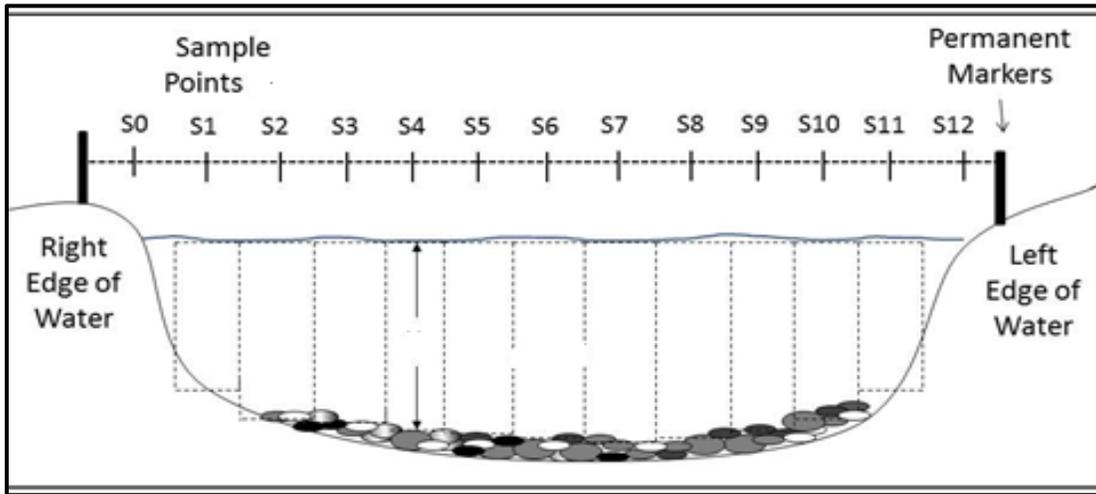


Figure 12. Example of well-distributed stations across a discharge transect at a wadable stream site using the Flowmeter Method. Note that laminar flow is assumed in this example. S0-S12 represent stations and dashed rectangles represent sub-sections.

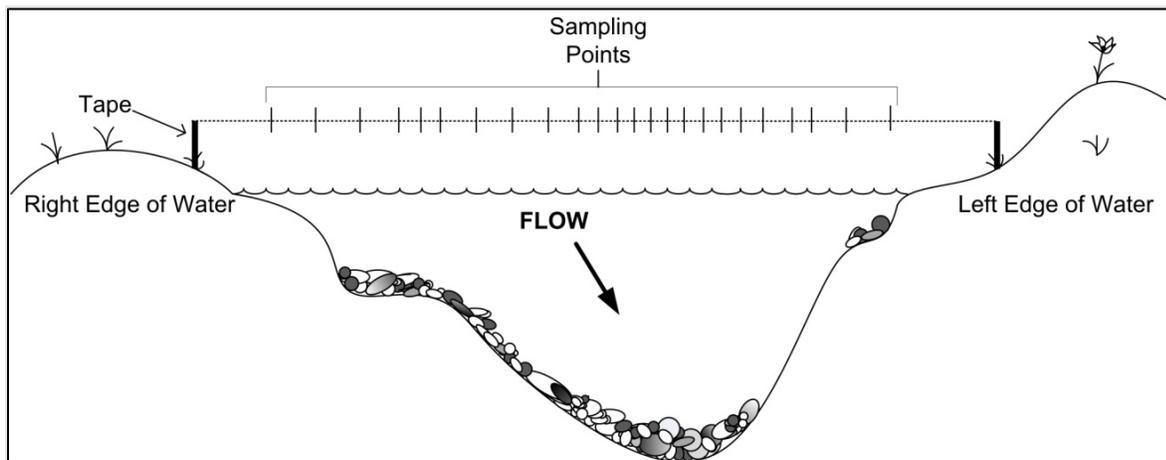


Figure 13. Example of uneven station spacing across a discharge transect at a wadable stream site using the Flowmeter Method. Note that non-laminar flow is assumed in this example.

B.2 Proper Techniques and File Setup

When collecting a discharge survey in a wadable stream using the Flowmeter Method the wading rod is to be held directly in front of the operator (at arm's length) at each station along the transect. The sensor bulb on the flowmeter must be pointed directly upstream into the flow and perpendicular to meter tape.

Do not stand upstream or downstream of the velocity meter but rather to the side (i.e. towards the right bank). Standing directly in front of or behind the flowmeter would create conditions that would cause errors in the velocity readings.



To set up a discharge file on the handheld flowmeter:

1. Turn the unit on by holding on the ON/OFF button.
2. In the main menu, select “Profiler” and press OK.
3. Under “Enter Operator Name”, enter the technician’s initials that is collecting the measurement and press OK.
4. Select “Stream” and press OK.
5. Select “Enter name for Stream” and press OK.
6. Enter the 4-letter site code for the stream name (i.e. “ARIK”) and press OK.
 - a. Note: Special characters, numbers, or any other deviations from the 4-letter site code will prevent the discharge file from being uploaded.
7. Select “Enter Stage Reference” and press OK.
 - a. Note: Discharge should not be measured if a staff gauge is either not installed, or is displaced at the site. The only exception is if discharge is being conducted during a reaeration sampling bout.
 - b. Submit a trouble ticket to Science.
8. Enter the water level on the staff gauge.
 - a. Note: During periods of moderate to high flow, waves may be creating fluctuating water levels at the staff gauge.
 - b. In these instances observe where the water level hits the gauge at the highest and lowest crest and record the value between those as the stage reference value.
 - c. Submit a trouble ticket to Science if the accuracy of a staff gauge measurement is in question.

B.3 Collecting Velocity and Depth Measurements

Once station spacing has been determined, navigate to the first station (01) along the meter tape at the right edge of water (REW) to begin the discharge measurement. Assess whether the right bank is undercut or not and follow the appropriate steps to begin the discharge measurement.

Setting the first station if the right bank is undercut:

1. Enter Edge/Obstruction = “Right”, as this is at the first station, the REW.
2. Select “Dist. To Vertical” value.



- a. Estimate where the edge of water is located along the meter tape and enter this value. Sometimes it's helpful to stick your foot or the flowmeter rod under the bank to help with this estimate.
3. Enter a Station Depth of 0.00m and select "Set Depth".
4. Note that with a depth of 0.00m entered the flowmeter will not allow you to measure velocity.
5. Scroll down to the screen and select "Next" to measure velocity at the next station.
6. Place the next station (02) just outside of where the bank meets the edge of water. Choose a station location that is close to the bank but allow some space so that the bulb of the flowmeter is not touching the side of the bank. Keep in mind that the velocity measured at this location will be extrapolated to the right edge of water.
7. Continue to **Step 3** below to measure velocity at sub-stations across the transect towards the left bank.

Setting the first station if the right bank is not undercut:

1. Enter Edge/Obstruction = "Right", as this is at the first station, the REW.
2. If prompted, enter Edge Factor = "0.75". This is the standard edge factor value for all NEON aquatic sites.
3. Select "Dist. To Vertical" value. Enter the value where the station location falls along the meter tape.
4. Determine the station depth.
 - a. Position the base of the flowmeter rod flat on the bottom of the streambed and note where the stream surface meets the graduated marks etched into the flowmeter rod.
 - b. Graduated marks are etched into the flowmeter hexagonal rod to allow for water depth measurement.
 - 1) The marks are delineated into 2 cm (one band mark), 10 cm (two band marks – the bottom double band), and 50 cm (three band marks).
 - c. Water depth measurements should be rounded to the nearest 1 cm.
 - d. If needed, practice this step prior to collecting the discharge measurement in order to familiarize yourself with the increments.
 - e. If the bank angle is negligible at the water's edge then the depth is typically zero, as this is the point where the water meets the surface.
 - 1) A depth of 0.00m should then entered and velocity cannot be measured.
 - a) If this is the case press OK and proceed to the next station.
5. Select "Set Depth" to enter the depth value at the station.



6. Select “Measure Velocity” (if depth >0.00m) and press OK.
7. Determine Velocity Point Method: one-point (60%), or two-point (20% and 80%) (**Table 7**).
 - a. If station depth is <0.45m, collect a one-point velocity measurement at 60% of the depth below the surface.
 - b. This velocity measured at this point of the water column is assumed to equal the mean velocity within the sampling station.
 - c. See **Section A.5.2** for instructions on setting the flowmeter rod to the appropriate depth.
8. If station depth is >0.45m, collect a two-point velocity measurement at 20% and 80% of the depth below the surface.
 - a. The average of these two measurements is assumed to equal the mean velocity within the sampling station.
 - b. See **Section A.5.2** for instructions on setting the flowmeter rod to the appropriate depth.
 - c. One-point (60% depth) and two-point (20% and 80% depth) measurements are relative to the stream surface equaling 0m.
 - 1) For example, if station depth = 0.50m, the first of the two-point velocity measurements (20% depth) would be collected 0.10m below the water surface, or 0.40m above the streambed.
 - 2) The second of the two-point velocity measurement (80% depth) would be collected 0.40m below the water surface, or 0.10m above the streambed.
9. Select “One Point” or “Two Point” Velocity Method depending on depth.
10. Set the wading rod to appropriate depth.
 - a. The wading rod must be adjusted in order to set the velocity meter at the correct depth in the streamflow (. . .)
 - b. The round sliding rod (located behind the hexagonal rod) is used to set the measurement depth and is scaled with 0.10m graduations from top (0.00m) to bottom.
 - c. A smaller scale on the handle of the hexagonal fixed rod is used to fine-tune the depth, and is scaled with 1 cm graduations (0 to 0.1m).
11. Listed below are three examples on how to collect velocity measurements at desired depths on the wading rod. See **Section B.1** to determine the amount and locations of velocity measurements required for various water depths in the field.
 - a. One-Point Velocity Method: 60% Depth, Station Depth = 0.36m
 - 1) The one-point velocity method requires no calculations by the user.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 2) Line up the 3 on the sliding rod (represents 0.30m total station depth) with the 6 on the handle of the fixed hexagonal rod (represents 0.06m total station depth).
 - a) Coupled, these two settings set the flowmeter at 60% of station depth 0.36m.
- b. Two-Point Velocity Method: 20% Depth, Station Depth = 0.72m
 - 1) Multiply the station depth by two ($0.72 * 2 = 1.44$ m) and round to the nearest centimeter (1.44).
 - 2) Line up the 14 on the sliding rod (represents 1.40m of the total station depth) with the 4 on the handle of the fixed hexagonal rod (represents 0.04m of total station depth).
 - a) Coupled, these two settings set the flowmeter at 20% of the station depth at 0.72m.
- c. Two-Point Velocity Method: 80% Depth, Station Depth = 0.72m
 - 1) Divide the station depth by two ($0.72 / 2 = 0.36$ m) and round to the nearest centimeter (0.36).
 - 2) Line up the 3 on the sliding rod (represents .30m of the total station depth) with the 6 on the handle of the fixed hexagonal rod (represents 0.06m of the total station depth).
 - a) Coupled, these two settings set the flowmeter at 80% of station depth 0.72m.
12. Once the flowmeter has been set to the correct depth and the correct velocity method has been selected, select "Capture" on the handheld flowmeter to begin measuring velocity.
13. The screen will display a graph showing the instantaneous values and the progress of the reading.
14. If velocities appear to be inaccurate or are fluctuating $> \pm 5\%$, repeat the reading.
15. If repeated velocity values seem inaccurate or are fluctuating $> 5\%$ during the measurement collection, consider the following causes:
 - a. Streamflow is turbulent. Increase the Fixed Period Averaging Time to 60 seconds in the Filter Parameters settings (See **Section A.4**).
 - b. There is an obstruction immediately upstream or downstream of the station location. Move the station location so that is not directly above or below the obstruction and try another velocity measurement.
 - c. Flowmeter was not calibrated correctly. Re-calibrate flowmeter and start discharge measurement over.
 - d. Flowmeter is low on batteries. Replace batteries in flowmeter and repeat measurement.
 - e. If you cannot diagnose the source of the problem, continue discharge measurement and submit a trouble ticket explaining the issue.



- f. Once the measurement has been completed (minimum 40 seconds) press OK to save data and move to the next station location.
16. Move to the next station location and repeat **Steps 3-16**. Note that you will not need to enter an Edge value as these stations should be in open water environments (not along the edge of a bank or near an obstruction).
17. If the left bank is undercut:
- a. The second to last station should be located just outside of where the left bank meets the edge of water.
 - b. Choose a station location that is close to the bank but allow some space so that the bulb of the flowmeter is not touching the side of the left bank.
 - c. Keep in mind that the velocity measured at this location will be extrapolated to the left edge of water.
 - d. Enter Edge/Obstruction = "Left".
 - e. Select "Dist. To Vertical" value.
 - f. Estimate where the left edge of water is located along the meter tape and enter this value.
 - 1) Sometimes it's helpful to stick your foot or the flowmeter rod under the bank to help with this estimate.
 - g. Enter a Station Depth of 0.00m and select "Set Depth".
 - 1) Note that with a depth of 0.00m entered the flowmeter will not allow you to measure velocity.
 - h. Proceed to **Step 19**.
18. If the left bank is not undercut:
- a. Enter Edge/Obstruction = "Left"
 - b. Select "Dist. To Vertical" value.
 - c. Enter a Station Depth (enter 0.00m if the bank angle is negligible).
 - d. Measure velocity (if possible).
19. Once the LEW station has been completed, select "Summarize Collection and Save Data".
- a. Observe "Channel Summary" and verify that units are in liters/second.
 - b. Verify that the last graph does not contain any red lines (a given vertical contains >10% of total discharge).
 - 1) If possible return to the station that contains >10% discharge and insert an additional station nearby so that the total discharge per vertical is reduced.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 2) Note that this may not be possible under certain low-flow conditions.
- c. Select "Save Data and Exit". This is a critical step as all data will be erased if this is not completed.
- d. Enter "Name of File".
- e. Use a unique file name to delineate discharge measurement in the following format "XXXXMMDD" where:
 - f. XXXX = 4-digit site ID (i.e. "GUIL")
 - g. MMDD = month, date of measurement
 - h. Example: "GUIL0927"
- 1) The flowmeter software only allows 8 characters to be used for each filename which makes it not possible to enter the year of the measurement. As such, at the end of each calendar year, delete all measurement files on the flowmeter, only after ensuring that each file on the flowmeter has been properly saved on the AOS dropbox and uploaded onto the SOM portal.

Table 7. Velocity point methods based on station depth using the Flowmeter Method at wadable stream sites.

Stream Depth at Measurement Location	Velocity Point Method
< 0.45 meters	One point - 60% of Depth
≥ 0.45 meters	Two point - 20% and 80% of Depth

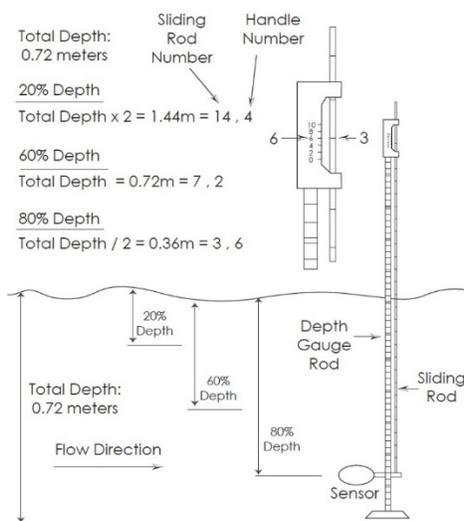


Figure 14. Wading rod adjustments at 60% (one-point), and 20% and 80% (two-point) depths. Station depth = 0.72m.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

B.4 Evaluating the Discharge Measurement in the Field

Following the discharge survey, the measurement file must be evaluated both in the field prior to leaving the site and again in the office prior to upload. In addition to impacts to data quality, certain errors in the discharge file will prevent the file from being uploaded.

The following criteria must be checked prior to leaving the field site (described in detail below):

- Potential data entry and configuration errors in the measurement file.
- Percentage of total discharge measured at each measurement station.
- Measured discharge vs. predicted discharge using the stage-discharge rating curve equation (if available).

Check for the following data entry and configuration errors in the measurement file before leaving the site:

1. Station (or location) values are increasing from the right (the first station) to the left (the last station).
2. Depth values were entered correctly (i.e. check decimal points, “0.8” instead of “8”).
3. Depth value at a given station is less than 10 times greater than the preceding station.
 - a. If this error occurs than stations were likely set too far apart in the transect.
 - 1) Additional velocity measurements should be collected between stations.
 - 2) Other than at the left/right edges, zero depth values (0.00m) should not be present within the discharge transect as continuous, laminar flow is desired throughout the cross-section.
 - 3) Consider clearing the cross-section of larger cobble in order to connect the transect hydrologically or move slightly upstream or downstream to a cross-section where water is flowing uniformly (more or less) across the transect.
 - a) Never measure discharge in a cross-section that is under a different hydrologic control than the staff gauge and pressure transducer.
 - b) Submit a trouble ticket to Science if the discharge transect was temporary re-located to facilitate these conditions.
4. The stream profile name was entered correctly (4-digit site code).
5. The stage reference value was entered correctly.
6. All units were set correctly.
7. The filter parameter was set correctly in flowmeter settings (minimum 40 seconds).

Evaluate the total percentage of discharge collected at each station before leaving the site:



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

NEON uses the mid-section method to compute stream discharge. In this method, the discharge transect is divided into rectangular sub-sections. The sub-section area extends laterally from half the distance from the proceeding station to half the distance to the next station. The width of the sub-section (variable across the transect) is calculated by subtracting the distance to the previous station from the distance to next station, then dividing by 2. The area of the sub-section is the width of the sub-section times the depth of each station. Discharge per station equals the sub-section area times the measured velocity. The total discharge is the summation of the discharge of all stations.

Most flowmeter models (HACH FH950) automatically calculate discharge per station and total discharge per measurement. Ideally, no more than 5% of the total measured discharge should be measured within a single station, but this can be difficult to achieve in small streams with narrow or irregular channels. In the flowmeter Channel Summary screen, the colors of each graph bar indicate the following conditions:

- Green: < 5% of total discharge was measured at the station
- Yellow: 5-10% of the total discharge was measured at the station
- Red: > 10% of total discharge was measured at the station

In general, no more than 10% of the total measured discharge should be measured within a single station. Following the discharge measurement, check the file to verify that this has not occurred (this functionality may not be available depending on the make and model of the flowmeter).

If it is observed that >10% of the total discharge was measured in one or more stations:

1. If >10% of the total discharge was measured in one or more stations in streams with a wetted width $\leq 2\text{m}$:
 - a. Reduce station spacing by increasing the total number of stations within the discharge transect.
 - 1) Concentrate additional stations in areas with more concentrated flow (maintain a minimum station spacing of 0.05m).
 - 2) This requirement may be very difficult to achieve in shallow, narrow, and/or irregularly-shaped stream channels.
2. If, despite these attempts, >10% of the total discharge is still collected in more than one station:
 - a. Save and upload the discharge measurement.
 - b. Submit a trouble ticket to Science that documents this occurrence.



Check the measured discharge value against the stage-discharge rating equation, if available:

Once a stage-discharge rating curve has been developed and validated for a site, a rating equation is derived that predicts discharge given stream stage (supplementary information on rating curves is available in **Appendix D**). Once established, rating equations will be provided to Field Science staff by Science. Rating equations are commonly expressed as power relationships:

$$Q = C_r(G - \alpha)^\beta$$

Where:

Q = discharge;

G = the stage, or gauge height;

α = the gauge reading corresponding to zero discharge; and

C_r and β = rating curve constants

Following the discharge measurement:

1. Enter the stream stage (G) into the rating equation that is associated with the site.
2. Calculate predicted discharge.
3. Evaluate whether the measured discharge is $\pm 10\%$ of the discharge predicted by the equation.
 - a. If the measured discharge is $< \pm 10\%$ than predicted discharge:
 - 1) Another discharge survey is not required.
 - b. If the measured discharge is $> \pm 10\%$ than predicted discharge (and the stream stage did not change during the site visit):
 - 1) Conduct another discharge survey immediately.
 - 2) If, after a second attempt, the measured discharge remains $> \pm 10\%$ the predicted rating discharge:
 - a) Check the second discharge measurement file for errors.
 - b) Upload both discharge measurements.
 - c) Submit a trouble ticket to Science.
 - (1) This may indicate a shift in the rating, which, if validated by additional measurements, would warrant an increase in the frequency of discharge measurements at the site. Post-Field Sampling Tasks: Wadable Stream Sites using the Flowmeter Method



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

SOP C Post-Field Sampling Tasks: Wadable Stream Sites using the ADCP Method

Once field verification of the measurement file is complete, 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.

C.1 Document Incomplete Sampling Within a Site

Discharge sampling is scheduled to occur at the prescribed sampling location according to the frequency and timing described in **Section 4** and **Appendix E**. Ideally, sampling will occur at this sampling location for the lifetime of the Observatory (core sites) or the duration of the site's affiliation with the NEON project (relocatable sites). However, sampling may be shifted from one location to another when sampling is compromised. In general, a sampling location is compromised when sampling becomes so limited that data quality is significantly reduced.

There are two main pathways by which sampling can be compromised. First, sampling locations can become inappropriately suited to answer meaningful biological questions – e.g., stream morphology changes in such a way that the discharge measurement quality is reduced. Second, sampling locations may be located in areas that are logistically impossible to sample on a schedule that is biologically meaningful.

For the wadable stream discharge sampling program, a given discharge transect must be sampled during 100% of the bouts expected for the site (see **Appendix E** for the number of expected bouts and associated site sampling documentation) over a one-year period. Transects that cannot be sampled on this schedule should be considered compromised.

If sampling at a given transect is not possible during a given bout a trouble ticket should be submitted by Field Science staff.

To document a missed discharge bout:

1. Create an incident with the following naming convention to document the missed sampling: 'AOS/TOS Sampling Incomplete: MOD – [Root Cause Description]'
 - a. Example: 'TOS Sampling Incomplete: CDW – Could not access plot due to permanently closed road'
2. Staff scientists review incident tickets periodically to determine whether a sampling location is compromised.



SOP D Data Entry and Verification: Wadable Streams using the Flowmeter Method

The handheld flowmeter serves as the data collection and storage device for discharge surveys at wadable streams using the Flowmeter Method. There are no field data sheets for this protocol. Electronic data should be uploaded via the handheld flowmeter to the appropriate location within seven days of collection. The maximum timeline for entering data is within 14 days of collection. See RD[04] for complete instructions regarding manual data transcription.

Export discharge measurement files from the handheld flowmeter to a local computer using the correct cable type (e.g., a USB to micro-USB cord) using the following steps:

1. Locate the USB connection port. Plug the correct ends of the connection cord into the display unit and the computer.
2. Turn the handheld flowmeter on.
 - a. A “PVM Drive” should appear on the computer screen.
 - b. Locate the utility via My Computer. Two folders should be present: P and RT.
 - c. Select the “P” folder.
 - d. 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., POSE0930.TSV). Copy the file to the computer in the appropriate folder.
4. Rename the file if needed (i.e. SITEYYYYMMDD.TSV).
5. Re-check the discharge files for potential errors as described in **Section B.4**.
 - a. If errors are present in the .TSV file make appropriate changes in a text editing program (i.e. NotePad ++)
– DO NOT use Microsoft Excel as this will disrupt file formatting.
 - b. Note that any changes made to station or depth values will not change station discharge or total discharge values.
 - 1) Once the file is uploaded onto the SOM Portal an R-script is generated that re-calculates station discharge and total discharge based on station, depth, and velocity values contained in the file. The total discharge value produced from this calculation is what is ultimate loaded onto the NEON Data Portal.
6. Upload one copy of the discharge file onto the AOS Dropbox in the appropriate site folder.
7. Upload another copy of the discharge file onto the SOM/WebUI Portal.
 - a. Resolve any upload errors that occur (**Table 8**).
 - b. If errors cannot be resolved submit a trouble ticket to Science.



Table 8. Troubleshooting errors encountered while uploading wadable stream discharge files collected with the Flowmeter Method onto the NEON SOM Data Portal.

SOM Upload Error	Error Description	Resolution
Locations values are not increasing.	Location values (or meter tape distances) must be increasing order in the discharge file. This error is usually a result of a recording typo.	If the error is clearly identifiable and can be fixed with confidence, edit the value in Notepad ++ and re-upload the .TSV file. If it is unknown what the value should be changed to, do not upload the discharge file.
Depth value is greater than 10 times that of the previous depth value (does not apply to the depth value in the second vertical).	This is meant to address recording typos such as entering "6.50m" instead of "0.65m". The second depth value is not subject to this rule as oftentimes the first vertical contains a depth value of 0m.	If the error is clearly identifiable and can be fixed with confidence, edit the value in Notepad ++ and re-upload the .TSV file. If it is unknown what the value should be changed to, do not upload the discharge file.
Invalid profile name. See line 1 in the .TSV file.	The Profile Name listed on the first line of the discharge file must be the 4-letter site code (i.e. "ARIK").	Edit the profile name in Notepad ++ to the correct 4-letter site code (no dates, etc.) and re-upload the discharge file.
Filter parameter time is set to a value less than 10 seconds (i.e. 6). See line 17 in the .TSV file.	This is a setting in the HACH flowmeter used for fixed point averaging that controls the length of time each velocity measurement was collected.	If this error exists in the discharge measurement file it cannot be fixed and the file cannot be uploaded. Prior to the next discharge measurement, set the filter parameter time to = 40 seconds in HACH settings.
Stage reference value is >8.00 meters. See line 5 in the .TSV file.	Observed stream stage for wadeable stream discharge measurements is not likely to exceed 8.00m. This error is usually a result of a recording typo.	If the error is clearly identifiable and can be fixed with confidence, edit the value in Notepad ++ and re-upload the .TSV file. If it is unknown what the value should be changed to, do not upload the discharge file.



8 REFERENCES

- Braca, Giovanni. 2008. Stage-discharge relationships in open channels: Practices and Problems. FORALPS Technical Report, 11. Universita degli Studi di Trento, Dipartimento di Ingegneria Civile e Ambientale, Trento, Italy, 24 pp.
- Clow, D. W. 2010. Changes in the timing of snowmelt and stream flow in Colorado: a response to recent warming. *Journal of Climate* 23:2293–2306.
- Cuffney, T. F., R. A. Brightbill, J. T. May, and I. R. Waite. 2010. Response of benthic macroinvertebrates to environmental changes associated with urbanization in nine metropolitan areas. *Ecological Applications* 20:1384–1401.
- Den Herder, J. (2018, April). Acoustic Doppler Current Profilers: Theory of Operation. Presentation at CC Lynch Acoustic Doppler Current Profiler Workshop, Houston, TX.
- Dodds, W. K., K. Gido, M. R. Whiles, K. M. Fritz, and W. J. Matthews. 2004. Life on the edge: the ecology of Great Plains prairie streams. *BioScience* 54:205–216.
- Grimm, N. B., and S. G. Fisher. 1984. Exchange between interstitial and surface water: Implications for stream metabolism and nutrient cycling. *Hydrobiologia* 111:219–228.
- Mims, M. C., and J. D. Olden. 2012. Life history theory predicts fish assemblage response to hydrologic regimes. *Ecology* 93:35–45.
- Mueller, D.S., and Wagner, C.R., 2006, Application of the loop method for correcting acoustic Doppler current profiler discharge measurements biased by sediment transport: U.S. Geological Survey Scientific Investigations Report 2006–5079, 18 p.
- Mueller, D.S., Wagner, C.R., Rehm, M.S., Oberg, K.A., and Rainville, Francois, 2013, Measuring discharge with acoustic Doppler current profilers from a moving boat (ver. 2.0, December 2013): U.S. Geological Survey Techniques and Methods, book 3, chap. A22, 95 p.
- Poole, G. C., and C. H. Berman. 2001. An ecological perspective on in-stream temperature: natural heat dynamics and mechanisms of human-caused thermal degradation. *Environmental Management* 27:787–802.
- Rantz, S. E., et al., 1982. Measurement and Computation of Streamflow, Vols. 1 and 2. U.S. Geological Survey Water-Supply Paper 2175.
- Schoonover, J. E., B. G. Lockaby, and B. S. Helms. 2006. Impacts of land cover on stream hydrology in the west Georgia Piedmont, USA. *Journal of Environmental Quality* 35:2123–2131.
- Simpson, M. R., 2001. Discharge measurements using a broadband acoustic Doppler current profiler. USGS Open-File Report 01-1.



<i>Title:</i> AOS Protocol and Procedure: Stream Discharge		<i>Date:</i> 06/19/2020
<i>NEON Doc. #:</i> NEON.DOC.001085	<i>Author:</i> N. Harrison	<i>Revision:</i> G

Teledyne RD Instruments, 2015. RiverPro and RioPro ADCP User's Guide.

Teledyne RD Instruments, 2018. WinRiver II Software User's Guide.

Turnipseed, T.P., and Sauer, V.B.. 2010. Discharge Measurements at Gaging Stations: U.S. Geological Survey Techniques and Methods 3-A8. From <http://pubs.usgs.gov/tm/tm3-a8/>, accessed March 25, 2011.

Zeigler, M. P., A. S. Todd, and C. A. Caldwell. 2012. Evidence of Recent Climate Change within the Historic Range of Rio Grande Cutthroat Trout: Implications for Management and Future Persistence. Transactions of the American Fisheries Society 141:1045–1059.



APPENDIX A DISCHARGE MEASUREMENTS AT WADEABLE STREAM SITES USING THE ADCP METHOD

The following sections provides instruction on how to complete discharge surveys at NEON wadable stream sites using acoustic Doppler current profiler (ADCP) instrumentation.

A.1 Introduction: Discharge Measurements at Wadable Stream Sites Using the ADCP Method

An acoustic Doppler current profiler (ADCP) uses sound to measure water velocity based on the Doppler Effect, a principal of physics discovered by Christian Johann Doppler in 1842. Doppler's principal relates the change in frequency of a source to the relative velocities between the source and the observer. An ADCP applies the Doppler principle by reflecting an acoustic signal off small particles of sediment and other material (scatterers) that are present in water. The velocity measured by the Doppler principle is parallel to the direction of the transducer emitting the signal and receiving the backscattered acoustic energy.

NEON utilizes ADCPs to measure discharge at NEON aquatic sites that contain wadable stream and rivers. NEON stream discharge measurement collection at wadable stream sites involves mounting a StreamPro ADCP (TRDI) within a trimaran float and utilizing a tethered rope system to pull the float back and forth across the channel so that so that the base of the ADCP is beneath the water surface. The ADCP contains four beams pointed at 20 degrees from the vertical that can continuously measure water depth, water velocity, and instrument speed. Discharge and velocity calculations performed by ADCPs during streamflow measurements are well-documented in the literature (Mueller et al., 2013; TRDI, 2015) but the basic premise is as follows (Den Herder, 2018):

- The ADCP instrument transmits short pulses of sound at fixed frequencies into the water.
- The transmitted sound bounces off scattered material suspended in the water (sediment, microscopic organisms, etc.). The returned signals from these scatterers are shifted in frequency.
- The returned signals from each beam are used to create the water currents in east, North, and Vertical velocity vectors.
- Returned signals are continuously processed into separate depth cells (or bins) to provide a profile of the water column
- Binned velocity and depth are integrated to calculate bin discharge, which are then summed to calculate total discharge
- Multiple discharge transect measurements are completed and mean discharge across transect measurements is calculated and reported as total discharge.

The ADCP measures the relative motion of the water to the ADCP by correcting the measured water velocity with the measured velocity of the vessel used to deploy the instrument (boat, trimaran float, etc.). The velocity of the vessel can be calculated in two ways: externally via a global positioning system unit (GPS), or internally utilizing ADCP bottom tracking technology. The ADCP divides the water column into depth cells (or bins) and reports a velocity for each depth cell.

The ADCP software integrates total bin velocity over the bin depth to obtain bin discharge. The resulting sub-section discharges are then summed over the width of the cross-section to obtain total measured



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

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 stream 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. On average it is expected to take an experienced field crew 30-75 minutes to complete a stream discharge measurement from start to finish.

SOP E Preparing for Sampling: Wadable Stream Sites Using the ADCP Method

E.1 Preparing for Data Capture

Prior to leaving the office ensure that the following criteria are met:

- All necessary equipment is gathered and prepared (**Table 12**)
- Make sure GPS is fully charged and batteries in ADCP are fully charged
- Setup ADCP and GPS on trimaran float
- Setup and test Bluetooth communications between the ADCP and laptop
- Setup and test GPS communications
- If the site has an approved stage-discharge rating curve, the current rating equation is available for measurement comparison/validation.

E.2 Installing the StreamPro ADCP and SX Blue II GPS Antenna onto the Trimaran Float

The StreamPro ADCP and SX Blue II GPS antenna (includes electronics housing with sun shield) are used in conjunction at most NEON wadable stream sites (**Appendix E**). Both units must be securely connected to the trimaran float (**Figure 14**) prior to beginning the discharge survey. An Allen wrench and the hand tool that is provided with the GPS are required. This is a one-time installation that must be conducted upon receiving the instrumentation. Following this installation the full configured unit (trimaran float with ADCP and GPS instrumentation) can be transported and stored as is, with batteries replaced as needed. The GPS can be removed later at the DSF to charge.

To assemble the StreamPro ADCP and SX Blue II GPS antenna to the trimaran float:

1. Attach the ADCP arm to the bow of the trimaran float using thumbscrews.
2. Pull the StreamPro ADCP through the bottom of the hole of the ADCP arm.
 - a. Line up the arrow on the ADCP to the front of the ADCP arm (facing towards the bow of the trimaran float).



- b. Line up the grooves in the side of the StreamPro ADCP with those in the ADCP arm.
 - c. Pull through all the way but don't tighten the adjacent thumbscrew yet.
 3. Plug the ADCP cable into the electronics housing.
 - a. Line up the prongs and twist the outer ring to secure the cable.
 4. Connect the GPS arm to the GPS antennae using an Allen or adjustable wrench.
 - a. Hand tightening will cause the antennae to come loose from the arm.
 5. Remove the thumbscrew on the side of the ADCP arm in front of the ADCP.
 6. Place the GPS arm over the ADCP arm.
 - a. Make sure that the thinner side of the GPS arm rests on the front left side of the ADCP arm.
 7. Slide the thumbscrew through the hole in the GPS arm and tighten to connect it to the ADCP arm. Ensure this is tight as this screw and arm secure the sensor in place by tightening the clamp/opening.
 8. Remove the front plate of the ADCP electronics housing by disconnecting the three thumbscrews.
 9. Remove the battery pack and insert 8 charged AA batteries.
 10. Insert battery pack and replace front plate of the ADCP electronics housing.
 - a. Make sure the thin rubber lining is still in place around the top of the battery pack enclosure.
 - b. Remove batteries following Bluetooth configuration and testing so that they do not drain.
 11. Remove the two corner screws that connect the GPS battery pack to the GPS electronics housing.
 - a. These are the screws that line up to the holes in the GPS sun shield.
 - b. These screws are no longer used in the assembly.
 12. Using the two sets of GPS hardware provided (screws, spacers, washers) connect the GPS sunshield to the base of the GPS electronics housing (at the battery pack).
 13. Connect the GPS sun shield to the top of the ADCP electronics housing using the four thumbscrews.
 14. Connect the GPS antennae to the GPS electronics housing using the thin copper cable.
 - a. The straight end of the cable connects to the GPS antenna, the angled end connects to the GPS electronics housing.
 15. Installation is now complete. The unit can remain installed as is during times of transport, measurement use, and storage.

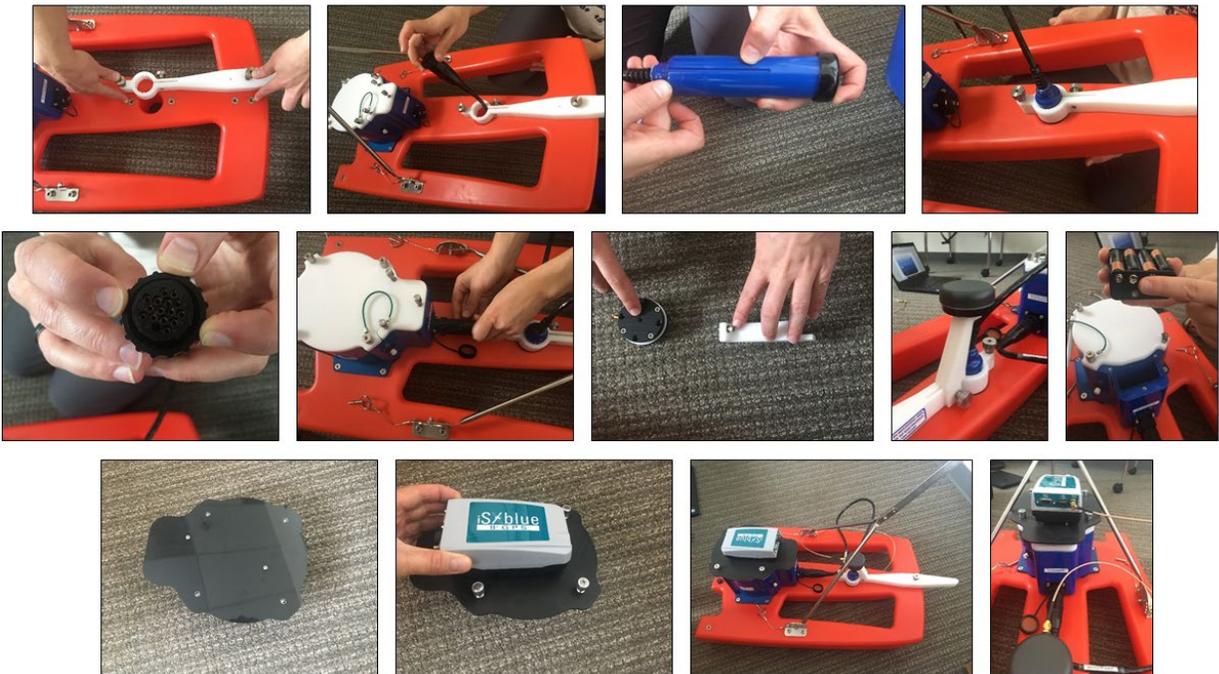
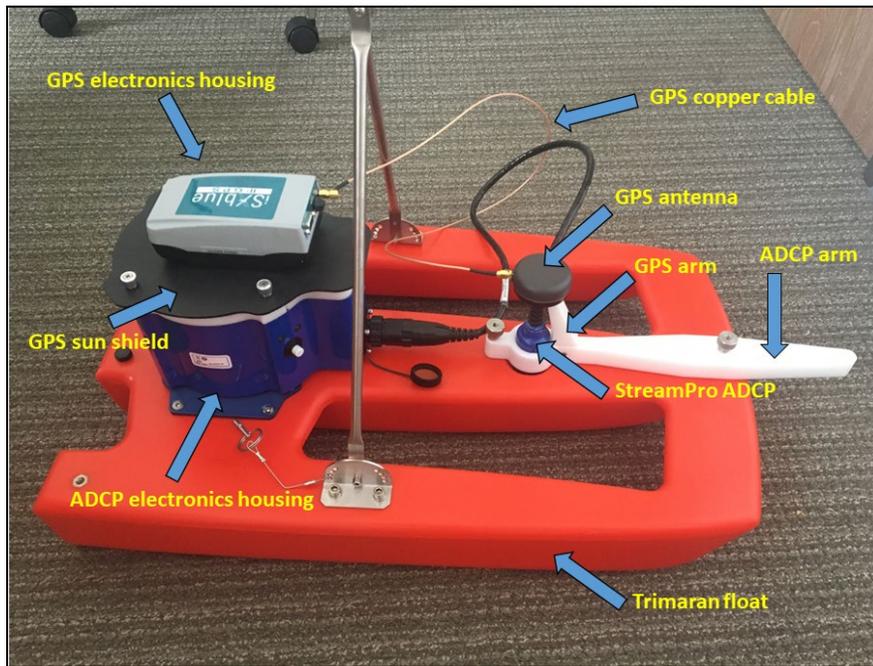


Figure 15. Above: Trimaran float, StreamPro ADCP, and SX Blue II GPS antenna components; Below: Illustrated workflow (top left to bottom right) detailing how to configure the StreamPro ADCP unit and SX Blue II GPS antenna to the trimaran float.



E.3 Installing the RiverPro ADCP and Hemisphere V102 GPS Antenna onto the Trimaran Float

The RiverPro ADCP and Hemisphere V102 GPS antenna + electronics housing are used at select NEON wadable stream sites (**Appendix E**). Both units must be securely connected to the trimaran float (**Figure 15**) prior to beginning the discharge survey. Note that the trimaran float used to house the RiverPro ADCP is a larger model than the one used to house the StreamPro ADCP.

To assemble the RiverPro ADCP and Hemisphere V102 GPS antenna to the trimaran float:

1. Unfold the outrigger hulls from main hull by removing the pin in the bridle.
2. Connect the RiverPro ADCP to the GPS mount using M6 socket head cap screws (5mm Hex) and flat washers.
3. Insert the ADCP mounting plate into the moon pool lid.
4. Connect the ADCP cable from the trimaran float.
 - a. Ensure that the Teledyne logo (flower) lines up when it the cable is plugged into the ADCP. The instrument will not work if the cable is plugged in upside down.
5. Connect the GPS cable to the Hemisphere V102 GPS and attach the GPS antenna to the GPS mount using 4 M8x16mm screws with lock and flat washers.
6. Attach the support braces, ADCP mounting plate and the GPS mount (with GPS antenna attached) to the main hull by aligning screw holes and tightening thumb screws.
7. Attach the GPS cable to the main hull by unscrewing the yellow cap and tightening the cable connector to the port.
 - a. These are the same type of cable connectors on the GPS antenna, ensure that the port is aligned, push in to connect, and rotate to tighten the connection.
8. Unscrew the cap to the electronics compartment.
9. Insert the 12V battery into the foam block to the secure battery.
10. Connect the two internal cables (GPS and ADCP/battery) within the compartment.
11. Connect the black spade lug connector to the battery negative terminal.
12. Connect the red spade lug connector to the battery positive terminal.
13. Close and tighten the electronics compartment lid so that it is completely sealed.
14. Unfold the rear boat fins.
15. During operation and testing, turn on the main power switch located on the main hull to power the ADCP and GPS units.

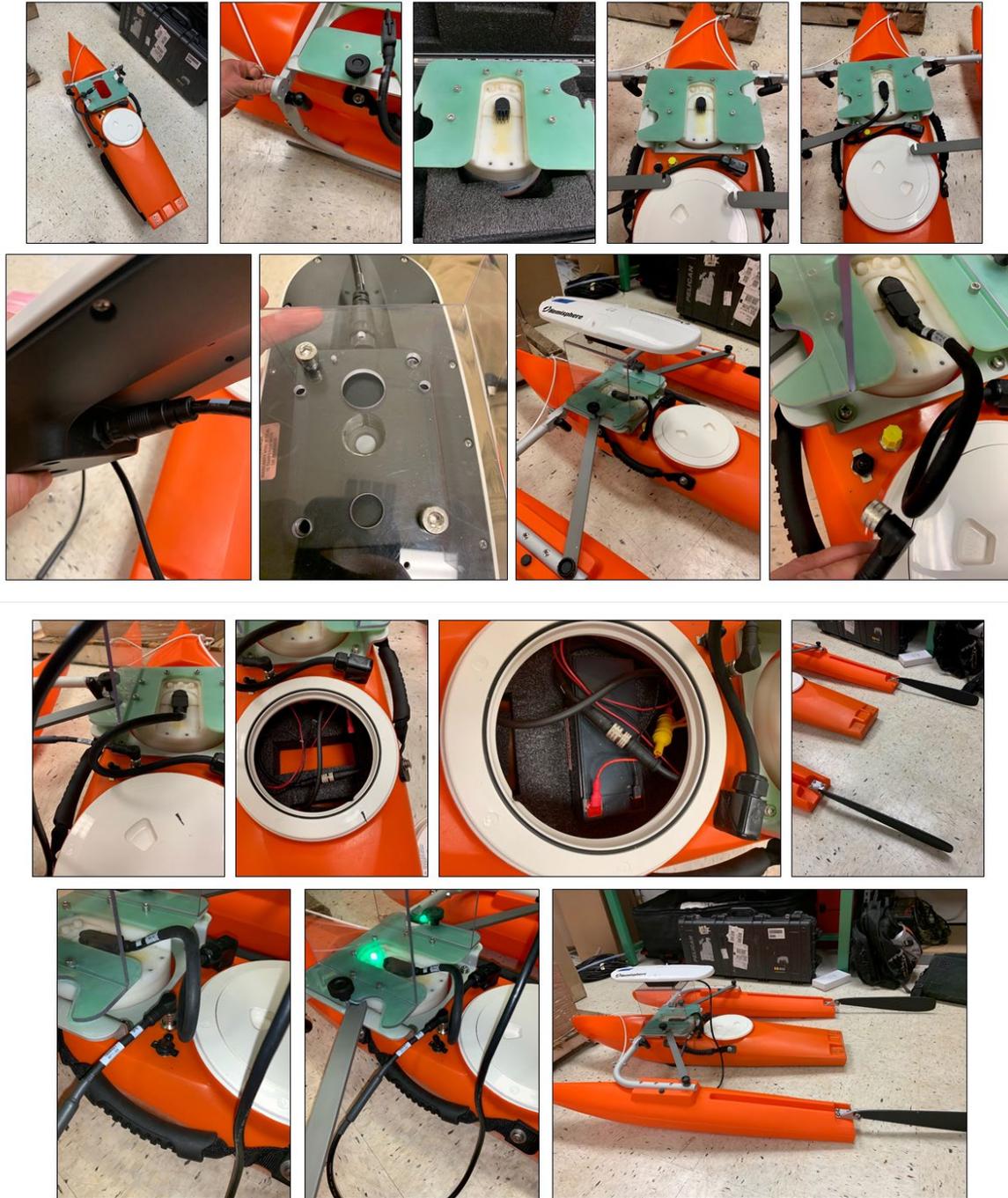


Figure 16. Illustrated workflow (top left to bottom right) detailing how to configure the RiverPro ADCP unit and the Hemisphere GPS antenna to the trimaran float.



E.4 Establishing Bluetooth Connections for the ADCP and SX Blue II GPS antenna

The StreamPro ADCP and SX Blue II GPS antenna communicate with WinRiver II software (installed on the laptop) wirelessly via a Bluetooth (wireless) connection. Two Parani SD1000U Bluetooth transmitters, or dongles, are required to send data – one for the ADCP and one for the GPS antenna. It is a good idea to have an extra dongle on hand in the field as a spare. The Parani Bluetooth dongle contains a USB interface adapter that is plugged into a laptop COM port. Parani Bluetooth dongles are setup and configured using [ParaniWin software](#). This executable must be downloaded and installed on the laptop used for ADCP discharge measurement.

If the same laptop is used for ADCP measurements (this is recommended for ease of communication setup and software availability) the following setup should only need to occur prior to the initial measurement. Following the initial setup, the ADCP and GPS antenna should automatically connect to the laptop software via the dongles. These steps should also be used when troubleshooting connection problems. Setup, testing, and troubleshooting is best done in the office prior to deployment in case an internet connection is needed. An ADCP discharge measurement cannot be completed if Bluetooth communications are not properly configured.

To avoid confusion, it is helpful to label one dongle “ADCP” and the other “GPS” and place a sticky note near the laptop port each are plugged into that designates an “ADCP” or “GPS” connection.

Physically configure the ADCP and the GPS Bluetooth dongles (**Figure 16**):

1. Each Parani dongle has a set of four DIP switches that are used to set the Bluetooth adapter’s baud rate and data flow control.
2. These DIP switches need to be in the correct physical configuration using a small screwdriver, pocket knife, pen, or similar tool.
3. Move the DIP switches to the correct position in order to set the Baud Rate to 11520Kb on both Parani dongles. The diagram on the left of each dongle shows which how the positions of each switch relate to baud rate configuration.
4. Set the first and second DIP switches to the right.
5. Set the third switch to the left (115200 baud rate)
6. Set the fourth (bottom) switch to the left (HW Flow Control OFF).

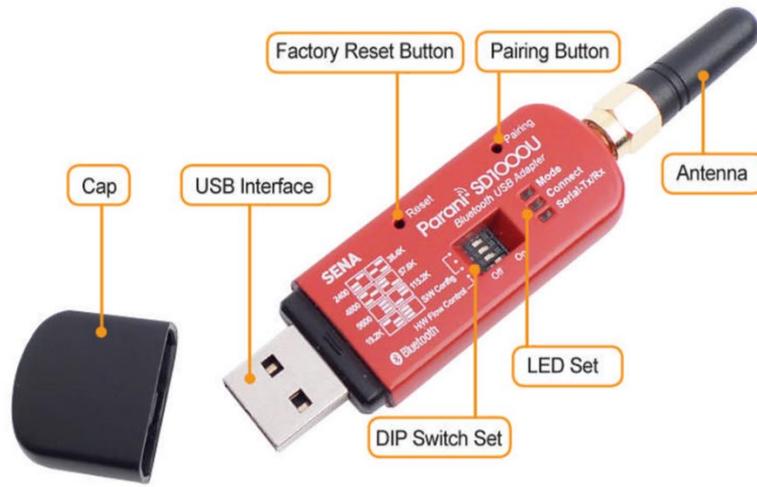


Figure 17. Top: Parani-SD1000U USB Bluetooth Adapter with default settings. Bottom: Correct settings for ADCP and GPS Bluetooth configuration.

Once physically configured, each dongle needs to be initially setup with the ParaniWin software. Complete the following steps for the ADCP dongle, then repeat for the SX Blue II GPS dongle (note that this information is also contained in the document entitled “Guidance for StreamPro Bluetooth setups” that is included with all ADCP materials):

1. Ensure that the ADCP and GPS units are powered and fully connected to the trimaran float.
2. Plug the Parani dongle into a USB port on the laptop.
3. Use Windows Device Manager to determine the laptop COM (communication) port that the Parani is assigned to.
 - a. Navigate to the Windows Device Manager.
 - 1) Start Menu > Search “Device Manager”
 - b. Open the “Ports (COM & LPT)” node.
 - c. Note the COM port number assigned to.



- 1) Unplug and re-connect the Parani dongle to note which COM Port number appears and re-appears. This is the COM Port the Parani dongle is assigned to.
 - (1) If using Windows XP and later systems, the driver will likely load automatically when you plug in the Parani dongle.
 - (2) If the Parani is not showing up in the Ports (COM & LPT) node, it may show up in the "Other Devices" node.
 - (a) If this is the case an update to [Parani firmware](#) is required (under the picture of the dongle, find the Downloads tab, click on the firmware link, and click the download button to save the file to a known folder).
 - (b) Once complete, open Windows Device Manager, right click on the appropriate COM Port that the Parani is assigned to and navigate to the Drivers window.
 - (c) Choose "Browse my computer software for driver software". Click next and it will respond with a message of success or failure.
 - (d) If successful, close this window and return to Windows Device Manager. The Parani should now appear under the COM Ports node.
 - (e) If unsuccessful contact Science for troubleshooting.
- d. Select the Parani SD100U dongle COM Port and set the baud rate to 115200.
 - 1) Right click on the COM port assigned to the Parani dongle and select "Properties" > "Port Settings".
 - 2) Configure Port Settings.
 - a) Bits per second = 115200.
 - b) Data bits = 8
 - c) Parity = None
 - d) Stop bits = 1
 - e) Flow control = None
 - 3) Click on the Advance Settings button.
 - a) Check the COM Port number assigned to the Parani in the top of the Advanced Settings window.
 - b) In the BM Options section, select the Latency Timer drop down and set to 1msec.
 - c) Click OK twice to exit Windows Device Manager.
4. Note the LED indicators on the Parani dongle.



- a. The “Mode” LED indicates which mode the Parani dongle is currently configured to.
 - b. Ensure the Parani dongle is set to MODE1, the LED will blink green at 1 second intervals.
 - c. The “Connect” LED indicates whether the Parani dongle is connected to the ADCP/GPS unit, the LED will blink green at 1 second intervals.
5. Open ParaniWin software to configure the Bluetooth connection.
- a. The UART Setting window will automatically pop up that displays the communication settings between the Parani dongle and the laptop. Ensure that the configured settings are set correctly. Notes: these settings must COM Port and physical dongle settings or the connection will not be possible.
 - 1) Serial port: Select the laptop COM port number the Parani dongle is assigned to (as shown in Windows Device Manager).
 - 2) Baud rate: 115200
 - 3) Parity: None
 - 4) StopBit: 1
 - 5) Click “OK”. Initial configuration should be complete.
 - b. Select the “Device Setting” tab.
 - 1) Set “Operation Mode” to “Mode1”.
 - 2) Check that Device Settings are the same as what was entered in the UART Setting Window.
 - 3) Under “Security Option” check the “Authentication” box and enter “0000” for the “Pin Code”.
 - 4) Click “Apply”.
 - 5) A “Completed Configuration” message should pop up.
 - a) If the connection was unsuccessful: review physical Parani dongle settings, COM port settings in Windows Device manager, and settings entered in ParaniWin and repeat process.
6. Select the “Connection (out)” tab.
- a. Click the “Search” button. This will ping all available wireless networks that are within range of the laptop.
 - b. Chose the desired instrument to connect to and click “Connect”.
 - 1) The ADCP should be shown as “RDI SPro”.
 - 2) The GPS should be shown as “iX Blue GPS”.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- a) These labels may vary.
- 3) Click “Connect”.
- c. A window will pop up with a “Connected successfully message”.
- d. One of the lights on the ADCP will turn blue, indicating that the Bluetooth connection was successful.
 - 1) If the connection was unsuccessful:
 - a) Review physical Parani dongle settings, COM port settings in Windows Device Manager, and all settings entered in ParaniWin.
 - b) Repeat process.
7. Repeat the above steps for the GPS dongle.
8. Once both ADCP and GPS dongle connections have been successfully connected, close the ParaniWin program.
 - a. **If the ParaniWin program is not closed, WinRiver II will not be able to connect to the ADCP.**

E.5 Testing GPS and ADCP connections in WinRiver II

Once both ADCP and SX Blue II GPS dongle connections have been successfully connected via Bluetooth, the connections must be tested in WinRiver II in order to ensure that data can be transmitted to the program. This must be done prior to each discharge survey that utilizes ADCP instrumentation and is best completed in the office in case additional troubleshooting is needed.

1. Ensure that the ADCP is fully powered (green light on) and setup for Bluetooth communications via the Parani dongle (blue light on).
2. Open WinRiver II.
3. In the WinRiver II main screen, click Configure > Peripherals.
 - a. Test ADCP communications.
 - 1) Ensure that the ADCP is fully powered (green light should be on) and the ADCP Parani dongle is installed in the designated COM Port.
 - 2) In the “Peripheral Configuration Dialog” window, under the “Peripherals” node, double click on “Read Serial Raw ADCP Data”
 - 3) Double click on “Port: ADCP Serial Port”
 - 4) Check that COM settings are correct and press OK.
 - 5) With “Port: ADCP Serial Port” still highlighted, click the “Test Port” button on the right.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 6) A dialogue box will open and you should see some information begin streaming regarding Teledyne StreamPro firmware. This indicates that the ADCP is recognized by the WinRiver II program (**Figure 17**).
 - a) If nothing appears than WinRiver II is not recognizing the ADCP.
 - b) Ensure that ParaniWin is closed. If open, close this program and repeat the Peripheral test.
 - c) If ParaniWin is closed and the Bluetooth connection was successful in that program, check COM settings in “Port: ADCP Serial Port” and repeat the Peripheral test.
 - d) If nothing appears in the test window continue on to the next step for GPS testing. Further ADCP testing can be completed in the Configuration Dialogue tab of the Measurement Wizard window.
- 7) Click “Stop” and “Close” to cease testing and close the test dialogue window.
- b. Test GPS communications.
 - 1) Ensure that the GPS antenna is fully powered (green light should be on) and the GPS Parani dongle is installed in the designated COM Port.
 - 2) In the “Peripheral Configuration Dialog” window, under the “Peripherals” node, double click on “Read NMEA GPS Data 1”.
 - 3) Double click on “Port: GPS Serial Port”
 - 4) Check that COM settings are correct and press OK.
 - 5) With “Port: GPS Serial Port” still highlighted, click the “Test Port” button on the right.
 - 6) A dialogue box will open and you should see streaming GPS data (**Figure 18**). This indicates that the GPS is being recognized by the WinRiver II program.
 - a) If nothing appears than WinRiver II is not recognizing the GPS.
 - b) Ensure that ParaniWin is closed. If open, close this program and repeat the Peripheral test.
 - c) If ParaniWin is closed and the Bluetooth connection was successful in that program, check COM settings in “Port: GPS Serial Port” and repeat the Peripheral test.
 - d) If nothing appears in the test further GPS testing can be completed in the Configuration Dialogue tab of the Measurement Wizard window.
 - 7) Click “Stop” and “Close” to cease testing and close the test dialogue window.
- c. Click “Close” to return to the main WinRiver II screen.
4. Once all configuration and testing is complete ADCP batteries should be removed and stored with field gear so as not to drain them.



E.6 Navigate to the Discharge Transect

If a discharge transect, or cross-section, has already been established, the bounds should be permanently marked using stakes or plot markers (one on each side of the stream). Navigate to this location and proceed to **Section E.7**.

If a discharge transect has not been established at the site proceed with the following steps:

1. Determine an appropriate location to establish a discharge transect.
 - a. At wadable stream sites the transect location must be located in the riffle habitat unit in close proximity (just downstream) of the pool where the staff gauge and sensor set are installed. Consult with Science if the sensor set location is unknown, has not yet been established, or if an alternative location is best suited to measure discharge at higher flows.
 - b. An ideal discharge transect will:
 - 1) Be located in a reasonably straight channel with velocity lines that are more or less parallel to each other.
 - 2) Contain velocities that are, for the most part, > 0.15 m/s, and depths that are, for the most part, > 0.15 m.
 - 3) Contain a stable streambed free of obstructions that would create eddies, slack water, and turbulence.
 - 4) Contain measurement sections that are roughly parabolic, trapezoidal, or rectangular.
 - 5) Contain a stable downstream control feature.
 - c. Take a picture of the transect location that best meets this criteria as well as the downstream control feature and send to Science for consultation.

E.7 Assess the Discharge Transect

Prior to collecting the discharge measurement identify any instrumentation or environmental issues that would negatively affect data quality. Document any temporary hydrologic conditions in the (AOS) Field Metadata and Gauge Height [PROD] app in Fulcrum. If conditions are unfavorable to discharge measurement collection, submit a trouble ticket and consult with Science.

Unfavorable conditions include, but are not limited to:

1. The staff gauge is either not present or has been displaced in some way.
 - a. A discharge measurement should not be collected if a staff gauge is not present at the site or the gauge has been displaced in any way.
 - b. Submit a trouble ticket to Science that includes photos of the gauge.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- c. If the staff gauge is topped during high flows and a discharge measurement can be safely collected, attempt to mark or in some way reference the elevation of the edge of water (only do so if this can be accomplished in a safe manner). A future survey of this location (relative to the staff gauge) can provide an estimate of gauge height during the measurement.
 - d. Note that if a discharge survey is associated with a reaeration sampling event, discharge should still be measured regardless of staff gauge presence.
2. A pressure transducer is either not present or has been displaced in some way.
 - a. A discharge measurement **may be collected** in the event that the pressure transducer is missing or has been displaced. However the absence of this instrument prevents continuous discharge from being estimated.
 - b. Submit a trouble ticket to Science immediately if the pressure transducer is missing or has become displaced.
 3. Streamflow is exceeding the banks causing unsafe conditions on the floodplain.
 - a. Refer to NEON Operations Field Safety and Security Plan (AD[02]) for details.
 4. There is an insufficient amount of water in the channel or bed conditions are not suitable to conduct ADCP velocity measurements.
 - a. Consider using the Flowmeter Method.
 - b. See **Section 4.2.1**.
 5. Refer to NEON Operations Field Safety and Security Plan (AD[02]) and NEON Operations Field Safety and Security Plan (AD[02]) for further details.

SOP F Field Sampling: Wadable Stream Sites Using the ADCP Method

F.1 Install the Temporary High Line ADCP Deployment Assembly

The Temporary High Line is a mechanical assembly used to deploy ADCP's with trimaran floats at NEON wadable stream sites. A guideline runs through a tripod system and across the channel to orient the trimaran float in the streamflow. An additional line runs through the guideline and is supported by crew members on each side of the stream that work together to pull the float steadily across the discharge cross-section.

The Temporary High Line is comprised of the following components (**Figure 19**):

- Tripod (supports the winch and pulley posts on the near bank, levels the guideline)
- Winch post (connects to pulley post, tightens the guideline)
- Pulley post (connects to winch post, guides the guideline)



- Guideline rope (rope or twine that is set between the tripod on the near shore and a fixed point on the opposite shore, orients the float as it is pulled across the channel by the Control Rope)
- Guideline support (metal tube that connects the Guideline rope to Trimaran rope)
- Guy wire + earth anchor (supports winch post/pulley post/tripod assembly on the near bank)
- Guy wire driving rod (support guy wire)

Additional materials required:

- Control rope (long length of rope used to pull the float back and forth across the channel)
 - Strong rope such as climbing rope is recommended.
 - Length required: twice the wetted width of the stream + extra length to accommodate the distance between the wetted width and where staff are operating the rope on both banks.
- Trimaran rope (a short section of rope that connects and orients the float off the Guideline rope).
 - Strong rope such as climbing rope is recommended.
 - Length required: dependent on surface water velocity conditions during the time of the measurement (maximum length needed is not likely to exceed ~1.5 meters).
 - Higher velocity levels mandate a longer section.
 - Lower velocity levels mandate a shorter section.
- Carabiner (connects the float to the Trimaran rope)
 - Locking carabiners are recommended.
 - Two spares are recommended.
- A small hammer to drive the guy wire earth anchor into the substrate.

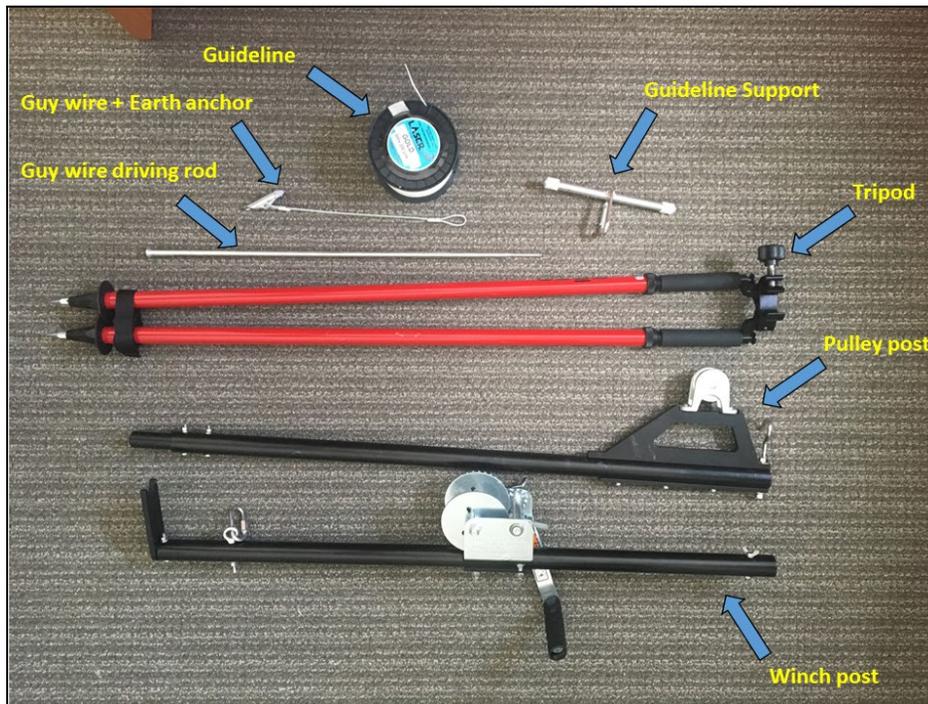


Figure 20. Parts included with the Temporary High Line Assembly.

To assemble the Temporary High Line (**Figure 20**):

1. Remove the wingnuts on the top of the winch post.
2. Slide the base of the pulley post into the top of the winch post.
3. Set connect winch and pulley at an angle into the tripod.
4. Set the winch handle so that is facing away from the winch gears.
5. Loop the guideline through the two holes on the side of the winch and knot them together.
6. Crank the winch handle so that the guideline is looped through the winch assembly.
7. Once a sufficient length of guideline is looped through the winch assembly bring the end of the guideline over the pulley (at the top of the pulley post) and through the hook.
8. Securely attach the end of the guideline to a point on the opposite bank keeping in mind the following criteria.
 - a. A tree, post, or stake can be used to secure the guideline on the opposite bank so that it is very sturdy and will not move during the measurement.
 - b. The guideline should be slightly upstream ($\sim 0.5 - 1.0\text{m}$) of the discharge transect.
 - c. The guideline must be perpendicular to the streamflow.
 - d. The guideline should be nearly level from the near to opposite bank.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

9. Lock the winch by setting the trigger tab at the top of the assembly to “ON”.
10. Crank the winch until there is no slack in the guideline between the tripod and the opposite bank.
11. Attach the guy wire to the base of the winch post using the carabiner and thread this wire through the notch at the very bottom of the post.
12. Set the driving rod into the guy wire earth anchor and hammer the rod into the substrate to refusal.
13. On the Guideline support, line up the space between the white plastic lockers and the space that runs along the length of the bracket.
14. Attach the Guideline support to the Guideline between the tripod and the opposite bank.
 - a. Place the guideline through the carabiner.
 - b. Slide the guideline through the space along the length of the Guideline support (so that the guideline is inside the metal tube).
 - c. Twist the white lockers to hold the guideline in place within the Guideline support.
15. Connect the middle of the Control rope to the carabiner on the Guideline support using a knot.
16. Install the ADCP and GPS in the trimaran float (**Section E.2**) and turn both units on.
17. Bring the Guideline Rope with the Guideline support to the edge of water on the near bank.
18. Attach the section of Trimaran rope through the carabiner on the Guideline support.
 - a. Adjust the length of the Trimaran rope based on the surface water velocity conditions.
 - b. Set the length of the Trimaran rope so that the boat lies flat in the water and the surface velocity maintains the orientation of the bow pointed upstream.
 - 1) During low velocity regimes the Trimaran rope should be shorter.
 - 2) During high velocity regimes the Trimaran rope should be longer.
19. Remove the transducer cap on the bottom of the ADCP that protects the beam lenses.
20. Gently place the trimaran float in the water to let sensors equilibrate. Secure both end of the Control Rope to keep the float in position prior to the first measurement.



Figure 21. Assembling the Temporary High Line.

F.2 Practice Operating the High Line Assembly

If needed, practice pulling the trimaran float back and forth across the channel to get comfortable with the High Line operation prior to measurement collection.

The High Line Assembly is operated as follows:

1. One person stands on each side of the bank holding the Control Rope.
2. The Control Rope should always be held taught to limit lateral movement of the float.
3. To move the boat across the channel the person on the bank where the boat is headed must gently pull on the Control rope while the person on the opposite bank gently releases the Control rope.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- a. The Control Rope must remain taught during this operation.
- b. Gloves are recommended to limit hand abrasion from the rope.
4. The float must be moved at a slow and steady pace with the bow of the float pointed upstream.
 - a. Sudden movements of the float will adversely affect data quality.
 - b. Each transect measurement must last a minimum of 180 seconds. It is helpful for staff to call out the measurement duration during the measurement in order to adjust float speeds if needed.
 - c. Ideally the speed of the float should be below the water velocity, although this can be very difficult during low flow regimes.
 - 1) In all conditions a steady operation of the float across the channel is paramount.
5. Practice bringing the trimaran float back and forth across the channel until boat staff members are accustomed to the operation.

F.3 Start a New Measurement in WinRiver II

Once the trimaran float and High Line Assembly are properly configured, a new measurement file can be created using WinRiver II software.

1. Set the laptop system time zone to UTC (Coordinated Universal Time).
2. Start the WinRiver II program.
3. In the WinRiver II main screen, click Configure > Units > All SI to set units to metric.
4. In the WinRiver II main screen, click File > New Measurement to run the Measurement Wizard.
5. Fill in all information in the Site Information tab:
 - a. Station Name: Four digit site code of where you will be measuring discharge (i.e. "TOMB").
 - b. Station Number: Leave blank.
 - c. Measurement Number: The sequential discharge measurement number for the site.
 - d. Agency: "NEON".
 - e. District: Leave blank.
 - f. Hydrologic Unit: Leave blank.
 - g. Field Party: Initials of all crew involved in measurement.
 - 1) Separate initials with a comma delimiter (i.e. NH, LFS).
 - h. Processed By: Initials of technician operating the WinRiver II software and evaluating data collection.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- i. Deployment Type: "Trimaran Float".
 - j. Boat/Motor: Leave blank.
 - k. Meas. Location: If measured at the regular discharge cross-section enter "DSC1", if measured at a different cross-section within the site denote that with a different code here, (i.e. "DSC_US" if the cross-section is upstream of the regular location).
 - 1) Make sure to also include notes in the main remarks section that describe alternative transect locations (be sure to include an estimate of how many meters away the measurement was conducted from the regular location).
 - a) To add a note to the main Remarks section of the measurement file, right-click Site Information on the Measurement Control window.
 - b) Enter notes into Remarks section.
 - l. Grid Reference: Leave blank.
6. Select the "Rating Information" tab.
- a. Inside Gage Height: Enter the water level measurement on inside of staff gauge.
 - b. Outside Gage Height: Same value as "Outside Gage Height".
 - c. Rating Discharge: Enter the predicted discharge given gauge height from rating curve, if available.
 - d. Index Velocity: Leave blank.
 - e. Rated Area: Leave blank.
 - f. Rating Number: Leave blank.
 - g. Water Temp: Enter the water temperature (°C) measured using a thermometer submerged in the stream for at least 5 minutes.
 - 1) The measured water temperature should be within 2 degrees of the ADCP temperature measurement.
 - a) To check the temperature being measured by the ADCP, open the Test Result dialogue box under the QAQC > ADCP node. The measured temperature will be displayed along with other sensor data.
 - b) You can also view temperature time series data during or after a transect measurement by selecting View > Graphs > Time Series > Temperature.
 - c) The ADCP must be sitting in the water for at least 5 minutes to allow the instrument to fully equilibrate to the water temperature.
 - d) In general ADCP temperature measurements do not drift until there is a major issue. If this does occur, the ADCP-measured temperature will deviate greatly from the



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

thermometer measurement. If this is the case make a note in the measurement note window and contact Science following the measurement bout.

- h. Tail Water Level: Leave blank.
 - i. Magn Variation Method: Model.
 - j. Measurement Rating: fill this out at the end of the measurement based on your judgment of the measurement quality.
 - 1) This is a subjective assessment. Discretion is given to the hydrographer who led the survey. Include any relevant field notes that formulated the basis of this rating in the remarks section.
 - k. Control Codes: select any that apply to the measurement.
 - l. Wind Speed: Enter the measured wind speed (kph) using an anemometer.
 - 1) If wind speed was entered in units other than kph, note the units used in the remarks section.
 - m. Wind Direction: Enter the measured wind direction using an anemometer.
 - 1) If the anemometer does not provide a direction measurement enter:
 - a) "Upstream": if the wind is blowing up from upstream to downstream.
 - b) "Downstream": if the wind is blowing from downstream to upstream.
 - c) "Cross-wind": if the wind is blowing across the river.
 - d) "Mixed": if the wind is not blowing in any particular direction.
 - n. Edge Method: Enter the method used for determining bank distances (i.e. laser rangefinder, meter tape, eye estimate, etc.).
7. Select the "Configuration Dialogue" tab.
- a. The software will immediately try to recognize the ADCP ("Interrogating the ADCP...").
 - 1) If the connection is successful, the button next to "ADCP" will eventually turn green.
 - a) This can take a few minutes.
 - b) This means that the software recognizes the ADCP via the ADCP Parani Bluetooth dongle.
 - c) The connection should be successful if the ADCP Peripheral test was a success.
 - d) If a window pops up that says "The ADCP is not responding..." this means that the ADCP was not recognized by the software.
 - (1) Click "No" ("Yes" will have the software cycle through all available ports).



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- (2) Ensure that ParaniWin configuration was successful for the ADCP dongle and that the software is closed.
 - (3) In the “Serial Communication Settings” window, ensure that COM Port settings match what was entered in ParaniWin software. Click OK.
 - (4) If the “The ADCP is not responding...” message returns, click Cancel.
 - (5) In the “ADCP” dropdown, ensure that the correct ADCP model (StreamPro) is selected in the dropdown box. Click the “Check ADCP” button to re-test configuration.
 - (6) The ADCP must be recognized by the software for the discharge measurement to be conducted. If communication problems persist, submit a trouble ticket and contact Science.
- b. Check GPS configuration settings.
- 1) Ensure that the GPS antenna is attached, powered and properly configured within the trimaran float.
 - 2) If using the SX Blue II GPS antenna (most NEON wadable stream sites):
 - a) Check the “External GPS” box.
 - b) The green light indicates that the GPS antenna is recognized by the software.
 - c) An error message indicates that the GPS is not recognized by the software.
 - (1) Press OK twice. Oftentimes trying to connect a second time will be successful. If software still fails to recognize the GPS antenna:
 - (a) Check that all cables are securely connected.
 - (b) Check the COM port settings are correctly configured in Windows Device Manager, ParaniWin, and WinRiver II.
 - (c) Re-test GPS communications in Configure > Peripherals.
 - (d) If GPS is unable to be integrated with the software the discharge measurement should still be conducted.
 - (e) Document this occurrence as a note in the Remarks Section and submit a trouble ticket to Science.
 - (f) Continue with the discharge measurement.
 - 3) If using the Hemisphere V102 GPS antenna:
 - a) Check the “Int. GPS” box.
 - (a) Set the baud rate to 19200.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- b) Check the “Ext. Heading” box.
 - (a) Leave the “Hdg Off [deg]” box blank.
 - (b) An error message will appear.
 - (c) Click cancel, this error can be ignored.
- c. The Depth Sounder box can be left blank.
- d. Under Offsets:
 - 1) Enter Transducer Depth.
 - (1) The standard transducer depth for StreamPro ADCPs deployed in the trimaran float is 0.02m.
 - (2) Verify the transducer depth is 0.02m with a meter tape prior to the first measurement.
 - (a) Ensure that the boat is steady and stable in the water column prior to taking this measurement.
 - (b) Measure from the water level to the center of the slant in the transducer faces with a ruler or metric tape.
 - (c) This is a very important measurement! Repeat it two or three times to ensure accuracy.
 - (d) Once the transducer depth is confirmed this value can be entered prior to all subsequent measurements, it should not change unless the unit is disassembled.
- e. Enter Magnetic Variation, the angle of declination relative to your location in the world.
 - 1) For greatest accuracy, check the [National Geophysical Data Center website](#) to find the declination angle based on your latitude and longitude.
 - 2) Some examples:
 - a) Butler, AL: $-2^{\circ} 27' W$ (-2.27)
 - b) Newton, GA: $-4^{\circ} 59' W$ (-4.59)
 - c) Arcata, CA: $+14^{\circ} 16' E$ (+14.16)
- f. Enter the Max Water Depth.
 - 1) This is an estimate of the maximum water depth (m) that is expected to be measured during the discharge measurement.
- g. Enter the Secondary Water Depth



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 1) This is an estimate of the minimum water depth (m) that is expected to be measured during the discharge measurement.
- h. Enter the Max Boat Speed
 - 1) This is an estimate of the maximum boat speed (m/s) that is expected during the discharge measurement.
 - i. All other values can be left as defaults.
8. Select the “Output Filename Options” tab.
 - a. Under the “Recording” section:
 - 1) In the “Filename Prefix” box enter the four-digit side code.
 - a) Example: “LEWI”.
 - 2) Ensure the “Use Prefix in Filename” box is checked.
 - 3) Leave the output directory at the default location (C:\Measurements\).
 - b. In the “Include Filename Options” section:
 - 1) Uncheck the “Measurement Number” box.
 - 2) Leave “Transect Number” at “0”.
 - 3) Leave “Geographic Current Survey” and “Sequence Number” boxes unchecked.
 - c. In the “Use Date/Time in Filename” section:
 - 1) Select “Long (YY-MM-DD-hhmmss)”.
 - d. In the “Use Delimiter in File” section:
 - 1) Select “Underscore” (default).
 - e. Check in the Filename Preview section that the above settings are correctly applied (**Figure 21**).
 - f. Note that these settings can only be entered at the start of a New Measurement. Once the Measurement Wizard is closed, filename settings can only be changed by starting a new measurement.
9. Open the Command Preview tab.
 - a. Review all information to ensure that is correct.
 - b. Ensure that green checks are present for ADCP and GPS communications.
 - c. Click the Finish button to complete wizard.
10. Review the Summary Page tab to ensure all information was correctly entered.
11. Click Finish to exit the Measurement Wizard.



12. Verify that GPS data is being collected.

- a. Once powered, allow a few minutes for the GPS to connect to available satellites.
- b. Click Acquire > Start Pinging.
- c. Click View > Tabular > GPS to confirm the availability of GPS data (**Figure 22**).
 - 1) External/Integrated (GGA) refers to differential GPS data collected by the external GPS antenna (i.e. SX Blue II or Hemisphere V102).
 - 2) Internal (GGA2) refers to the georeferenced GPS data collected by the GPS unit that is internal to the ADCP.
 - 3) External GPS data is much more accurate than the internal data as reflected in position (latitude/longitude) digits.
 - 4) The number of satellites will often be less in the external GPS column due to the higher quality threshold for picking satellites (i.e. elevation angle) contained in the external unit.
 - 5) HDOP is the measure of possible error due to the geometry of the available satellites, therefore as this value decreases the quality GPS data increases.
 - a) Ideally HDOP values should be < 2.
- d. Click View > Time Series > Graphs > GPS data to confirm GPS data stream (**Figure 22**).

13. Once GPS data has been verified end ADCP pinging by clicking Acquire > Stop Pinging.

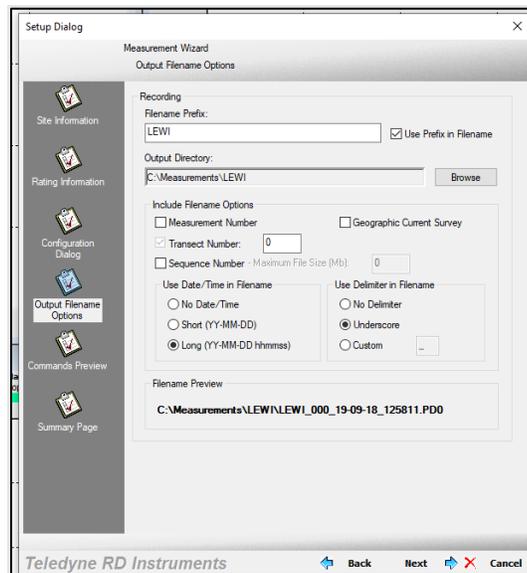


Figure 22. Required settings in the WinRiver II Output Filename Options dialogue box within the Measurement Wizard.

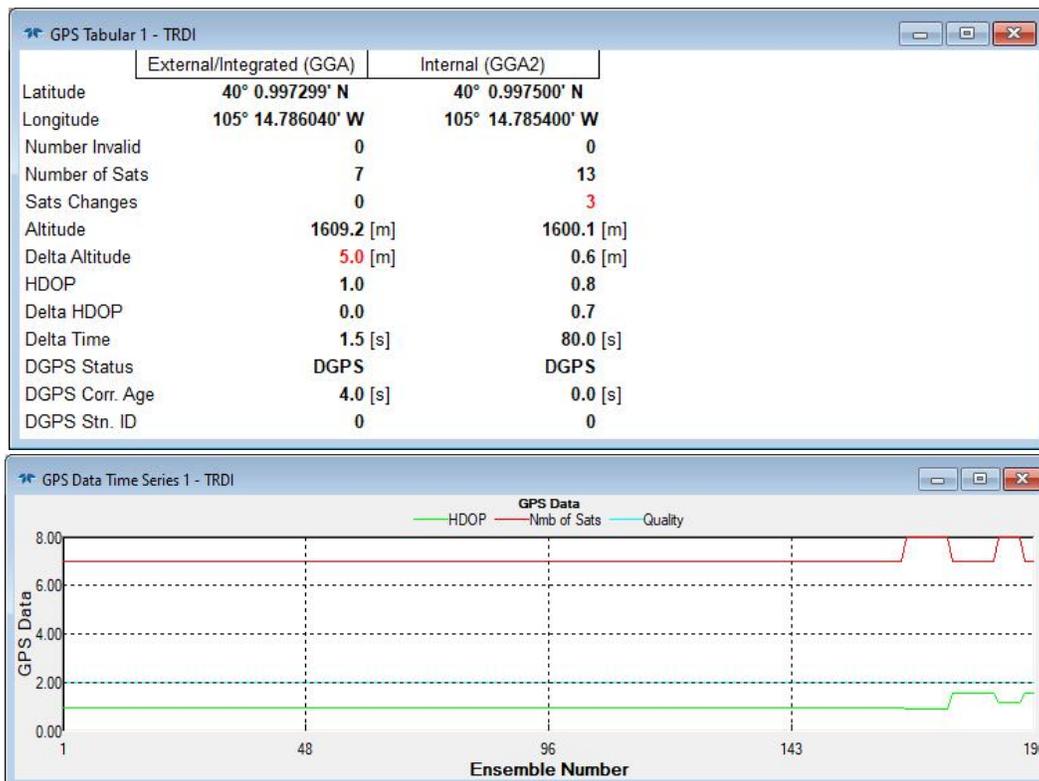


Figure 23. Above: GPS Tabular window that confirms GPS data is available and is being collected; Below: GPS Time Series window that indicates GPS data is streaming.

F.4 Pre-Measurement QAQC: Overview

The following QAQC protocols are critical to quality data collection and must be initiated prior to the first transect measurement of each ADCP discharge bout.

The following procedures are outlined below:

- Set the ADCP clock
- Collect a temperature measurement
- Execute an ADCP test
- Calibrate the internal ADCP compass
- Perform a moving bed test and assess moving bed test summary
- Configure the reference navigation

F.5 Pre-Measurement QAQC: Set the ADCP Clock

Prior to the initial transect measurement the ADCP clock must be set to match the PC time (UTC). Failure to properly set the ADCP clock will result in data files with incorrect timestamps.

1. Set the time zone on the PC to (UTC) Coordinated Universal Time (**Figure 23**).



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- a. Right click on the date time in the lower right corner of the screen.
 - b. Select “Adjust date/time”.
 - c. In the “Time zone” dropdown, select “(UTC) Coordinated Universal Time”.
2. In the WinRiver II main screen, click on Acquire > Set ADCP Clock.
 3. Set the ADCP clock to match the PC time (UTC).
 4. Click the “Set Clock” button.
 - a. Note: only clicking the “OK” button will not set the clock, the “Set Clock” button must be selected.

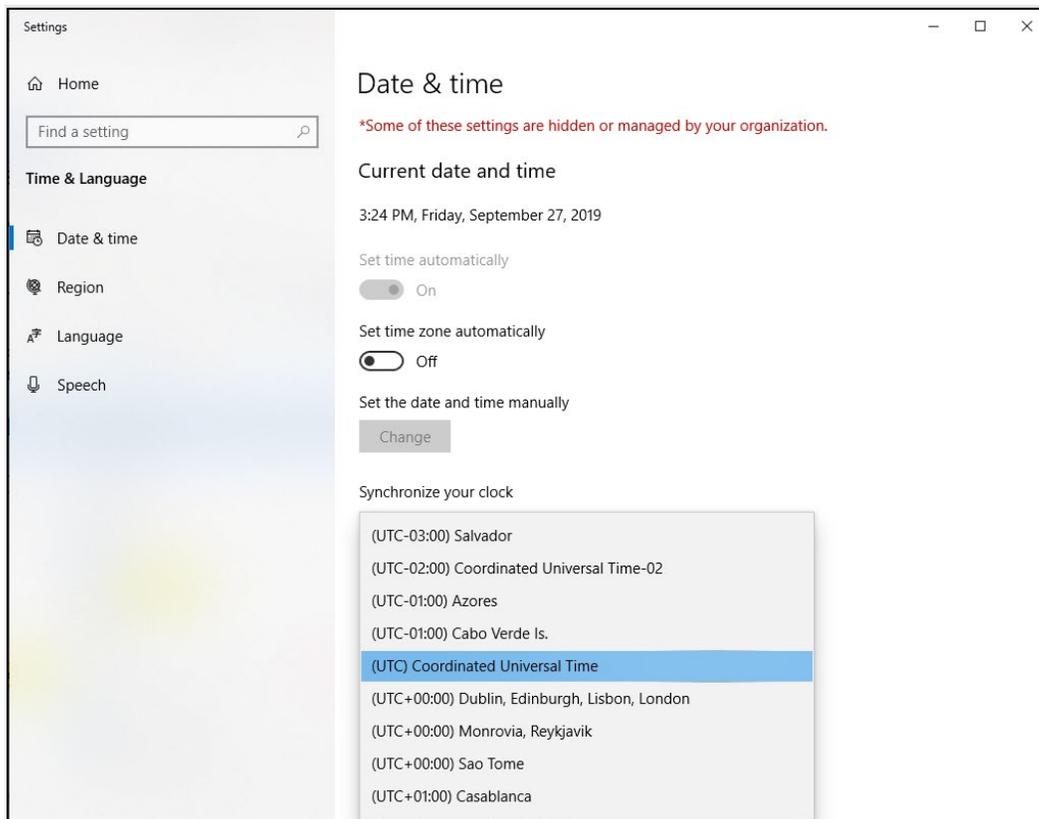


Figure 24. Set the PC used for the discharge measurement to (UTC) Coordinated Universal Time and match the ADCP clock to this setting.

F.6 Pre-Measurement QAQC: Collect a Temperature Measurement

1. Allow the ADCP to equilibrate in the water for at least 5 minutes prior to taking a temperature measurement with the thermometer.
2. Place the thermometer into the water to begin collecting a temperature measurement.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

3. Enter this value into the Measurement Wizard Rating Information Tab under “Water Temp”.

F.7 Pre-Measurement QAQC: Execute an ADCP Test

This test verifies that the ADCP is functioning properly and communicating with WinRiver II software.

1. In the WinRiver II main screen, click on Acquire > Execute ADCP Test.
 - a. Note that the ADCP must be installed in the mount and submerged in non-flowing water to obtain the best test results.
2. A series of six tests will be initiated that evaluate ROM, RAM, Communications, RTC, Compass, and Temperature performance.
 - a. Check that all tests pass on the left pane of the dialog window.
3. After the tests have been run, sensor data will begin to be sampled and displayed in a loop.
4. Click the “Stop PC20” and “Stop PC40” buttons to end testing and close the dialog window.

F.8 Pre-Measurement QAQC: Calibrate the Internal ADCP Compass

A calibrated compass is essential for conducting Moving Bed Tests and for using GPS data as the navigation reference. This is a two person task, one staff member must monitor the calibration data in real time while another rotates the ARC-Boat.

1. Ensure that the ADCP is secured within the trimaran float in the exact position it will remain throughout the discharge measurement.
2. Ensure that the float is not located near vehicles, steel bridges, or other large ferro-magnetic masses.
3. Check for any materials near the trimaran float could disrupt the compass calibration – this includes tools, tool boxes, cell phones, hot hands, etc. Move these materials away from the ADCP during calibration and throughout the discharge measurement.
4. In the WinRiver II main screen, click on Acquire > Execute Compass Calibration.
5. Select Use Pitch/Roll?
 - a. Click “No” if the ADCP will not be subject to pitch and roll (i.e. calm water). This calibration test requires two rotations, one for calibration and one for verification.
 - b. Click “Yes” if the ADCP will be subject to very high pitch and roll conditions. This calibration test requires up to eight rotations, four for calibration and four for verification. Typically, no pitch and roll calibration is required.
6. Placing the ADCP and trimaran float on the surface of a (non-metallic) Lazy Susan can ensure smooth rotation and significantly reduce compass calibration error.



7. Click the Start Calibration button and wait a moment until the compass is initialized by the software.
8. Begin to slowly and smoothly rotate the trimaran float by hand in either direction.
 - a. Do not cause sudden accelerations or decelerations.
9. Rotate the float until all of the red bars in the dialogue window have been replaced by a different dark green color (**Figure 24**).
 - a. The greener the bars, the better the data.
 - b. If a bar is not dark green, rotate the boat more slowly and more smoothly.
 - c. Correct any non-dark green bars when they occurs by going back 10-20° until that bar is once again highlighted. Then, when it becomes dark green, proceed as before.
 - d. Clear and constant communication between the staff member moving the boat and the staff member viewing the test on the laptop is critical during this period.
10. Once -calibration rotations are complete, click OK and continue with the verification rotation.
 - a. If Pitch/Roll is selected there will be more initial rotations.
11. Once the verification rotation is complete a calibration error will be calculated and presented.
 - a. Ensure that the calibration error is less than 2°. Aim for a total error of < 1°.
 - b. If calibration error is < 2°, the compass calibration is complete and the window can be closed (< 1° is preferred – try to obtain this).
 - c. If calibration error is ≥ 2°, do not accept the compass calibration and repeat calibration procedures. Look around for magnetic materials that may be affecting the compass. Move these materials away from the ADCP or move the ADCP away from them, if possible.
 - d. If, after three attempts, a calibration error of < 2° cannot be achieved, reference the troubleshooting steps below.
 - 1) If, following troubleshooting, a compass calibration of < 2° cannot be achieved, accept the lowest calibration error possible and proceed.
 - 2) Document this occurrence as a note in the Remarks Section, it will be a very important component in evaluation the measurement during post-processing.
12. Once complete, check that the correct Magnetic Variation Correction value was entered by the software during the measurement wizard setup.
 - a. In the WinRiver II main screen, in the upper left Measurement Control window, open the Collect Data node and right click on Field Configuration, and select Properties.
 - b. Under Properties, select Offsets.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- c. Under Offsets > Compass, verify or set the Magnetic Variation value.
- d. Note that other settings can be verified and entered in this window.

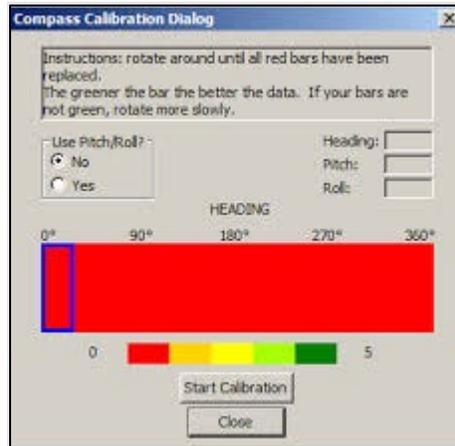


Figure 25. WinRiver II compass calibration dialog box. Upon initializing the compass calibration, all bars begin as bright red as shown above. Perform the compass calibration until all bars are the dark green color indicated in the far right side of the color scale.

Troubleshooting Compass Calibration Issues

- There may be too much magnetic interference in the area you are attempting to calibrate the compass. Ensure that no magnetic materials are near the ADCP. Try moving the boat to a different area of the stream and repeating the calibration. It may be that material on the streambed (rebar, trash) is affecting the calibration.
- Computational errors may occur during calibration. If you receive an error message indicating that a computational error occurred, repeat the calibration and be sure to rotate the ADCP slow and smooth. Ensure that all points in the calibration display are of good quality (dark green).
- Communication errors may occur during calibration when using a slow communication Baud rate. If you receive a “Failed to get calibration data...” message verify that all ADCP communications are set to the 115200 Baud rate.
- If you receive a “360 degrees” compass error message then the compass calibration test has failed and needs to be performed again.
- Disable GPS output (if enabled).
 - This is the least preferred option and should be attempted if all large errors are encountered after all other solutions have been attempted.
 - Un-check the Ext. GPS box in the Measurement Window Configuration Dialog tab.
 - Repeat Compass Calibration test.



F.9 Pre-Measurement QAQC: Perform a Moving Bed Test

Moving Bed Tests (MBT) are used to determine if the bed of the discharge cross-section is in motion. An un-accounted for moving bed can lead

to 5-10% bias in discharge measurements performed with the StreamPro ADCP.

MBTs must be performed prior to each ADCP discharge bout. WinRiver II software analyzes the data collected during the MBT to assess the moving bed characteristics of the site and to detect common error conditions, which may invalidate the test. The loop method is presented below as a means to test whether a moving bed is present. The loop method must be applied properly, or it may produce incorrect results.

Note that the accuracy of the loop method is not adequate for mean velocities less than 0.8 ft/second (0.24 m/s). If mean velocity is below 0.8 ft/s (0.24 m/s), water velocity is low throughout the water column and the probability that the bed is in motion is decreased. If the bed is in fact in motion at these velocities (or particles on the surface of the bed are in transit) it is likely that not accounting for it will exert only a minimum bias in the overall discharge estimation.

A properly calibrated compass is critical to application of the loop method, the error caused by an improperly or un-calibrated compass can be in either direction, resulting in either more or less moving bed than actually is present.

To perform a moving bed test:

1. Begin the MBT from an initial point on the near shore where you will be able to return to with precision (**Figure 26**).
 - a. Navigate the boat to a starting location near the edge of the water on the near bank.
 - b. Use a ziptie, clip, Sharpie or some device to mark the location on the tagline where the MBT will start and end.
2. In the WinRiver II main screen, click on Acquire > Start Pinging (shortcut key: F4).
3. Open the Ship Track graph. This allows for a better view of the boat path as it does not show the velocity paths (**Figure 25**).
 - a. View > Graphs > Ship Tracks > Ship Track
 - b. The green square is where the float is located when the test starts.
4. On the Acquire menu, click Select Moving Bed Test.
5. Select "Loop Test" and click the Start button (shortcut key: F6).
6. Once you start the test, immediately begin to pull the boat across the river to the opposite bank in a slow and steady manner.



- a. Maintain a steady speed that, if possible, does not exceed the stream velocity.
- b. Note that the green square in the Ship Track graph denotes your starting location.

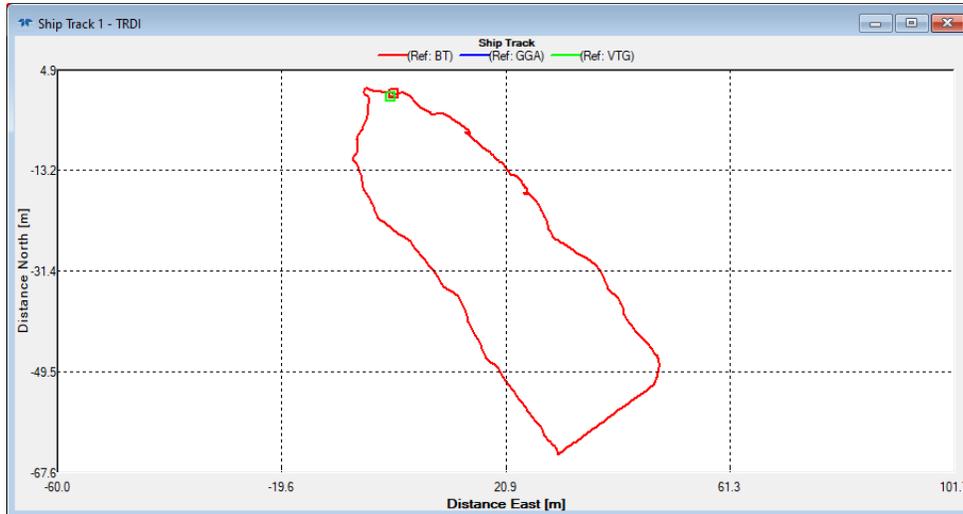


Figure 26. The WinRiver II Ship Track window observed during a loop moving bed test. The green box indicates the boat starting position, the line shows the boat path as it is navigating across the channel and turned back around toward the starting bank, and the red box indicates the boat ending position.

7. The MBT Test must last a minimum of 180 seconds (3 minutes).
 - a. This duration encompasses the time spent moving the boat across the channel and back to the near bank.
 - b. It is helpful for a staff member using or nearby the laptop to call out the measurement duration to the other staff member moving the boat so the speed can be adjusted if needed.
8. When the opposite bank is reached, gently pull the boat in the other direction (don't stop) and head back to the exact starting point where the test was initiated.
 - a. This is a critical part of the moving bed test, make sure this is a smooth and slow turn by gently pulling the tethered line so that the boat is moving back toward the near shore.

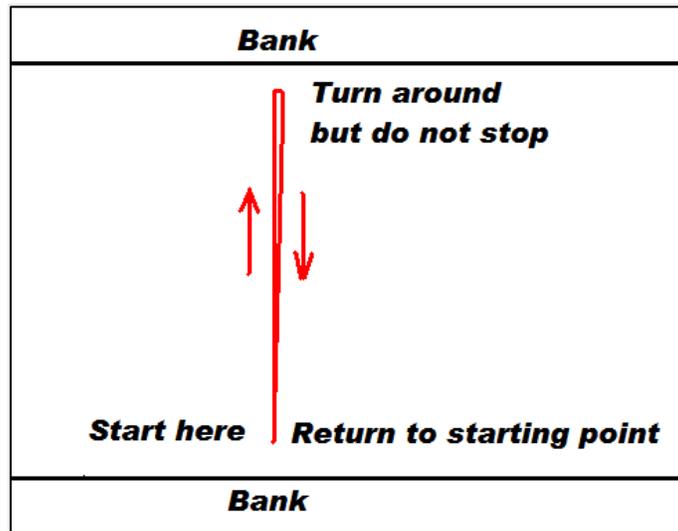


Figure 27. Illustration of the Loop Moving Bed Test procedure.

9. Once the boat returns back to the exact starting point on the near shore where you began the MBT, stop the test immediately (shortcut: F6 or Acquire > Stop Moving Bed Test).
 - a. Note the green square in the Ship Track Graph indicating where the float was located when the test began and the red square indicating where the float was located when the test ended.
 - b. If you don't hit the F6 button right at the starting point this could falsely indicate that the bed is moving.
10. Review the Ship Track window (Figure 27).
 - a. If the track (red line) contains an "open mouth" (i.e. the green and red squares do not line up and the red line is not connected) this may indicate that there is a moving bed.
 - b. If the track does not contain an "open mouth" (i.e. the green and red squares are on top of each other and the red line is connected), this indicates that a moving bed is likely not present.
 - c. Moving bed conditions will always cause the ship track to move upstream – if the ship track moves downstream the loop test is not valid.
 - d. If the trimaran float was not returned to the *exact* starting point it can result in the end point being upstream or downstream of the starting point. This results in a potentially false positive for moving bed conditions (endpoint is upstream of the starting point) or an invalid result (endpoint is downstream of the starting point).

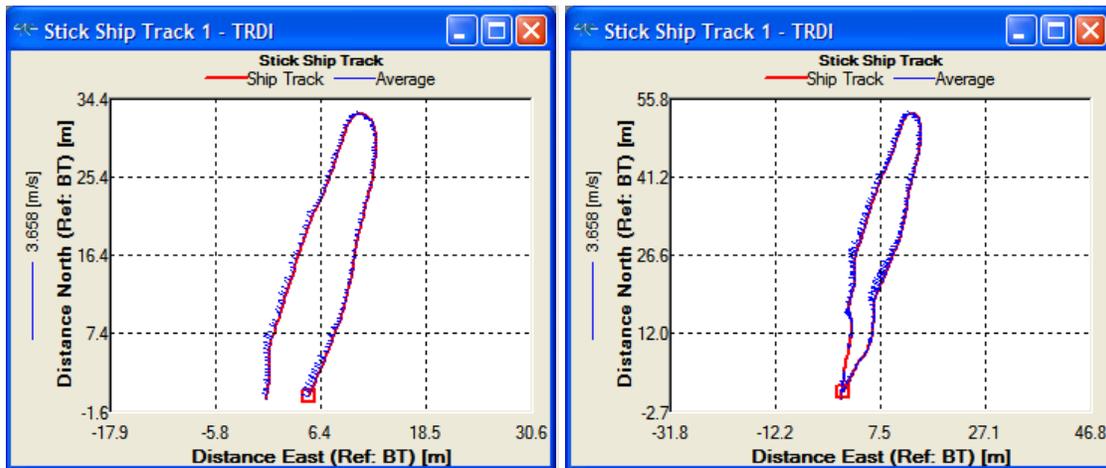


Figure 28. Left: A moving bed is likely present (not open loop); Right: a moving bed is not likely present (note closed loop).

11. Document all relevant notes that apply to the MBT.
 - a. To add a note that relate to a specific MBT, right click on the test node (i.e. “Loop 000”), and select “Add Note”.
12. Review the Moving Bed Test Result window to evaluate the results of the MBT (**Figure 28**).
 - a. In the Measurement Control window, under QA/QC, click on the Moving Bed Test node and open the Test Result icon for the test that was just completed (Loop tests begin as “Loop 000”).
 - b. The Test Result window provides metrics that describe the MBT. At the bottom of the window reference the “NOTE” – it will indicate whether correction is recommended.
 - 1) If a correction is recommended, check the box to the left of the MBT (i.e. “Loop 000”). This will apply a correction to the measured discharge to account for the moving bed velocity.
 - a) If a moving bed is detected (and GPS data is valid), the Navigation Reference must be changed from Bottom Track to GPS (**Section F.10**).
 - (1) On the main WinRiver II screen select Configure > Reference and change reference GPS (GGA).
 - b) If GPS is not available then Bottom Track should be used as the reference navigation (**Section F.10**).
 - (1) Document this in the main measurement file remarks window.
 - (a) To add a note to the main Remarks section of the measurement file, right-click Site Information on the Measurement Control window.
 - (b) Enter notes into Remarks section.



- c) Once the correction has been applied and the appropriate reference navigation has been set, proceed with the next pre-measurement QAQC procedure.
- 2) If a correction is not recommended and all other aspects of the MBT are valid then no correction is needed and Bottom Track can be used as the reference navigation.
 - a) Proceed with the next pre-measurement QAQC procedure.

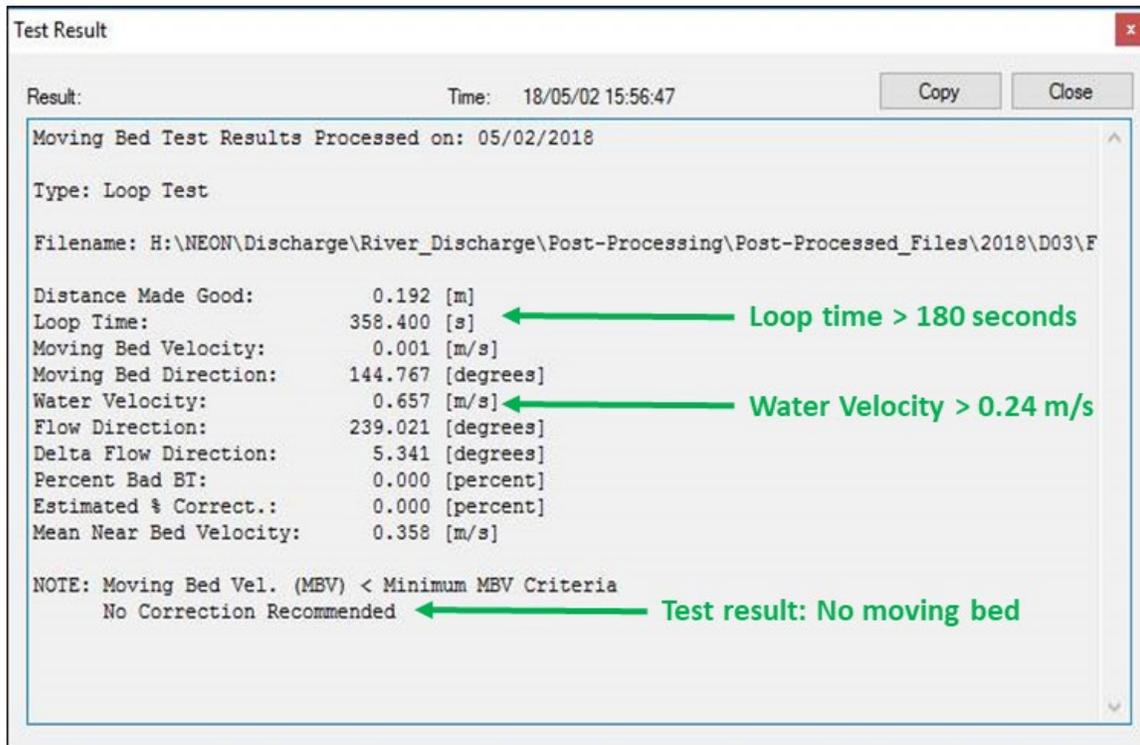


Figure 29. Moving Bed Loop Test Result window. In this example the required conditions were met to in order to evaluate a moving bed (Loop time, water velocity) and a moving bed was not detected (the moving bed velocity < the moving bed velocity criteria), thus no correction was recommended.

13. If there is confusion whether or not the MBT was completed correctly or questions arise interpreting the results, consider the following common sources of errors associated with the Loop Method.
 - a. Water velocity must be > 0.24 m/s in order for a moving bed to be evaluated.
 - 1) If velocity is below this threshold a loop test cannot be evaluated by WinRiver II.
 - 2) At low velocities such as these it is likely that a moving bed is not present or is negligible in terms of affecting measured discharge.
 - 3) Conducting an additional loop test is not required.
 - 4) Proceed with the pre-measurement QAQC procedures in this instance.



- b. Systematic compass errors.
 - 1) Check the direction of the velocity vectors (blue lines) during the Loop Test in the Stick Ship Track window. They should be pointed in the same direction during both loop paths.
 - 2) If vectors are in opposite or in an erratic direction this is a symptom of poor compass calibration.
 - 3) Conducting another compass calibration followed by a second MBT may be helpful.
 - c. Bottom-tracking bias and uncertainty.
 - 1) Check the Velocity Contour Profile associated with the Loop Test.
 - 2) Are there large unmeasured areas along the streambed?
 - a) If so a MBT may be difficult to validate.
 - 3) Conducting another MBT along a different transect (upstream or downstream) may be helpful.
 - d. Failure to return to the initial starting point.
 - 1) Ensure that the float was returned to the exact starting location at the end of the MBT.
 - 2) Make sure that you ended the MBT at the exact time you reached the starting location.
 - e. Irregular or insufficient sampling of the cross section because of loss of bottom track, non-uniform boat speed, and loitering at the banks.
14. If any of the above criteria are in doubt:
- a. Conduct another Moving Bed Loop Test in a slow, steady manner with a smooth transition at the opposite bank.
 - b. It may be helpful to begin the second Loop Test from the opposite bank or from a different transect location.
 - 1) Be sure not to get too far away from where you will be collecting the discharge measurement.
15. If, after the second Loop Test the results are still unclear, use the GPS as the reference method (if available).
16. If, after the second Loop Test the results are still unclear, and GPS is not available, conduct a Stationary Moving Bed Test.
- a. Stationary Moving Bed Tests can only be used to determine if there is a moving bed, not correct for one, therefore only use this if problems occur during the Loop Test and GPS data is not available.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- b. To conduct a Stationary Moving Bed Test:
 - 1) Move the trimaran float to the thalweg, or deepest section of the stream.
 - 2) In the WinRiver II main screen, click on Acquire > Start Pinging (F4).
 - 3) On the Acquire menu, click Select Moving Bed Test.
 - 4) Select “Stationary Test” and click the Start button (F6).
 - 5) Hold the ADCP in that location for at least for 300 seconds (5 minutes).
 - 6) Stop the test (shortcut: F6 or Acquire > Stop Moving Bed Test).
 - 7) Add any pertinent notes to the Stationary Moving Bed Test.
 - a) Right click on the test node (i.e. “Stationary 000”), and select “Add Note”.
- c. Review the Moving Bed Test Result window to evaluate the results of the test.
 - 1) If a moving bed is detected and a correction is recommended, check the box to the left of the MBT (i.e. “Loop 001”). This will apply a correction to the measured discharge to account for the moving bed velocity.
 - a) Continue to use Bottom Track as the Reference Navigation (since GPS data is not available).
 - b) Document this in the main measurement file remarks window.
 - (1) To add a note to the main Remarks section of the measurement file, right-click Site Information on the Measurement Control window.
 - (2) Enter notes into Remarks section.
 - c) Proceed with the next pre-measurement QAQC procedure.
 - 2) If a moving bed is not detected proceed with the next pre-measurement QAQC procedure.

F.10 Pre-Measurement QAQC: Configure the Reference Navigation

The reference navigation determines how the direction or bearing (heading) of the instrument is measured. The following references are available during an ADCP discharge measurement:

- Bottom Track
 - ADCP Bottom-Track velocity (standard configuration).
 - This is primary choice for the reference navigation if a moving bed was not detected.
 - The ability of the ADCP to Bottom Track can become compromised during periods of high turbidity and suspended sediment concentrations (SSC). An overload of scatterers are produced in these conditions which prevent the ADCP beams from reaching the bottom and



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

measuring velocity throughout the channel profile. If turbidity is high and the ADCP is having difficulty bottom tracking (this is evidenced by a large bands of missing ensembles in the velocity contour profile and warnings in the Measurement Control Window), consider using GPS as the reference navigation.

- GPS (GGA)
 - Differential GPS position from NMEA GGA string (WinRiver II will differentiate position to calculate velocity).
 - If a moving bed is detected and/or during periods of high turbidity and suspended sediment concentration, this is the primary choice for GPS reference as GGA data contains more information than VTG.
 - GGA messages can be affected by multipath errors caused by large trees or structures nearby the measurement site.
- GPS(VTG)
 - GPS velocity from NMEA 0183 VTG string.
 - If a moving bed is detected, and/or during periods of high turbidity and suspended sediment concentration, this is the secondary choice for GPS reference as VTG data serves as a backup for GGA.
 - VTG messages are not affected by multipath errors but VTG GPS data is oftentimes less accurate than GGA, particularly when moving at lower speeds.

If a moving bed was not detected during the previous pre-measurement QAQC procedure (**Section F.9**) and turbidity/SSC levels are low it is always preferred to use Bottom Track as the reference navigation. This allows for the boat movement and water movement to both be referenced to the instrument. Note that GPS data should still be configured and collected even if it is not used as the reference navigation.

If a moving bed was detected and/or turbidity and SSC levels are high enough to adversely affect bottom tracking, GPS reference is preferred. GPS data can also be used as a good quality indicator of the Bottom Track data as well.

To change the reference navigation:

1. In the WinRiver II main screen, click on Configure > Reference.
 - a. If a moving bed is not present, ensure that “Bottom Track” is selected from the list.
 - b. When bottom track is used as the velocity reference, the speed of the ADCP over ground is subtracted from the measured relative velocity to give true Earth referenced water velocity.
 - c. If, following a moving bed test, a moving bed is present and GPS can be utilized, choose GPS (GGA) as the reference navigation.
 - d. If GPS does not have enough satellites to acquire a strong signal, Bottom Track should be used as the reference navigation.



- 1) The number of available GPS satellites is shown by selecting View > Tabular > GPS (**Figure 22**).
 - 2) The absolute minimum number of satellites needed to provide a position is 3.
 - 3) Position will not be as accurate until at least 4 satellites are available due to timing limitations of GPS receivers.
 - 4) The greater the number of satellites, the greater the position accuracy, 7+ is preferred.
- e. GPS latency can be detected using the Ship Track windows (View > Graphs > Ship Tracks) (**Figure 29**).
- 1) Compare the red lines (Bottom Track) vs the blue and green lines (GPS).
 - 2) Separation between GPS and Bottom Track may denote:
 - a) GPS latency.
 - b) That an offset is required to the External Heading.
- (1) See **Section I.3** for details on applying External Heading offsets.

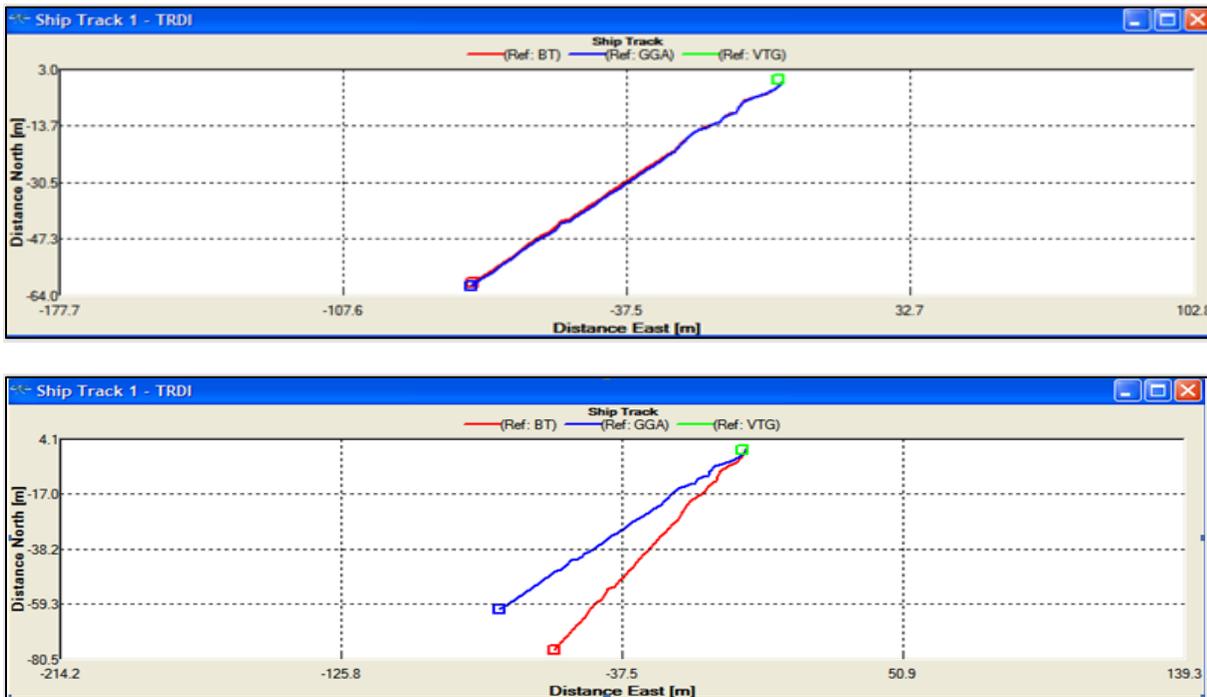


Figure 30. Above: Bottom Track and GPS data are in good agreement, indicating proper compass calibration, an accurate Magnetic Variation value, and low GPS latency; Below: Bottom Track and GPS data are in poor agreement, indicating poor compass calibration, an inaccurate Magnetic Variation value, and/or high GPS latency.



F.11 Conduct Discharge Measurements with the ADCP and Trimaran Float

WinRiver II software calculates discharge using real-time velocity measurements acquired during transects across the stream. Perform the following steps in order to successfully collect a high-quality stream discharge measurement using the ADCP method at wadable stream sites. Each step is presented in greater detail throughout this section.

1. Start ADCP pinging.
2. Establish transect start and end points.
3. Enter staff gauge height prior to each transect measurement.
4. Measure discharge across the channel (minimum 4 transects).
5. Evaluate whether additional transects are required.
6. Save transect locations (optional).

1. Start ADCP Pinging

Setting the ADCP to start pinging enables ADCP and GPS data collection. In general, after you have started the ADCP pinging, there is no reason to stop pinging until you are finished the entire discharge survey and ready to remove the ADCP from the water. An exception would be if you were operating with batteries of limited capacity, under that circumstance stopping ADCP pinging will conserve power.

1. Ensure that the trimaran float is in the water and the ADCP and GPS antenna are powered on.
2. Press F4 to start the ADCP pinging (or Acquire > Start Pinging).
3. In a few seconds, ensembles will begin to be generated and changing values will appear within several of the WinRiver II data windows.
 - a. An ensemble is the data output generated by multiple ADCP pings that are averaged together. Ensembles are tracked in numerical order, timestamp, and position.
 - b. If the ADCP is positioned in sufficient depth, velocity profiles will become available.
 - c. Note that WinRiver II will not display meaningful data unless the trimaran float is in the water.
4. If enabled, GPS positions will be displayed at the bottom of the Composite Tabular display window and valid GGA positions are being received from the GPS system. External Heading data will be displayed if that functionality is enabled.
5. The ADCP can continue pinging when it is not in the water.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

2. Establish Transect Start and End Points

The locations at each side of the channel where the discharge measurement begins and ends must be established before recording discharge transect data. Because stream depths eventually become too shallow for valid data collection as the ADCP approaches a bank, it is necessary to estimate discharge in the near-shore unmeasured zones using the WinRiver II and Q-Rev software. To ensure the accuracy of near-shore discharge estimates, the distances from the edge of water to the starting and stopping points of each transect must be measured using a distance-measurement device (such as a laser or optical rangefinder), tagline, or some other accurate measurement device.

Placing markers on the Guideline Rope (zipties, carabiners, flagging, etc.) at the start and end points of transects is advantageous for keeping consistent edges and ensuring that the same cross-section profile is measured during each transect. If it is not possible to reach the opposite side of the river to measure the edge distance, the “Distance MG [Made Good]” values displayed on the right side of the Composite Tabular 1 window can be used to calculate the edge distance from transect end point to the edge of water on the opposite bank.

Other notes on transect start and end points:

- Measurement uncertainty increases as the distance increases between the start and end points and the edges of water due to less measurements and more interpolation.
- Try to ensure that the velocity profile at the start and end locations are representative of the velocity profiles leading up to the bank in order to limit interpolation bias.
- In channels that contain vertical walls at the edges, start and end points for transects should be no closer to the wall than the depth of water at the wall to prevent acoustic interference from the main beam or side lobes impinging on the wall.
 - For example, if the depth at a vertical wall is 10 feet, transects should start or stop at least 10 feet away from the wall.
- If the cross-section has been measured previously at the same location, WinRiver II “Locations” can be utilized to help determine the start and end points that were previously used and to help navigate the float across the channel.
 - See **Section F.11** for instructions on loading available locations and how to save new ones.

To establish transect start and end points:

1. Move the trimaran float just off the edge of water on the near shore and into open water until the ADCP transducers are submerged.
2. Note the number of “Good Bins” listed in the Composite Tabular window shown in the right panel of the main WinRiver II screen (**Figure 30**).



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- a. Two “Good Bins” (or depth cells) are required in order to start and end the transect measurement.
3. Using the Control Rope, move the float slowly away from the bank until the tabular display indicates you are at a sufficient depth to set the transect start point (>2 Good Bins, closest to 2 is preferred).
4. Mark this location on the Guideline Rope with a physical marker (ziptie, carabiner, flagging, etc.).
5. Using the Control Rope, move the float slowly towards the opposite shore.
 - a. Travel smoothly and slowly with the bow of the boat pointed upstream.
6. While moving the float across the channel, observe the Velocity Contour graph to view channel conditions and ensure that the ADCP is working as expected with the loaded configuration.
 - a. Observe the Velocity Contour Profile located on the bottom panel of the WinRiver II main screen (**Figure 31**). This display illustrates water velocity and depth across the channel.
 - 1) The very top and the very bottom of the channel will always be unmeasured by the ADCP and discharge in these locations will be interpolated. The top unmeasured area is a function of transducer depth and the blanking distance of the instrument, the bottom unmeasured area is to prevent any side lobe interference which would adversely affect the measurement.
 - 2) Vertical white bands within the profile are unmeasured areas that can occur for a variety of reasons including biota, woody debris, physical structures, or simply moving the float too fast or abruptly across the channel.
 - a) Work to limit the number of white bands in the profile as an increase in unmeasured area results in an increase in measurement uncertainty.
 - b) If the unmeasured area within the cross-section is significant a different discharge transect upstream or downstream may be necessary.
 - 3) Note regions where the channel depth changes abruptly.
 - a) Make a mental note to move more slowly across these regions during data acquisition to help bottom tracking maintain a valid lock on the bottom.
7. As the float approaches the opposite shore note the Number of Good Bins in the Composite Tabular window (**Figure 30**) and stop the float at the opposite edge of water where two good bins are available.
8. Mark this location on the Guideline Rope with a physical marker (ziptie, carabiner, flagging, etc.).



9. Proceed to the next step once transect start and end points are established at each side of the channel.

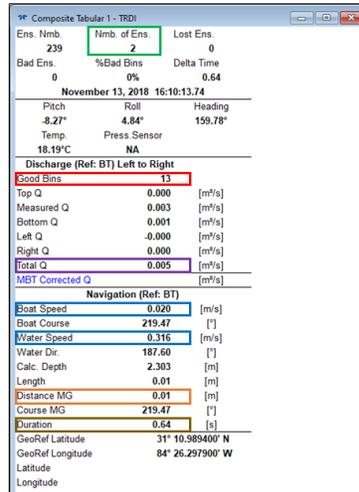


Figure 31. Composite Tabular window in WinRiver II, green box: Number of Ensembles (hold until 10 at transect start/end points); red box: Number of Good Bins (must be >2 to begin transect); purple box: Total Discharge; blue boxes: Water and Boat speed; orange box: Distance made good (MG = total transect length); brown box: Duration (total transect duration must be ≥180 seconds).

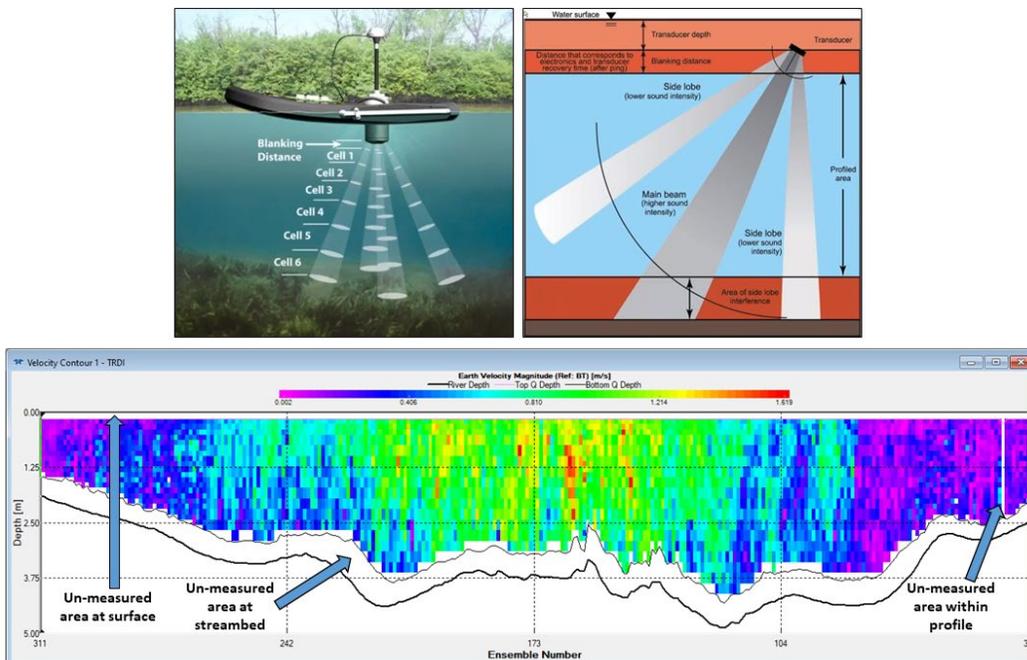


Figure 32. Unmeasured areas in the ADCP profile where velocity is extrapolated. Top left: ADCP blanking distance and cell size distribution (credit: SonTek); top right: unmeasured areas of the profile relative to ADCP beams (credit: SonTek); below: the WinRiver II velocity contour with unmeasured areas delineated.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

3. Enter Staff Gauge Height Prior to Each Transect

The staff gauge height must be entered prior to each transect measurement using the Fulcrum app. The mean gauge height recorded prior to all transect measurements is the stage value associated with the mean discharge measured during all transect measurements. Notes regarding conditions observed during individual transects (high/low flows, changing gauge heights, wind conditions, the passage of other vessels during measurement, any noteworthy events, etc.) can be entered in the main Remarks section of the Measurement Wizard as well as in the individual transect notes.

Gauge height observation and recording must immediately precede the transect discharge measurement so the stage level during the discharge measurement is accurately characterized.

To enter the staff gauge height prior to each transect measurement:

1. Open the (AOS) Field Metadata and Gauge Height [PROD] app in Fulcrum.
2. Enter the appropriate information in the Metadata, Spatial and Temporal Information tables.
3. In the Stage Height table, enter the current staff gauge height in the “Initial Stage Height (m)” field.
 - a. Note that this does not necessary have to equal the staff gauge height prior to the first measurement transect.
4. Under the Stage Height table note the “Collecting Discharge with an ADCP Today?” field and select “Yes”.
5. Click the “ADCP Transect Stage Measurements” button that appears.
6. Click the red plus (+) button at the top right of the window to create a record.
7. Enter the time the staff gauge is measured in the Staff Gauge Height Reading Time field.
 - a. This must be done immediately preceding the discharge measurement.
8. Enter the Staff Gauge Asset Tag.
 - a. This is located on the top of the staff gauge you are reading.
9. Enter the Transect Number.
 - a. This must correspond to the transect number generated in WinRiver II.
 - b. By default, transect numbers begin at 000 and increase to 001, 002, 003, etc.
10. Enter the Staff Gauge Height.
11. Enter the Staff Gauge Height units.
12. Click the green check button in the top right corner of the window to save the record.
13. Additional ADCP Transect Stage Measurements can be added by clicking the red plus button at the top right of the window.
14. ADCP transect stage measurements can be deleted by clicking the black X button to the left of each record.
 - a. Records should be deleted if:
 - i. Errors are present in any of the fields.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- ii. The measurement transect is not to be used in the calculation of total discharge (the transect will remain unchecked in WinRiver II due to measurement error, the transect was started by mistake, etc.).
15. The ADCP Transect Stage Measurements window should remain open throughout the discharge survey so that staff gauge height can be measured prior to each transect measurement.
16. The window can be closed by clicking the green check mark at the top right of the window once all transect discharge measurements are complete.
17. Enter Weather Information, Post Fieldwork Observations, and General Comments information to the record as needed.
18. Click the green check mark at the top right of the window to save the record.
19. Fulcrum data will load automatically when the record is saved and the device receives a wireless internet signal.

4. Measure Discharge Across the Channel (Minimum 4 Transects)

A “transect” is considered a single discharge measurement that begins at the transect start/end point on one side of the channel and ends at the transect start/end point on the opposite side of the channel. Each ADCP discharge survey must contain a reciprocal number of transects (i.e. if a transect is measured from the near bank to the opposite, another transect measurement must be included from the opposite bank to the near bank). A minimum of four transects are required for each ADCP discharge survey but more may be necessary. Each transect must last a minimum of 180 seconds and the total time for all transects must be >720 seconds.

Complete the following steps to measure discharge during each transect:

1. Hold the position of the trimaran float steady at one of the marked transect start or end points.
2. Using a stadia rod, meter tape, or laser range finder, determine the distance from the transect start point to the edge of water. This is referred to as the “edge distance”.
 - a. Measure the area from the center of the ADCP to the edge of the water.
 - b. If using a rangefinder make sure that the laser is not hitting leaves or branches hanging over the channel. Take a few shots and make sure they are all the same.
 - c. If it is not possible to measure this distance with an instrument, use the “Distance MG [Made Good]” values displayed on the right side of the Composite Tabular 1 window to calculate the edge distance from beginning/end of the transect to the adjacent edge of water.
 - d. If you start from the same location for each transect, this distance does not need to be measured each time (it is recommended to mark the transect start point for this reason).
3. Click Acquire > Start Transect (shortcut: F5) to begin data recording.



- a. Note that the measurement has now been initiated.
4. When prompted, enter the edge distance (measured in **Step 2**).
5. Define whether you started the measurement from the left or right bank.
 - a. When facing downstream, the left bank is on your left side.
6. Hold the position of the float at the transect start point for at least 10 shore ensembles.
 - a. This is equivalent to about 10 seconds.
 - b. The number of ensembles can be viewed in the Composite Tabular window (**Figure 30**).
7. Once 10 ensembles are recorded at the transect start point use the Control Rope to slowly and steadily move the float toward the opposite bank.
8. Move the float **slowly and steadily** across the channel.
 - a. The total duration of each transect (moving the float from one side of the channel to the other) must be ≥ 180 seconds.
 - b. The cumulative time spent measuring each transect is directly correlated to measurement quality.
 - 1) The slower and steadier the float crosses the channel the higher the data quality.
 - c. Maintain an average boat speed that is less than or equal to the water velocity.
 - 1) Water vs. Boat speed can be monitored using the Water Speed vs Boat Speed graph.
 - a) Click View > Graphs > Time Series > Water/Boat Speed (**Figure 32**).
 - 2) When water velocity is very slow, keeping the boat speed below the water velocity may not be a possible (or practical) approach. Under these conditions the smoothness of boat operation becomes critical.
 - 3) Avoid fast and sudden accelerations.
 - d. The bow of the float should always be pointed upstream so that the boat crabs , or moves across the channel.
 - 1) If this is not occurring make necessary adjustments to the Trimaran Rope.
 - e. Observe data displayed on other graphs as needed to monitor data quality.
 - 1) Click View > Graphs/Tabular to explore other graphical and tabular interfaces.
 - a) Graph display settings can be configured by right clicking on the graph and selecting "Properties".
 9. Continue across the channel until you reach the transect end point on the opposite shore.



10. Ensure that two good bins are available at this location using the Composite Tabular window (**Figure 30**).
11. Hold the float steady at this location and wait until at least 10 shore ensembles have been collected.
 - a. This is equivalent to about 10 seconds.
 - b. The number of ensembles can be viewed in the Composite Tabular window (**Figure 30**).
12. Using a stadia rod, meter tape, or laser range finder, determine the distance from the transect end point to the edge of water. This is referred to as the “edge distance”.
 - a. Measure the area from the center of the ADCP to the edge of the water.
 - b. If using a rangefinder make sure that the laser is not hitting leaves or branches hanging over the channel. Take a few shots and make sure they are all the same.
 - c. If it is not possible to measure this distance with an instrument, use the “Distance MG [Made Good]” values displayed on the right side of the Composite Tabular 1 window to calculate the edge distance from beginning/end of the transect to the adjacent edge of water.
 - d. If you end from the same location for each transect, this distance does not need to be measured each time (it is recommended to mark the transect end point for this reason).
13. Click Acquire > Stop Transect (shortcut: F5) to stop data recording.
 - a. Note that the measurement has now ended.
14. When prompted, enter the edge distance (measured in **Step 12**).
15. Define whether you ended the measurement at the left or right bank.
 - a. When facing downstream, the left bank is on your left side.
16. To add notes that document important information relating to each transect right click on the transect node in the Measurement Control window (upper left pane in the WinRiver II main screen) and select “Add Note”.
 - a. Notes that describe individual transect measurements help explain the data that was collected and are thus extremely beneficial to post-processing/data QAQC. Always provide clear, descriptive documentation regarding the discharge measurement. Examples of individual transect notes include:
 - 1) “A barge went through prior to/following the transect measurement”.
 - 2) “The wind picked up considerably during the transect measurement”.
 - 3) “It was difficult to maintain a boat velocity less than the mean velocity of the river during the transect measurement due to...”.



- 4) "Poor bottom tracking/GPS tracking occurred during this transect due this measurement due to..."
- 5) "River stage appeared to rise/fall during this transect"
- 6) "High sediment concentration was present during this transect"

17. The transect measurement is now complete.

18. To view the data you collected during the transect open the node (+) under the Transect name in the Measurement Control window and double-click the disc button.

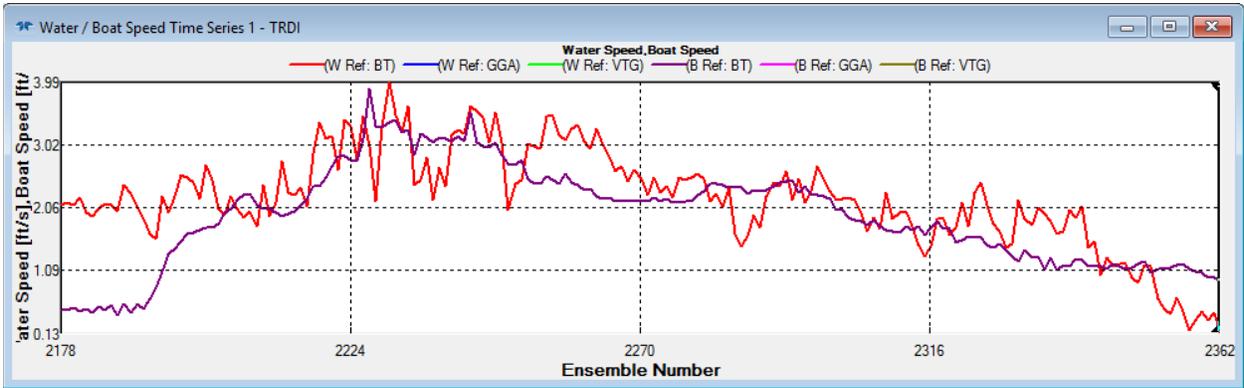
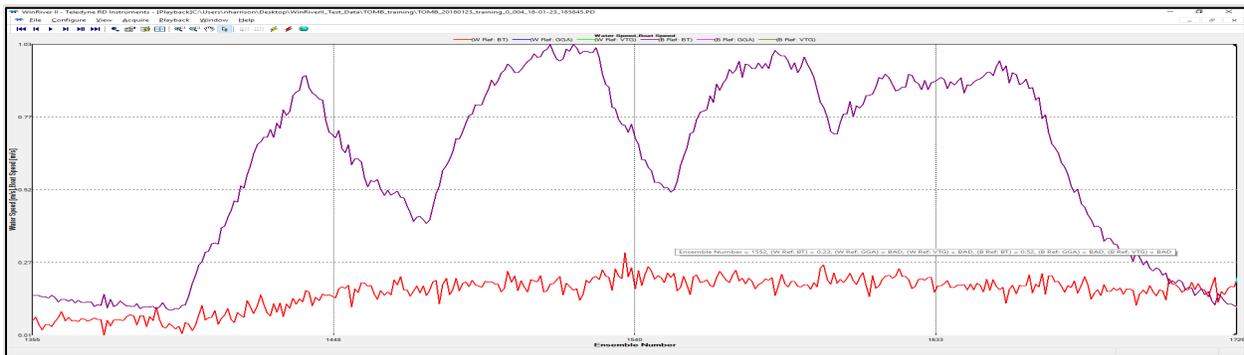


Figure 33. Water Speed vs. Boat Speed graph. Above: Improper technique. The boat speed (purple line) is erratic and higher than the water velocity (red line). Below: Proper technique. Maintain an even boat speed so that the purple and red lines are more in line and boat speed remains generally lower than water speed.

Collect (At Least) Three Additional Transect Discharge Measurements (Minimum of Four Total)

Repeat the previous steps, moving the trimaran float across the channel from each transect start and end point until a total of four transects have been measured (two in each direction). A minimum of four transects (each lasting a minimum of 180 seconds) must be collected during each discharge measurement, two in each direction. The measured discharge is the average of the discharge collected during each transect.



Enter the staff gauge height prior to each transect measurement in the Fulcrum app. Record all other notes in the individual transect notes and/or the Remarks window of the WinRiver II Site Wizard (typically notes that affect all transects can be entered in the Site Wizard notes and notes that affect individual transects are to be entered in the individual transect notes).

A new data file and Transect node will be created in the Measurement Control window each time you start and stop recording during each transect (ex: Transect 0000, Transect 001, Transect 002, Transect 003). Once the fourth transect is complete stop data collection and evaluate whether additional transects are needed.

5. Evaluate Whether Additional Transects Are Required

More than four transects must be measured if:

1. Total duration of all transects does not exceed 720 seconds.
2. The discharge measured during at least one transect is greater than 5% of the average discharge of all transect measured.
3. An observed gauge height change is associated with a notable change in discharge for a given transect.

Evaluate the total duration of all transects:

1. In the Measurement Control window (top left panel in the WinRiver II main screen) ensure that each transect measurement you wish to evaluate is checked.
 - a. Uncheck any Transects were measured that contained errors and are not meant to be included in the evaluation.
 - b. A minimum of four reciprocal transects (that do not contain errors) must be checked.
2. In the WinRiver II main screen, hit the F12 button to bring up a summary table that provides information on each transect measured.
3. Scroll over to the fifth to last column, "Duration".

Ensure that each transect duration is ≥ 180 seconds and the sum of all transect duration is ≥ 720 seconds.

4. If individual and total transect duration requirements are met, proceed to the next evaluation step.
5. If an individual transect durations is < 180 seconds or the sum of all transect durations are < 720 seconds, collect two additional transect measurements (reciprocal pairs of transects must always be measured, one that begins from each side of the channel) and re-evaluate the summary window.



Evaluate the discharge of each transect relative to average discharge of all transects:

1. In the Measurement Control window (top left panel in the WinRiver II main screen) ensure that each transect measurement you wish to evaluate is checked.
 - a. Uncheck any Transects were measured that contained errors and are not meant to be included in the evaluation.
 - b. A minimum of four reciprocal transects (that do not contain errors) must be checked.
2. In the WinRiver II main screen, hit the F12 button to bring up a summary table that provides information on each transect measured (**Figure 33**).
3. Note the value listed in the fifth column, "Total Q", for each transect row.
 - a. This is the total discharge measured during each transect.
4. Note the value listed in the "Average" row of the "Total Q" column.
 - a. This is the average discharge of all transects measured.
5. Note the value listed in the sixth column, "Delta Q", for each transect row.
 - a. This is the percent difference of total discharge measured during each transect relative to the average discharge across all transects.
6. If the Delta Q value for each transect is $\leq 5\%$, discharge requirements are met and no additional discharge transects are necessary.
 - a. Proceed to the next evaluation step.
7. If the Delta Q value for any individual transect is $> 5\%$:
 - a. Collect two additional transect measurements (one from each side of the channel) and re-evaluate the summary window (reciprocal pairs of transects must always be measured, one that begins from each side of the channel).
 - 1) Note that under changing hydrologic conditions (stage is rising or falling) Delta Q requirements may be difficult to meet.
 - 2) If stream stage was fluctuating dramatically throughout the transect measurements, proceed to the next evaluation step.
 - 3) As total measured discharge values decrease during the low flow regime, achieving $< 5\%$ Delta Q values becomes increasingly difficult.
 - a) The instrumentation approaches the lower limits of its measurement ability at low stages and there is an overall increase in uncertainty when measuring low-flow discharge (environmental factors such as bed and bank geometry exert a larger influence on velocity paths and can adversely affect measurement ability).



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- b) A high level of precision is required to obtain repeatable discharge values per transect.
 - c) As more measurements are collected a given site over time, Science and Field Science staff can work together to develop applicable Delta Q thresholds based on stage levels.
- b. If Delta Q values still exceed 5% for a given transect collect two additional transect measurements (reciprocal pairs of transects must always be measured, one that begins from each side of the channel), and re-evaluate the summary window.
 - c. If, after collecting a total of 10 transects, Delta Q values still exceed 5% for a given transect, proceed to the next evaluation step.
 - 1) Submit a trouble ticket to Science upon return to the office.
 - d. Keep in mind that the more transects that are measured increases the probability that the true mean discharge will be measured but it also increases the probability that an outlier measurement will be collected.

Transect	Start Bank	# Ens.	Start Time	Total Q m ³ /s	Delta Q %	Top Q m ³ /s	Meas. Q m ³ /s	Bottom Q m ³ /s	Left Q m ³ /s	Left Dist. m	Right Q m ³ /s
01000	Right	417	19:27:56	1151.505	1.92	67.125	957.347	120.280	2.978	9.00	3.775
01001	Left	487	19:33:48	1121.736	-0.71	64.965	933.882	114.248	2.344	9.00	6.297
01002	Right	469	19:45:47	1123.982	-0.51	65.115	932.999	116.472	3.878	11.60	5.518
01003	Left	398	19:52:15	1121.822	-0.70	65.398	934.828	114.624	2.516	11.60	4.457
Average		442		1129.761	0.00	65.651	939.764	116.406	2.929	10.30	5.012
Std Dev.		42		14.533	1.29	0.999	11.746	2.760	0.687	1.50	1.117
Std./ Avg. (%)		9.50		1.29	0.00	1.52	1.25	2.37	23.46	14.57	22.29

Figure 34. Discharge summary window in WinRiver II. The red box highlights Delta Q values. In this example all are < 5%, an indication that no additional transect measurements are required.

Evaluate changes in transect discharge relative to changes in gauge height

Gauge height must be observed and recorded in the app prior to each transect measurement in order to calculate mean stage and assess unsteady flow conditions. Unsteady flow conditions occur during periods of rising or falling stage which may occur during or immediately following heavy rain events, upstream dam or lock flow regulation, tidal effects, downstream backwater effects, or flood waves. Always document unsteady flow conditions in the main Remarks section and/or individual transect notes.

If a gauge height change is associated with a notable change in discharge for a given transect (i.e. > ~3% of the mean):

1. Attempt to collect a pair of reciprocal transects that correspond with a given gauge height.
2. If stage is changing too rapidly and this is not possible, save transect location files (if needed) and proceed to **Section F.12**.
3. Submit a trouble ticket to Science upon return to the office.



6. Create Transect Location Files (Optional)

Location files use GPS data to save the location of transect start and end points so that they can be utilized during subsequent discharge surveys. This feature cannot be utilized if GPS data was not integrated into the measurement. Once a transect has been measured it appears in the WinRiver II Measurement Control window, and the location can be saved. Multiple transect locations can be saved using unique files names (i.e. if discharge was measured 5 meters upstream during a particular survey).

To create a Transect Location file:

1. Complete a discharge measurement at a given transect.
2. Identify the transect location to be saved in the WinRiver II Measurement Control window.
 - a. The discharge measurement associated with the transect must contain GPS data.
3. Rick-click on the transect node and select “Define Transect Location” (**Figure 34**).
4. The Edit Locations window will appear.
 - a. Click on the map to zoom.
5. Enter a Location Name and any relevant notes about the transect.
6. Click the Save & Close button.
 - a. You must click the “Save & Close” button to create the location file.
 - b. Selecting Cancel or closing the Edit Locations window will not create the location file.
7. Click Save on the Save Location screen.
 - a. The *.dat location file will be saved to the C:\Measurements\Locations folder by default, this location can also be edited.

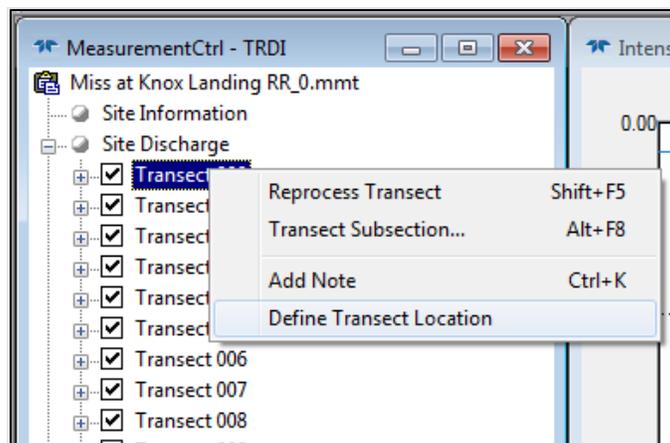


Figure 35. Defining transect locations In WinRiver II.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

F.12 Evaluating the Discharge Measurement in the Field

Following the completion of the discharge survey, the following data review steps must be completed:

1. Review, finalize, and save data in WinRiver II.
2. Check measured discharge value against the stage-discharge rating equation (if available).
3. Review data in Q-Rev.

Data review must be conducted while still on site so that the discharge survey can be repeated if necessary.

Review, Finalize, and Save Data in WinRiver II:

1. Playback each measured transect and check parameters.
 - a. Open the node (+) under each transect.
 - b. Right click on the Transect number and select “Re-process Transect”. The transect data will appear in all graphs that are currently on display.
 - c. Right click on Playback Configuration and select “Properties”.
 - 1) In the Edge Estimates page on the right, verify that the Begin Transect and End Transect information was entered correctly.
 - 2) In the Offsets page check that the ADCP transducer depth was entered correctly (this depth should not have changed during the discharge survey).
 - 3) In the Discharge page choose the correct Left Bank and Right Bank Edge Type.
 - a) A custom coefficient value can be entered if a given bank does not conform to triangular or square shape.
 - b) Consult Science with any questions regarding bank coefficients. These values are very important in estimating edge discharge.
 - 4) Once any value has been entered in the Playback Configuration > Properties window, you can right click on the box and select “Apply to All Active Checked Transects” if you wish to apply this value to all selected transects.
 - a) This will apply the setting to all transects in the measurement that are checked.
 - b) Each transect will need to be re-processed for this change to be applied.
 - d. Enter all applicable notes in the general Remarks section and in individual transect notes, as necessary.
2. Following the WinRiver II review save the measurement file on the laptop and a USB dongle for backup.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- a. An .MMT file will be created along with .PDO files that are unique to individual transects. Each of these files must be contained in a folder on the laptop and backed up onto a USB dongle.

Check the measured discharge value against the stage-discharge rating equation, if available:

Once a stage-discharge rating curve has been developed and validated for a site, a rating equation is derived that predicts discharge given stream stage (supplementary information on rating curves is available in **Appendix D**). Once established, rating equations will be provided to field staff by Science. Rating equations are commonly expressed as power relationships:

$$Q = C_r(G - \alpha)^\beta$$

Where:

- Q = discharge;
- G = the stage, or gauge height;
- α = the gauge reading corresponding to zero discharge; and
- C_r and β = rating curve constants

Following the discharge measurement:

1. Enter the stream stage (G) into the rating equation that is associated with the site.
2. Calculate predicted discharge.
3. Evaluate whether the measured discharge is $\pm 10\%$ of the discharge predicted by the equation.
 - a. If the measured discharge is $< \pm 10\%$ than predicted discharge:
 - 1) Another discharge survey is not required.
 - b. If the measured discharge is $> \pm 10\%$ than predicted discharge (and the stream stage did not change during the site visit):
 - 1) Conduct another discharge survey immediately.
 - 2) If, after a second attempt, the measured discharge remains $> \pm 10\%$ the predicted rating discharge:
 - a) Check the second discharge measurement file for errors using steps provided in previous sections.
 - b) Save both discharge measurements.
 - c) Submit a trouble ticket to Science.



- (1) This may indicate a shift in the rating, which, if validated by additional measurements, would warrant an increase in the frequency of discharge measurements at the site.

Review, Finalize, and Save Data in Q-Rev:

QRev software (USGS) serves a final means to QAQC ADCP discharge data. The following procedures must be done in the field prior to leaving the site.

1. Open Q-Rev.
2. Open the .mmt file (the file that was just saved in WinRiver) in Q-Rev.
 - a. In the main Q-Rev window: Select Data > TRDI > select the WinRiver II .mmt file.
 - b. Note that the location where the .mmt file is stored must also contain all of the .PDO files that correspond with the measurement.
3. Note the color of the buttons on the left side of the main window. These colors indicate data quality for specific measurement parameters.
 - a. Green: Good, no investigation required.
 - b. Yellow: Problems could be presented and may be able to be corrected, investigation is required.
 - c. Red: Problems are present that are negatively affecting measurement data, investigation is required.
4. Select the "Options" button (this button will never be colored).
 - a. Ensure that "Units" are set to SI.
 - b. Click OK.
5. In the main window, select the "Moving Bed Test" button (regardless of color).
 - a. Uncheck any tests that are not valid in the "User Valid" column.
 - 1) Note the "Quality" rating, and the text contained in the Messages window.
 - b. If any tests contain "Moving Bed" = "Yes" consider checking "Use for Correction" if the tests were valid.
 - c. Note this will change the measured discharge value.
6. Evaluate the remaining buttons if they are not green:
 - a. ADCP/Site Info
 - 1) Here the Station Name and Number can be edited.
 - b. System Test



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 1) Provides the results of the ADCP system test.
- c. Compass/P/R
- 1) Provides heading, pitch and roll, and magnetic variation data for each transect.
 - a) If the pitch and roll time series data are too high and the extended compass calibration was not performed, Q-Rev will apply a flag.
 - 2) This button will be yellow if Compass Calibration Error is > 1 degree.
 - 3) Here you can change the magnetic variation for some or all transects by clicking on the Magnetic Variation value within the Heading, Pitch, & Roll table.
 - 4) You can view the Compass Calibration data by clicking the “View” button under Compass Cal/Error on the right side of the screen.
- d. Temp/Salinity
- 1) Here you can evaluate the ADCP thermistor which controls temperature, salinity, and speed of sound data.
 - a) Fluctuations in the time series data may indicate (1) the ADCP was not allowed to fully equilibrate to the water temperature prior to measurement, or (2) actual temperature variations present in the channel.
 - 2) Check the Average Temperature vs. the User Temperature (entered at the start of the ADCP measurement).
 - 3) The temperature source can be changed from internal (ADCP) to User for one or all transects by clicking on the Temperature Source value in the Speed of Sound Settings table.
 - a) Note this will change speed of sound and discharge values.
- e. BT Filters
- 1) If GPS data was used as the reference navigation this button never needs to be evaluated. Reference the GPS Filters button instead.
 - 2) Here you can evaluate time series velocity data, velocity errors, and how the data can be adjusted using different filter and interpolation settings.
 - 3) Consult with Science if you feel that BT Filters require adjustment.
- f. GPS Filters
- 1) If Bottom Track was used as the reference navigation this button never needs to be evaluated. Reference the BT Filters instead.
 - 2) Here you can evaluate time series velocity data, velocity errors, and how the data can be adjusted using different filter and interpolation settings.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 3) The ATL-g Plot to Google Earth plots the transects for the discharge measurement to the Google Earth App. This will only work if the Google Earth App is installed on the computer that QRev is running on.
 - 4) Consult with Science if you feel that GPS Filters require adjustment.
- g. Selected Reference
- 1) The Selected Reference button will be grayed out and this window will not be accessible if there is no GPS data in the file loaded to QRev.
 - 2) The summary table provides details on the navigation data available, and describes changes in calculated discharge based on filter changes in QRev.
 - 3) The Reference Used panel displays the navigation reference currently being used for the transect selected in the summary table.
 - 4) The boat speed time series shows the boat speed for each of the navigation reference data types in the same graph per transect.
 - 5) The ship track time series shows the ship track for each of the navigation reference data types in the same graph per transect.
 - 6) In the Selected Reference panel, the reference navigation data type used for computing discharge can be changed. Refer back to the summary table to see how a change affects the calculated discharge.
 - 7) The Composite Tracks feature can automatically substitute one of the other valid navigation references for the selected navigation reference, if the selected navigation reference is invalid.
 - a) Composite tracks default to off.
- h. Depth Filters/Draft
- 1) Here data from each beam can be reviewed and the combined cross-sectional value.
 - 2) QRev defaults to using inverse depth weighting to compute the mean depth when the 4 slant beams are used.
 - 3) The filter type can be changed to eliminate erroneous spikes. Note this will change the discharge value.
- i. WT Filters
- 1) Here raw and processed water track data can be reviewed and adjusted.
 - 2) Note that the error and vertical velocity filters do not always perform well on data from ADCPs with auto adaptive modes (the RiverPro being one such model) due to the change in error velocity distribution for the different modes.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- a) If this button is yellow or red try turning error and vertical velocity filters off. Note the change in total discharge.
- j. Extrapolation
 - 1) Default edge extrapolation settings are determined automatically from algorithms created for the Extrap program.
 - 2) The data panel displays average normalized depths for segments of the channel, with each segment equating to 5 percent of the total discharge.
 - 3) The Profile Panel is the primary panel in this window.
 - a) Gray Dots represent raw data, normalized discharge or velocity (depending on which is selected) in each depth cell for all transects selected in the Fit panel.
 - b) Green circles represent the top cell for each ensemble, the cell at the water's surface.
 - c) The Red/Black Squares are median points for the raw data in each segment. They are color coded:
 - (1) Red: contains less values in the segment than the threshold requires, and is not used in the computation of extrapolation.
 - (2) Black: Median values of the composite of all the transects in the measurements.
 - d) The horizontal Red/Black lines (Whiskers) on either side of each median value extend to the 25th and 75th percentile of all the data in that segment (i.e. 50% of the raw data will fall inside the whiskers).
 - e) The center line, going through the median squares is the extrapolation line, which is also color coded:
 - (1) Magenta: transects collected while crossing the channel from left bank to right bank (facing upstream).
 - (2) Blue: transects collected while crossing the channel from right bank to left bank (facing upstream).
 - (3) Black: is a composite of all the transects.
 - f) The fit panel allows a separate fit edge for each transect.
 - (1) Leave "Fit" set to "Automatic" for default algorithms to be used (recommended default setting).
 - (2) Change "Fit" to "Manual" to change the extrapolation method at the Top and Bottom of the graph to different fit options – Power, Constant, or 3-Point (Top) or Power or No-Slip (Bottom).



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

(a) Set the Exponent value incrementally for Power or No-Slip extrapolations. The graph will update as the exponent is changed.

(3) Note that discharge values will change as extrapolation fits are adjusted.

k. Edges

- 1) This window displays the edge settings for computing the left and right edge discharges and displays graphs for evaluation.
- 2) The Edges button will be yellow if any of the extrapolated edge discharge contributes >5% of the total measured discharge for the transect.
 - a) Uncertainty in the total estimated discharge increases with increased contribution of edge discharge to the total estimate.
 - b) Check the “Left Distance (m)” and “Right Distance (m)” values to ensure the left and right edge distances were entered correctly.
 - (1) These values are directly correlated to the percentage of total discharge contributed by the edges.
 - (2) To edit an edge distance click on the “Left/Right Distance (m)” value you wish to edit. The new value can be applied to a singular transect or all transects in the measurement.
 - c) If edge distances are correct but edge discharge remains >5% of the total measured discharge, not much else can be done during post-processing other than re-measuring additional transects during which you begin and end the measurement closer to the edge of water.

7. Save the file and exit Q-Rev.

SOP G Post-Field Sampling Tasks: Wadable Stream Sites using the ADCP Method

Once field verification of the measurement file is complete, the trimaran float with ADCP and GPS antenna and all components of the Temporary High Line Assembly shall be cleaned following standard operating procedures for cleaning field equipment used in aquatic systems. Batteries for the ADCP and GPS antenna shall be charged or replaced as needed.

G.1 Document Incomplete Sampling Within a Site

Discharge sampling is scheduled to occur at the prescribed sampling location according to the frequency and timing described in **Section 4**. Ideally, sampling will occur at this sampling location for the lifetime of the Observatory (core sites) or the duration of the site’s affiliation with the NEON project (relocatable sites). However, sampling may be shifted from one location to another when sampling is compromised. In general, a sampling location is compromised when sampling becomes so limited that data quality is significantly reduced.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

There are two main pathways by which sampling can be compromised. First, sampling locations can become inappropriately suited to answer meaningful biological questions – e.g., stream morphology changes in such a way that discharge measurement quality is reduced. Second, sampling locations may be located in areas that are logistically impossible to sample on a schedule that that is biologically meaningful.

For the wadable stream discharge sampling program, a given discharge transect must be sampled during 100% of the bouts expected for the site (see **Appendix E** for the number of expected bouts and site-specific sampling documentation) over a one-year period. Transects that cannot be sampled on this schedule should be considered compromised.

If sampling at a given transect is not possible during a given bout a trouble ticket should be submitted by Field Science staff.

To document a missed discharge bout:

1. Create an incident with the following naming convention to document the missed sampling: ‘AOS Sampling Incomplete: MOD – [Root Cause Description]’
 - a. Example: ‘AOS Sampling Incomplete: DSC – Could not access discharge location due to flooding’

Staff scientists review incident tickets periodically to determine whether a sampling location is compromised.

SOP H Data Entry and Verification: Wadable Stream Sites Using the ADCP Method

Raw ADCP discharge measurement files (i.e. files that have been evaluated in WinRiver II and Q-Rev but not post-processed by Science) are stored on an online file storage page and post-processed by Science. Complete the following steps to upload discharge measurement files.

2. In the office (or location with internet connection), store the measurement file on the cloud-based Box.com folder.
 - a. Navigate to the main Box.com folder where raw ADCP files are stored.
 - 1) “NEON ADCP Discharge Measurement Files” <https://app.box.com/folder/48084982589>
 - 2) “Raw_Data”
 - b. Navigate to the applicable Domain folder for raw files.
 - 1) Ex: “Domain_03_Raw_Files”
 - c. Navigate to the appropriate site folder.
 - 1) Ex: “FLNT”
 - d. Navigate to the appropriate calendar year.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- e. Create a new folder that is unique to your discharge measurement.
 - 1) Click the “New” dropdown and select “Folder”.
 - 2) Ensure that the folder name is in a standardized format.
 - a) Ex: “SITE_YYYYMMDD” (FLNT_20180317)
- f. Move all of the measurement files into this folder.
 - 1) This includes .MMT, .PDO files, and _GPS.TXT file (StreamPro only) - everything that was saved on the laptop/USB.
 - 2) If any other relevant materials correspond to the discharge measurement (i.e. pictures, screen shots, etc.) create a sub-folder here where they can be stored.
 - 3) In addition to .PDO and _GPS.TXT files (of which there will be many depending on the number of transects measured), include only one (1) .MMT file (from WinRiver II) and one (1) .XML file in the sub-folder.
- g. Once the all data is available on the Box folder, Science will assume it is ready for post-processing.

APPENDIX B DISCHARGE MEASUREMENTS AT RIVER SITES USING THE REMOTE CONTROLLED BOAT METHOD

The following sections provides instruction on how to complete discharge surveys at NEON river sites using acoustic Doppler current profiler (ADCP) instrumentation deployed with a remoted controlled boat.

B.1 Introduction

An acoustic Doppler current profiler (ADCP) uses sound to measure water velocity based on the Doppler Effect, a principal of physics discovered by Christian Johann Doppler in 1842. Doppler’s principal relates the change in frequency of a source to the relative velocities between the source and the observer. An ADCP applies the Doppler principle by reflecting an acoustic signal off small particles of sediment and other material (scatterers) that are present in water. The velocity measured by the Doppler principle is parallel to the direction of the transducer emitting the signal and receiving the backscattered acoustic energy.

NEON utilizes ADCPs to measure discharge at NEON aquatic sites that contain wadable stream and rivers. NEON stream discharge measurement collection at river sites can be facilitated using two unique deployment methods: (1) mounting a RiverPro ADCP (TRDI) to a remote controlled boat (ARC-Boat by HR Wallingford) or (2) mounting a RiverPro ADCP (TRDI) off the side of a piloted boat. In both instances the boats are driven back and forth across the channel a number of times with the base the base of the ADCP beneath the water surface. The ADCP contains four beams pointed at 20 degrees from



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

the vertical that can continuously measure water depth, water velocity, and instrument speed. Discharge and velocity calculations performed by ADCPs during streamflow measurements are well-documented in the literature (Mueller et al., 2013; TRDI, 2015) but the basic premise is as follows (Den Herder, 2018):

- The ADCP instrument transmits short pulses of sound at fixed frequencies into the water.
- The transmitted sound bounces off scattered material suspended in the water (sediment, microscopic organisms, etc.). The returned signals from these scatterers are shifted in frequency.
- The returned signals from each beam are used to create the water currents in east, North, and Vertical velocity vectors.
- Returned signals are continuously processed into separate depth cells (or bins) to provide a profile of the water column
- Binned velocity and depth are integrated to calculate bin discharge, which are then summed to calculate total discharge
- Multiple discharge transect measurements are completed and mean discharge across transect measurements is calculated and reported as total discharge.

The ADCP measures the relative motion of the water to the ADCP by correcting the measured water velocity with the measured velocity of the vessel used to deploy the instrument (boat, trimaran float, etc.). The velocity of the vessel can be calculated in two ways: externally via a global positioning system unit (GPS), or internally utilizing ADCP bottom tracking technology. The ADCP divides the water column into depth cells (or bins) and reports a velocity for each depth cell.

The ADCP software integrates total bin velocity over the bin depth to obtain bin discharge. The resulting sub-section 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 stream 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. On average it expected to take an experienced field crew 30-60 minutes to complete a stream discharge measurement from start to finish.

SOP I Preparing for Sampling: River Sites Using the Remote Controlled Boat Method

The RiverPro ADCP (Teledyne) (Figure 35) and ARC-Boat (Figure 36) remote controlled boat are the preferred means to measure discharge at NEON river sites. Hemisphere V102 antenna units provide GPS heading and positioning data during each ADCP measurement. Three software packages are



required for all ADCP discharge surveys: (1) WinRiver II software (Teledyne), a discharge data application for data collection and post-processing, and (2) [QRev](#) (USGS OSW), a Matlab program for advanced post-processing of WinRiver II measurement files, and (3) [ParaniWin](#), an executable that sets up and configures the Parani Bluetooth dongle. If an ARC-Boat deployment is not available, the Piloted Boat method (**Appendix C**) can be used as an alternative means to capture ADCP data.



Figure 36. RiverPro ADCP. Left: base of the ADCP showing the five beam lenses; Right: top of the ADCP with indicator lights and power cord.



Figure 37. The ARC-Boat is the preferred deployment method to measure discharge at NEON river sites.

I.1 Preparing for Data Capture

Prior to leaving the office ensure that the following criteria are met (each point explained in detail below):

- All necessary equipment is gathered and prepared (**Table 13**).
- Attach the RiverPro ADCP to the ARC-Boat ADCP Adapter.
- Setup and test Bluetooth communications.
- Setup and test GPS communications.
- If the site has an approved stage-discharge rating curve, the current rating equation is available for measurement comparison/validation.

I.2 Attaching the ADCP to the ARC-Boat ADCP Adapter

The ARC-Boat ADCP adapter powers the RiverPro ADCP and holds it in place within the ADCP compartment of the boat (**Figure 37**). Prior to deploying the ARC-Boat into the water, always leave the protective cover on the base of the ADCP so that the beam lenses (**Figure 35**) do not get scratched.



1. Connect a fully charged 12V battery to the internal compartment of the ADCP adapter. The ADCP must be powered in order to communicate and collect measurements.
 - a. To access the inside of the ADCP adapter the GPS mount plate must first be removed by disconnecting the four nuts on the base.
 - b. The ADCP adapter can be then be removed by loosening the four plastic screws at each of the corners.
2. Attach one end of the long set screws into the top of the ADCP.
3. Attach the other end of the long set screws to circular base plate of the ADCP adapter using the wingnuts.
4. Connect the ADCP cable coming out of the ADCP adapter to the ADCP. Lubricate the connection with dielectric grease prior to connecting the cables.
5. Flip the adapter switch to "Power ON". The red light on the ADCP adapter should light up.
6. One of the three LED lights on the ADCP will turn green when the instrument is powered.
7. A red light on the ADCP indicates a system error. Contact Science if this light turns on.
8. Attach the circular base plate of the ADCP adapter to the hull of the ARC-Boat using the small set screws.

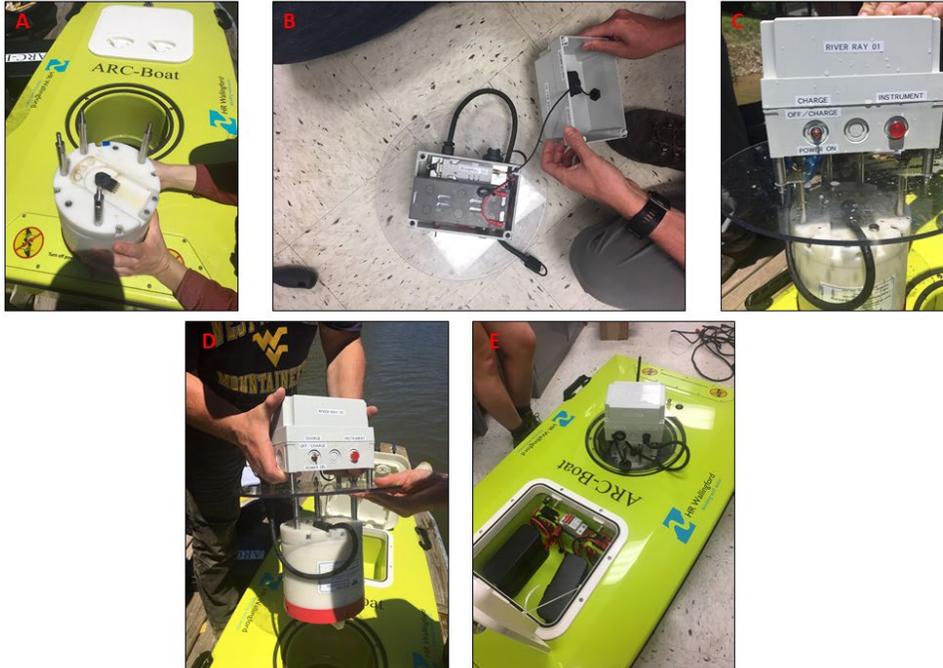


Figure 38. The ARC-Boat setup with the RiverPro ADCP adapter. A: connect the long set screws to the top of the ADCP; B: connect a fully charged 12V battery inside the ADCP adapter; C: connect the long set screws to the circular base plate of the adapter with the wingnuts, connect the ADCP cable coming out of the adapter to the ADCP, and flip the adapter switch to “Power On” (ADCP light should be green); D: the RiverPro ADCP and ARC-Boat ADCP adapter fully integrated; E: set the ADCP adapter with the ADCP into the ADCP compartment of the ARC-Boat and connect the circular base of the adapter to the boat using small set screws. Not shown: GPS mounting plate on top of the ADCP adapter.

I.3 Attaching the GPS Antenna to the ARC-Boat ADCP Adapter

A GPS mount plate is installed above the ARC-Boat ADCP adapter to hold the Hemisphere V102 GPS so that GPS data is available during river discharge measurements. A 3/16” Allen wrench is required to install the GPS antenna onto the GPS mount. The GPS antenna must be located directly above the ADCP adapter and aligned with ADCP Beam 3 (**Figure 38**).

To install the Hemisphere V102 GPS antenna onto the GPS mount:

1. Connect the ADCP Adapter to the ARC-Boat with the ADCP installed (**Section I.2**).
2. Disconnect the GPS cable at the back port of the GPS antenna.
 - a. Loosen the cable connector by twisting it clockwise.
 - b. Gently pull the cable so that it is released from the antenna.
3. Place the GPS antenna on top of the GPS mount, lining up the female threads in the antenna and the male threads on the mount.
4. Gently turn the GPS antenna clockwise until it is fully seated on the GPS mount.



5. Adjust the GPS antenna so that the front of the antenna is aligned with ADCP Beam 3 and the space between the two small holes in the back of the antenna is directly over the center of the ADCP adapter (**Figure 39**).
 - a. The “front” of the GPS antenna is indicated by an arrow underneath the antenna.
 - i. It may be helpful to place a marker on top of the GPS antenna to ensure the front is always facing the correct direction.
 - b. The area to be centered over the ADCP is indicated by the space between two small screws in the back of the unit.
6. Once the GPS is properly oriented, use a 3/16” Allen wrench to tighten each of the two set screws located on each side of the black base on the bottom of the GPS antenna.
 - a. These screws set the GPS antenna in place so that it cannot move on the mount.
7. Connect the GPS cable into the back port of the GPS antenna.
 - a. Make sure to line up the cable with the port properly. A small notch in the top of the cable indicates the correct orientation (the cable should be placed into the port so this notch is on the top)
 - b. Once lined up gently push the cable into the port.
 - c. Tighten the cable connect so that it is securely connected to the GPS antenna.
8. When not in use the GPS antenna should be disconnected from the GPS mount and stored in a protected location during transportation.



Figure 39. Installing the Hemisphere V102 GPS antenna onto the ARC-Boat GPS mount.

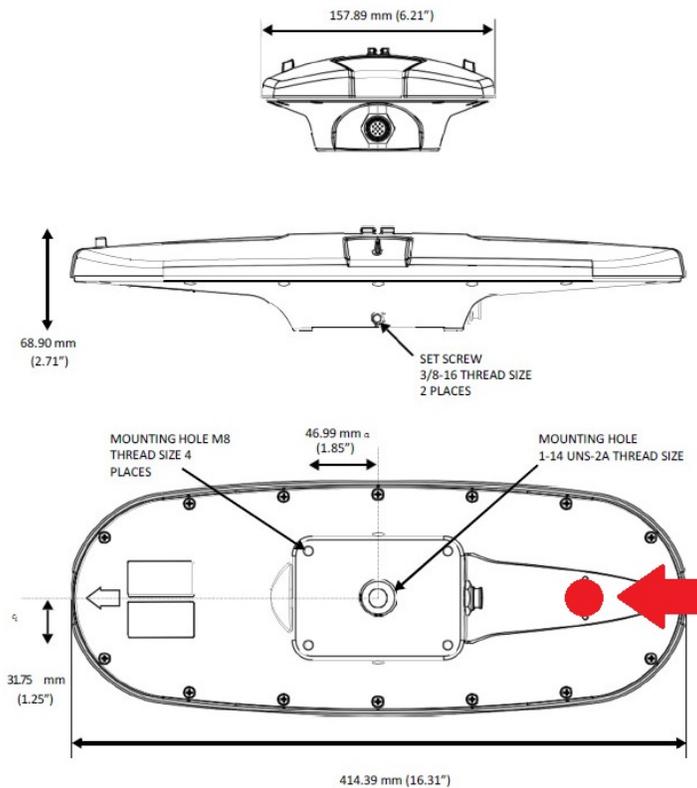


Figure 40. Hemisphere V102 GPS antenna schematics. Top: the back of the unit with cable port show; Middle: the side of the unit showing one of two set screw locations; Bottom: the base of the unit, the red circle to the right of the unit indicates the location that must be centered over the ADCP, the white arrow to the left of the unit indicates the direction the unit must face so that it is oriented toward Beam 3 of the ADCP.

The GPS antenna is considered an external heading, i.e. the internal ADCP heading is not being used. When an External Heading is applied, the Bottom Track reference assumes the External Heading device is aligned with Beam 3 of the ADCP. Therefore the Bottom Track reference is directly affected by the relationship between the GPS heading and the ADCP heading. The GPS antenna is not required to face towards the bow of the boat but it must be aligned with the ADCP Beam 3.

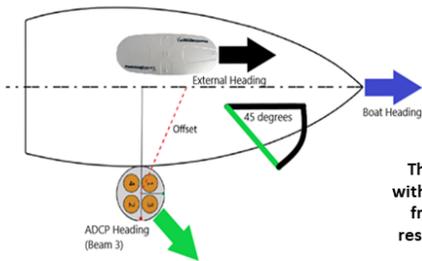
If the GPS antenna is not aligned with the ADCP Beam 3, a heading offset must be entered to align the External Heading and Bottom Track Ship Tracks in the WinRiver II settings (**Figure 40**). This can be done prior to the transect measurement in the Field Configuration Settings or following the transect measurement in the Playback Configuration settings.

To enter an External Heading offset:

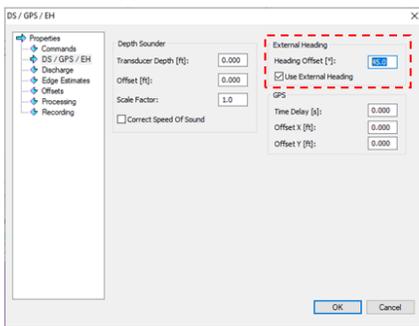
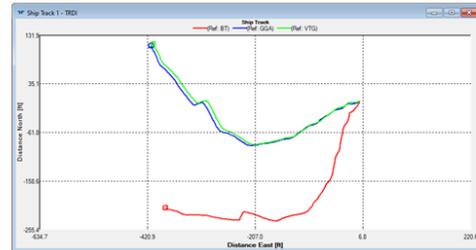
1. Open the Transect node.
2. Select "Playback Configuration".
3. Open the "DS/GPS/EH" tab.



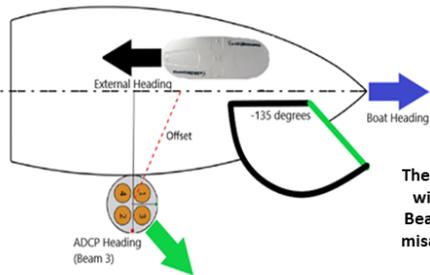
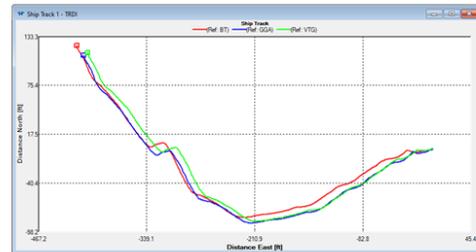
4. Under the “External Heading” section, enter a Heading Offset value.
5. Right click on the value to apply to all transects (if required).
6. Playback the transect to apply the offset.



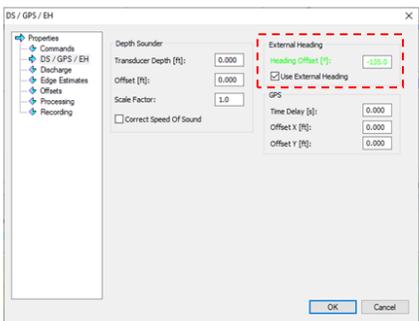
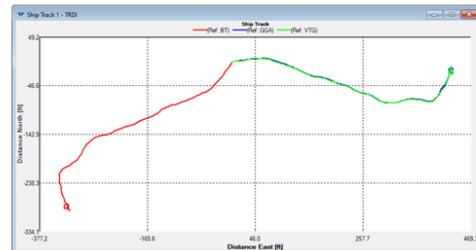
The GPS External Heading is aligned with the Boat Heading but is misaligned from ADCP Beam 3 heading by 45°, resulting in a misalignment of GPS and BT Ship Tracks



Applying a 45° offset to the External Heading aligns GPS and BT Ship Tracks



The GPS External Heading is misaligned with the Boat Heading and the ADCP Beam 3 heading by -135°, resulting in a misalignment of GPS and BT Ship Tracks



Applying a -135° offset to the External Heading aligns GPS and BT Ship Tracks

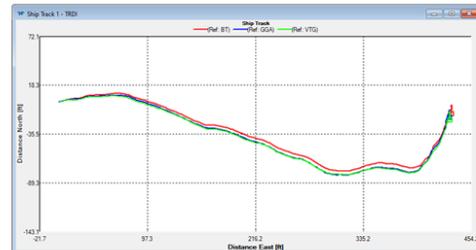


Figure 41. Applying External Heading offsets to align GPS and Bottom Track Ship Tracks.



I.4 Establishing Bluetooth Connections for the ADCP and GPS Antenna

The RiverPro ADCP and Hemisphere V102 GPS antenna communicate with WinRiver II software (installed on the laptop) wirelessly via a Bluetooth (wireless) connection. One Parani SD1000U Bluetooth transmitter, or dongle, is required to send ADCP and GPS data. It is best practice to have another one in the field as a spare. The Parani Bluetooth dongle contains a USB interface adapter that is plugged into a laptop COM port. Parani Bluetooth dongles are setup and configured using [ParaniWin software](#). This executable must be downloaded and installed on the laptop used for ADCP discharge measurement.

If the same laptop is used for ADCP measurements (this is recommended for ease of communication setup and software availability) the following setup should only need to occur prior to the initial measurement. Following the initial setup, the ADCP and GPS antenna should automatically connect to the laptop software via the dongle. These steps should also be used when troubleshooting connection problems. Setup, testing, and troubleshooting is best done in the office prior to deployment in case an internet connection is needed. An ADCP discharge measurement cannot be completed if Bluetooth communications are not configured.

Physically configure the Parani dongle (**Figure 41**):

1. The Parani dongle has a set of four DIP switches that are used to set the Bluetooth adapter's baud rate and data flow control.
2. These DIP switches need to be in the correct physical configuration using a small screwdriver, pocket knife, pen, or similar tool.
3. Move the DIP switches to the correct position in order to set the Baud Rate to 11520Kb. The diagram on the left of the dongle shows how the positions of each switch relate to baud rate configuration.
4. Set the first and second DIP switches to the right.
5. Set the third switch to the left (115200 baud rate)
6. Set the fourth (bottom) switch to the left (HW Flow Control OFF).



Figure 42. Top: Parani-SD1000U USB Bluetooth Adapter with default settings. Bottom: Correct settings for ADCP and GPS Bluetooth configuration.

Once physically configured, each dongle needs to be initially setup with the ParaniWin software. Complete the following steps for the ADCP dongle, then repeat for the GPS dongle:

7. Ensure that the ADCP and GPS units are powered and fully connected to the ARC-Boat ADCP Adapter.
8. Plug the Parani dongle into a USB port on the laptop.
9. Use Windows Device Manager to determine the laptop COM (communication) port that the Parani is assigned to.
 - a. Navigate to the Windows Device Manager.
 - 1) Start Menu > Search "Device Manager"
 - b. Open the "Ports (COM & LPT)" node.
 - c. Note the COM port number the Parani dongle is assigned to.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 1) Unplug and re-connect the Parani dongle to note which COM Port number appears and re-appears. This is the COM Port the Parani dongle is assigned to.
 - (1) If using Windows XP and later systems, the driver will likely load automatically when you plug in the Parani dongle.
 - (2) If the Parani is not showing up in the Ports (COM & LPT) node, it may show up in the "Other Devices" node.
 - (a) If this is the case an update to [Parani firmware](#) is required (under the picture of the dongle, find the Downloads tab, click on the firmware link, and click the download button to save the file to a known folder).
 - (b) Once complete, open Windows Device Manager, right click on the appropriate COM Port that the Parani is assigned to and navigate to the Drivers window.
 - (c) Choose "Browse my computer software for driver software". Click next and it will respond with a message of success or failure.
 - (d) If successful, close this window and return to Windows Device Manager. The Parani should now appear under the COM Ports node.
 - (e) If unsuccessful contact Science for troubleshooting.
 - d. Select the Parani SD100U dongle COM Port and set the baud rate to 115200.
 - 1) Right click on the COM port assigned to the Parani dongle and select "Properties" > "Port Settings".
 - 2) Configure Port Settings.
 - a) Bits per second = 115200.
 - b) Data bits = 8
 - c) Parity = None
 - d) Stop bits = 1
 - e) Flow control = None
 - 3) Click on the Advance Settings button.
 - a) Check the COM Port number assigned to the Parani in the top of the Advanced Settings window.
 - b) In the BM Options section, select the Latency Timer drop down and set to 1msec.
 - c) Click OK twice to exit Windows Device Manager.
10. Note the LED indicators on the Parani dongle.



- a. The “Mode” LED indicates which mode the Parani dongle is currently configured to.
 - b. Ensure the Parani dongle is set to MODE1, the LED will blink green at 1 second intervals.
 - c. The “Connect” LED indicates whether the Parani dongle is connected to the ADCP/GPS unit, the LED will blink green at 1 second intervals.
11. Open ParaniWin software to configure the Bluetooth connection.
- a. The UART Setting window will automatically pop up that displays the communication settings between the Parani dongle and the laptop. Ensure that the configured settings are set correctly. Notes: these settings must COM Port and physical dongle settings or the connection will not be possible.
 - 1) Serial port: Select the laptop COM port number the Parani dongle is assigned to (as shown in Windows Device Manager).
 - 2) Baud rate: 115200
 - 3) Parity: None
 - 4) StopBit: 1
 - 5) Click “OK”. Initial configuration should be complete.
 - b. Select the “Device Setting” tab.
 - 1) Set “Operation Mode” to “Mode1”.
 - 2) Check that Device Settings are the same as what was entered in the UART Setting Window.
 - 3) Under “Security Option” check the “Authentication” box and enter “0000” for the “Pin Code”.
 - 4) Click “Apply”.
 - 5) A “Completed Configuration” message should pop up.
 - a) If the connection was unsuccessful: review physical Parani dongle settings, COM port settings in Windows Device manager, and settings entered in ParaniWin and repeat process.
12. Select the “Connection (out)” tab.
- a. Click the “Search” button. This will ping all available wireless networks that are within range of the laptop.
 - b. Chose the desired instrument to connect to and click “Connect”.
 - 1) The ADCP should be shown as “RDI RPro”.
 - a) This label may vary.



- 2) Click "Connect".
 - c. A window will pop up with a "Connected successfully message".
 - d. One of the lights on the ADCP will turn blue, indicating that the Bluetooth connection was successful.
 - 1) If the connection was unsuccessful:
 - a) Review physical Parani dongle settings, COM port settings in Windows Device Manager, and all settings entered in ParaniWin.
 - b) Repeat process.
13. Once the dongle has successfully connected, close the ParaniWin program.
- a. **If the ParaniWin program is not closed, WinRiver II will not be able to connect to the ADCP.**

I.5 Testing GPS and ADCP connections in WinRiver II

Once the ADCP/GPS dongle connection has been successfully connected via Bluetooth, the connection must be tested in WinRiver II in order to ensure that data can be transmitted to the program. This must be done prior to each discharge survey that utilizes ADCP instrumentation and is best completed in the office in case additional troubleshooting is needed.

1. Ensure that the ADCP is fully powered (green light on) and setup for Bluetooth communications via the Parani dongle (blue light on).
2. Open WinRiver II.
3. In the WinRiver II main screen, click Configure > Peripherals.
 - a. Test ADCP communications.
 - 1) Ensure that the ADCP is fully powered (green light should be on) and the Parani dongle is installed in the designated COM Port.
 - 2) In the "Peripheral Configuration Dialog" window, under the "Peripherals" node, double click on "Read Serial Raw ADCP Data"
 - 3) Double click on "Port: ADCP Serial Port"
 - 4) Check that COM settings are correct and press OK.
 - 5) With "Port: ADCP Serial Port" still highlighted, click the "Test Port" button on the right.
 - 6) A dialogue box will open and you should see some information begin streaming regarding Teledyne RiverPro firmware. This indicates that the ADCP is recognized by the WinRiver II program (**Figure 42**).
 - a) If nothing appears than WinRiver II is not recognizing the ADCP.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- b) Ensure that ParaniWin is closed. If open, close this program and repeat the Peripheral test.
 - c) If ParaniWin is closed and the Bluetooth connection was successful in that program, check COM settings in “Port: ADCP Serial Port” and repeat the Peripheral test.
 - d) If nothing appears in the test window, further ADCP testing can be completed in the Configuration Dialogue tab of the Measurement Wizard window.
- 7) Click “Stop” and “Close” to cease testing and close the test dialogue window.
- 8) Once all configuration and testing is complete the ADCP Adapter battery should be switched off.
- a) Note: because GPS data is wired through the RiverPro ADCP cables the GPS Port cannot be tested in the WinRiver II Peripheral environment. In most cases ADCP data recognition in the Test Port Dialog indicates that GPS data is properly configured. Confirmation of GPS data availability is covered in future steps.

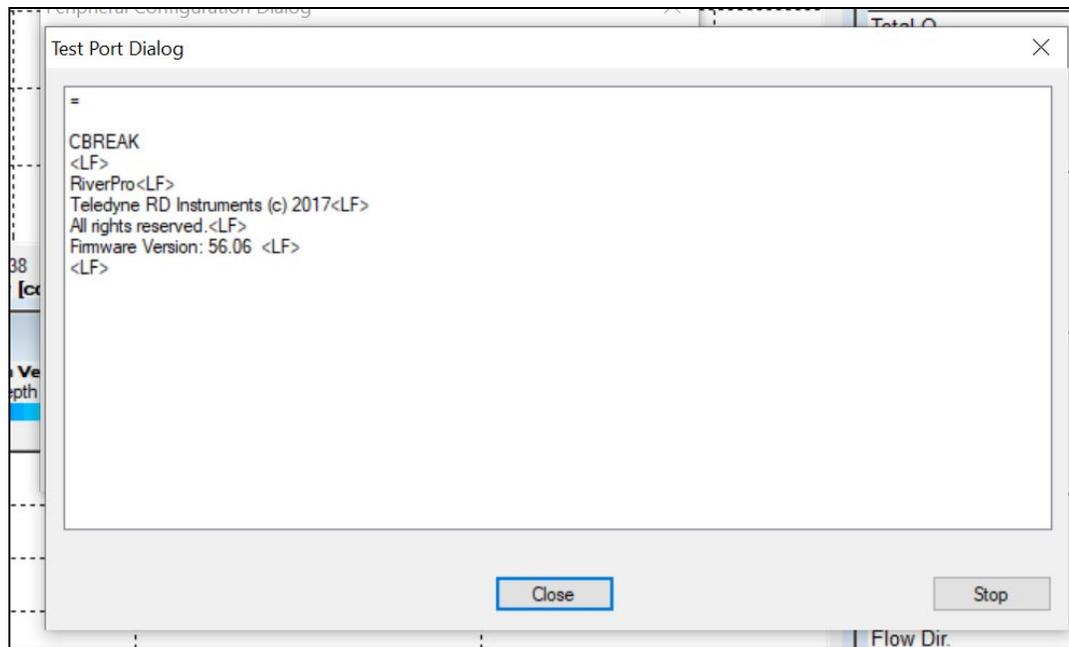


Figure 43. RiverPro ADCP Test Port Dialog indicating that ADCP data is streaming from the ADCP to the laptop.

I.6 Navigate to the Discharge Transect

If a discharge transect, or cross-section, has already been established, the bounds should be permanently marked using stakes or plot markers (one on each side of the stream). Navigate to this location and proceed to **Section I.7**.

If a discharge transect has not been established at the site proceed with the following steps:

1. Determine an appropriate location to establish a discharge transect.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- a. At river sites, the transect location must be located in a straight reach in relatively close proximity of the staff gauge and pressure transducer. Consult with Science if the pressure transducer location is unknown or has not yet been established.
- b. An ideal discharge transect will:
 - 1) Be located in a reasonably straight channel with velocity lines that are more or less parallel to each other.
 - 2) Contain velocities that are, for the most part, > 0.15 m/s, and depths that are, for the most part, > 0.15 m.
 - 3) Contain a stable streambed free of obstructions that would create eddies, slack water, and turbulence.
 - 4) Contain measurement sections that are roughly parabolic, trapezoidal, or rectangular.
 - 5) Contain a stable downstream control feature.
- c. Take a picture of the transect location that best meets this criteria as well as the downstream control feature and send to Science for consultation.

I.7 Assess the Discharge Transect

Prior to collecting the discharge measurement identify any instrumentation or environmental issues that would negatively affect data quality. Document any temporary hydrologic conditions in the (AOS) Field Metadata and Gauge Height [PROD] app in Fulcrum. If conditions are unfavorable to discharge measurement collection, submit a trouble ticket and consult with Science.

Unfavorable conditions include, but are not limited to:

1. The staff gauge is either not present or has been displaced in some way.
 - a. A discharge measurement should not be collected if a staff gauge is not present at the site or the gauge has been displaced in any way.
 - b. Submit a trouble ticket to Science that includes photos of the gauge.
 - c. If the staff gauge is topped during high flows and a discharge measurement can be safely collected, attempt to mark or in some way reference the elevation of the edge of water (only do so if this can be accomplished in a safe manner). A future survey of this location (relative to the staff gauge) can provide an estimate of gauge height during the measurement.
 - d. Note that if a discharge survey is associated with a reaeration sampling event, discharge should still be measured regardless of staff gauge presence.
2. A pressure transducer is either not present or has been displaced in some way.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- a. A discharge measurement may be collected in the event that the pressure transducer is missing or has been displaced. However the absence of this instrument prevents continuous discharge from being estimated.
- b. Submit a trouble ticket to Science immediately if the pressure transducer is missing or has become displaced.
3. Streamflow is exceeding the banks causing unsafe conditions on the floodplain.
 - a. Refer to NEON Operations Field Safety and Security Plan (AD[02]) for details.
4. There is an insufficient amount of water in the channel to conduct velocity measurements.
 - a. See **Section 4.2.1**.
5. Refer to NEON Operations Field Safety and Security Plan (AD[02]) and NEON Operations Field Safety and Security Plan (AD[02]) for further details.

SOP J Field Sampling: River Sites Using the Remote Controlled Boat Method

J.1 Start a New Measurement in WinRiver II

Once the discharge cross-section has been established or assessed, configure the ARC-Boat following steps detailed in **Sections I.2 and I.3**. A new measurement file can now be created in WinRiver II using the following steps:

1. Set the laptop system time zone to UTC (Coordinated Universal Time).
2. Start the WinRiver II program.
3. In the WinRiver II main screen, click Configure > Units > All SI to set units to metric.
4. In the WinRiver II main screen, click File > New Measurement to run the Measurement Wizard.
5. Fill in all information in the Site Information tab:
 - a. Station Name: Four digit site code of where you will be measuring discharge (i.e. "TOMB")
 - b. Station Number: Leave blank.
 - c. Measurement Number: The sequential discharge measurement number for the site
 - d. Agency: "NEON".
 - e. District: Leave blank.
 - f. Hydrologic Unit: Leave blank.
 - g. Field Party: Initials of all crew involved in measurement.
 - 1) Separate initials with a comma delimiter (i.e. NH, LFS).
 - h. Processed By: Initials of technician operating the WinRiver II software and evaluating data collection.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- i. Deployment Type: "RC Boat".
 - j. Boat/Motor: Leave blank.
 - k. Meas. Location: If measured at the regular discharge cross-section enter "DSC1", if measured at a different cross-section within the site denote that with a different code here (i.e. "DSC_US" if the cross-section is upstream of the regular location).
 - 1) Make sure to also include notes in the main remarks section that describe alternative transect locations (be sure to include an estimate of how many meters away the measurement was conducted from the regular location).
 - a) To add a note to the main Remarks section of the measurement file, right-click Site Information on the Measurement Control window.
 - b) Enter notes into Remarks section.
 - l. Grid Reference: Leave blank.
6. Select the "Rating Information" tab.
- a. Inside Gage Height: Enter the water level measurement on inside of staff gauge.
 - b. Outside Gage Height: Same value as "Outside Gage Height".
 - c. Rating Discharge: Enter the predicted discharge given gauge height from rating curve, if available.
 - d. Index Velocity: Leave blank.
 - e. Rated Area: Leave blank.
 - f. Rating Number: Leave blank.
 - g. Water Temp: Enter the water temperature (°C) measured using a thermometer submerged in the stream for at least 5 minutes.
 - 1) The measured water temperature should be within 2 degrees of the ADCP temperature measurement.
 - a) To check the temperature being measured by the ADCP, open the Test Result dialogue box under the QAQC > ADCP node. The measured temperature will be displayed along with other sensor data.
 - b) You can also view temperature time series data during or after a transect measurement by selecting View > Graphs > Time Series > Temperature.
 - c) The ADCP must be sitting in the water for at least 5 minutes to allow the instrument to fully equilibrate to the water temperature.
 - d) In general ADCP temperature measurements do not drift until there is a major issue. If this does occur, the ADCP-measured temperature will deviate greatly from the



thermometer measurement. If this is the case make a note in the measurement note window and contact Science following the measurement bout.

- h. Tail Water Level: Leave blank.
 - i. Magn Variation Method: Model
 - j. Measurement Rating: fill this out at the end of the measurement based on your judgment of the measurement quality
 - 1) This is a subjective assessment. Discretion is given to the hydrographer who led the survey. Include any relevant field notes that formulated the basis of this rating in the remarks section.
 - k. Control Codes: select any that apply to the measurement.
 - l. Wind Speed: Enter the measured wind speed (kph) using an anemometer.
 - 1) If wind speed was entered in units other than kph, note the units used in the remarks section.
 - m. Wind Direction: Enter the measured wind direction using an anemometer.
 - 1) If the anemometer does not provide a direction measurement enter:
 - a) "Upstream": if the wind is blowing up river
 - b) "Downstream": if the wind is blowing down river
 - c) "Cross-wind": if the wind is blowing across the river
 - d) "Mixed": if the wind is not blowing in any particular direction
 - n. Edge Method: Enter the method used for determining bank distances (i.e. laser rangefinder, meter tape, eye estimate, etc.).
7. Select the "Configuration Dialogue" tab.
- a. The software will immediately try to recognize the ADCP ("Interrogating the ADCP...").
 - 1) If the connection is successful, the button next to "ADCP" will eventually turn green.
 - a) This can take a few minutes.
 - b) This means that the software recognizes the ADCP via the Parani Bluetooth dongle.
 - c) The connection should be successful if the ADCP Peripheral test was a success.
 - d) If a window pops up that says "The ADCP is not responding..." this means that the ADCP was not recognized by the software.
 - (1) Click "No" (clicking "Yes" will have the software cycle through all available ports).



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- (2) Ensure that ParaniWin configuration was successful for the dongle and that the software is closed.
 - (3) In the “Serial Communication Settings” window, ensure that COM Port settings match what was entered in ParaniWin software. Click OK.
 - (4) If the “The ADCP is not responding...” message returns, click Cancel.
 - (5) In the “ADCP” dropdown, ensure that the correct ADCP model (RiverPro) is selected in the dropdown box. Click the “Check ADCP” button to re-test configuration.
 - (6) The ADCP must be recognized by the software for the discharge measurement to be conducted. If communication problems persist, submit a trouble ticket and contact Science.
- b. Check GPS configuration settings.
- 1) Ensure that the GPS antenna is attached, powered and properly configured above the ADCP adapter (**Section I.3**).
 - 2) Check the “Int. GPS” box.
 - (1) Set the baud rate to 19200.
 - 3) Check the “Ext. Heading” box.
 - (1) Leave the “Hdg Off [deg]” box blank.
 - (2) An error message will appear.
 - (3) Click cancel, this error can be ignored.
- c. The Depth Sounder box can be left blank.
- d. Under Offsets:
- 1) Enter Transducer Depth.
 - a) Ensure that the boat is steady and stable in the water column prior to taking this measurement.
 - b) Measure from the water level to the center of the slant in the transducer faces with a ruler or metric tape.
 - c) This is a very important measurement! Repeat it two or three times to ensure accuracy.
- e. Enter Magnetic Variation, the angle of declination relative to your location in the world.
- 1) For greatest accuracy, check the [National Geophysical Data Center website](#) to find the declination angle based on your latitude and longitude.



- 2) Some examples:
 - a) Butler, AL: $-2^{\circ} 27' W$ (-2.27)
 - b) Newton, GA: $-4^{\circ} 59' W$ (-4.59)
 - c) Arcata, CA: $+14^{\circ} 16' E$ (+14.16)
- f. Enter the Max Water Depth.
 - 1) This is an estimate of the maximum water depth (m) that is expected to be measured during the discharge measurement.
- g. Enter the Secondary Water Depth
 - 1) This is an estimate of the minimum water depth (m) that is expected to be measured during the discharge measurement.
- h. Enter the Max Boat Speed
 - 1) This is an estimate of the maximum boat speed (m/s) that is expected during the discharge measurement.
- i. All other values can be left as defaults.
8. Select the "Output Filename Options" tab.
 - a. Under the "Recording" section:
 - 1) In the "Filename Prefix" box enter the four-digit side code.
 - a) Example: "LEWI".
 - 1) Ensure the "Use Prefix in Filename" box is checked.
 - 2) Leave the output directory at the default location (C:\Measurements\).
 - g. In the "Include Filename Options" section:
 - 1) Uncheck the "Measurement Number" box.
 - 2) Leave "Transect Number" at "0".
 - 3) Leave "Geographic Current Survey" and "Sequence Number" boxes unchecked.
 - h. In the "Use Date/Time in Filename" section:
 - 1) Select "Long (YY-MM-DD-hhmmss)".
 - i. In the "Use Delimiter in File" section:
 - 1) Select "Underscore" (default).
 - j. Check in the Filename Preview section that the above settings are correctly applied (**Figure 43**).



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- k. Note that these settings can only be entered at the start of a New Measurement. Once the Measurement Wizard is closed, filename settings can only be changed by starting a new measurement.
9. Open the Command Preview tab.
 - a. Review all information to ensure that is correct.
 - b. Ensure that green checks are present for ADCP and GPS communications.
 - c. Click the Finish button to complete wizard.
 10. Review the Summary Page tab to ensure all information was correctly entered.
 11. Click Finish to exit the Measurement Wizard.
 12. Verify that GPS data is being collected.
 - a. Once powered, allow a few minutes for the GPS to connect to available satellites.
 - b. On the WinRiver II main screen, Click Acquire > Start Pinging.
 - c. Click View > Tabular > GPS to confirm the availability of GPS data (**Figure 22**).
 - 1) External/Integrated (GGA) refers to differential GPS data collected by the external GPS antenna (i.e. SX Blue II or Hemisphere V102).
 - 2) Internal (GGA2) refers to the georeferenced GPS data collected by the GPS unit that is internal to the ADCP.
 - 3) External GPS data is much more accurate than the internal data as reflected in position (latitude/longitude) digits.
 - 4) The number of satellites will often be less in the external GPS column due to the higher quality threshold for picking satellites (i.e. elevation angle) contained in the external unit.
 - 5) HDOP is the measure of possible error due to the geometry of the available satellites, therefore as this value decreases the quality GPS data increases.
 - a) Ideally HDOP values should be < 2.
 - d. Click View > Time Series > Graphs > GPS data to confirm GPS data stream (**Figure 44**).
 13. Once GPS data has been verified, end ADCP pinging by clicking Acquire > Stop Pinging.

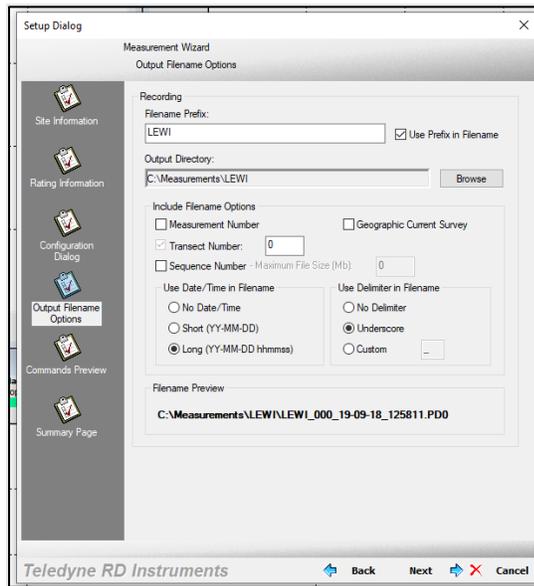


Figure 44. Required settings in the WinRiver II Output Filename Options dialogue box within the Measurement Wizard.

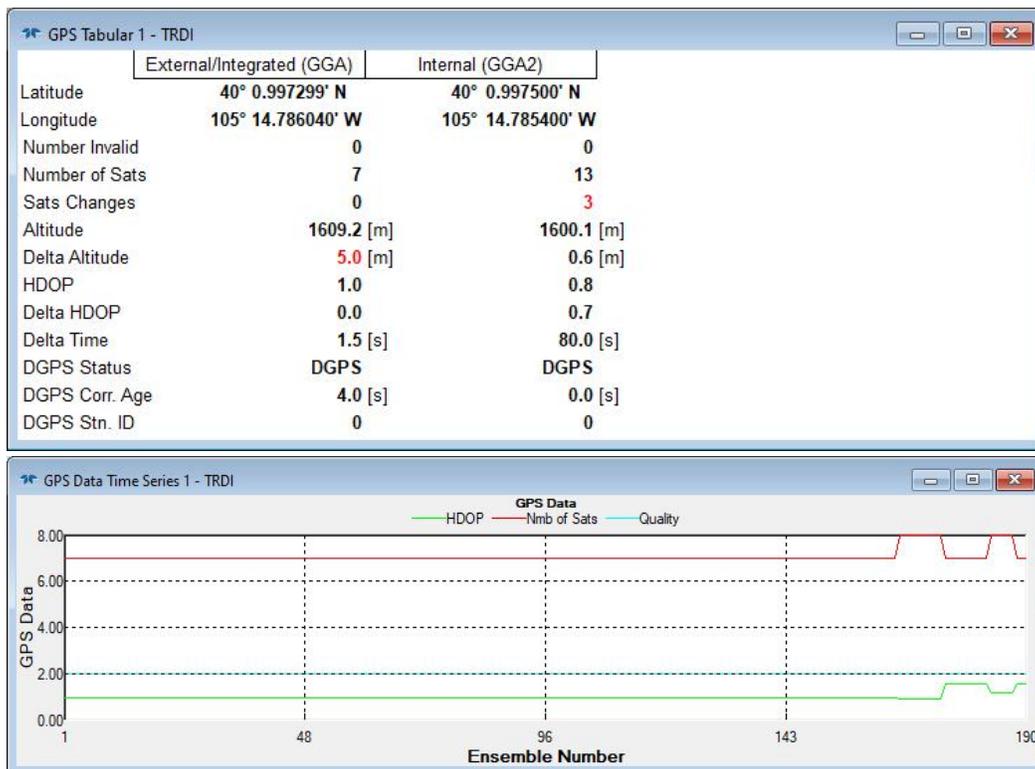


Figure 45. Above: GPS Tabular window that confirms GPS data is available and is being collected; Below: GPS Time Series window that indicates GPS data is streaming.



J.2 Pre-Measurement QAQC: Overview

The following QAQC protocols are critical to quality data collection and must be initiated prior to the first transect measurement of each ADCP discharge bout.

- Set the ADCP clock
- Setup the ARC-Boat
- Deploy the ARC-Boat
- Practice operating the ARC-Boat
- Collect a temperature measurement
- Execute an ADCP test
- Calibrate the internal ADCP compass
- Perform a moving bed test and assess moving bed test summary
- Configure the reference navigation

J.3 Pre-Measurement QAQC: Set the ADCP clock

Prior to the initial transect measurement the ADCP clock must be set to match the PC time (UTC). Failure to properly set the ADCP clock will result in data files with incorrect timestamps.

1. Set the time zone on the PC to (UTC) Coordinated Universal Time (**Figure 45**).
 - a. Right click on the date time in the lower right corner of the screen.
 - b. Select "Adjust date/time".
 - c. In the "Time zone" dropdown, select "(UTC) Coordinated Universal Time".
2. In the WinRiver II main screen, click on Acquire > Set ADCP Clock.
3. Set the ADCP clock to match the PC time (UTC).
4. Click the "Set Clock" button.
 - a. Note: only clicking the "OK" button will not set the clock, the "Set Clock" button must be selected.

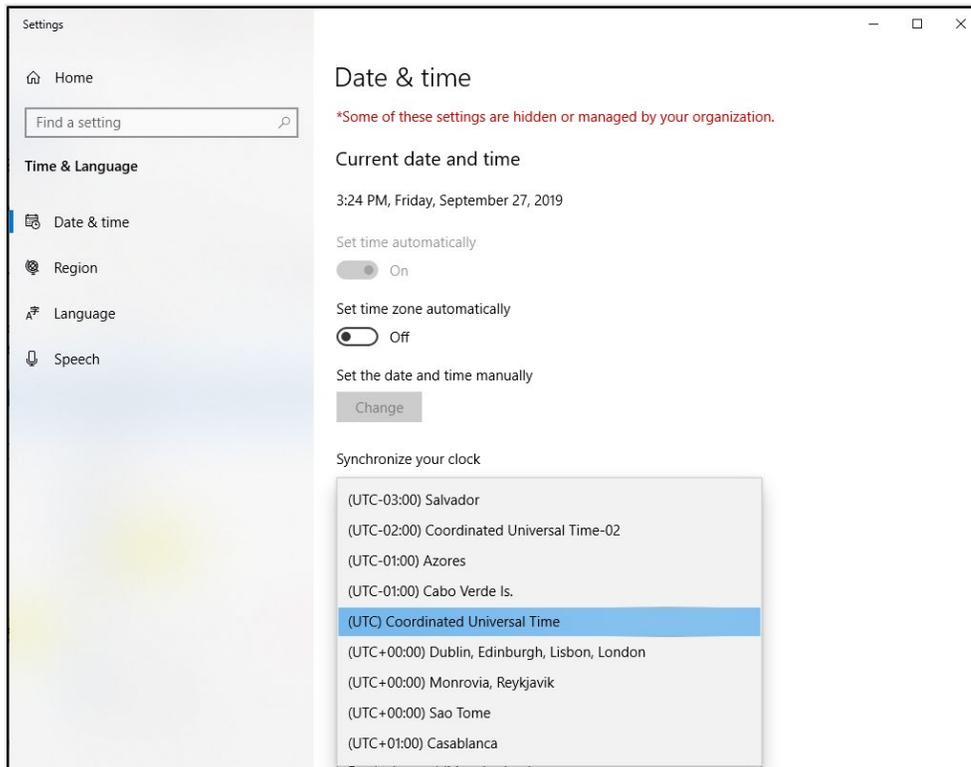


Figure 46. Set the PC used for the discharge measurement to (UTC) Coordinated Universal Time and match the ADCP clock to this setting.

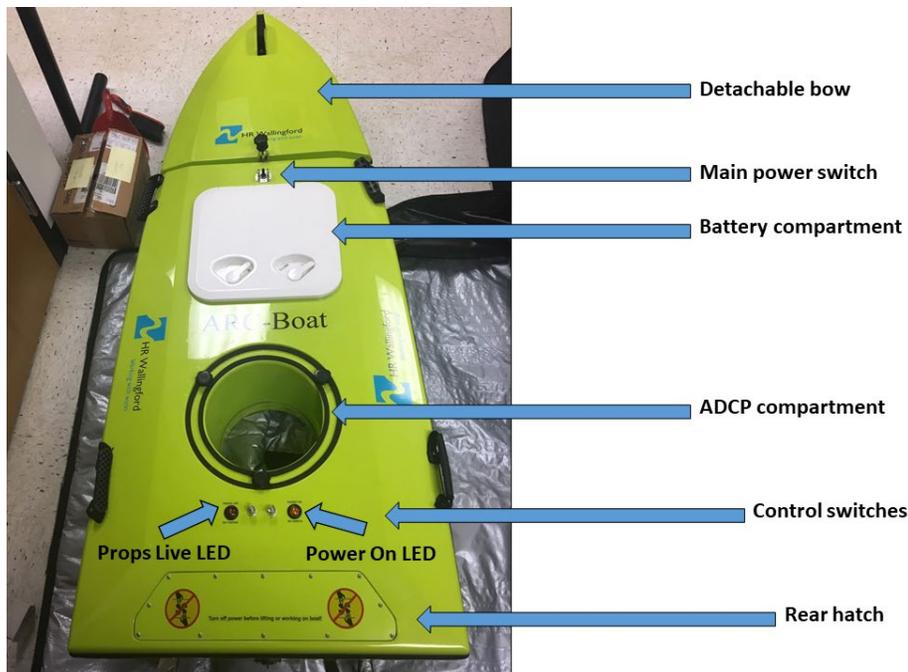
J.4 Pre-Measurement QAQC: Setup the ARC-Boat

Follow the steps below to configure components of the ARC-Boat (**Figure 46**) prior to additional QAQC procedures.

1. Ensure that the ADCP adapter is connected to the ADCP and secured within the ADCP compartment of the boat.
2. Install the GPS antenna onto the GPS mount (**Section I.3**).
3. Ensure that the detachable bow is connected to main body.
4. Ensure the bilge plug is in place and tightened. It must form a secure seal with the hull to prevent the boat from filling with water and capsizing.
5. Set up the boat power supply.
 - a. Unlock and open the battery compartment.
 - b. Make sure all of the controls switches are in OFF or neutral position.
 - 1) Isolator switch is in OFF position.
 - 2) Radio controller power switch is in the OFF position.



- 3) Both control sticks are centered in the neutral position.
- 4) Main power switch on the “deck” or the top of the ARC-Boat bow near the front handles is in the OFF position.
6. Place two fully charged batteries in the battery compartment and connect them to the internal wiring connections within the compartment.
7. Turn on the isolator switch.
 - a. The power LED will light up orange if power is connected.
8. Close the battery compartment and secure the latches, checking the watertight seal is in place. Water in this compartment will cause damage to the equipment.
9. Turn on the main power switch.
 - a. The ‘Props Live’ LED will turn red, indicating the ARC-Boat is powered ON and the props are capable of movement.
 - b. Use caution around the propellers and rudders when this switch is set to ON.
10. Ensure that the remote control battery is fully charged.
11. If the remote is not fully charged, insert fresh batteries prior to the discharge measurement.
12. Center both sticks on the radio controller again to put the ARC-Boat in neutral, so that the boat can be moved safely.



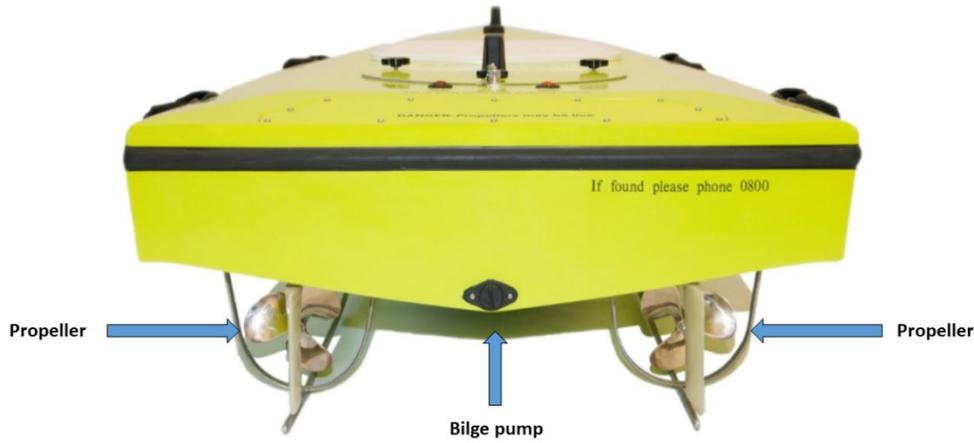


Figure 47. Above: Top of the ARC-Boat (not pictured: ADCP Adapter with GPS mount); Below: Stern of the ARC-Boat

J.5 Pre-Measurement QAQC: Deploy the ARC-Boat

1. Ensure that the ADCP and the Hemisphere GPS units are securely connected to the ARC-boat.
2. Remove the protective cover on the base of the ADCP.
3. Before placing the boat in the water, test that the propellers and rudders are functioning correctly with the radio controller.
4. Using the handles on the side of the boat, gently place the boat into the water. This is best done with two people on solid footing.
5. Allow the ADCP transducers to be submerged in the water for at least 5 minutes prior to discharge measurements in order to sufficiently equilibrate to the water temperature. Failure to do so will impact measurement accuracy.

J.6 Pre-Measurement QAQC: Practice Operating the ARC-Boat

It is critical to become familiar with the ARC-Boat controller and comfortable with instrument operation before continuing on with additional pre-measurement QA procedures and prior to measurement collection.

ARC-Boat Operation

Consider the river conditions that are currently present. ARC-Boats are designed to work in streamflow conditions from low flows to floods (surface water velocities of up to 5 m/s). Surface velocities outside of this range will cause the boat batteries to drain quickly and make controlling the boat very difficult. If



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

velocities are such that the boat cannot be operated in a safe and efficient manner, do not proceed with the measurement and contact Science.

Practice using the remote control to drive and turn the boat. The remote control must always remain strapped around the neck of the operator to prevent it from falling into the water.

If the batteries are too low or the signal between the radio controller and the ARC-Boat is lost, the motor in the ARC-Boat will shut down stopping the rudders and propellers. The ARC-Boat is deliberately programmed to shut down in these situations for safety reasons. It will drift with the current and have to be recovered. It is best practice to have a recovery plan in mind and an idea of where the boat could end up prior to deployment.

If surface water velocity is sufficient, operate the ARC-Boat so that the bow is pointed upstream and into the velocity path during the discharge measurement (**Figure 47**). To obtain a sense of the velocity flow paths try letting the boat drift momentarily in the streamflow, this usually allows the gauge which way the velocity vectors are pointed within the discharge cross-section. Crabbing across the channel is not always possible during periods of low flow, in these situations it is allowable to have the bow of the boat pointed more towards the opposite shore (**Figure 48**).

The ARC-Boat rudders require motion in order to control the direction of the boat. In cases where the boat is not in motion, the throttle will need to be activated to change the boat direction using the rudders. Standing slightly downstream of the ARC-Boat allows for easier orientation of how movements with the remote control relate to the ARC-Boat. If operating the remote control from a piloted boat, it is very important to remain far enough downstream so that the piloted boat motors and hull do not create velocity disturbances within the measurement transect. Operation of the remote controller will vary based on where the boat is in the channel and the desired path of the boat (**Table 9**).

Ensure that all boat and remote control batteries are fully charged prior to the measurement and that spares are on hand if needed. Charged batteries are critical for maintaining control of the boat during operation. As remote control and ARC-Boat batteries become low (the radio has a voltage indicator, low batteries in the boat can be observed by sluggish or lagging response to operation) operational performance will decrease. At a certain point, low voltage in either the remote or the boat batteries will result in the total loss of control of the boat.

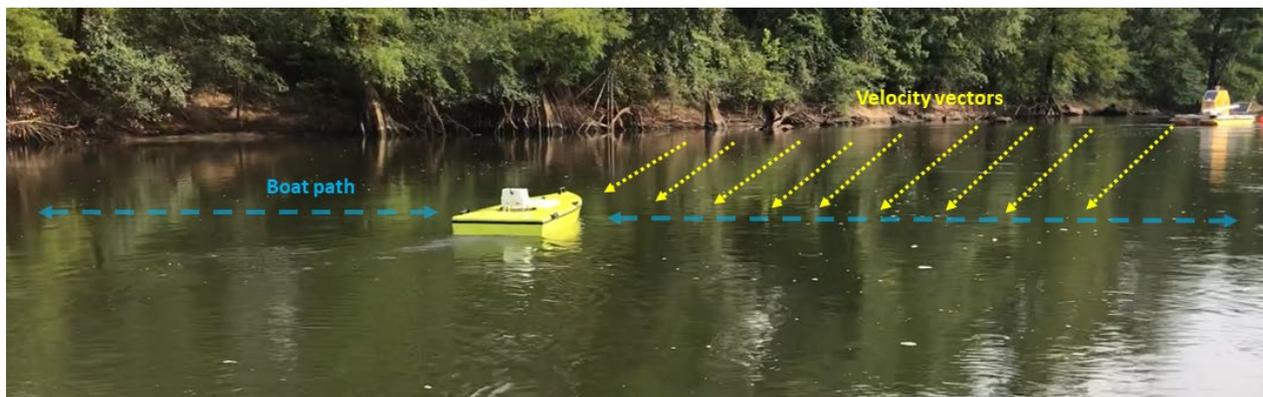


Figure 48. When surface water velocity is sufficient operate the ARC-Boat in such a way that the bow is pointed into the velocity vectors and the boat is crabbed across the channel.

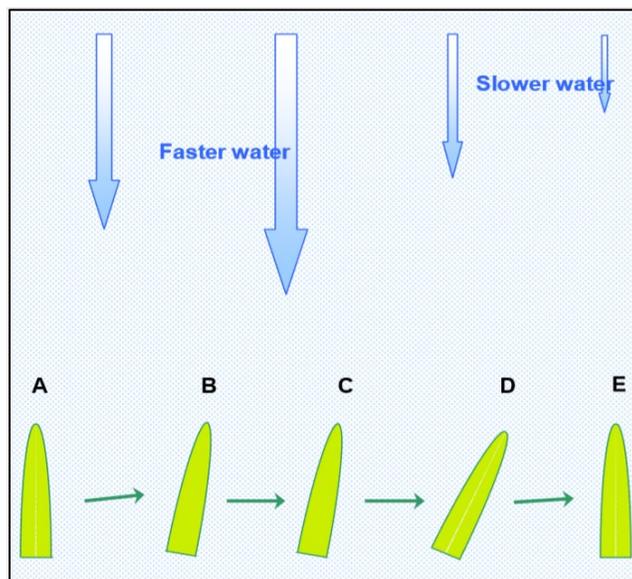


Figure 49. Illustration on different ways to control the ARC-Boat in a variety of streamflow levels.

Table 9. ARC-Boat controller tips during a variety of operation settings.

Operation	Controller Tips
Place the ARC-Boat in neutral (A)	Center the joy sticks on the radio controller.
Pulling away from shore (A)	Use low throttle and move the left joy stick gently forward. Move the rudder in the intended direction using the right joy stick.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

Operating in slow water (D)	Lower the throttle and reduce the direction of the rudder. This allows the boat to remain steady.
Operating in fast water (B/C)	Increase the throttle to counter the increase in velocity and move the rudder further in the desired direction until the boat responds.
Approaching a bank (E)	Move the rudder strongly in the current direction and use very low throttle to make the stern come steadily towards the bank.
Making a smooth turn	Gently use the rudder and throttle controls at the same time. The ARC-Boat was designed to be capable of spinning on its own axis.
Maintaining a steady pace	Set the throttle to a constant pace. This minimizes battery consumption and overall wear on the boat.

J.7 Pre-Measurement QAQC: Collect a Temperature Measurement

1. Place the thermometer into the water to begin collecting a temperature measurement.
2. Enter this value into the Measurement Wizard Rating Information Tab under “Water Temp”.

J.8 Pre-Measurement QAQC: Execute an ADCP Test

This test verifies that the ADCP is functioning properly and communicating with WinRiver II software.

1. In the WinRiver II main screen, click on Acquire > Execute ADCP Test.
 - a. Note that the ADCP must be installed in the mount and submerged in non-flowing water to obtain the best test results.
2. A series of six tests will be initiated that evaluate ROM, RAM, Communications, RTC, Compass, and Temperature performance. Check that all tests pass on the left pane of the dialog window.
3. After the tests have been run, sensor data will begin to be sampled and displayed in a loop.
4. Click the “Stop PC20” and “Stop PC40” buttons to end testing and close the dialog window.

J.9 Pre-Measurement QAQC: Calibrate the Internal ADCP Compass

A calibrated compass is essential for conducting Moving Bed Tests and for using GPS data as the navigation reference. This is a two person task, one person turns the boat slowly in the water while another person monitors the data and communicates the test results.

1. Ensure that the ADCP is secured within the ARC-Boat in the exact position it will remain throughout the discharge measurement.
2. Ensure that the boat is not located near vehicles, steel bridges, or other large ferro-magnetic masses.



- a. Check for any materials near the boat that could disrupt the compass calibration – this includes tools, tool boxes, cell phones, hot hands, etc.
- b. Move these materials away from the ADCP during calibration and throughout the discharge measurement.
3. In the WinRiver II main screen, click on Acquire > Execute Compass Calibration.
4. Select Use Pitch/Roll?
 - a. Click “No” if the ADCP will not be subject to pitch and roll (i.e. calm water). This calibration test requires two rotations, one for calibration and one for verification.
 - b. Click “Yes” if the ADCP will be subject to very high pitch and roll conditions. This calibration test requires up to eight rotations, four for calibration and four for verification. Typically, no pitch and roll calibration is required.
5. Click the Start Calibration button and wait a moment until the compass is initialized by the software.
6. Begin to slowly and smoothly rotate the ARC-Boat by hand in either direction.
 - a. Do not cause sudden accelerations or decelerations.
7. Rotate the boat until all of the red bars in the dialogue window have been replaced by a dark green color (**Figure 49**).
 - a. The greener the bars, the better the data.
 - b. If a bar is not dark green, rotate the boat more slowly and more smoothly.
 - c. Correct any non-dark green bars when they occur by rotating the boat back 10-20° until that bar is once again highlighted. Then, when it becomes dark green, proceed as before.
 - d. Clear and constant communication between the staff member moving the boat and the staff member evaluating the test results on the laptop is critical during this period.
8. Once calibration rotations are complete, click OK and continue with the verification rotation.
 - a. If Pitch/Roll is selected there will be more initial rotations.
9. Once the verification rotation is complete a calibration error will be calculated and presented.
 - a. Ensure that the calibration error is less than 2°.
 - b. Aim for a total error of < 1°.
 - c. If calibration error is < 2°, the compass calibration is complete and the window can be closed (< 1° is preferred – try to obtain this).
 - d. If calibration error is ≥ 2°, do not accept the compass calibration.
 - e. Repeat calibration procedures.



- 1) Look around for magnetic materials that may be affecting the compass.
- 2) Move these materials away from the ADCP or move the ADCP away from them, if possible.
- f. If, after three attempts, a calibration error of $< 2^\circ$ cannot be achieved, reference the troubleshooting steps below.
 - 1) If, following troubleshooting, a compass calibration of $< 2^\circ$ cannot be achieved, accept the lowest calibration error possible and proceed.
 - 2) Document this occurrence as a note in the Remarks Section, it will be a very important component in evaluation the measurement during post-processing.
10. Once complete, check that the correct Magnetic Variation Correction value was entered by the software during the measurement wizard setup (**Section J.1**).

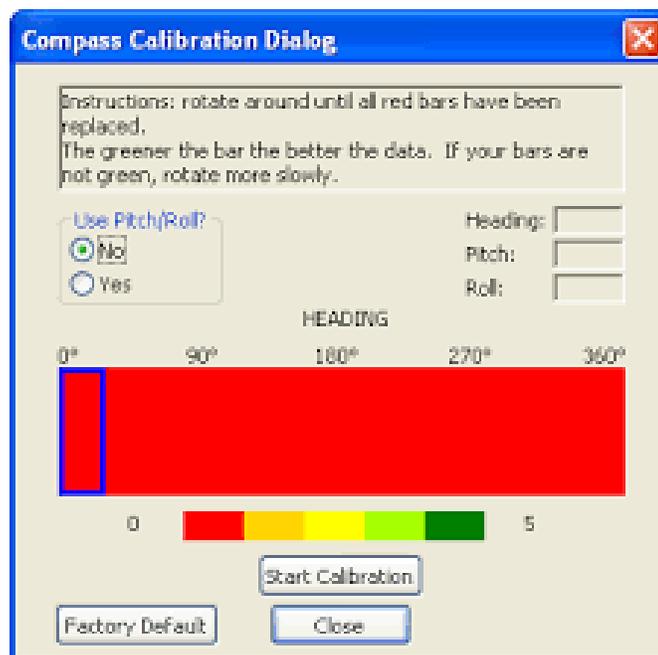


Figure 50. ADCP Compass Calibration dialog box. The entirety of the horizontal bar is red upon initiating the test. Rotate the boat slowly and steadily so that bar is colored dark green throughout.

Troubleshooting Compass Calibration Issues

- There may be too much magnetic interference in the area you are attempting to calibrate the compass.
 - Ensure that no magnetic materials are near the ADCP.
 - Try moving the boat to a different area of the stream and repeating the calibration.
 - It may be that material on the streambed (rebar, trash) is affecting the calibration.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- Computational errors may occur during calibration. If you receive an error message indicating that a computational error occurred, repeat the calibration and be sure to rotate the ADCP slow and smooth.
 - Ensure that all points in the calibration display are of good quality (dark green).
 - Rotating the ARC-Boat by hand in the water or removing the ADCP and rotating it on a Lazy Susan are two ways to reduce compass error.
- Communication errors may occur during calibration when using a slow communication Baud rate.
 - If you receive a “Failed to get calibration data...” message verify that all ADCP communications are set to the 115200 Baud rate.
 - If you receive a “360 degrees” compass error message then the compass calibration test has failed and needs to be performed again.
- Disable GPS output (if enabled).
 - This is the least preferred option and should be attempted if all large errors are encountered after all other solutions have been attempted.
 - Un-check the Ext. GPS box in the Measurement Window Configuration Dialog tab.
 - Repeat Compass Calibration test.

J.10 Pre-Measurement QAQC: Perform a Moving Bed Test

Moving Bed Tests (MBT) are used to determine if the bed of the discharge cross-section is in motion. An un-accounted for moving bed can lead to 5-10% bias in discharge measurements performed with the RiverPro ADCP.

MBTs must be performed prior to each ADCP discharge bout. WinRiver II software analyzes the data collected during the MBT to assess the moving bed characteristics of the site and to detect common error conditions, which may invalidate the test. The loop method is presented below as a means to test whether a moving bed is present. The loop method must be applied properly, or it may produce incorrect results.

Note that the accuracy of the loop method is not adequate for mean velocities less than 0.8 ft/second (0.24 m/s). If mean velocity is below 0.8 ft/s (0.24 m/s), water velocity is low throughout the water column and the probability that the bed is in motion is decreased. If the bed is in fact in motion at these velocities (or particles on the surface of the bed are in transit) it is likely that not accounting for it will exert only a minimum bias in the overall discharge estimation.

A properly calibrated compass is critical to application of the loop method, the error caused by an improperly or un-calibrated compass can be in either direction, resulting in either more or less moving bed than actually is present.

To perform a moving bed test:



1. Begin the MBT from an initial point on the near shore where you will be able to return to with precision (**Figure 51**).
 - a. Navigate the boat to a starting location near the edge of the water on the near bank.
 - b. Mark this location using some physical reference for the starting point (anchored float, etc.).
2. When running the MBT it is optimal for the person using the radio controller to guide the ARC-Boat so that is slightly downstream of the controller.
 - a. This allows for easier orientation of how the controller movements affect the boat.
 - b. If operating the remote control from a piloted boat, it is very important to remain far enough downstream so that the piloted boat motors and hull do not create velocity disturbances within the measurement transect.
3. In the WinRiver II main screen, click on Acquire > Start Pinging (shortcut key: F4).
4. Open the Ship Track graph. This allows for a better view of the boat path as it does not show the velocity paths (**Figure 50**).
 - a. View > Graphs > Ship Tracks > Ship Track.
 - b. The green square is where the float is located when the test starts.
5. On the Acquire menu, click Select Moving Bed Test.
6. Select "Loop Test" and click the Start button (shortcut key: F6).
7. Once you start the test, immediately begin navigate the boat across the river to the opposite bank in a slow and steady manner.
 - a. Maintain a steady speed that, if possible, does not exceed the stream velocity.
 - b. Note that the green square in the Ship Track graph denotes your starting location.

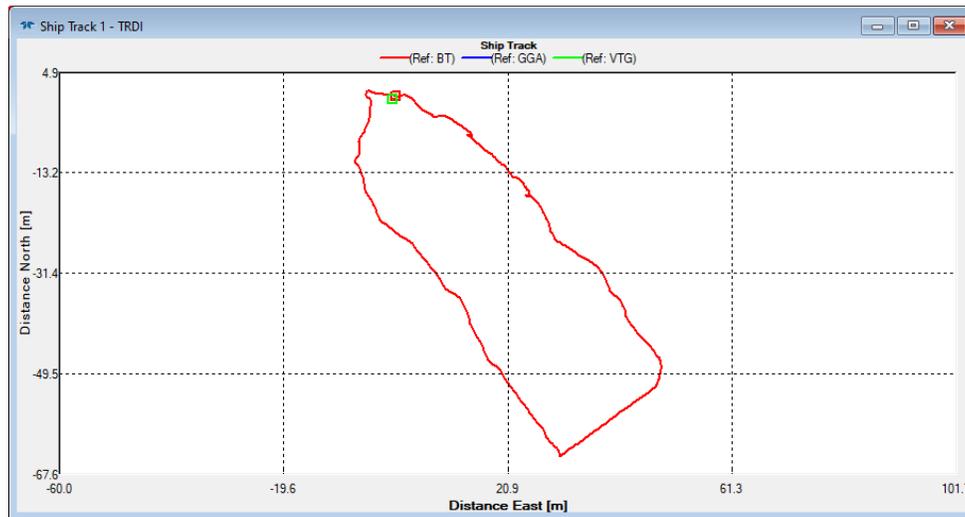


Figure 51. The WinRiver II Ship Track window observed during a loop moving bed test. The green box indicates the boat starting position, the line shows the boat path as it is navigating across the channel and turned back around toward the starting bank, and the red box indicates the boat ending position.

8. The MBT Test must last a minimum of 180 seconds (3 minutes).
 - a. This duration encompasses the time spent moving the boat across the channel and back to the near bank.
 - b. It is helpful for a staff member using or nearby the laptop to call out the measurement duration to the other staff member moving the boat so the speed can be adjusted if needed.
9. When the opposite bank is reached, gently turn the boat around (don't stop) and head back to the exact starting point where the test was initiated.
 - a. This is a critical part of the moving bed test, make sure this is a smooth and slow turn by gently using the rudders and throttle together.

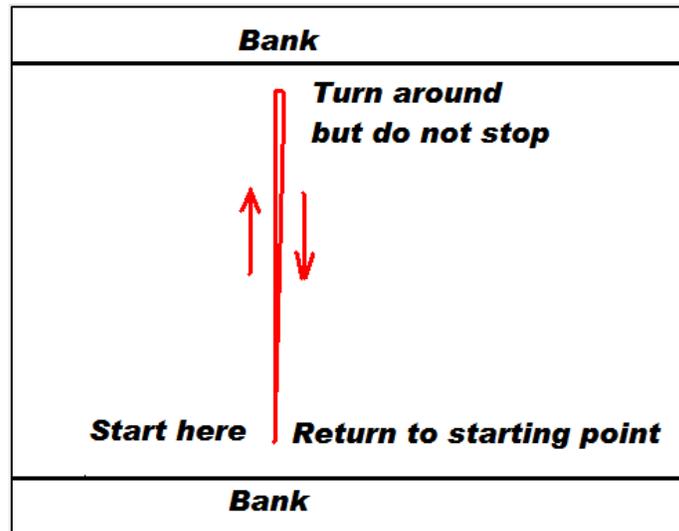


Figure 52. Illustration of the Loop Moving Bed Test procedure.

10. Once the boat returns back to the exact starting point on the near shore where you began the MBT, stop the test immediately (shortcut: F6 or Acquire > Stop Moving Bed Test).
 - a. Note the green square in the Ship Track Graph indicating where the boat was located when the test began and the red square indicating where the boat was located when the test ended.
 - b. If you don't hit the F6 button right at the starting point this could falsely indicate that the bed is moving.
11. Review the Ship Track window (Figure 52).
 - a. If the track (red line) contains an "open mouth" (i.e. the green and red squares do not line up and the red line is not connected) this may indicate that there is a moving bed.
 - b. If the track does not contain an "open mouth" (i.e. the green and red squares are on top of each other and the red line is connected), this indicates that a moving bed is likely not present.
 - c. Moving bed conditions will always cause the ship track to move upstream – if the ship track moves downstream the loop test is not valid.
 - d. If the boat was not returned to the *exact* starting point it can result in the end point being upstream or downstream of the starting point. This results in a potentially false positive for moving bed conditions (endpoint is upstream of the starting point) or an invalid result (endpoint is downstream of the starting point).

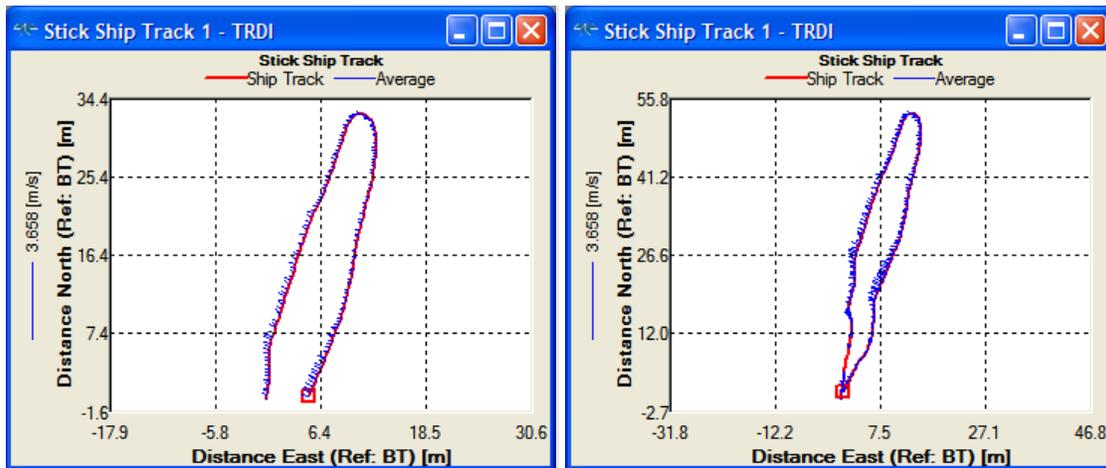


Figure 53. Left: A moving bed is likely present as indicated by the open loop; Right: a moving bed is not likely present as indicated by the closed loop.

12. Document all relevant notes that apply to the MBT.
 - a. To add a note that relate to a specific MBT, right click on the test node (i.e. “Loop 000”) and select “Add Note”.
13. Review the Moving Bed Test Result window to evaluate the results of the MBT (**Figure 53**).
 - a. In the Measurement Control window, under QA/QC, click on the Moving Bed Test node and open the Test Result icon for the test that was just completed (Loop tests begin as “Loop 000”).
 - b. The Test Result window provides metrics that describe the MBT. At the bottom of the window reference the “NOTE” – it will indicate whether correction is recommended.
 - 1) If a correction is recommended, check the box to the left of the MBT (i.e. “Loop 000”). This will apply a correction to the measured discharge to account for the moving bed velocity.
 - a) If a moving bed is detected (and GPS data is valid), the Navigation Reference must be changed from Bottom Track to GPS (**Section J.11**).
 - (1) On the main WinRiver II screen select Configure > Reference and change reference GPS (GGA)
 - b) If GPS is not available then Bottom Track should be used as the reference navigation (**Section J.11**).
 - (1) Document this in the main measurement file remarks window.
 - (a) To add a note to the main Remarks section of the measurement file, right-click Site Information on the Measurement Control window.
 - (b) Enter notes into Remarks section.



- c) Once the correction has been applied and the appropriate reference navigation has been set, proceed with the next pre-measurement QAQC procedure.
- 2) If a correction is not recommended and all other aspects of the MBT are valid then no correction is needed and Bottom Track can be used as the reference navigation.
 - a) Proceed with the next pre-measurement QAQC procedure.

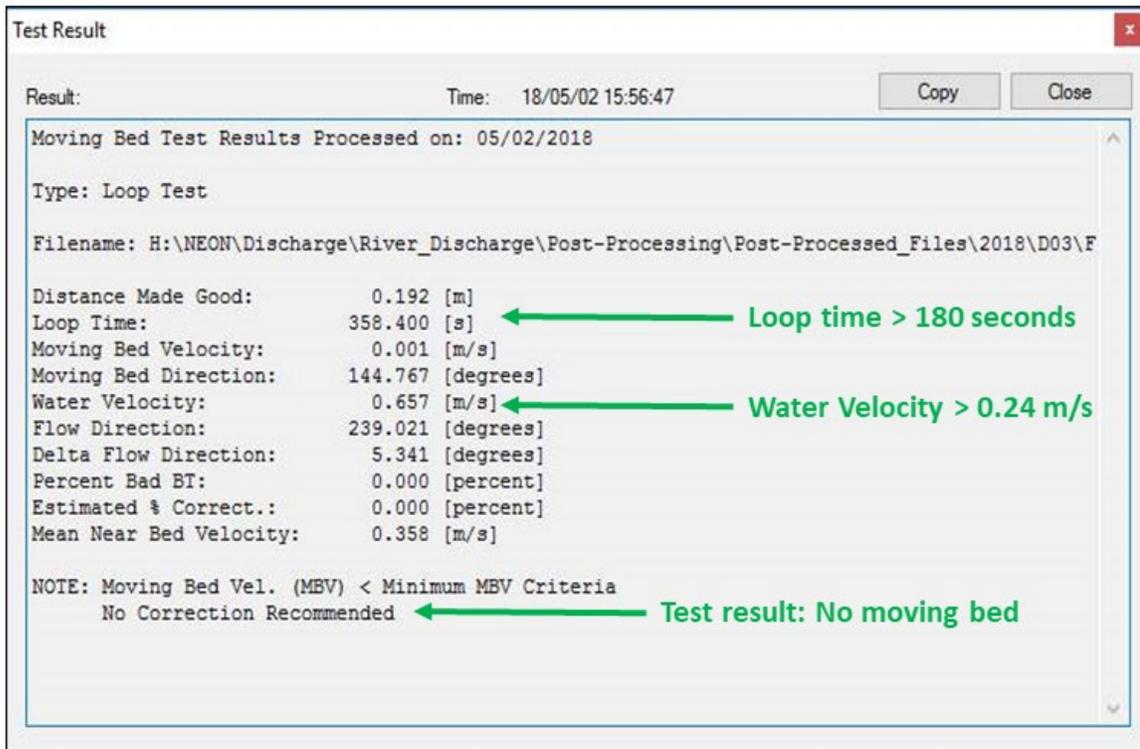


Figure 54. Moving Bed Loop Test Result window. In this example the required conditions were met in order to evaluate a moving bed (Loop time, water velocity) and a moving bed was not detected (the moving bed velocity < the moving bed velocity criteria), thus no correction was recommended.

14. If there is confusion whether or not the MBT was completed correctly or questions arise interpreting the results, consider the following common sources of errors associated with the Loop Method.
 - a. Water velocity must be > 0.24 m/s in order for a moving bed to be evaluated.
 - 1) If velocity is below this threshold a loop test cannot be evaluated by WinRiver II.
 - 2) At low velocities such as these it is likely that a moving bed is not present or is negligible in terms of affecting measured discharge.
 - 3) Conducting an additional loop test is not required.
 - 4) Proceed with the pre-measurement QAQC procedures in this instance.



- b. Systematic compass errors.
 - 1) Check the direction of the velocity vectors (blue lines) during the Loop Test in the Stick Ship Track window. They should be pointed in the same direction during both loop paths.
 - 2) If vectors are in opposite or in an erratic direction this is a symptom of poor compass calibration.
 - 3) Conducting another compass calibration followed by a second MBT may be helpful.
 - c. Bottom-tracking bias and uncertainty.
 - 1) Check the Velocity Contour Profile associated with the Loop Test.
 - 2) Are there large unmeasured areas along the streambed?
 - a) If so a MBT may be difficult to validate.
 - 3) Conducting another MBT along a different transect (upstream or downstream) may be helpful.
 - d. Failure to return to the initial starting point.
 - 1) Ensure that the boat was returned to the exact starting location at the end of the MBT.
 - 2) Make sure that you ended the MBT at the exact time you reached the starting location.
 - e. Irregular or insufficient sampling of the cross section because of loss of bottom track, non-uniform boat speed, and loitering at the banks.
15. If any of the above criteria are in doubt:
- a. Conduct another Moving Bed Loop Test in a slow, steady manner with a smooth transition at the opposite bank.
 - b. It may be helpful to begin the second Loop Test from the opposite bank or from a different transect location.
 - 1) Be sure not to get too far away from where you will be collecting the discharge measurement.
16. If, after the second Loop Test the results are still unclear, use the GPS as the reference method (if available).
17. If, after the second Loop Test the results are still unclear, and GPS is not available, conduct a Stationary Moving Bed Test.
- a. Stationary Moving Bed Tests can only be used to determine if there is a moving bed, not correct for one, therefore only use this if problems occur during the Loop Test and GPS data is not available.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

b. To conduct a Stationary Moving Bed Test:

- 1) Move the boat to the thalweg, or deepest section of the stream.
- 2) In the WinRiver II main screen, click on Acquire > Start Pinging (F4).
- 3) On the Acquire menu, click Select Moving Bed Test.
- 4) Select “Stationary Test” and click the Start button (F6).
- 5) Hold the ADCP in that location for at least for 300 seconds (5 minutes).
- 6) Stop the test (shortcut: F6 or Acquire > Stop Moving Bed Test).
- 7) Add any pertinent notes to the Stationary Moving Bed Test.
 - a) Right click on the test node (i.e. “Stationary 000”) and select “Add Note”.
 - b) Document that a moving bed was detected using a Stationary Test in the main measurement file remarks window.
 - (1) To add a note to the main Remarks section of the measurement file, right-click Site Information on the Measurement Control window.
 - (2) Enter notes into Remarks section.
 - c) Proceed with the next pre-measurement QAQC procedure.
- 8) If a moving bed is not detected proceed with the next pre-measurement QAQC procedure.

J.11 Pre-Measurement QAQC: Configure the Reference Navigation

The reference navigation determines how the direction or bearing (heading) of the instrument is measured. The following references are available during an ADCP discharge measurement:

- Bottom Track
 - ADCP Bottom-Track velocity (standard configuration).
 - This is primary choice for the reference navigation if a moving bed was not detected.
 - The ability of the ADCP to Bottom Track can become compromised during periods of high turbidity and suspended sediment concentrations (SSC). An overload of scatterers are produced in these conditions which prevent the ADCP beams from reaching the bottom and measuring velocity throughout the channel profile. If turbidity is high and the ADCP is having difficulty bottom tracking (this is evidenced by a large bands of missing ensembles in the velocity contour profile and warnings in the Measurement Control Window), consider using GPS as the reference navigation.
- GPS (GGA)
 - Differential GPS position from NMEA GGA string (WinRiver II will differentiate position to calculate velocity).



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- If a moving bed is detected and/or during periods of high turbidity and suspended sediment concentration, this is the primary choice for GPS reference as GGA data contains more information than VTG.
- GGA messages can be affected by multipath errors caused by large trees or structures nearby the measurement site.
- GPS(VTG)
 - GPS velocity from NMEA 0183 VTG string.
 - If a moving bed is detected, and/or during periods of high turbidity and suspended sediment concentration, this is the secondary choice for GPS reference as VTG data serves as a backup for GGA.
 - VTG messages are not affected by multipath errors but VTG GPS data is oftentimes less accurate than GGA, particularly when moving at lower speeds.

If a moving bed was not detected during pre-measurement QAQC procedures (**Section J.10**) and turbidity/SSC levels are low, it is always preferred to use Bottom Track as the reference navigation. This allows for the boat movement and water movement to both be referenced to the instrument. Note that GPS data should still be configured and collected even if it is not used as the reference navigation.

If a moving bed was detected and/or turbidity/SSC levels are high enough to adversely affect bottom tracking, GPS reference is preferred. GPS data can also be used as a good quality indicator of the Bottom Track data as well.

To change the reference navigation:

1. In the WinRiver II main screen, click on Configure > Reference.
 - a. If a moving bed is not present, ensure that “Bottom Track” is selected from the list.
 - b. When bottom track is used as the velocity reference, the speed of the ADCP over ground is subtracted from the measured relative velocity to give true Earth referenced water velocity.
 - c. If, following a moving bed test, a moving bed is present and GPS can be utilized, choose GPS (GGA) as the reference navigation.
 - d. If GPS does not have enough satellites to acquire a strong signal, Bottom Track should be used as the reference navigation.
 - 1) The number of available GPS satellites is shown by selecting View > Tabular > GPS (**Figure 44**).
 - 2) The absolute minimum number of satellites needed to provide a position is 3.
 - 3) Position will not be as accurate until at least 4 satellites are available due to timing limitations of GPS receivers.
 - 4) The greater the number of satellites, the greater the position accuracy, 7+ is preferred.



e. GPS latency can be detected using the Ship Track windows (View > Graphs > Ship Tracks) (Figure 54).

- 1) Compare the red lines (Bottom Track) vs the blue and green lines (GPS).
- 2) Separation between GPS and Bottom Track may denote:
 - a) GPS latency.
 - b) That an offset is required to the External Heading.

(1) See Section I.3 for details on applying External Heading offsets.

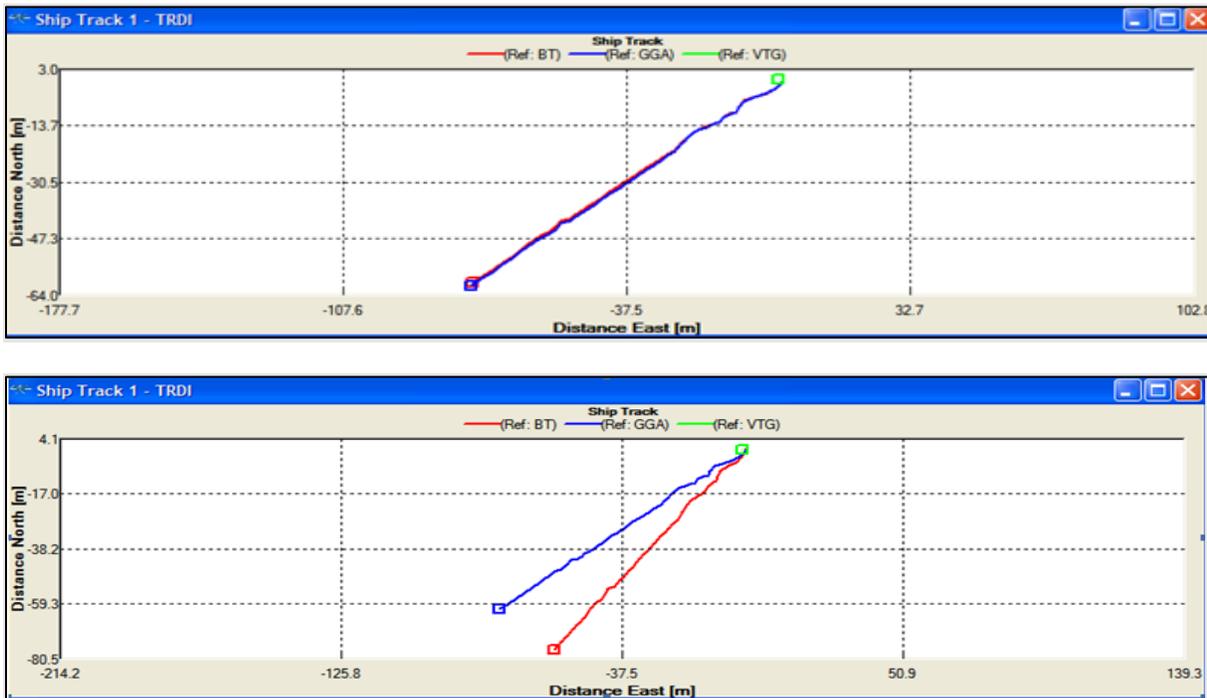


Figure 55. Above: Ship Track graphs to evaluate Bottom Track vs GPS data. Above: Track and GPS data are in good agreement, indicating proper compass calibration, an accurate Magnetic Variation value, and low GPS latency; Below: Bottom Track and GPS data are in poor agreement, indicating poor compass calibration, an inaccurate Magnetic Variation value, and/or high GPS latency.

J.12 Conduct Discharge Measurements with the ADCP and ARC-Boat

WinRiver II software calculates discharge using real-time velocity measurements acquired during transects across the stream. Perform the following steps in order to successfully collect a high-quality stream discharge measurement using the remote controlled boat method at river sites. Each step is presented in greater detail throughout this section.

1. Start ADCP pinging.
2. Establish transect start and end points.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

3. Enter staff gauge height prior to each transect measurement.
4. Measure discharge across the channel (minimum 4 transects).
5. Evaluate whether additional transects are required.
6. Save transect locations (optional).

1. Start ADCP Pinging

Setting the ADCP to start pinging enables ADCP and GPS data collection. In general, after you have started the ADCP pinging, there is no reason to stop pinging until you are finished the entire discharge survey and ready to remove the ADCP from the water. An exception would be if you were operating with batteries of limited capacity, under that circumstance stopping ADCP pinging will conserve power.

1. Ensure that the ARC-Boat is in the water and the ADCP and GPS antenna are powered on.
2. Press F4 to start the ADCP pinging (or Acquire > Start Pinging).
3. In a few seconds, ensembles will begin to be generated and changing values will appear within several of the WinRiver II data windows.
 - a. An ensemble is the data output generated by multiple ADCP pings that are averaged together. Ensembles are tracked in numerical order, timestamp, and position.
 - b. If the ADCP is positioned in sufficient depth, velocity profiles will become available.
 - c. Note that WinRiver II will not display meaningful data unless the Arc-Boat is in the water.
4. If enabled, GPS positions will be displayed at the bottom of the Composite Tabular display window and valid GGA positions are being received from the GPS system. External Heading data will be displayed if that functionality is enabled.
5. The ADCP can continue pinging when it is not in the water.

2. Establish Transect Start and End Points

The locations at each side of the channel where the discharge measurement begins and ends must be established before recording discharge transect data. Because stream depths eventually become too shallow for valid data collection as the ADCP approaches a bank, it is necessary to estimate discharge in the near-shore unmeasured zones using the WinRiver II and Q-Rev software. To ensure the accuracy of near-shore discharge estimates, the distances from the edge of water to the starting and stopping points of each transect must be measured using a distance-measurement device (such as a laser or optical rangefinder), tagline, or some other accurate measurement device.

Placing anchored marker buoys at the start and end points of transects is advantageous for keeping consistent edges and ensuring that the same cross-section profile is measured during each transect. If placing marker buoys in the channel is not possible try to remember these locations using some physical



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

reference. If it is not possible to reach the opposite side of the river to measure the edge distance, the “Distance MG [Made Good]” values displayed on the right side of the Composite Tabular 1 window can be used to calculate the edge distance from transect end point to the edge of water on the opposite bank. Be careful not to accidentally beach the ARC-Boat by getting too close to the opposite bank.

Other notes on transect start and end points:

- Measurement uncertainty increases as the distance increases between the start and end points and the edges of water due to less measurements and more interpolation.
- Try to ensure that the velocity profile at the start and end locations are representative of the velocity profiles leading up to the bank in order to limit interpolation bias.
- In channels that contain vertical walls at the edges, start and end points for transects should be no closer to the wall than the depth of water at the wall to prevent acoustic interference from the main beam or side lobes impinging on the wall.
 - For example, if the depth at a vertical wall is 10 feet, transects should start or stop at least 10 feet away from the wall.
- If the cross-section has been measured previously at the same location, WinRiver II “Locations” can be utilized to help determine the start and end points that were previously used and to help navigate the float across the channel.
 - See **Section J.12 Step 6** for instructions on loading available locations and how to save new ones.

To establish transect start and end points:

1. Navigate the boat just off the edge of water on the near shore and into open water until the ADCP transducers are submerged.
2. Note the number of “Good Bins” listed in the Composite Tabular window shown in the right panel of the main WinRiver II screen (**Figure 55**).
 - a. Two “Good Bins” (or depth cells) are required in order to start and end the transect measurement.
3. Navigate the boat slowly away from the bank until the tabular display indicates you are at a sufficient depth to set the transect start point (>2 Good Bins, closest to 2 is preferred).
4. If possible, mark this location with a marker buoy or weighted float. Otherwise try to remember this position by using some physical reference.
5. Navigate the boat slowly towards the opposite shore.



- a. Travel smoothly and slowly with the bow of the boat pointed upstream (note this may be difficult during periods of low flow, see **Section J.6** for boat operation tips).
6. While moving across the channel observe the Velocity Contour graph to view channel conditions and ensure that the ADCP is working as expected with the loaded configuration.
 - a. Observe the Velocity Contour Profile located on the bottom panel of the WinRiver II main screen (**Figure 56**). This display illustrates water velocity and depth across the channel.
 - 1) The very top and the very bottom of the channel will always be unmeasured by the ADCP and discharge in these locations will be interpolated. The top unmeasured area is a function of transducer depth, or how low the ADCP is in the water column.
 - 2) Vertical white bands within the profile are unmeasured areas that can occur for a variety of reasons including biota, woody debris, physical structures, or simply moving the float too fast or abruptly across the channel.
 - a) Work to limit the number of white bands in the profile as an increase in unmeasured area results in an increase in measurement uncertainty.
 - b) If the unmeasured area within the cross-section is significant a different discharge transect upstream or downstream may be necessary.
 - 3) Note regions where the channel depth changes abruptly.
 - a) Make a mental note to move more slowly across these regions during data acquisition to help bottom tracking maintain a valid lock on the bottom.
7. As the boat approaches the opposite shore note the Number of Good Bins in the Composite Tabular window (**Figure 55**) and stop the boat at the opposite edge of water where two good bins are available.
8. If possible, mark this location with a marker buoy or weighted float.
9. Proceed to the next step once transect start and end points are established at each side of the channel.

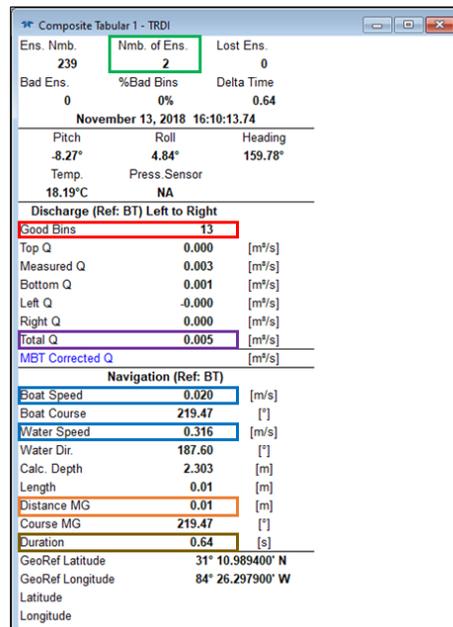


Figure 56. Composite Tabular window in WinRiver II, green box: number of ensembles (hold until 10 at transect start/end points); red box: Number of Good Bins (must be >2 to begin transect); purple box: total discharge; blue boxes: water and boat speed; orange box: distance made good (total transect length); brown box: duration (total transect duration must be ≥180 seconds).

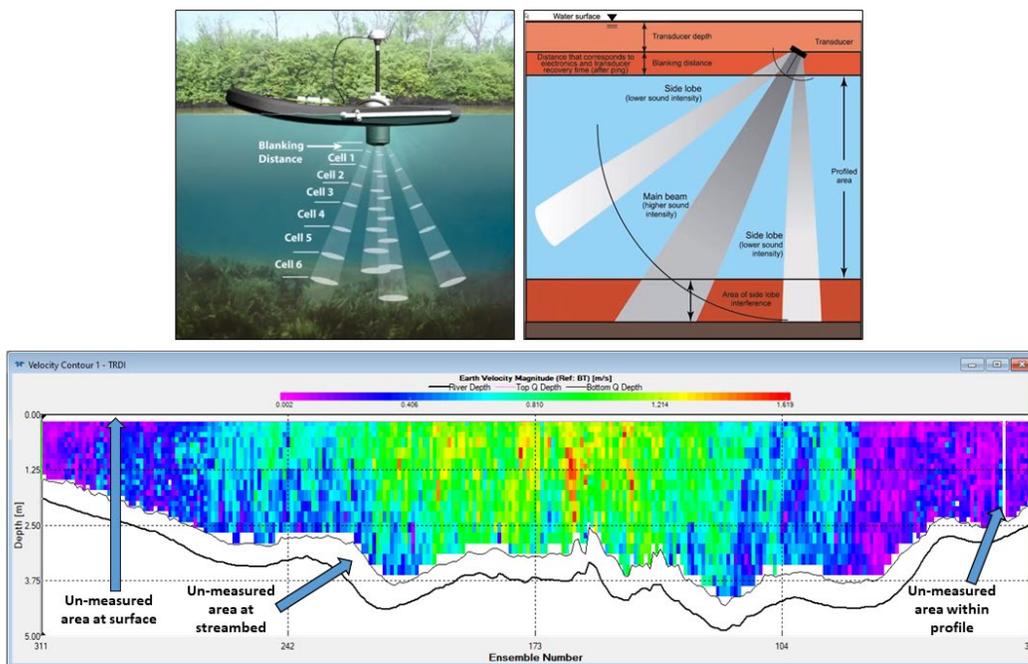


Figure 57. Unmeasured areas in the ADCP profile where velocity is extrapolated. Top left: ADCP blanking distance and cell size distribution (credit: SonTek); top right: unmeasured areas of the profile relative to ADCP beams (credit: SonTek); below: the WinRiver II velocity contour with unmeasured areas delineated.



3. Enter Staff Gauge Height Prior to Measuring Discharge at Each Transect

The staff gauge height must be entered prior to each transect measurement using the Fulcrum app. The mean gauge height recorded prior to all transect measurements is the stage value associated with the mean discharge measured during all transect measurements. Notes regarding conditions observed during individual transects (high/low flows, changing gauge heights, wind conditions, the passage of other vessels during measurement, any noteworthy events, etc.) can be entered in the main Remarks section of the Measurement Wizard as well as in the individual transect notes.

Gauge height observation and recording must immediately precede the transect discharge so the stage level during the discharge measurement is accurately characterized.

To enter the staff gauge height prior to each transect measurement:

1. Open the (AOS) Field Metadata and Gauge Height [PROD] app in Fulcrum.
2. Enter the appropriate information in the Metadata, Spatial and Temporal Information tables.
3. In the Stage Height table, enter the current staff gauge height in the “Initial Stage Height (m)” field.
 - a. Note that this does not necessary have to equal the staff gauge height prior to the first measurement transect.
4. Under the Stage Height table note the “Collecting Discharge with an ADCP Today?” field and select “Yes”.
5. Click the “ADCP Transect Stage Measurements” button that appears.
6. Click the red plus (+) button at the top right of the window to create a record.
7. Enter the time the staff gauge is measured in the Staff Gauge Height Reading Time field.
 - a. This must be done immediately preceding the discharge measurement.
8. Enter the Staff Gauge Asset Tag.
 - a. This is located on the top of the staff gauge you are reading.
9. Enter the Transect Number.
 - a. This must correspond to the transect number generated in WinRiver II.
 - b. By default, transect numbers begin at 000 and increase to 001, 002, 003, etc.
10. Enter the Staff Gauge Height.
11. Enter the Staff Gauge Height units.
12. Click the green check button in the top right corner of the window to save the record.
13. Additional ADCP Transect Stage Measurements can be added by clicking the red plus button at the top right of the window.
14. ADCP transect stage measurements can be deleted by clicking the black X button to the left of each record.
 - a. Records should be deleted if:
 - i. Errors are present in any of the fields.



- ii. The measurement transect is not to be used in the calculation of total discharge (the transect will remain unchecked in WinRiver II due to measurement error, the transect was started by mistake, etc.).
15. The ADCP Transect Stage Measurements window should remain open throughout the discharge survey so that staff gauge height can be measured prior to each transect measurement.
16. The window can be closed by clicking the green check mark at the top right of the window once all transect discharge measurements are complete.
17. Enter Weather Information, Post Fieldwork Observations, and General Comments information to the record as needed.
18. Click the green check mark at the top right of the window to save the record.
19. Fulcrum data will load automatically when the record is saved and the device receives a wireless internet signal.

4. Measure Discharge Across the Channel (Minimum 4 Transects)

A “transect” is considered a single discharge measurement that begins at the transect start/end point on one side of the channel and ends at the transect start/end point on the opposite side of the channel. Each ADCP discharge survey must contain a reciprocal number of transects (i.e. if a transect is measured from the near bank to the opposite bank, another transect measurement must be included from the opposite bank to the near bank). A minimum of four transects are required for each ADCP discharge survey but more may be necessary. Each transect must last a minimum of 180 seconds and the total time for all transects must be >720 seconds.

Complete the following steps to measure discharge during each transect:

1. Hold the position of the boat steady at one of the marked transect start or end points.
2. Using a stadia rod, meter tape, or laser range finder, determine the distance from the transect start point to the edge of water. This is referred to as the “edge distance”.
 - a. Measure the area from the center of the ADCP to the edge of the water.
 - b. If using a rangefinder make sure that the laser is not hitting leaves or branches hanging over the channel. Take a few shots and make sure they are all the same.
 - c. If it is not possible to measure this distance with an instrument, use the “Distance MG [Made Good]” values displayed on the right side of the Composite Tabular 1 window to calculate the edge distance from beginning/end of the transect to the adjacent edge of water. Be careful not to accidentally beach the ARC-Boat by getting too close to the opposite bank.
 - d. If you start from the same location for each transect, this distance does not need to be measured each time (it is recommended to mark the transect start point for this reason).
3. Click Acquire > Start Transect (shortcut: F5) to begin data recording.



- a. Note that the measurement has now been initiated.
4. When prompted, enter the edge distance (measured in **Step 2**).
5. Define whether you started the measurement from the left or right bank.
 - a. When facing downstream, the left bank is on your left side.
6. Hold the position of the boat at the transect start point for at least 10 shore ensembles.
 - a. This is equivalent to about 10 seconds.
 - b. The number of ensembles can be viewed in the Composite Tabular window (**Figure 55**).
7. Once 10 ensembles are recorded at the transect start point slowly and steadily navigate the boat toward the opposite bank.
8. Move the boat **slowly and steadily** across the channel.
 - a. The total duration of each transect (moving the boat from one side of the channel to the other) must be ≥ 180 seconds.
 - b. The cumulative time spent measuring each transect is directly correlated to measurement quality.
 - 1) The slower and steadier the float crosses the channel the higher the data quality.
 - c. Maintain an average boat speed that is less than or equal to the water velocity.
 - 1) Water vs. Boat speed can be monitored using the Water Speed vs Boat Speed graph.
 - a) Click View > Graphs > Time Series > Water/Boat Speed (**Figure 57**).
 - 2) When water velocity is very slow, keeping the boat speed below the water velocity may not be a possible (or practical) approach. Under these conditions the smoothness of boat operation becomes critical.
 - 3) Avoid fast and sudden accelerations.
 - d. Attempt to point the bow of the ARC-Boat upriver and crab across the channel.
 - 1) If this is not possible due to low surface water velocities, point the bow of the boat toward the opposite shore and slowly move towards it.
 - e. Observe data displayed on other graphs as needed to monitor data quality.
 - 1) Click View > Graphs/Tabular to explore other graphical and tabular interfaces.
 - a) Graph display settings can be configured by right clicking on the graph and selecting "Properties".
 9. Continue across the channel until you reach the transect end point on the opposite shore.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

10. Ensure that two good bins are available at this location using the Composite Tabular window (**Figure 55**).
11. Hold the boat steady at this location and wait until at least 10 shore ensembles have been collected.
 - a. This is equivalent to about 10 seconds.
 - b. The number of ensembles can be viewed in the Composite Tabular window (**Figure 55**).
12. Using a stadia rod, meter tape, or laser range finder, determine the distance from the transect end point to the edge of water. This is referred to as the “edge distance”.
 - a. Measure the area from the center of the ADCP to the edge of the water.
 - b. If using a rangefinder make sure that the laser is not hitting leaves or branches hanging over the channel. Take a few shots and make sure they are all the same.
 - c. If it is not possible to measure this distance with an instrument, use the “Distance MG [Made Good]” values displayed on the right side of the Composite Tabular 1 window to calculate the edge distance from beginning/end of the transect to the adjacent edge of water. Be careful not to accidentally beach the ARC-Boat by getting too close to the opposite bank.
 - d. If you end from the same location for each transect, this distance does not need to be measured each time (it is recommended to mark the transect end point for this reason).
13. Click Acquire > Stop Transect (shortcut: F5) to stop data recording.
 - a. Note that the measurement has now ended.
14. When prompted, enter the edge distance (measured in **Step 12**).
15. Define whether you ended the measurement at the left or right bank.
 - a. When facing downstream, the left bank is on your left side.
16. To add notes that document important information relating to each transect right click on the transect node in the Measurement Control window (upper left pane in the WinRiver II main scree) and select “Add Note”.
 - a. Notes that describe individual transect measurements help explain the data that was collected and are thus extremely beneficial to post-processing/data QAQC. Always provide clear, descriptive documentation regarding the discharge measurement. Examples of individual transect notes include:
 - 1) “A barge went through prior to/following the transect measurement”.
 - 2) “The wind picked up considerably during the transect measurement”.



- 3) "It was difficult to maintain a boat velocity less than the mean velocity of the river during the transect measurement due to..."
- 4) "Poor bottom tracking/GPS tracking occurred during this transect due this measurement due to..."
- 5) "River stage appeared to rise/fall during this transect"
- 6) "High sediment concentration was present during this transect"

17. The transect measurement is now complete.

18. To view the data you collected during the transect open the node (+) under the Transect name in the Measurement Control window and double-click the disc button.

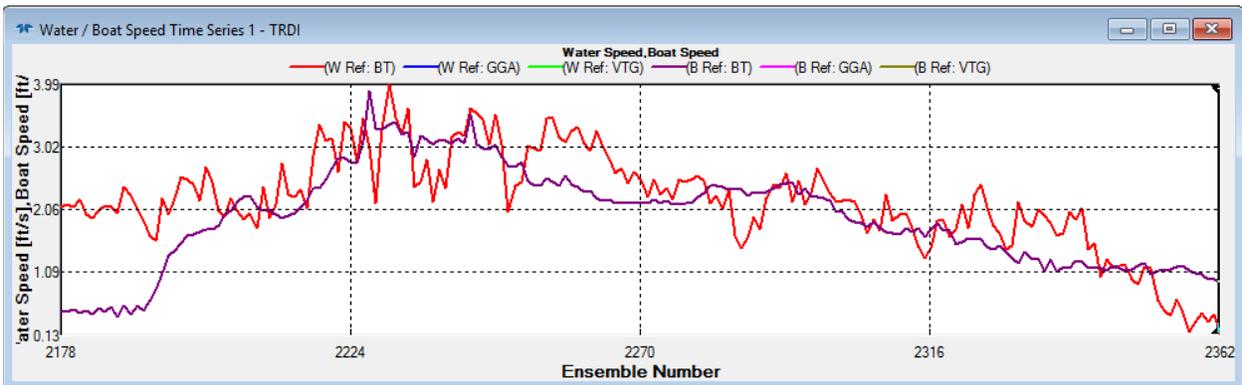
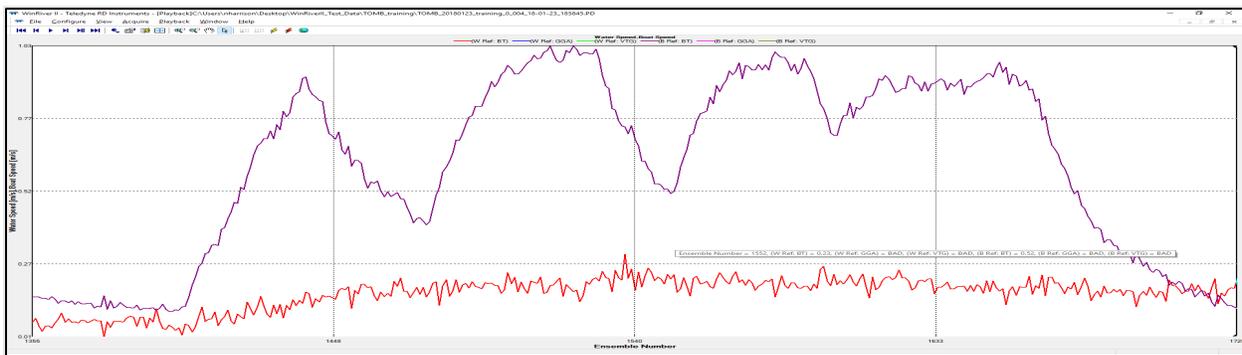


Figure 58. Water Speed vs. Boat Speed graph. Above: Improper technique. The boat speed (purple line) is erratic and higher than the water velocity (red line). Below: Proper technique. Maintain an even boat speed so that the purple and red lines are more in line and boat speed remains generally lower than water speed.

Collect (At Least) Three Additional Transect Discharge Measurements (Minimum of Four Total)

Repeat the previous steps, navigating the boat across the channel from each transect start and end point until a total of four transects have been measured (two in each direction). A minimum of four transects (each lasting a minimum of 180 seconds) must be collected during each discharge



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

measurement, two in each direction. The measured discharge is the average of the discharge collected during each transect.

Enter the staff gauge height prior to each transect measurement in the Fulcrum app. Record all other notes in the individual transect notes and/or the Remarks window of the Site Wizard (typically notes that affect all transects can be entered in the Site Wizard notes and notes that affect individual transects are to be entered in the individual transect notes).

A new data file and Transect node will be created in the Measurement Control window each time you start and stop recording during each transect (ex: Transect 0000, Transect 001, Transect 002, Transect 003). Once the fourth transect is complete stop data collection and evaluate whether additional transects are needed.

5. Evaluate Whether Additional Transects Are Required

More than four transects must be measured if:

1. Total duration of all transects does not exceed 720 seconds.
2. The discharge measured during at least one transect is greater than 5% of the average discharge of all transect measured.
3. An observed gauge height change is associated with a notable change in discharge for a given transect.

Evaluate the total duration of all transects:

1. In the Measurement Control window (top left panel in the WinRiver II main screen) ensure that each transect measurement you wish to evaluate is checked.
 - a. Uncheck any Transects were measured that contained errors and are not meant to be included in the evaluation.
 - b. A minimum of four reciprocal transects (that do not contain errors) must be checked.
2. In the WinRiver II main screen, hit the F12 button to bring up a summary table that provides information on each transect measured.
3. Scroll over to the fifth to last column, "Duration".
4. Ensure that each transect duration is ≥ 180 seconds and the sum of all transect duration is ≥ 720 seconds.
5. If individual and total transect duration requirements are met, proceed to the next evaluation step.
6. If an individual transect is < 180 seconds or the sum of all transect durations is < 720 seconds, collect two additional transect measurements (reciprocal pairs of transects must always be



measured, one that begins from each side of the channel) and re-evaluate the summary window.

Evaluate the discharge of each transect relative to average discharge of all transects:

1. In the Measurement Control window (top left panel in the WinRiver II main screen) ensure that each transect measurement you wish to evaluate is checked.
 - a. Uncheck any Transects were measured that contained errors and are not meant to be included in the evaluation.
 - b. A minimum of four reciprocal transects (that do not contain errors) must be checked.
2. In the WinRiver II main screen, hit the F12 button to bring up a summary table that provides information on each transect measured (**Figure 58**).
3. Note the value listed in the fifth column, "Total Q", for each transect row.
 - a. This is the total discharge measured during each transect.
4. Note the value listed in the "Average" row of the "Total Q" column.
 - a. This is the average discharge of all transects measured.
5. Note the value listed in the sixth column, "Delta Q", for each transect row.
 - a. This is the percent difference of total discharge measured during each transect relative to the average discharge across all transects.
6. If the Delta Q value for each transect is $\leq 5\%$, discharge requirements are met and no additional discharge transects are necessary.
 - a. Proceed to the next evaluation step.
7. If the Delta Q value for any individual transect is $> 5\%$:
 - a. Collect two additional transect measurements (one from each side of the channel) and re-evaluate the summary window (reciprocal pairs of transects must always be measured, one that begins from each side of the channel).
 - 1) Note that under changing hydrologic conditions (stage is rising or falling) Delta Q requirements may be difficult to meet.
 - 2) If river stage was fluctuating dramatically throughout the transect measurements, proceed to the next evaluation step.
 - 3) As total measured discharge values decrease during the low flow regime, achieving $< 5\%$ Delta Q values becomes increasingly difficult.
 - a) The instrumentation approaches the lower limits of its measurement ability at low stages and there is an overall increase in uncertainty when measuring low-flow



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

discharge (environmental factors such as bed and bank geometry exert a larger influence on velocity paths and can adversely affect measurement ability).

- b) A high level of precision is required to obtain repeatable discharge values per transect.
 - c) As more measurements are collected a given site over time, Science and Field Science staff can work together to develop applicable Delta Q thresholds based on stage levels.
- b. If Delta Q values still exceed 5% for a given transect collect two additional transect measurements (reciprocal pairs of transects must always be measured, one that begins from each side of the channel), and re-evaluate the summary window.
 - c. If, after collecting a total of 10 transects, Delta Q values still exceed 5% for a given transect, proceed to the next evaluation step.
 - 1) Submit a trouble ticket to Science upon return to the office.
 - d. Keep in mind that the more transects that are measured increases the probability that the true mean discharge will be measured but it also increases the probability that an outlier measurement will be collected.

Transect	Start Bank	# Ens.	Start Time	Total Q m ³ /s	Delta Q %	Top Q m ³ /s	Meas. Q m ³ /s	Bottom Q m ³ /s	Left Q m ³ /s	Left Dist. m	Right Q m ³ /s
01000	Right	417	19:27:56	1151.505	1.92	67.125	957.347	120.280	2.978	9.00	3.775
01001	Left	487	19:33:48	1121.736	-0.71	64.965	933.882	114.248	2.344	9.00	6.297
01002	Right	469	19:45:47	1123.982	-0.51	65.115	932.999	116.472	3.878	11.60	5.518
01003	Left	398	19:52:15	1121.822	-0.70	65.398	934.828	114.624	2.516	11.60	4.457
Average		442		1129.761	0.00	65.651	939.764	116.406	2.929	10.30	5.012
Std Dev.		42		14.533	1.29	0.999	11.746	2.760	0.687	1.50	1.117
Std./ Avg. (%)		9.50		1.29	0.00	1.52	1.25	2.37	23.46	14.57	22.29

Figure 59. Discharge summary window in WinRiver II. The red box highlights Delta Q values. In this example all are < 5%, an indication that no additional transect measurements are required.

Evaluate changes in transect discharge relative to changes in gauge height

Gauge height must be observed and recorded in the app prior to each transect measurement in order to calculate mean stage and assess unsteady flow conditions. Unsteady flow conditions occur during periods of rising or falling stage which may occur during or immediately following heavy rain events, upstream dam or lock flow regulation, tidal effects, downstream backwater effects, or flood waves. Always document unsteady flow conditions in the main Remarks section and/or in individual transect notes.

If changes in gauge height are associated with a notable change in discharge for a given transect (i.e. > ~3% of the mean):

1. Attempt to collect a pair of reciprocal transects that correspond with a given gauge height.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

2. If stage is changing too rapidly and this is not possible, save transect location files (if needed) and proceed to **Section J.13**.
3. Submit a trouble ticket to Science upon return to the office.

6. Create Transect Location Files (Optional)

Location files use GPS data to save the location of transect start and end points so that they can be utilized during subsequent discharge surveys. This feature cannot be utilized if GPS data was not integrated into the measurement. Once a transect has been measured it appears in the WinRiver II Measurement Control window, and the location can be saved. Multiple transect locations can be saved using unique files names (i.e. if discharge was measured 5 meters upstream during a particular survey).

To create a Transect Location file:

1. Complete a discharge measurement at a given transect.
2. Identify the transect location to be saved in the WinRiver II Measurement Control window.
 - a. The discharge measurement associated with the transect must contain GPS data.
3. Rick-click on the transect node and select “Define Transect Location” (**Figure 59**).
4. The Edit Locations window will appear.
 - a. Click on the map to zoom.
5. Enter a Location Name and any relevant notes about the transect.
6. Click the Save & Close button.
 - a. You must click the “Save & Close” button to create the location file.
 - b. Selecting Cancel or closing the Edit Locations window will not create the location file.
7. Click Save on the Save Location screen.
 - a. The *.dat location file will be saved to the C:\Measurements\Locations folder by default, this location can also be edited.

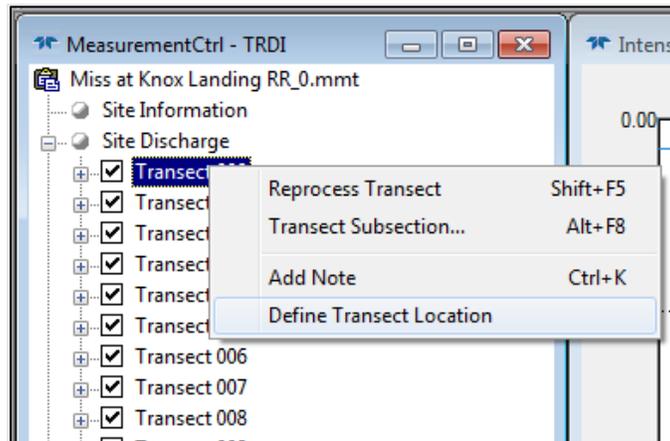


Figure 60. Defining transect locations in WinRiver II.

J.13 Evaluating the Discharge Measurement in the Field

Following the completion of the discharge survey, the following data review steps must be completed:

1. Review, finalize, and save data in WinRiver II.
2. Check measured discharge value against the stage-discharge rating equation (if available).
3. Review data in Q-Rev.

Data review must be conducted while still on site so that the discharge survey can be repeated if necessary.

Review, Finalize, and Save Data in WinRiver II:

1. Playback each measured transect and check parameters.
 - a. Open the node (+) under each transect.
 - b. Right click on the Transect number and select “Re-process Transect”. The transect data will appear in all graphs that are currently on display.
 - c. Right click on Playback Configuration and select “Properties”.
 - 1) In the Edge Estimates page on the right, verify that the Begin Transect and End Transect information was entered correctly.
 - 2) In the Offsets page check that the ADCP transducer depth was entered correctly (this depth should not have changed during the discharge survey).
 - 3) In the Discharge page choose the correct Left Bank and Right Bank Edge Type.
 - a) A custom coefficient value can be entered if a given bank does not conform to triangular or square shape.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- b) Consult Science with any questions regarding bank coefficients. These values are very important in estimating edge discharge.
- 4) Once any value has been entered in the Playback Configuration > Properties window, you can right click on the box and select “Apply to All Active Checked Transects” if you wish to apply this value to all selected transects.
 - a) This will apply the setting to all transects in the measurement that are checked.
 - b) Each transect will need to be re-processed for this change to be applied.
- d. Enter all applicable notes in the general Remarks section and in individual transect notes, as necessary.
- 2. Following the WinRiver II review save the measurement file on the laptop and a USB dongle for backup.
 - a. An .MMT file will be created along with .PDO files that are unique to individual transects. Each of these files must be contained in a folder on the laptop and backed up onto a USB dongle.

Check the measured discharge value against the stage-discharge rating equation, if available:

Once a stage-discharge rating curve has been developed and validated for a site, a rating equation is derived that predicts discharge given stream stage (supplementary information on rating curves is available in **(Appendix D)**). Once established, rating equations will be provided to field staff by Science. Rating equations are commonly expressed as power relationships:

$$Q = C_r(G - \alpha)^\beta$$

Where:

- Q = discharge;
- G = the stage, or gauge height;
- α = the gauge reading corresponding to zero discharge; and
- C_r and β = rating curve constants

Following the discharge measurement:

- 3. Enter the stream stage (G) into the rating equation that is associated with the site.
- 4. Calculate predicted discharge.
- 5. Evaluate whether the measured discharge is $\pm 10\%$ of the discharge predicted by the equation.
 - a. If the measured discharge is $< \pm 10\%$ than predicted discharge:
 - 1) Another discharge survey is not required.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- b. If the measured discharge is $\geq \pm 10\%$ than predicted discharge (and the stream stage did not change during the site visit):
 - 1) Conduct another discharge survey immediately.
 - 2) If, after a second attempt, the measured discharge remains $\geq \pm 10\%$ the predicted rating discharge:
 - a) Check the second discharge measurement file for errors using steps provided in previous sections.
 - b) Save both discharge measurements.
 - c) Submit a trouble ticket to Science.
 - (1) This may indicate a shift in the rating, which, if validated by additional measurements, would warrant an increase in the frequency of discharge measurements at the site.

Review, Finalize, and Save Data in Q-Rev:

QRev software (USGS) serves a final means to QAQC ADCP discharge data. The following procedures must be done in the field prior to leaving the site.

1. Open Q-Rev.
2. Open the .mmt file (the file that was just saved in WinRiver II) in Q-Rev.
 - a. In the main Q-Rev window: Select Data > TRDI > select the WinRiver II .mmt file.
 - b. Note that the location where the .mmt file is stored must also contain all of the .PDO files that correspond with the measurement.
3. Note the color of the buttons on the left side of the main window. These colors indicate data quality for specific measurement parameters.
 - a. Green: Good, no investigation required.
 - b. Yellow: Problems could be presented and may be able to be corrected, investigation is required.
 - c. Red: Problems are present that are negatively affecting measurement data, investigation is required.
4. Select the "Options" button (this button will never be colored).
 - a. Ensure that "Units" are set to SI.
 - b. Click OK.
5. In the main window, select the "Moving Bed Test" button (regardless of color).
 - a. Uncheck any tests that are not valid in the "User Valid" column.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 1) Note the “Quality” rating, and the text contained in the Messages window.
 - b. If any tests contain “Moving Bed” = “Yes” consider checking “Use for Correction” if the tests were valid.
 - c. Note this will change the measured discharge value.
6. Evaluate the remaining buttons if they are not green:
- a. ADCP/Site Info
 - 1) Here the Station Name and Number can be edited, but this is not required.
 - b. System Test
 - 1) Provides the results of the ADCP system test.
 - c. Compass/P/R
 - 1) Provides heading, pitch and roll, and magnetic variation data for each transect.
 - a) If the pitch and roll time series data are too high and the extended compass calibration was not performed, Q-Rev will apply a flag.
 - 2) This button will be yellow if Compass Calibration Error is > 1 degree.
 - 3) Here you can change the magnetic variation for some or all transects by clicking on the Magnetic Variation value within the Heading, Pitch, & Roll table.
 - 4) You can view the Compass Calibration data by clicking the “View” button under Compass Cal/Error on the right side of the screen.
 - d. Temp/Salinity
 - 1) Here you can evaluate the ADCP thermistor which controls temperature, salinity, and speed of sound data.
 - a) Fluctuations in the time series data may indicate (1) the ADCP was not allowed to fully equilibrate to the water temperature prior to measurement, or (2) actual temperature variations present in the channel.
 - 2) Check the Average Temperature vs. the User Temperature (entered at the start of the ADCP measurement).
 - 3) The temperature source can be changed from internal (ADCP) to User for one or all transects by clicking on the Temperature Source value in the Speed of Sound Settings table.
 - a) Note this will change speed of sound and discharge values.
 - e. BT Filters



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 1) If GPS data was used as the reference navigation this button never needs to be evaluated. Reference the GPS Filters button instead.
 - 2) Here you can evaluate time series velocity data, velocity errors, and how the data can be adjusted using different filter and interpolation settings.
 - 3) Consult with Science if you feel that BT Filters require adjustment.
- f. GPS Filters
- 1) If Bottom Track was used as the reference navigation this button never needs to be evaluated. Reference the BT Filters instead.
 - 2) Here you can evaluate time series velocity data, velocity errors, and how the data can be adjusted using different filter and interpolation settings.
 - 3) The ATL-g Plot to Google Earth plots the transects for the discharge measurement to the Google Earth App. This will only work if the Google Earth App is installed on the computer that QRev is running on.
 - 4) Consult with Science if you feel that GPS Filters require adjustment.
- g. Selected Reference
- 1) The Selected Reference button will be grayed out and this window will not be accessible if there is no GPS data in the file loaded to QRev.
 - 2) The summary table provides details on the navigation data available, and describes changes in calculated discharge based on filter changes in QRev.
 - 3) The Reference Used panel displays the navigation reference currently being used for the transect selected in the summary table.
 - 4) The boat speed time series shows the boat speed for each of the navigation reference data types in the same graph per transect.
 - 5) The ship track time series shows the ship track for each of the navigation reference data types in the same graph per transect.
 - 6) In the Selected Reference panel, the reference navigation data type used for computing discharge can be changed. Refer back to the summary table to see how a change affects the calculated discharge.
 - 7) The Composite Tracks feature can automatically substitute one of the other valid navigation references for the selected navigation reference, if the selected navigation reference is invalid.
 - a) Composite tracks default to off.
- h. Depth Filters/Draft



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 1) Here data from each beam can be reviewed and the combined cross-sectional value.
 - 2) QRev defaults to using inverse depth weighting to compute the mean depth when the 4 slant beams are used.
 - 3) The filter type can be changed to eliminate erroneous spikes. Note this will change the discharge value.
- i. WT Filters
- 1) Here raw and processed water track data can be reviewed and adjusted.
 - 2) Note that the error and vertical velocity filters do not always perform well on data from ADCPs with auto adaptive modes (the RiverPro being one such model) due to the change in error velocity distribution for the different modes.
 - a) If this button is yellow or red try turning error and vertical velocity filters off. Note the change in total discharge.
- j. Extrapolation
- 1) Default edge extrapolation settings are determined automatically from algorithms created for the Extrap program.
 - 2) The data panel displays average normalized depths for segments of the channel, with each segment equating to 5 percent of the total discharge.
 - 3) The Profile Panel is the primary panel in this window.
 - a) Gray Dots represent raw data, normalized discharge or velocity (depending on which is selected) in each depth cell for all transects selected in the Fit panel.
 - b) Green circles represent the top cell for each ensemble, the cell at the water's surface.
 - c) The Red/Black Squares are median points for the raw data in each segment. They are color coded:
 - (1) Red: contains less values in the segment than the threshold requires, and is not used in the computation of extrapolation.
 - (2) Black: Median values of the composite of all the transects in the measurements.
 - d) The horizontal Red/Black lines (Whiskers) on either side of each median value extend to the 25th and 75th percentile of all the data in that segment (i.e. 50% of the raw data will fall inside the whiskers).
 - e) The center line, going through the median squares is the extrapolation line, which is also color coded:



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- (1) Magenta: transects collected while crossing the channel from left bank to right bank (facing upstream).
 - (2) Blue: transects collected while crossing the channel from right bank to left bank (facing upstream).
 - (3) Black: is a composite of all the transects.
- f) The fit panel allows a separate fit edge for each transect.
- (1) Leave “Fit” set to “Automatic” for default algorithms to be used (recommended default setting).
 - (2) Change “Fit” to “Manual” to change the extrapolation method at the Top and Bottom of the graph to different fit options – Power, Constant, or 3-Point (Top) or Power or No-Slip (Bottom).
 - (a) Set the Exponent value incrementally for Power or No-Slip extrapolations. The graph will update as the exponent is changed.
 - (3) Note that discharge values will change as extrapolation fits are adjusted.

k. Edges

- 1) This window displays the edge settings for computing the left and right edge discharges and displays graphs for evaluation.
- 2) The Edges button will be yellow if any of the extrapolated edge discharge contributes >5% of the total measured discharge for the transect.
 - a) Uncertainty in the total estimated discharge increases with increased contribution of edge discharge to the total estimate.
 - b) Check the “Left Distance (m)” and “Right Distance (m)” values to ensure the left and right edge distances were entered correctly.
 - (1) These values are directly correlated to the percentage of total discharge contributed by the edges.
 - (2) To edit an edge distance click on the “Left/Right Distance (m)” value you wish to edit. The new value can be applied to a singular transect or all transects in the measurement.
 - c) If edge distances are correct but edge discharge remains >5% of the total measured discharge, not much else can be done during post-processing other than re-measuring additional transects during which you begin and end the measurement closer to the edge of water.

7. Save the file and exit Q-Rev.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

SOP K Post-Field Sampling Tasks: River Sites using the Remote Controlled Boat Method

Once field verification of the measurement file is complete, the ARC-Boat and GPS antenna shall be cleaned following standard operating procedures for cleaning field equipment used in aquatic systems. Batteries for the ARC-Boat and ADCP/GPS antenna shall be charged or replaced as needed.

K.1 Document Incomplete Sampling Within a Site

Discharge sampling is scheduled to occur at the prescribed sampling location according to the frequency and timing described in **Section 4** and **Appendix E.1**. Ideally, sampling will occur at this sampling location for the lifetime of the Observatory (core sites) or the duration of the site's affiliation with the NEON project (relocatable sites). However, sampling may be shifted from one location to another when sampling is compromised. In general, a sampling location is compromised when sampling becomes so limited that data quality is significantly reduced.

There are two main pathways by which sampling can be compromised. First, sampling locations can become inappropriately suited to answer meaningful biological questions – e.g., stream morphology changes in such a way that discharge measurement quality is reduced. Second, sampling locations may be located in areas that are logistically impossible to sample on a schedule that that is biologically meaningful.

For the river discharge sampling program, a given discharge transect must be sampled during 100% of the bouts expected for the site (see **Appendix E** for the number of expected bouts and site-specific documentation) over a one-year period. Transects that cannot be sampled on this schedule should be considered compromised.

If sampling at a given transect is not possible during a given bout a trouble ticket should be submitted by Field Science staff.

To document a missed discharge bout:

1. Create an incident with the following naming convention to document the missed sampling: 'AOS/TOS Sampling Incomplete: MOD – [Root Cause Description]'
 - a. Example: 'TOS Sampling Incomplete: CDW – Could not access plot due to permanently closed road'

Staff scientists review incident tickets periodically to determine whether a sampling location is compromised.



SOP L Data Entry and Verification: River Sites Using the Remote Controlled Boat Method

Raw ADCP discharge measurement files (i.e. files that have been evaluated in WinRiver II and Q-Rev but not post-processed by Science) are stored on an online file storage page and post-processed by Science. Complete the following steps to upload discharge measurement files.

1. In the office (or location with internet connection), store the measurement file on the cloud-based Box.com folder.
 - a. Navigate to the main Box.com folder where raw ADCP files are stored.
 - 1) "NEON ADCP Discharge Measurement Files" <https://app.box.com/folder/48084982589>
 - 2) "Raw_Data"
 - b. Navigate to the applicable Domain folder for raw files.
 - 1) Ex: "Domain_03_Raw_Files"
 - c. Navigate to the appropriate site folder.
 - 1) Ex: "FLNT"
 - d. Navigate to the appropriate calendar year.
 - e. Create a new folder that is unique to your discharge measurement.
 - 1) Click the "New" dropdown and select "Folder".
 - 2) Ensure that the folder name is in a standardized format.
 - a) Ex: "SITE_YYYYMMDD" (FLNT_20180317)
 - f. Move all of the measurement files into this folder.
 - 1) This includes .MMT, .PDO files, and _GPS.TXT file (StreamPro only) - everything that was saved on the laptop/USB.
 - 2) If any other relevant materials correspond to the discharge measurement (i.e. pictures, screen shots, etc.) create a sub-folder here where they can be stored.
 - 3) In addition to .PDO and _GPS.TXT files (of which there will be many depending on the number of transects measured), include only one (1) .MMT file (from WinRiver II) and one (1) .XML file in the sub-folder.
 - g. Once the all data is available on the Box folder, Science will assume it is ready for post-processing.



APPENDIX C DISCHARGE MEASUREMENTS AT RIVER SITES USING THE PILOTED BOAT METHOD

The following sections provides instruction on how to complete discharge surveys at NEON river sites using acoustic Doppler current profiler (ADCP) instrumentation deployed with a piloted boat.

C.1 Introduction

An acoustic Doppler current profiler (ADCP) uses sound to measure water velocity based on the Doppler Effect, a principal of physics discovered by Christian Johann Doppler in 1842. Doppler's principal relates the change in frequency of a source to the relative velocities between the source and the observer. An ADCP applies the Doppler principle by reflecting an acoustic signal off small particles of sediment and other material (scatterers) that are present in water. The velocity measured by the Doppler principle is parallel to the direction of the transducer emitting the signal and receiving the backscattered acoustic energy.

NEON utilizes ADCPs to measure discharge at NEON aquatic sites that contain wadable stream and rivers. NEON stream discharge measurement collection at river sites can be facilitated using two unique deployment methods: (1) mounting a RiverPro ADCP (TRDI) to a remote controlled boat (ARC-Boat by HR Wallingford) or (2) mounting a RiverPro ADCP (TRDI) off the side of a piloted boat. In both instances the boats are driven back and forth across the channel a number of times with the base the base of the ADCP beneath the water surface. The ADCP contains four beams pointed at 20 degrees from the vertical that can continuously measure water depth, water velocity, and instrument speed. Discharge and velocity calculations performed by ADCPs during streamflow measurements are well-documented in the literature (Mueller et al., 2013; TRDI, 2015) but the basic premise is as follows (Den Herder, 2018):

- The ADCP instrument transmits short pulses of sound at fixed frequencies into the water.
- The transmitted sound bounces off scattered material suspended in the water (sediment, microscopic organisms, etc.). The returned signals from these scatterers are shifted in frequency.
- The returned signals from each beam are used to create the water currents in east, North, and Vertical velocity vectors.
- Returned signals are continuously processed into separate depth cells (or bins) to provide a profile of the water column
- Binned velocity and depth are integrated to calculate bin discharge, which are then summed to calculate total discharge
- Multiple discharge transect measurements are completed and mean discharge across transect measurements is calculated and reported as total discharge.

The ADCP measures the relative motion of the water to the ADCP by correcting the measured water velocity with the measured velocity of the vessel used to deploy the instrument (boat, trimaran float, etc.). The velocity of the vessel can be calculated in two ways: externally via a global positioning system unit (GPS), or internally utilizing ADCP bottom tracking technology. The ADCP divides the water column into depth cells (or bins) and reports a velocity for each depth cell.



The ADCP software integrates total bin velocity over the bin depth to obtain bin discharge. The resulting sub-section 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 stream 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. On average it expected to take an experienced field crew 30-60 minutes to complete a stream discharge measurement from start to finish.

SOP M Preparing for Sampling: River Sites Using the Piloted Boat Method

The RiverPro ADCP (Teledyne) (**Figure 60**) and Kentucky II mount (originally developed by the USGS) (**Figure 61**) are used to measure discharge at NEON river sites from a piloted boat when an ARC-Boat deployment is not available. Two software packages are required for all ADCP discharge surveys using this method: (1) WinRiver II software (Teledyne), a discharge data application for data collection and post-processing, and (2) [QRev](#) (USGS OSW), a Matlab program for advanced post-processing of WinRiver II measurement files.



Figure 61. RiverPro ADCP. Left: base of the ADCP showing the five beam lenses; Right: top of the ADCP with indicator lights and power cord.



Figure 62. The Kentucky II mount (USGS) is used to deploy the ADCP when measuring discharge at NEON river sites using the piloted boat method.

M.1 Preparing for Data Capture

Prior to leaving the office ensure that the following criteria are met (each point explained in detail below):

- All necessary equipment is gathered and prepared (**Table 14**).
- Setup and test ADCP serial communications.
- If the site has an approved stage-discharge rating curve, the current rating equation is available for measurement comparison/validation.

M.2 Setup and Test ADCP Serial Communications

The RiverPro ADCP communicates with WinRiver II software (installed on the laptop) via a serial cable that connects the ADCP and the laptop. An RS-232 9-pin male to USB (with FTDI) adapter is used to connect the ADCP serial cable to a USB port in the laptop (**Figure 62**).



If the same laptop is used for ADCP measurements (this is recommended for ease of communication setup and software availability) the following setup should only need to occur prior to the initial measurement. Following the initial setup, the ADCP should automatically connect to the laptop software via the serial cable. Setup, testing, and troubleshooting is best done in the office prior to deployment in case an internet connection is needed. An ADCP discharge measurement cannot be completed if serial communications are not configured.

To date there is not a means to integrate GPS data into discharge measurements collected using the Piloted Boat method. As this method is meant as a back-up to the Remote Controlled Boat for discharge measurements at river sites, it is expected it will only be used sporadically. If use of this method becomes more common work can be conducted to incorporate GPS instrumentation.



Figure 63. Serial cables that connect the ADCP to the 12V battery and the laptop PC. Note the white RS-232 USB adapter that must be included in the set.

To setup the ADCP serial connection:

1. Remove the black cover plug from the ADCP serial cable and lubricate the end lightly with silicate lubricant.
2. Connect the ADCP serial cable to the ADCP so that the Teledyne logos are matched up.
3. Attach the RS-232 cable to the other end of the ADCP serial cable and connect the USB end of the RS-232 to a laptop port.
4. Use Windows Device Manager to determine the laptop COM (communication) port that the serial cable is assigned to.
 - a. Navigate to the Windows Device Manager.
 - 1) Start Menu > Search “Device Manager”
 - b. Open the “Ports (COM & LPT)” node.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- c. Note the COM port number the serial cable assigned to.
 - 1) Unplug and re-connect the serial cable to note which COM Port number appears and re-appears. This is the COM Port the serial cable is assigned to.
5. Select the RS-232 COM Port and set the baud rate to 115200.
 - a. Right click on the COM port assigned to the serial cable and select “Properties” > “Port Settings”.
 - b. Configure Port Settings.
 - 1) Bits per second = 115200.
 - 2) Data bits = 8
 - 3) Parity = None
 - 4) Stop bits = 1
 - 5) Flow control = None
 - c. Click on the Advance Settings button.
 - 1) Check the COM Port number assigned to the serial cable in the top of the Advanced Settings window.
 - 2) In the BM Options section, select the Latency Timer drop down and set to 1msec.
 - 3) Click OK twice to exit Windows Device Manager.
6. Connect the ADCP serial cable terminal ends to a fully charged 12V 7AH battery.
 - a. The green light on the ADCP should turn on to indicate that the instrument is receiving power.
7. Open WinRiver II software.
8. In the WinRiver II main screen, click Configure > Peripherals.
 - a. Test ADCP communications.
 - 1) Ensure that the ADCP is fully powered (green light should be on) and the serial cable is installed in the designated COM Port.
 - 2) In the “Peripheral Configuration Dialog” window, under the “Peripherals” node, double click on “Read Serial Raw ADCP Data”
 - 3) Double click on “Port: ADCP Serial Port”
 - 4) Check that COM settings are correct and press OK.
 - 5) With “Port: ADCP Serial Port” still highlighted, click the “Test Port” button on the right.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 6) A dialogue box will open and you should see some information begin streaming regarding Teledyne RiverPro firmware. This indicates that the ADCP is recognized by the WinRiver II program (**Figure 63**).
 - a) If nothing appears than WinRiver II is not recognizing the ADCP.
 - b) Check that COM settings are correct in both Windows Device Manager and WinRiver Peripherals setup.
 - c) If nothing appears in the test window, further ADCP testing can be completed in the Configuration Dialogue tab of the Measurement Wizard window.
- 7) Click “Stop” and “Close” to cease testing and close the test dialogue window.
9. Once all configuration and testing is complete the ADCP should be powered off by disconnecting the terminals from the 12V battery.

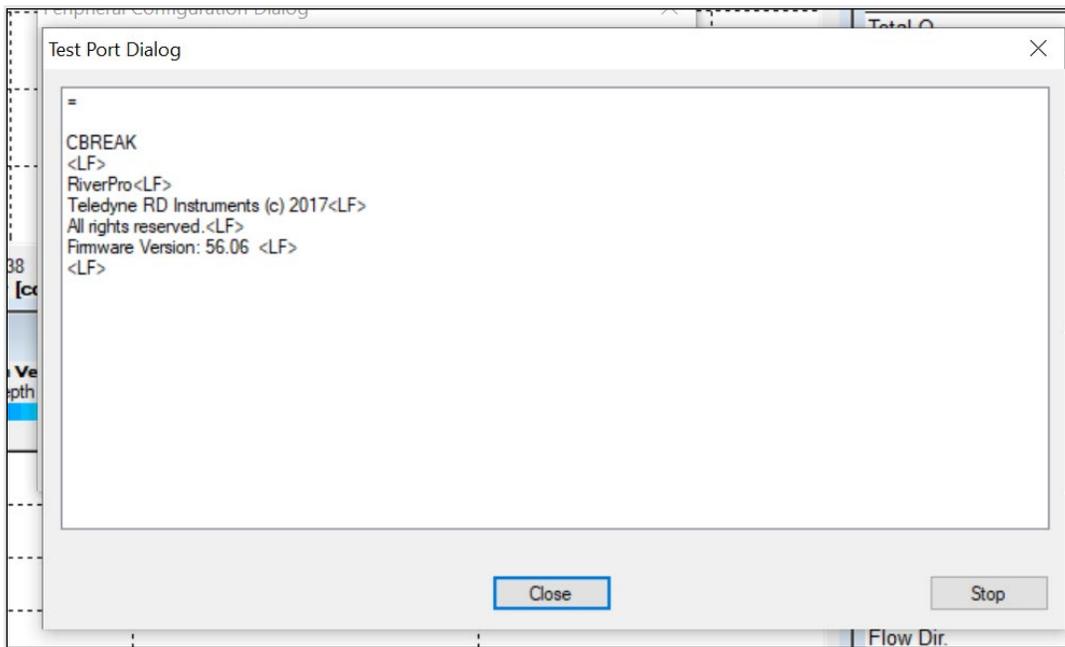


Figure 64. RiverPro ADCP Test Port Dialog indicating that ADCP data is streaming from the ADCP to the laptop.

M.3 Navigate to the Discharge Transect

If a discharge transect, or cross-section, has already been established, the bounds should be permanently marked using stakes or plot markers (one on each side of the river). Navigate to this location and proceed to **Section M.4**.

If a discharge transect has not been established at the site proceed with the following steps:

1. Determine an appropriate location to establish a discharge transect.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- a. At river sites, the transect location must be located in a straight reach in relatively close proximity of the staff gauge and pressure transducer. Consult with Science if the pressure transducer location is unknown or has not yet been established.
- b. An ideal discharge transect will:
 - 1) Be located in a reasonably straight channel with velocity lines that are more or less parallel to each other.
 - 2) Contain velocities that are, for the most part, > 0.15 m/s, and depths that are, for the most part, > 0.15m.
 - 3) Contain a stable streambed free of obstructions that would create eddies, slack water, and turbulence.
 - 4) Contain measurement sections that are roughly parabolic, trapezoidal, or rectangular.
 - 5) Contain a stable downstream control feature.
- c. Take a picture of the transect location that best meets this criteria as well as the downstream control feature and send to Science for consultation.

M.4 Assess the Discharge Transect

Prior to collecting the discharge measurement identify any instrumentation or environmental issues that would negatively affect data quality. Document any temporary hydrologic conditions in the (AOS) Field Metadata and Gauge Height [PROD] app in Fulcrum. If conditions are unfavorable to discharge measurement collection, submit a trouble ticket and consult with Science.

Unfavorable conditions include, but are not limited to:

1. The staff gauge is either not present or has been displaced in some way.
 - a. A discharge measurement **must not be collected** if a staff gauge is not present at the site or the gauge has been displaced in any way.
 - b. Submit a trouble ticket to Science that includes photos of the gauge.
 - c. If the staff gauge is topped during high flows and a discharge measurement can be safely collected, attempt to mark or in some way reference the elevation of the edge of water (only do so if this can be accomplished in a safe manner). A future survey of this location (relative to the staff gauge) can provide an estimate of gauge height during the measurement.
 - d. Note that if a discharge survey is associated with a reaeration sampling event, discharge should still be measured regardless of staff gauge presence.
2. A pressure transducer is either not present or has been displaced in some way.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- a. A discharge measurement **may be collected** in the event that the pressure transducer is missing or has been displaced. However the absence of this instrument prevents continuous discharge from being estimated.
- b. Submit a trouble ticket to Science immediately if the pressure transducer is missing or has become displaced.
3. Streamflow is exceeding the banks causing unsafe conditions on the floodplain.
 - a. Refer to NEON Operations Field Safety and Security Plan (AD[02]) for details.
4. There is an insufficient amount of water in the channel to conduct velocity measurements.
 - a. See **Section 4.2.1**.
5. Refer to NEON Operations Field Safety and Security Plan (AD[02]) and NEON Operations Field Safety and Security Plan (AD[02]) for further details.

SOP N Field Sampling: River Sites Using the Piloted Boat Method

N.1 Assemble the ADCP Mount to the Piloted Boat and Attach the ADCP

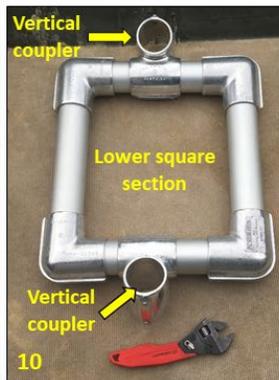
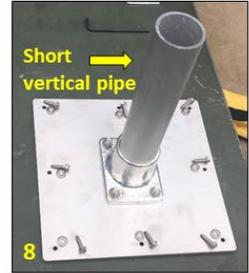
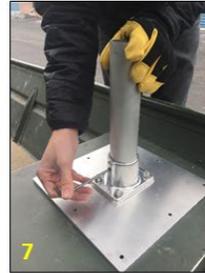
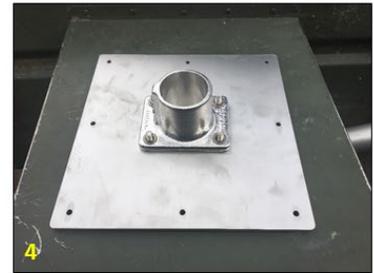
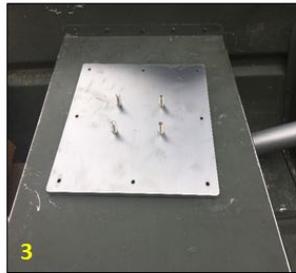
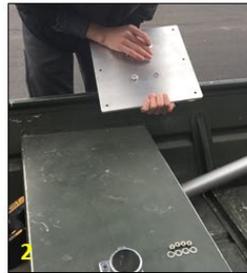
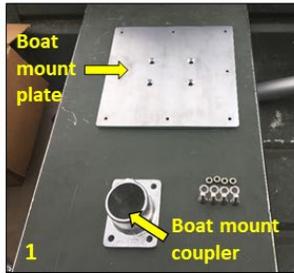
Once the discharge transect has been established or assessed, configure the ADCP mount on the boat and attach the ADCP. The ADCP mount deploys the ADCP over the side of the piloted boat during the discharge measurement. Prior to deploying the ADCP, always leave the protective cover on the base of the ADCP so that the beam lenses (**Figure 60**) do not get scratched.

To assemble the ADCP mount (**Figure 64**):

1. Ensure that the boat mount base plate is installed at the proper location of the boat where the ADCP can be securely deployed over the side and interference (proximity of magnetic materials, hull/motor effect) is minimized.
2. Install the boat mount coupler into the boat mount base plate.
3. Insert the short vertical pipe into the boat mount coupler.
4. Assemble the lower square section by attaching sections of pipe to the 90 degree elbows. Tighten each elbow with an Allen wrench. Place a vertical coupler at each end of the square.
5. Attach the lower square section to the short pipe in the boat mount base plate by sliding one of the vertical couplers on the lower square section over the short pipe in the boat mount base plate. Use an Allen wrench to tighten the vertical coupler to secure the lower square section to the short pipe. One end of the lower square section should now be sitting off the side of the boat.
6. Slide the long vertical pipe through the opposite vertical coupler (the one that is off the side of the boat) and secure it in place by tightening the vertical coupler with an Allen wrench.
7. Attach the tether hook to the ADCP coupler.



8. Attach the ADCP coupler (with tether hook) to the circular ADCP base plate using an adjustable wrench to tighten the screws, nuts, and washers together.
9. Attach the ADCP base plate with ADCP coupler to the base of the ADCP.
10. Attach the ADCP coupler to the end of the long vertical pipe so that the ADCP is securely deployed over the side of the boat.
11. Using a carabiner, attach a rope tether to the tether hook next to the ADCP coupler.
12. Attach the tether rope to secure location on or inside the boat.
13. The ADCP depth can be adjusted by adjusting the ADCP coupler and moving the long vertical pipe up or down.
14. Remove the protective cover from the ADCP transducer lense and lower the sensor into the water.
 - a. Adjust the depth of the long vertical pipe so that the base of the ADCP is fully submerged.
 - b. Do not lower the ADCP too far into the water column as this increases the unmeasured area at the top of the profile and creates a drag that negatively impacts velocity measurement.
 - c. Allow the ADCP transducers to be submerged in the water for at least 5 minutes prior to discharge measurements in order to sufficiently equilibrate to the water temperature.
 - 1) Failure to do so will impact measurement accuracy.



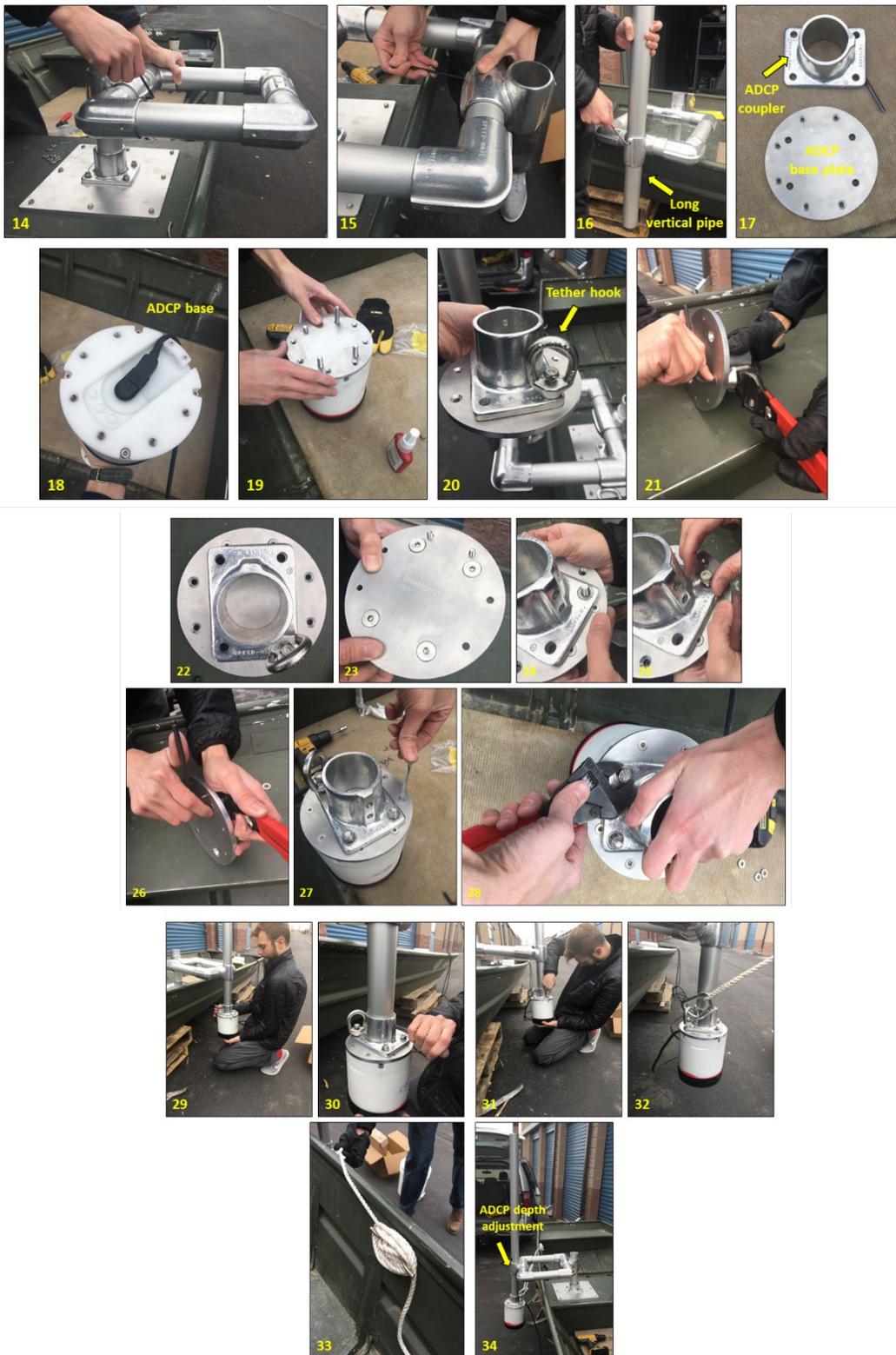


Figure 65. Assembly of the ADCP mount on a piloted boat.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

N.2 Start a New Measurement in WinRiver II

Once the discharge cross-section has been established or assessed, the ADCP mount has been configured and the ADCP is submerged in the water, a new measurement file can be created in WinRiver II by using the following steps:

1. Set the laptop system time zone to UTC (Coordinated Universal Time).
2. Start the WinRiver II program.
3. In the WinRiver II main screen, click Configure > Units > All SI to set units to metric.
4. In the WinRiver II main screen, click File > New Measurement to run the Measurement Wizard.
5. Fill in all information in the Site Information tab:
 - a. Station Name: Four digit site code of where you will be measuring discharge (i.e. "TOMB")
 - b. Station Number: Leave blank.
 - c. Measurement Number: The sequential discharge measurement number for the site.
 - d. Agency: "NEON".
 - e. District: Leave blank.
 - f. Hydrologic Unit: Leave blank.
 - g. Field Party: Initials of all crew involved in measurement.
 - 1) Separate initials with a comma delimiter (i.e. NH, LFS).
 - h. Processed By: Initials of technician operating the WinRiver II software and evaluating data collection.
 - i. Deployment Type: "Piloted Boat".
 - j. Boat/Motor: Leave blank.
 - k. Meas. Location: If measured at the regular discharge cross-section enter "DSC1", if measured at a different cross-section within the site denote that with a different code here (i.e. "DSC_US" if the cross-section is upstream of the regular location).
 - 1) Make sure to also include notes in the main remarks section that describe alternative transect locations (be sure to include an estimate of how many meters away the measurement was conducted from the regular location).
 - a) To add a note to the main Remarks section of the measurement file, right-click Site Information on the Measurement Control window.
 - b) Enter notes into Remarks section.
 - l. Grid Reference: Leave blank.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

6. Select the “Rating Information” tab.
 - a. Inside Gage Height: Enter the water level measurement on inside of staff gauge.
 - b. Outside Gage Height: Same value as “Outside Gage Height”.
 - c. Rating Discharge: Enter the predicted discharge given gauge height from rating curve, if available.
 - d. Index Velocity: Leave blank.
 - e. Rated Area: Leave blank.
 - f. Rating Number: Leave blank.
 - g. Water Temp: Enter the water temperature (°C) measured using a thermometer submerged in the stream for at least 5 minutes.
 - 1) The measured water temperature should be within 2 degrees of the ADCP temperature measurement.
 - a) To check the temperature being measured by the ADCP, open the Test Result dialogue box under the QAQC > ADCP node. The measured temperature will be displayed along with other sensor data.
 - b) You can also view temperature time series data during or after a transect measurement by selecting View > Graphs > Time Series > Temperature.
 - c) The ADCP must be sitting in the water for at least 5 minutes to allow the instrument to fully equilibrate to the water temperature.
 - d) In general ADCP temperature measurements do not drift until there is a major issue. If this does occur, the ADCP-measured temperature will deviate greatly from the thermometer measurement. If this is the case make a note in the measurement note window and contact Science following the measurement bout.
 - h. Tail Water Level: Leave blank.
 - i. Magn Variation Method: Model
 - j. Measurement Rating: fill this out at the end of the measurement based on your judgment of the measurement quality
 - 1) This is a subjective assessment. Discretion is given to the hydrographer who led the survey. Include any relevant field notes that formulated the basis of this rating in the remarks section.
 - k. Control Codes: select any that apply to the measurement.
 - l. Wind Speed: Enter the measured wind speed (kph) using an anemometer.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 1) If wind speed was entered in units other than kph, note the units used in the remarks section.
- m. Wind Direction: Enter the measured wind direction using an anemometer.
 - 1) If the anemometer does not provide a direction measurement enter:
 - a) "Upstream": if the wind is blowing up river.
 - b) "Downstream": if the wind is blowing down river.
 - c) "Cross-wind": if the wind is blowing across the river.
 - d) "Mixed": if the wind is not blowing in any particular direction.
 - n. Edge Method: Enter the method used for determining bank distances (i.e. laser rangefinder, meter tape, eye estimate, etc.).
7. Select the "Configuration Dialogue" tab.
 - a. The software will immediately try to recognize the ADCP ("Interrogating the ADCP...").
 - 1) If the connection is successful, the button next to "ADCP" will eventually turn green.
 - a) This can take a few minutes.
 - b) This means that the software recognizes the ADCP via the serial cable.
 - c) If a window pops up that says "The ADCP is not responding..." this means that the ADCP was not recognized by the software.
 - (1) Click "No" (clicking "Yes" will have the software cycle through all available ports).
 - (2) In the "Serial Communication Settings" window, ensure that COM Port settings match what was determined using Windows Device Manager. Click OK.
 - (3) If the "The ADCP is not responding..." message returns, click Cancel.
 - (4) In the "ADCP" dropdown, ensure that the correct ADCP model (RiverPro) is selected in the dropdown box. Click the "Check ADCP" button to re-test configuration.
 - (5) The ADCP must be recognized by the software for the discharge measurement to be conducted. If communication problems persist, submit a trouble ticket and contact Science.
 - b. The Depth Sounder box can be left blank.
 - c. Under Offsets:
 - 1) Enter Transducer Depth.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- a) Ensure that the boat is steady and stable in the water column prior to taking this measurement.
- b) Measure from the water level to the center of the slant in the transducer faces with a ruler or metric tape.
- c) This is a very important measurement! Repeat it two or three times to ensure accuracy.
- d. Enter Magnetic Variation, the angle of declination relative to your location in the world.
 - 1) For greatest accuracy, check the [National Geophysical Data Center website](#) to find the declination angle based on your latitude and longitude.
 - 2) Some examples:
 - a) Butler, AL: $-2^{\circ} 27' W$ (-2.27)
 - b) Newton, GA: $-4^{\circ} 59' W$ (-4.59)
 - c) Arcata, CA: $+14^{\circ} 16' E$ (+14.16)
- e. Enter the Max Water Depth.
 - 1) This is an estimate of the maximum water depth (m) that is expected to be measured during the discharge measurement.
- f. Enter the Secondary Water Depth.
 - 1) This is an estimate of the minimum water depth (m) that is expected to be measured during the discharge measurement.
- g. Enter the Max Boat Speed.
 - 1) This is an estimate of the maximum boat speed (m/s) that is expected during the discharge measurement.
- h. All other values can be left as defaults.
8. Select the "Output Filename Options" tab.
9. Under the "Recording" section:
 - a. In the "Filename Prefix" box enter the four-digit side code.
 - 1) Example: "LEWI".
 - b. Ensure the "Use Prefix in Filename" box is checked.
 - c. Leave the output directory at the default location (C:\Measurements\).
 - d. In the "Include Filename Options" section:
 - 1) Uncheck the "Measurement Number" box.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 2) Leave "Transect Number" at "0".
 - 3) Leave "Geographic Current Survey" and "Sequence Number" boxes unchecked.
 - e. In the "Use Date/Time in Filename" section:
 - 1) Select "Long (YY-MM-DD-hhmmss)".
 - f. In the "Use Delimiter in File" section:
 - 1) Select "Underscore" (default).
 - g. Check in the Filename Preview section that the above settings are correctly applied (**Figure 65**).
 - h. Note that these settings can only be entered at the start of a New Measurement. Once the Measurement Wizard is closed, filename settings can only be changed by starting a new measurement.
10. Open the Command Preview tab.
 - a. Review all information to ensure that is correct.
 - b. Ensure that green checks are present for ADCP and GPS communications.
 - c. Click the Finish button to complete wizard.
 11. Review the Summary Page tab to ensure all information was correctly entered.
 12. Click Finish to exit the Measurement Wizard.

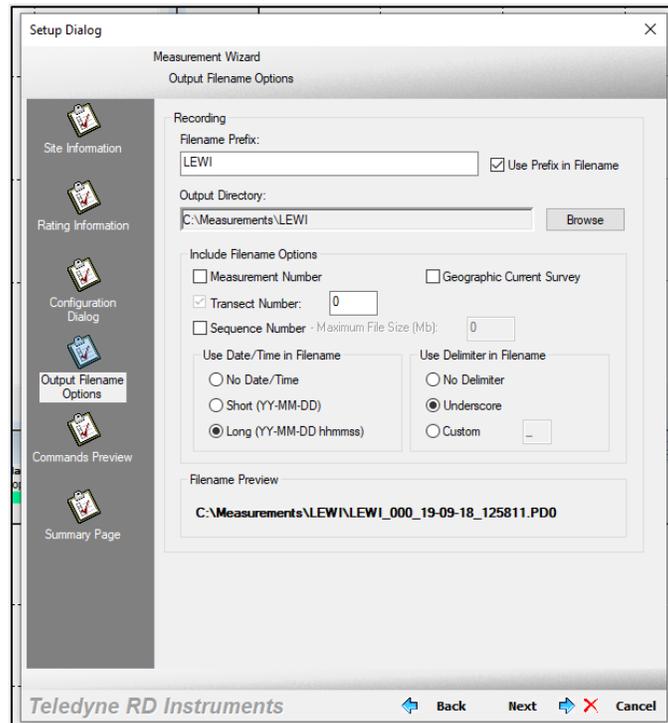


Figure 66. Required settings in the WinRiver Output Filename Options dialogue box within the Measurement Wizard.

N.3 Pre-Measurement QAQC: Overview

The following QAQC protocols are critical to quality data collection and must be initiated prior to the first transect measurement of each ADCP discharge bout.

- Set the ADCP clock
- Collect a temperature measurement
- Execute an ADCP test
- Calibrate the internal ADCP compass
- Perform a moving bed test and assess moving bed test summary
- Configure the reference navigation

N.4 Pre-Measurement QAQC: Set the ADCP clock

Prior to the initial transect measurement the ADCP clock must be set to match the PC time (UTC). Failure to properly set the ADCP clock will result in data files with incorrect timestamps.

1. Set the time zone on the PC to (UTC) Coordinated Universal Time (**Figure 66**).
 - a. Right click on the date time in the lower right corner of the screen.
 - b. Select "Adjust date/time"



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- c. In the “Time zone” dropdown, select “(UTC) Coordinated Universal Time”
2. In the WinRiver II main screen, click on Acquire > Set ADCP Clock.
3. Set the ADCP clock to match the PC time (UTC).
4. Click the “Set Clock” button.
 - a. Note: only clicking the “OK” button will not set the clock, the “Set Clock” button must be selected.

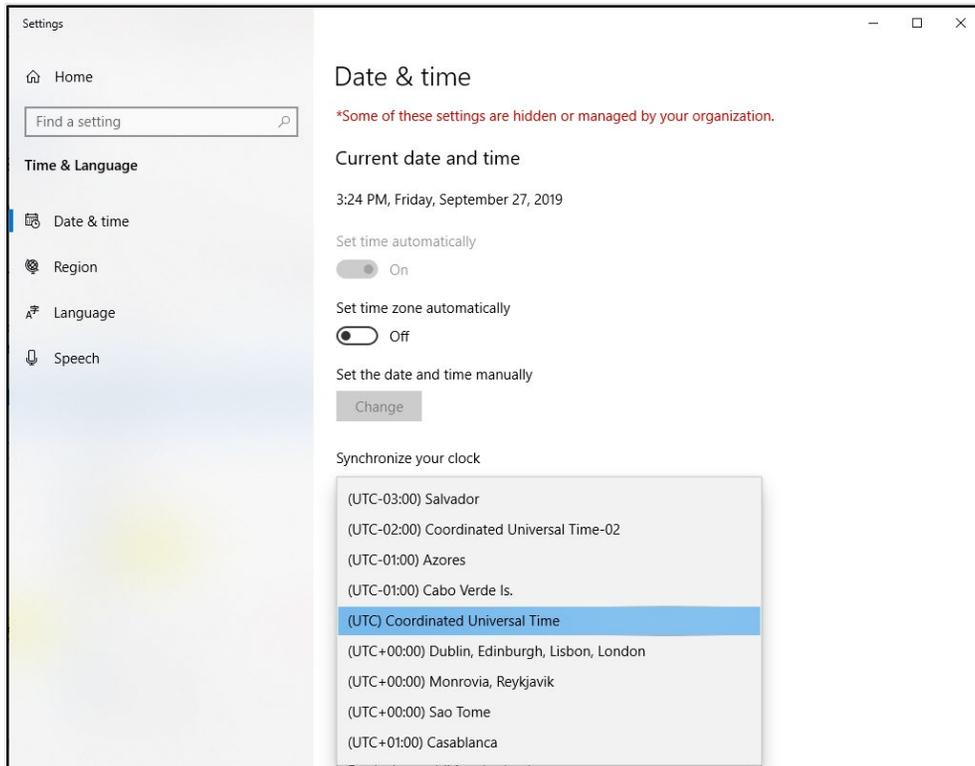


Figure 67. Set the PC used for the discharge measurement to (UTC) Coordinated Universal Time and match the ADCP clock to this setting.

N.5 Pre-Measurement QAQC: Collect a Temperature Measurement

1. Place the thermometer into the water to begin collecting a temperature measurement.
2. Enter this value into the Measurement Wizard Rating Information Tab under “Water Temp”.

N.6 Pre-Measurement QAQC: Execute an ADCP Test

This test verifies that the ADCP is functioning properly and communicating with WinRiver II software.

1. In the WinRiver II main screen, click on Acquire > Execute ADCP Test.
 - a. Note that the ADCP must be installed in the mount and submerged in non-flowing water to obtain the best test results.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

2. A series of six tests will be initiated that evaluate ROM, RAM, Communications, RTC, Compass, and Temperature performance. Check that all tests pass on the left pane of the dialog window.
3. After the tests have been run, sensor data will begin to be sampled and displayed in a loop.
4. Click the “Stop PC20” and “Stop PC40” buttons to end testing and close the dialog window.

N.7 Pre-Measurement QAQC: Calibrate the Internal ADCP Compass

A calibrated compass is essential for conducting Moving Bed Tests and for using GPS data as the navigation reference. This is a two person task, one person turning the boat slowly in the water while another person monitors the data and communicates the test results.

1. Ensure that the ADCP is secured within the ADCP mount in the exact position it will remain throughout the discharge measurement.
2. Ensure that the boat is not located near vehicles, steel bridges, or other large ferro-magnetic masses.
 - a. Check for any materials near the boat that could disrupt the compass calibration – this includes tools, tool boxes, cell phones, hot hands, etc.
 - b. Move these materials away from the ADCP during calibration and throughout the discharge measurement.
3. In the WinRiver II main screen, click on Acquire > Execute Compass Calibration.
4. Select Use Pitch/Roll?
 - a. Click “No” if the ADCP will not be subject to pitch and roll (i.e. calm water). This calibration test requires two rotations, one for calibration and one for verification.
 - b. Click “Yes” if the ADCP will be subject to very high pitch and roll conditions. This calibration test requires up to eight rotations, four for calibration and four for verification. Typically, no pitch and roll calibration is required.
5. Click the Start Calibration button and wait a moment until the compass is initialized by the software.
6. Begin to slowly and smoothly rotate the boat in either direction.
 - a. If it is safe to enter the water and rotate the boat by hand, do so as this allows for a much easier compass calibration. If it is not safe to enter the water, operate the boat using the motor.
 - b. Do not cause sudden accelerations or decelerations.
7. Rotate the boat until all of the red bars in the dialogue window have been replaced by a dark green color (**Figure 67**).
 - a. The greener the bars, the better the data.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- b. If a bar is not dark green, rotate the boat more slowly and more smoothly.
 - c. Correct any non-dark green bars when they occur by rotating the boat back 10-20° until that bar is once again highlighted. Then, when it becomes dark green, proceed as before.
 - d. Clear and constant communication between the staff member moving the boat and the staff member evaluating the test results on the laptop is critical during this period.
8. Once calibration rotations are complete, click OK and continue with the verification rotation.
- a. If Pitch/Roll is selected there will be more initial rotations.
9. Once the verification rotation is complete a calibration error will be calculated and presented.
- a. Ensure that the calibration error is less than 2°.
 - b. Aim for a total error of < 1°.
 - c. If calibration error is < 2°, the compass calibration is complete and the window can be closed (< 1° is preferred – try to obtain this).
 - d. If calibration error is $\geq 2^\circ$, do not accept the compass calibration.
 - e. Repeat calibration procedures.
 - 1) Look around for magnetic materials that may be affecting the compass.
 - 2) Move these materials away from the ADCP or move the ADCP away from them, if possible.
 - f. If, after three attempts, a calibration error of < 2° cannot be achieved, reference the troubleshooting steps below.
 - 1) If, following troubleshooting, a compass calibration of < 2° cannot be achieved, accept the lowest calibration error possible and proceed.
 - 2) Document this occurrence as a note in the Remarks Section, it will be a very important component in evaluation the measurement during post-processing.
10. Once complete, check that the correct Magnetic Variation Correction value was entered by the software during the measurement wizard setup (**Section N.2**).

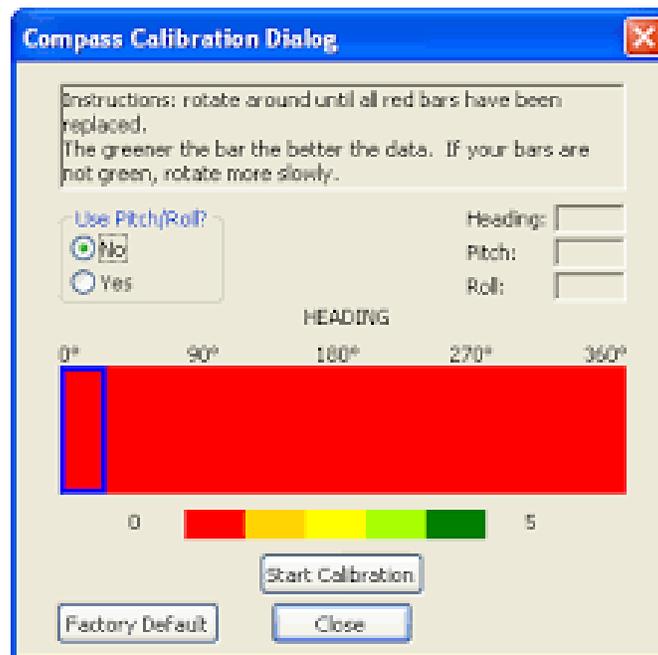


Figure 68. ADCP Compass Calibration dialog box. The entirety of the horizontal bar is red upon initiating the test. Rotate the boat slowly and steadily so that bar is colored dark green throughout.

Troubleshooting Compass Calibration Issues

- There may be too much magnetic interference in the area you are attempting to calibrate the compass.
 - Ensure that no magnetic materials are near the ADCP.
 - Try moving the boat to a different area of the stream and repeating the calibration.
 - It may be that material on the streambed (rebar, trash) is affecting the calibration.
- Computational errors may occur during calibration. If you receive an error message indicating that a computational error occurred, repeat the calibration and be sure to rotate the ADCP slow and smooth.
 - Ensure that all points in the calibration display are of good quality (dark green).
- Communication errors may occur during calibration when using a slow communication Baud rate.
 - If you receive a “Failed to get calibration data...” message verify that all ADCP communications are set to the 115200 Baud rate.
 - If you receive a “360 degrees” compass error message then the compass calibration test has failed and needs to be performed again.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

N.8 Pre-Measurement QAQC: Perform a Moving Bed Test

Moving Bed Tests (MBT) are used to determine if the bed of the discharge cross-section is in motion. An un-accounted for moving bed can lead to 5-10% bias in discharge measurements performed with the RiverPro ADCP.

MBTs must be performed prior to each ADCP discharge bout. WinRiver II software analyzes the data collected during the MBT to assess the moving bed characteristics of the site and to detect common error conditions, which may invalidate the test. The loop method is presented below as a means to test whether a moving bed is present. The loop method must be applied properly, or it may produce incorrect results.

Note that the accuracy of the loop method is not adequate for mean velocities less than 0.8 ft/second (0.24 m/s). If mean velocity is below 0.8 ft/s (0.24 m/s), water velocity is low throughout the water column and the probability that the bed is in motion is decreased. If the bed is in fact in motion at these velocities (or particles on the surface of the bed are in transit) it is likely that not accounting for it will exert only a minimum bias in the overall discharge estimation.

A properly calibrated compass is critical to application of the loop method, the error caused by an improperly or un-calibrated compass can be in either direction, resulting in either more or less moving bed than actually is present.

To perform a moving bed test:

1. Begin the MBT from an initial point on the near shore where you will be able to return to with precision (**Figure 69**).
 - a. Navigate the boat to a starting location near the edge of the water on the near bank.
 - b. Mark this location using some physical reference for the starting point (anchored float, etc.).
2. When running the MBT it is optimal for the person using the radio controller to guide the ARC-Boat so that is slightly downstream of the controller.
 - a. This allows for easier orientation of how the controller movements affect the boat.
 - b. If operating the remote control from a piloted boat, it is very important to remain far enough downstream so that the piloted boat motors and hull do not create velocity disturbances within the measurement transect.
3. In the WinRiver II main screen, click on Acquire > Start Pinging (shortcut key: F4).
4. Open the Ship Track graph. This allows for a better view of the boat path as it does not show the velocity paths (**Figure 68**).
 - a. View > Graphs > Ship Tracks > Ship Track
 - b. The green square is where the float is located when the test starts.



5. On the Acquire menu, click Select Moving Bed Test.
6. Select “Loop Test” and click the Start button (shortcut key: F6).
7. Once you start the test, immediately begin navigate the boat across the river to the opposite bank in a slow and steady manner.
 - a. Maintain a steady speed that, if possible, does not exceed the stream velocity.
 - b. Note that the green square in the Ship Track graph denotes your starting location.

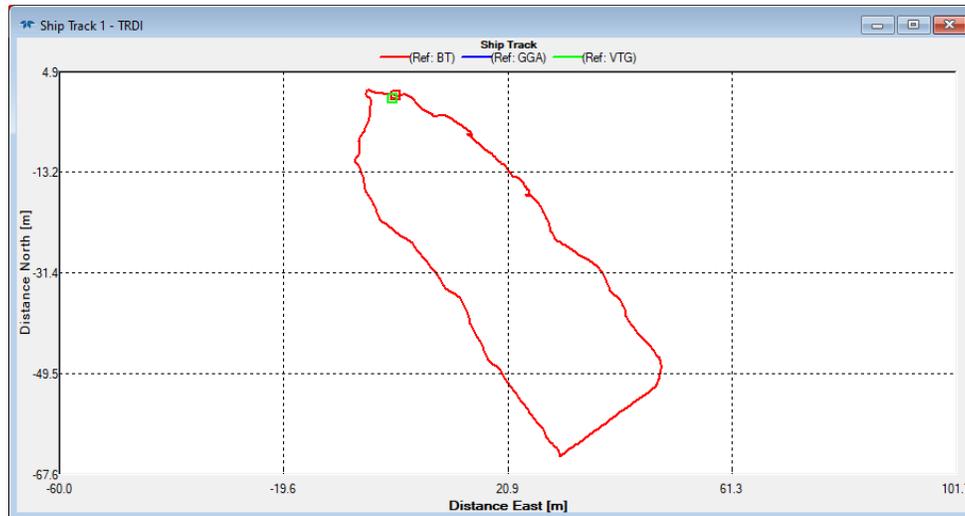


Figure 69. The WinRiver II Ship Track window observed during a loop moving bed test. The green box indicates the boat starting position, the line shows the boat path as it is navigating across the channel and turned back around toward the starting bank, and the red box indicates the boat ending position.

8. The MBT Test must last a minimum of 180 seconds (3 minutes).
 - a. This duration encompasses the time spent moving the boat across the channel and back to the near bank.
 - b. It is helpful for a staff member using or nearby the laptop to call out the measurement duration to the other staff member moving the boat so the speed can be adjusted if needed.
9. When the opposite bank is reached, gently turn the boat around (don't stop) and head back to the exact starting point where the test was initiated.
 - a. This is a critical part of the moving bed test, make sure this is a smooth and slow turn by gently using the rudders and throttle together.

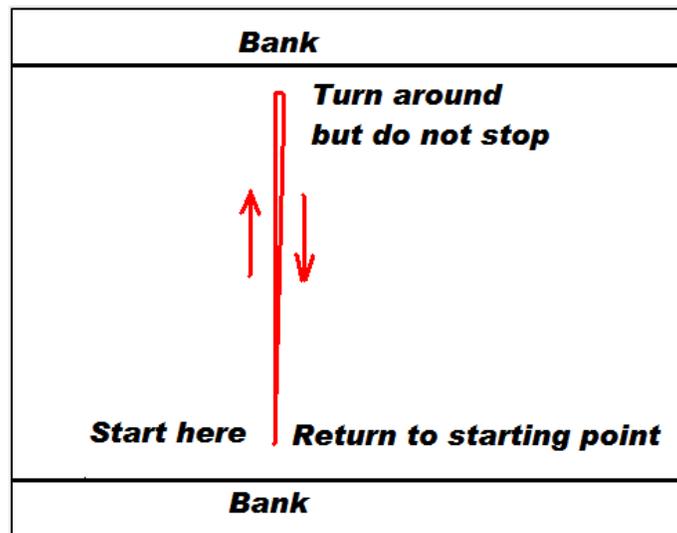


Figure 70. Illustration of the Loop Moving Bed Test procedure.

10. Once the boat returns back to the exact starting point on the near shore where you began the MBT, stop the test immediately (shortcut: F6 or Acquire > Stop Moving Bed Test).
 - a. Note the green square in the Ship Track Graph indicating where the boat was located when the test began and the red square indicating where the boat was located when the test ended.
 - b. If you don't hit the F6 button right at the starting point this could falsely indicate that the bed is moving.
11. Review the Ship Track window (Figure 70).
 - a. If the track (red line) contains an "open mouth" (i.e. the green and red squares do not line up and the red line is not connected) this may indicate that there is a moving bed.
 - b. If the track does not contain an "open mouth" (i.e. the green and red squares are on top of each other and the red line is connected), this indicates that a moving bed is likely not present.
 - c. Moving bed conditions will always cause the ship track to move upstream – if the ship track moves downstream the loop test is not valid.
 - d. If the boat was not returned to the *exact* starting point it can result in the end point being upstream or downstream of the starting point. This results in a potentially false positive for moving bed conditions (endpoint is upstream of the starting point) or an invalid result (endpoint is downstream of the starting point).

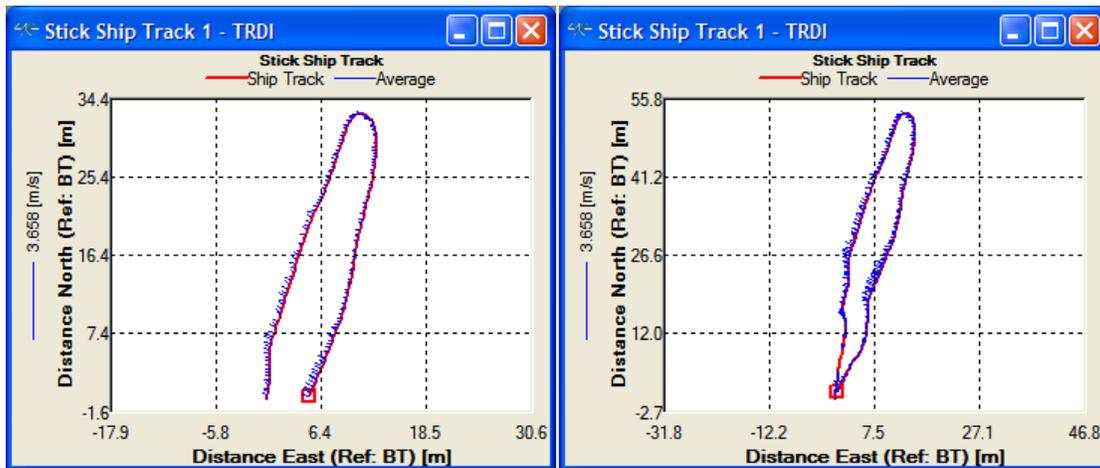


Figure 71. Left: A moving bed is likely present as indicated by the open loop; Right: a moving bed is not likely present as indicated by the closed loop.

12. Document all relevant notes that apply to the MBT.
 - a. To add a note that relate to a specific MBT, right click on the test node (i.e. “Loop 000”), and select “Add Note”.
13. Review the Moving Bed Test Result window to evaluate the results of the MBT (**Figure 71**).
 - a. In the Measurement Control window, under QA/QC, click on the Moving Bed Test node and open the Test Result icon for the test that was just completed (Loop tests begin as “Loop 000”).
 - b. The Test Result window provides metrics that describe the MBT. At the bottom of the window reference the “NOTE” – it will indicate whether correction is recommended.
 - 1) If a correction is recommended, check the box to the left of the MBT (i.e. “Loop 000”). This will apply a correction to the measured discharge to account for the moving bed velocity.
 - a) Once the correction has been applied, proceed with the next pre-measurement QAQC procedure.
 - 2) If a correction is not recommended and all other aspects of the MBT are valid then no correction is needed.
 - a) Proceed with the next pre-measurement QAQC procedure.
14. If there is confusion whether or not the MBT was completed correctly or questions arise interpreting the results, consider the following common sources of errors associated with the Loop Method.
 - a. Water velocity must be > 0.24 m/s in order for a moving bed to be evaluated.
 - 1) If velocity is below this threshold a loop test cannot be evaluated by WinRiver II.



- 2) At low velocities such as these it is likely that a moving bed is not present or is negligible in terms of affecting measured discharge.
 - 3) Conducting an additional loop test is not required.
 - 4) Proceed with the pre-measurement QAQC procedures in this instance.
- b. Systematic compass errors.
- 1) Check the direction of the velocity vectors (blue lines) during the Loop Test in the Stick Ship Track window. They should be pointed in the same direction during both loop paths.
 - 2) If vectors are in opposite or in an erratic direction this is a symptom of poor compass calibration.
 - 3) Conducting another compass calibration followed by a second MBT may be helpful.
- c. Bottom-tracking bias and uncertainty.
- 1) Check the Velocity Contour Profile associated with the Loop Test.
 - 2) Are there large unmeasured areas along the streambed?
 - a) If so a MBT may be difficult to validate.
 - 3) Conducting another MBT along a different transect (upstream or downstream) may be helpful.
- d. Failure to return to the initial starting point.
- 1) Ensure that the boat was returned to the exact starting location at the end of the MBT.
 - 2) Make sure that you ended the MBT at the exact time you reached the starting location.
- e. Irregular or insufficient sampling of the cross section because of loss of bottom track, non-uniform boat speed, and loitering at the banks.
15. If any of the above criteria are in doubt:
- a. Conduct another Moving Bed Loop Test in a slow, steady manner with a smooth transition at the opposite bank.
 - b. It may be helpful to begin the second Loop Test from the opposite bank or from a different transect location.
 - 1) Be sure not to get too far away from where you will be collecting the discharge measurement.
 - 2) Thorough notes are critical, always document all relevant information regarding MBT issues.

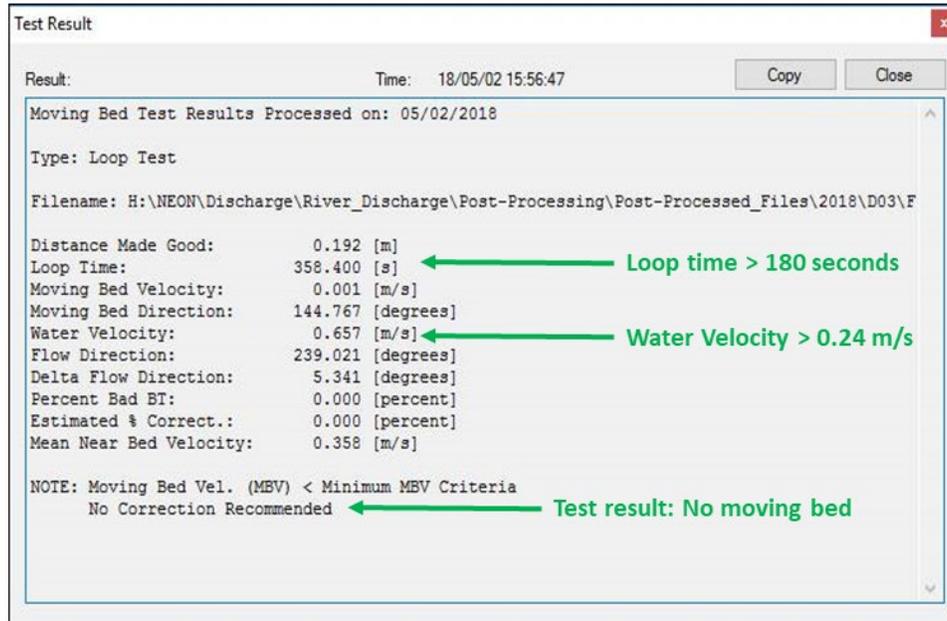


Figure 72. Moving Bed Loop Test Result window. In this example the required conditions were met in order to evaluate a moving bed (Loop time, water velocity) and a moving bed was not detected (the moving bed velocity < the moving bed velocity criteria), thus no correction was recommended.

N.9 Pre-Measurement QAQC: Configure the Reference Navigation

The reference navigation determines how the direction or bearing (heading) of the instrument is measured. While measuring discharge from a piloted boat, Bottom Track is the default and currently the only available choice for the reference navigation. If a moving bed was detected using a Loop Test, discharge can be corrected using the MBT results. The ability of the ADCP to Bottom Track can become compromised during periods of high turbidity and suspended sediment concentration (SSC). An overload of scatterers are produced in these conditions which prevent the ADCP beams from reaching the bottom and measuring velocity throughout the channel profile. If turbidity is high and the ADCP is having difficulty bottom tracking (this is evidenced by a large bands of missing ensembles in the velocity contour profile and warnings in the Measurement Control Window), conducting a measurement may not be possible. Submit a trouble ticket to Science in this instance.

N.10 Conduct Discharge Measurements with the ADCP and Piloted Boat

WinRiver II software calculates discharge using real-time velocity measurements acquired during transects across the stream. Perform the following steps in order to successfully collect a high-quality stream discharge measurement using the piloted boat method at river sites. Each step is presented in greater detail throughout this section.

1. Start ADCP pinging.
2. Establish transect start and end points.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

3. Enter staff gauge height prior to each transect measurement.
4. Measure discharge across the channel (minimum 4 transects).
5. Evaluate whether additional transects are required.

1. Start ADCP Pinging

Setting the ADCP to start pinging enables ADCP data collection. In general, after you have started the ADCP pinging, there is no reason to stop pinging until you are finished the entire discharge survey and ready to remove the ADCP from the water. An exception would be if you were operating with batteries of limited capacity, under that circumstance stopping ADCP pinging will conserve power.

1. Ensure that the ADCP is in the water powered on.
2. Press F4 to start the ADCP pinging (or Acquire > Start Pinging).
3. In a few seconds, ensembles will begin to be generated and changing values will appear within several of the WinRiver II data windows.
 - a. An ensemble is the data output generated by multiple ADCP pings that are averaged together. Ensembles are tracked in numerical order, timestamp, and position.
 - b. If the ADCP is positioned in sufficient depth, velocity profiles will become available.
 - c. Note that WinRiver II will not display meaningful data unless the trimaran float is in the water.
 - d. The ADCP can continue pinging when it is not in the water.

2. Establish Transect Start and End Points

The locations at each side of the channel where the discharge measurement begins and ends must be established before recording discharge transect data. Because stream depths eventually become too shallow for valid data collection as the ADCP approaches a bank, it is necessary to estimate discharge in the near-shore unmeasured zones using the WinRiver II and Q-Rev software. To ensure the accuracy of near-shore discharge estimates, the distances from the edge of water to the starting and stopping points of each transect must be measured using a distance-measurement device (such as a laser or optical rangefinder), tagline, or some other accurate measurement device.

Placing anchored marker buoys at the start and end points of transects is advantageous for keeping consistent edges and ensuring that the same cross-section profile is measured during each transect. If placing marker buoys in the channel is not possible try to remember these locations using some physical reference.

Other notes on transect start and end points:



- Measurement uncertainty increases as the distance increases between the start and end points and the edges of water due to less measurements and more interpolation.
- Try to ensure that the velocity profile at the start and end locations are representative of the velocity profiles leading up to the bank in order to limit interpolation bias.
- In channels that contain vertical walls at the edges, start and end points for transects should be no closer to the wall than the depth of water at the wall to prevent acoustic interference from the main beam or side lobes impinging on the wall.
 - For example, if the depth at a vertical wall is 10 feet, transects should start or stop at least 10 feet away from the wall.
- If the cross-section has been measured previously at the same location, WinRiver II “Locations” can be utilized to help determine the start and end points that were previously used and to help navigate the float across the channel.
 - See for instructions on loading available locations and how to save new ones.

To establish transect start and end points:

1. Navigate the boat just off the edge of water on the near shore and into open water until the ADCP transducers are submerged.
2. Note the number of “Good Bins” listed in the Composite Tabular window shown in the right panel of the main WinRiver II screen (**Figure 72**).
 - a. Two “Good Bins” (or depth cells) are required in order to start and end the transect measurement.
3. Navigate the boat slowly away from the bank until the tabular display indicates you are at a sufficient depth to set the transect start point (>2 Good Bins, closest to 2 is preferred).
4. If possible, mark this location with a marker buoy or weighted float. Otherwise try to remember this position by using some physical reference.
5. Navigate the boat slowly towards the opposite shore.
 - a. Travel smoothly and slowly with the bow of the boat pointed upstream.
 - 1) Crabbing across the channel may be difficult during periods of low flow, in those instances point the bow towards the opposite bank.
 - 2) Note any navigational challenges in the measurement notes.
6. While moving across the channel observe the Velocity Contour graph to view channel conditions and ensure that the ADCP is working as expected with the loaded configuration.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- a. Observe the Velocity Contour Profile located on the bottom panel of the WinRiver II main screen (**Figure 73**). This display illustrates water velocity and depth across the channel.
 - 1) The very top and the very bottom of the channel will always be unmeasured by the ADCP and discharge in these locations will be interpolated. The top unmeasured area is a function of transducer depth, or how low the ADCP is in the water column.
 - 2) Vertical white bands within the profile are unmeasured areas that can occur for a variety of reasons including biota, woody debris, physical structures, or simply moving the float too fast or abruptly across the channel.
 - a) Work to limit the number of white bands in the profile as an increase in unmeasured area results in an increase in measurement uncertainty.
 - b) If the unmeasured area within the cross-section is significant a different discharge transect upstream or downstream may be necessary.
 - 3) Note regions where the channel depth changes abruptly.
 - a) Make a mental note to move more slowly across these regions during data acquisition to help bottom tracking maintain a valid lock on the bottom.
7. As the boat approaches the opposite shore note the Number of Good Bins in the Composite Tabular window (**Figure 72**) and stop the boat at the opposite edge of water where two good bins are available.
8. If possible, mark this location with a marker buoy or weighted float.
9. Proceed to the next step once transect start and end points are established at each side of the channel.

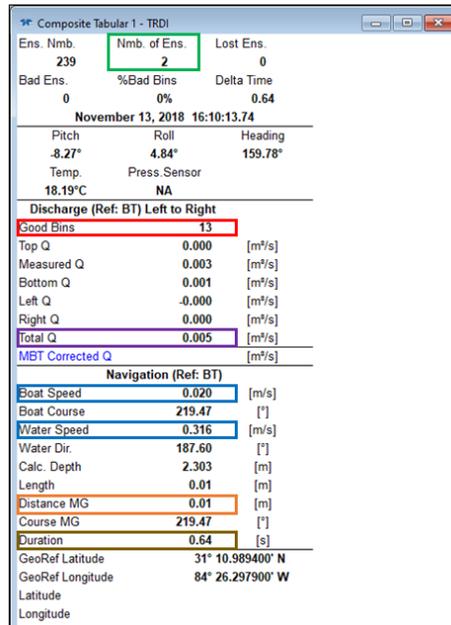


Figure 73. Composite Tabular window in WinRiver II, green box: number of ensembles (hold until 10 at transect start/end points); red box: Number of Good Bins (must be >2 to begin transect); purple box: total discharge; blue boxes: water and boat speed; orange box: distance made good (total transect length); brown box: duration (total transect duration must be ≥180 seconds).

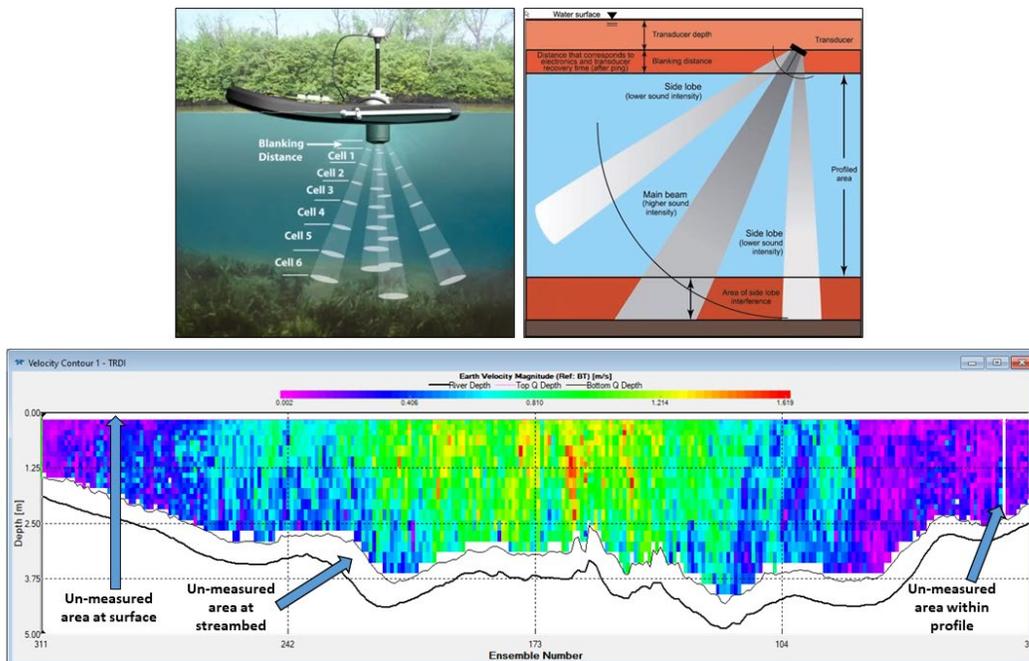


Figure 74. Unmeasured areas in the ADCP profile where velocity is extrapolated. Top left: ADCP blanking distance and cell size distribution (credit: SonTek); top right: unmeasured areas of the profile relative to ADCP beams (credit: SonTek); below: the WinRiver II velocity contour with unmeasured areas delineated.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

3. Enter Staff Gauge Height Prior to Measuring Discharge at Each Transect

The staff gauge height must be entered prior to each transect measurement using the Fulcrum app. The mean gauge height recorded prior to all transect measurements is the stage value associated with the mean discharge measured during all transect measurements. Notes regarding conditions observed during individual transects (high/low flows, changing gauge heights, wind conditions, the passage of other vessels during measurement, any noteworthy events, etc.) can be entered in the main Remarks section of the Measurement Wizard as well as in the individual transect notes.

Gauge height observation and recording must immediately precede the transect discharge so the stage level during the discharge measurement is accurately characterized.

To enter the staff gauge height prior to each transect measurement:

1. Open the (AOS) Field Metadata and Gauge Height [PROD] app in Fulcrum.
2. Enter the appropriate information in the Metadata, Spatial and Temporal Information tables.
3. In the Stage Height table, enter the current staff gauge height in the “Initial Stage Height (m)” field.
 - a. Note that this does not necessary have to equal the staff gauge height prior to the first measurement transect.
4. Under the Stage Height table note the “Collecting Discharge with an ADCP Today?” field and select “Yes”.
5. Click the “ADCP Transect Stage Measurements” button that appears.
6. Click the red plus (+) button at the top right of the window to create a record.
7. Enter the time the staff gauge is measured in the Staff Gauge Height Reading Time field.
 - a. This must be done immediately preceding the discharge measurement.
8. Enter the Staff Gauge Asset Tag.
 - a. This is located on the top of the staff gauge you are reading.
9. Enter the Transect Number.
 - a. This must correspond to the transect number generated in WinRiver II.
 - b. By default, transect numbers begin at 000 and increase to 001, 002, 003, etc.
10. Enter the Staff Gauge Height.
11. Enter the Staff Gauge Height units.
12. Click the green check button in the top right corner of the window to save the record.
13. Additional ADCP Transect Stage Measurements can be added by clicking the red plus button at the top right of the window.
14. ADCP transect stage measurements can be deleted by clicking the black X button to the left of each record.
 - a. Records should be deleted if:
 - i. Errors are present in any of the fields.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- ii. The measurement transect is not to be used in the calculation of total discharge (the transect will remain unchecked in WinRiver II due to measurement error, the transect was started by mistake, etc.).
15. The ADCP Transect Stage Measurements window should remain open throughout the discharge survey so that staff gauge height can be measured prior to each transect measurement.
16. The window can be closed by clicking the green check mark at the top right of the window once all transect discharge measurements are complete.
17. Enter Weather Information, Post Fieldwork Observations, and General Comments information to the record as needed.
18. Click the green check mark at the top right of the window to save the record.
19. Fulcrum data will load automatically when the record is saved and the device receives a wireless internet signal.

4. **Measure Discharge Across the Channel (Minimum 4 Transects)**

A “transect” is considered a single discharge measurement that begins at the transect start/end point on one side of the channel and ends at the transect start/end point on the opposite side of the channel. Each ADCP discharge survey must contain a reciprocal number of transects (i.e. if a transect is measured from the near bank to the opposite bank, another transect measurement must be included from the opposite bank to the near bank). A minimum of four transects are required for each ADCP discharge survey but more may be necessary. Each transect must last a minimum of 180 seconds and the total time for all transects must be >720 seconds.

Complete the following steps to measure discharge during each transect:

1. Hold the position of the boat steady at one of the marked transect start or end points.
2. Using a stadia rod, meter tape, or laser range finder, determine the distance from the transect start point to the edge of water. This is referred to as the “edge distance”.
 - a. Measure the area from the center of the ADCP to the edge of the water.
 - b. If using a rangefinder make sure that the laser is not hitting leaves or branches hanging over the channel. Take a few shots and make sure they are all the same.
 - c. If it is not possible to measure this distance with an instrument, use the “Distance MG [Made Good]” values displayed on the right side of the Composite Tabular 1 window to calculate the edge distance from beginning/end of the transect to the adjacent edge of water. Be careful not to accidentally beach the ARC-Boat by getting too close to the opposite bank.
3. Click Acquire > Start Transect (shortcut: F5) to begin data recording.
 - a. Note that the measurement has now been initiated.
4. When prompted, enter the edge distance (measured in **Step 2**).



5. Define whether you started the measurement from the left or right bank.
 - a. When facing downstream, the left bank is on your left side.
6. Hold the position of the boat at the transect start point for at least 10 shore ensembles.
 - a. This is equivalent to about 10 seconds.
 - b. The number of ensembles can be viewed in the Composite Tabular window (**Figure 72**).
7. Once 10 ensembles are recorded at the transect start point slowly and steadily navigate the boat toward the opposite bank.
8. Move the boat **slowly and steadily** across the channel.
 - a. The total duration of each transect (moving the boat from one side of the channel to the other) must be ≥ 180 seconds.
 - b. The cumulative time spent measuring each transect is directly correlated to measurement quality.
 - 1) The slower and steadier the float crosses the channel the higher the data quality.
 - c. Maintain an average boat speed that is less than or equal to the water velocity.
 - 1) Water vs. Boat speed can be monitored using the Water Speed vs Boat Speed graph.
 - a) Click View > Graphs > Time Series > Water/Boat Speed (**Figure 74**).
 - 2) When water velocity is very slow, keeping the boat speed below the water velocity may not be a possible (or practical) approach. Under these conditions the smoothness of boat operation becomes critical.
 - 3) Avoid fast and sudden accelerations.
 - d. Attempt to point the bow of the boat upriver and crab across the channel.
 - 1) If this is not possible due to low surface water velocities, point the bow of the boat toward the opposite shore and slowly move towards it.
 - e. Observe data displayed on other graphs as needed to monitor data quality.
 - 1) Click View > Graphs/Tabular to explore other graphical and tabular interfaces.
 - a) Graph display settings can be configured by right clicking on the graph and selecting "Properties".
 9. Continue across the channel until you reach the transect end point on the opposite shore.
 10. Ensure that two good bins are available at this location using the Composite Tabular window (**Figure 72**).
 11. Hold the boat steady at this location and wait until at least 10 shore ensembles have been collected.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- a. This is equivalent to about 10 seconds.
 - b. The number of ensembles can be viewed in the Composite Tabular window (**Figure 72**).
12. Using a stadia rod, meter tape, or laser range finder, determine the distance from the transect end point to the edge of water. This is referred to as the “edge distance”.
- a. Measure the area from the center of the ADCP to the edge of the water.
 - b. If using a rangefinder make sure that the laser is not hitting leaves or branches hanging over the channel. Take a few shots and make sure they are all the same.
 - c. If it is not possible to measure this distance with an instrument, use the “Distance MG [Made Good]” values displayed on the right side of the Composite Tabular 1 window to calculate the edge distance from beginning/end of the transect to the adjacent edge of water. Be careful not to accidentally beach the ARC-Boat by getting too close to the opposite bank.
13. Click Acquire > Stop Transect (shortcut: F5) to stop data recording.
- a. Note that the measurement has now ended.
14. When prompted, enter the edge distance (measured in **Step 12**).
15. Define whether you ended the measurement at the left or right bank.
- a. When facing downstream, the left bank is on your left side.
16. To add notes that document important information relating to each transect right click on the transect node in the Measurement Control window (upper left pane in the WinRiver II main screen) and select “Add Note”.
- a. Notes that describe individual transect measurements help explain the data that was collected and are thus extremely beneficial to post-processing/data QAQC. Always provide clear, descriptive documentation regarding the discharge measurement. Examples of individual transect notes include:
 - 1) “A barge went through prior to/following the transect measurement”.
 - 2) “The wind picked up considerably during the transect measurement”.
 - 3) “It was difficult to maintain a boat velocity less than the mean velocity of the river during the transect measurement due to...”.
 - 4) “Poor bottom tracking/GPS tracking occurred during this transect due this measurement due to...”.
 - 5) “River stage appeared to rise/fall during this transect”.
 - 6) “High sediment concentration was present during this transect”.
17. The transect measurement is now complete.



18. To view the data you collected during the transect open the node (+) under the Transect name in the Measurement Control window and double-click the disc button.

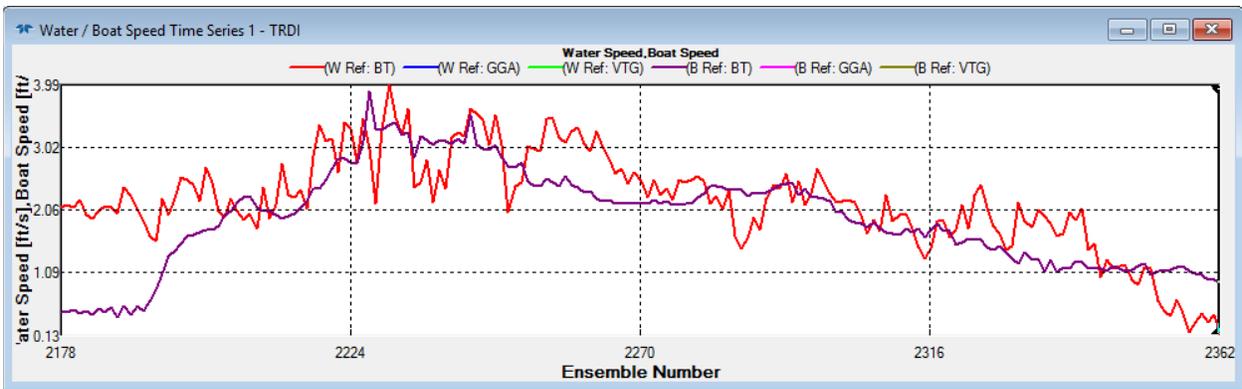
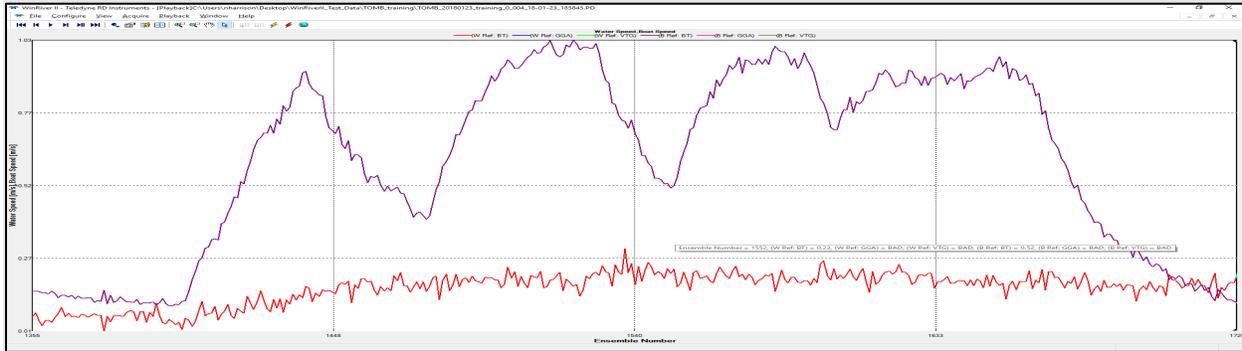


Figure 75. Water Speed vs. Boat Speed graph. Above: Improper technique. The boat speed (purple line) is erratic and higher than the water velocity (red line). Below: Proper technique. Maintain an even boat speed so that the purple and red lines are more in line and boat speed remains generally lower than water speed.

Collect (At Least) Three Additional Transect Discharge Measurements (Minimum of Four Total)

Repeat the previous steps, navigating the boat across the channel from each transect start and end point until a total of four transects have been measured (two in each direction). A minimum of four transects (each lasting a minimum of 180 seconds) must be collected during each discharge measurement, two in each direction. The measured discharge is the average of the discharge collected during each transect.

Enter the staff gauge height prior to each transect measurement in the Fulcrum app. Record all other notes in the individual transect notes and/or the Remarks window of the Site Wizard (typically notes that affect all transects can be entered in the Site Wizard notes and notes that affect individual transects are to be entered in the individual transect notes).

A new data file and Transect node will be created in the Measurement Control window each time you start and stop recording during each transect (ex: Transect 0000, Transect 001, Transect 002, Transect



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

003). Once the fourth transect is complete stop data collection and evaluate whether additional transects are needed.

5. **Evaluate Whether Additional Transects Are Required**

More than four transects must be measured if:

1. Total duration of all transects does not exceed 720 seconds.
2. The discharge measured during at least one transect is greater than 5% of the average discharge of all transect measured.
3. An observed gauge height change is associated with a notable change in discharge for a given transect.

Evaluate the total duration of all transects:

1. In the Measurement Control window (top left panel in the WinRiver II main screen) ensure that each transect measurement you wish to evaluate is checked.
 - a. Uncheck any Transects were measured that contained errors and are not meant to be included in the evaluation.
 - b. A minimum of four reciprocal transects (that do not contain errors) must be checked.
2. In the WinRiver II main screen, hit the F12 button to bring up a summary table that provides information on each transect measured.
3. Scroll over to the fifth to last column, "Duration".
4. Ensure that each transect duration is ≥ 180 seconds and the sum of all transect duration is ≥ 720 seconds.
5. If individual and total transect duration requirements are met, proceed to the next evaluation step.
6. If an individual transect is < 180 seconds or the sum of all transect durations is < 720 seconds, collect two additional transect measurements (one from each side of the channel) and re-evaluate the summary window.

Evaluate the discharge of each transect relative to average discharge of all transects:

1. In the Measurement Control window (top left panel in the WinRiver II main screen) ensure that each transect measurement you wish to evaluate is checked.
 - a. Uncheck any Transects were measured that contained errors and are not meant to be included in the evaluation.
 - b. A minimum of four reciprocal transects (that do not contain errors) must be checked.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

2. In the WinRiver II main screen, hit the F12 button to bring up a summary table that provides information on each transect measured (**Figure 75**).
3. Note the value listed in the fifth column, “Total Q”, for each transect row.
 - a. This is the total discharge measured during each transect.
4. Note the value listed in the “Average” row of the “Total Q” column.
 - a. This is the average discharge of all transects measured.
5. Note the value listed in the sixth column, “Delta Q”, for each transect row.
 - a. This is the percent difference of total discharge measured during each transect relative to the average discharge across all transects.
6. If the Delta Q value for each transect is $\leq 5\%$, discharge requirements are met and no additional discharge transects are necessary.
 - a. Proceed to the next evaluation step.
7. If the Delta Q value for any individual transect is $> 5\%$:
 - a. Collect two additional transect measurements (one from each side of the channel) and re-evaluate the summary window (reciprocal pairs of transects must always be measured, one that begins from each side of the channel).
 - 1) Note that under changing hydrologic conditions (stage is rising or falling) Delta Q requirements may be difficult to meet.
 - 2) If stream stage was fluctuating dramatically throughout the transect measurements, proceed to the next evaluation step.
 - 3) As total measured discharge values decrease during the low flow regime, achieving $< 5\%$ Delta Q values becomes increasingly difficult.
 - a) The instrumentation approaches the lower limits of its measurement ability at low stages and there is an overall increase in uncertainty when measuring low-flow discharge (environmental factors such as bed and bank geometry exert a larger influence on velocity paths and can adversely affect measurement ability).
 - b) A high level of precision is required to obtain repeatable discharge values per transect.
 - c) As more measurements are collected a given site over time, Science and Field Science staff can work together to develop applicable Delta Q thresholds based on stage levels.
 - b. If Delta Q values still exceed 5% for a given transect collect two additional transect measurements (one from each side of the channel) and re-evaluate the summary window.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- c. If, after collecting a total of 10 transects, Delta Q values still exceed 5% for a given transect, proceed to the next evaluation step.
 - 1) Submit a trouble ticket to Science upon return to the office.
- d. Keep in mind that the more transects that are measured increases the probability that the true mean discharge will be measured but it also increases the probability that an outlier measurement will be collected.

Transect	Start Bank	# Ens.	Start Time	Total Q m ³ /s	Delta Q %	Top Q m ³ /s	Meas. Q m ³ /s	Bottom Q m ³ /s	Left Q m ³ /s	Left Dist. m	Right Q m ³ /s
01000	Right	417	19:27:56	1151.505	1.92	67.125	957.347	120.280	2.978	9.00	3.775
01001	Left	487	19:33:48	1121.736	-0.71	64.965	933.882	114.248	2.344	9.00	6.297
01002	Right	469	19:45:47	1123.982	-0.51	65.115	932.999	116.472	3.878	11.60	5.518
01003	Left	398	19:52:15	1121.822	-0.70	65.398	934.828	114.624	2.516	11.60	4.457
Average		442		1129.761	0.00	65.651	939.764	116.406	2.929	10.30	5.012
Std Dev.		42		14.533	1.29	0.999	11.746	2.760	0.687	1.50	1.117
Std./Avg.] (%)		9.50		1.29	0.00	1.52	1.25	2.37	23.46	14.57	22.29

Figure 76. Discharge summary window in WinRiver II. The red box highlights Delta Q values. In this example all are < 5%, an indication that no additional transect measurements are required.

Evaluate changes in transect discharge relative to changes in gauge height

Gauge height must be observed and recorded in the app prior to each transect measurement in order to calculate mean stage and assess unsteady flow conditions. Unsteady flow conditions occur during periods of rising or falling stage which may occur during or immediately following heavy rain events, upstream dam or lock flow regulation, tidal effects, downstream backwater effects, or flood waves. Always document unsteady flow conditions in the main Remarks section and/or in individual transect notes.

If changes in gauge height are associated with a notable change in discharge for a given transect (i.e. > ~3% of the mean):

1. Attempt to collect a pair of reciprocal transects that correspond with a given gauge height.
2. If stage is changing too rapidly and this is not possible proceed to **Section N.11**.
3. Submit a trouble ticket to Science upon return to the office.

N.11 Evaluating the Discharge Measurement in the Field

Following the completion of the discharge survey, the following data review steps must be completed:

1. Review, finalize, and save data in WinRiver II.
2. Check measured discharge value against the stage-discharge rating equation (if available).
3. Review data in Q-Rev.

Data review must be conducted while still on site so that the discharge survey can be repeated if necessary.



Review, Finalize, and Save Data in WinRiver II:

1. Playback each measured transect and check parameters.
 - a. Open the node (+) under each transect.
 - b. Right click on the Transect number and select “Re-process Transect”. The transect data will appear in all graphs that are currently on display.
 - c. Right click on Playback Configuration and select “Properties”.
 - 1) In the Edge Estimates page on the right, verify that the Begin Transect and End Transect information was entered correctly.
 - 2) In the Offsets page check that the ADCP transducer depth was entered correctly (this depth should not have changed during the discharge survey).
 - 3) In the Discharge page choose the correct Left Bank and Right Bank Edge Type.
 - a) A custom coefficient value can be entered if a given bank does not conform to triangular or square shape.
 - b) Consult Science with any questions regarding bank coefficients. These values are very important in estimating edge discharge.
 - 4) Once any value has been entered in the Playback Configuration > Properties window, you can right click on the box and select “Apply to All Active Checked Transects” if you wish to apply this value to all selected transects.
 - a) This will apply the setting to all transects in the measurement that are checked.
 - b) Each transect will need to be re-processed for this change to be applied.
 - d. Enter all applicable notes in the general Remarks section and in individual transect notes, as necessary.
2. Following the WinRiver II review save the measurement file on the laptop and a USB dongle for backup.
 - a. An .MMT file will be created along with .PDO files that are unique to individual transects. Each of these files must be contained in a folder on the laptop and backed up onto a USB dongle.

Check the measured discharge value against the stage-discharge rating equation, if available:

Once a stage-discharge rating curve has been developed and validated for a site, a rating equation is derived that predicts discharge given stream stage (supplementary information on rating curves is available in **Appendix D**). Once established, rating equations will be provided to field staff by Science. Rating equations are commonly expressed as power relationships:



$$Q = C_r(G - \alpha)^\beta$$

Where:

Q = discharge;

G = the stage, or gauge height;

α = the gauge reading corresponding to zero discharge; and

C_r and β = rating curve constants

Following the discharge measurement:

1. Enter the stream stage (G) into the rating equation that is associated with the site.
2. Calculate predicted discharge.
3. Evaluate whether the measured discharge is $\pm 10\%$ of the discharge predicted by the equation.
 - a. If the measured discharge is $< \pm 10\%$ than predicted discharge:
 - 1) Another discharge survey is not required.
 - b. If the measured discharge is $> \pm 10\%$ than predicted discharge (and the stream stage did not change during the site visit):
 - 1) Conduct another discharge survey immediately.
 - 2) If, after a second attempt, the measured discharge remains $> \pm 10\%$ the predicted rating discharge:
 - a) Check the second discharge measurement file for errors using steps provided in previous sections.
 - b) Save both discharge measurements.
 - c) Submit a trouble ticket to Science.
 - (1) This may indicate a shift in the rating, which, if validated by additional measurements, would warrant an increase in the frequency of discharge measurements at the site.

Review, Finalize, and Save Data in Q-Rev:

QRev software (USGS) serves a final means to QAQC ADCP discharge data. The following procedures must be done in the field prior to leaving the site.

1. Open Q-Rev.
2. Open the .mmt file (the file that was just saved in WinRiver II) in Q-Rev.
 - a. In the main Q-Rev window: Select Data > TRDI > select the WinRiver II .mmt file.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- b. Note that the location where the .mmt file is stored must also contain all of the .PDO files that correspond with the measurement.
3. Note the color of the buttons on the left side of the main window. These colors indicate data quality for specific measurement parameters.
 - a. Green: Good, no investigation required.
 - b. Yellow: Problems could be presented and may be able to be corrected, investigation is required.
 - c. Red: Problems are present that are negatively affecting measurement data, investigation is required.
4. Select the “Options” button (this button will never be colored).
 - a. Ensure that “Units” are set to SI.
 - b. Click OK.
5. In the main window, select the “Moving Bed Test” button (regardless of color).
 - a. Uncheck any tests that are not valid in the “User Valid” column.
 - 1) Note the “Quality” rating, and the text contained in the Messages window.
 - b. If any tests contain “Moving Bed” = “Yes” consider checking “Use for Correction” if the tests were valid.
 - c. Note this will change the measured discharge value.
6. Evaluate the remaining buttons if they are not green:
 - a. ADCP/Site Info
 - 1) Here the Station Name and Number can be edited.
 - b. System Test
 - 1) Provides the results of the ADCP system test.
 - c. Compass/P/R
 - 1) Provides heading, pitch and roll, and magnetic variation data for each transect.
 - a) If the pitch and roll time series data are too high and the extended compass calibration was not performed, Q-Rev will apply a flag.
 - 2) This button will be yellow if Compass Calibration Error is > 1 degree.
 - 3) Here you can change the magnetic variation for some or all transects by clicking on the Magnetic Variation value within the Heading, Pitch, & Roll table.



- 4) You can view the Compass Calibration data by clicking the “View” button under Compass Cal/Error on the right side of the screen.
- d. Temp/Salinity
- 1) Here you can evaluate the ADCP thermistor which controls temperature, salinity, and speed of sound data.
 - a) Fluctuations in the time series data may indicate (1) the ADCP was not allowed to fully equilibrate to the water temperature prior to measurement, or (2) actual temperature variations present in the channel.
 - 2) Check the Average Temperature vs. the User Temperature (entered at the start of the ADCP measurement).
 - 3) The temperature source can be changed from internal (ADCP) to User for one or all transects by clicking on the Temperature Source value in the Speed of Sound Settings table.
 - a) Note this will change speed of sound and discharge values.
- e. BT Filters
- 1) If GPS data was used as the reference navigation this button never needs to be evaluated. Reference the GPS Filters button instead.
 - 2) Here you can evaluate time series velocity data, velocity errors, and how the data can be adjusted using different filter and interpolation settings.
 - 3) Consult with Science if you feel that BT Filters require adjustment.
- f. GPS Filters
- 1) If Bottom Track was used as the reference navigation this button never needs to be evaluated. Reference the BT Filters instead.
 - 2) Here you can evaluate time series velocity data, velocity errors, and how the data can be adjusted using different filter and interpolation settings.
 - 3) The ATL-g Plot to Google Earth plots the transects for the discharge measurement to the Google Earth App. This will only work if the Google Earth App is installed on the computer that QRev is running on.
 - 4) Consult with Science if you feel that GPS Filters require adjustment.
- g. Selected Reference
- 1) The Selected Reference button will be grayed out and this window will not be accessible if there is no GPS data in the file loaded to QRev.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 2) The summary table provides details on the navigation data available, and describes changes in calculated discharge based on filter changes in QRev.
 - 3) The Reference Used panel displays the navigation reference currently being used for the transect selected in the summary table.
 - 4) The boat speed time series shows the boat speed for each of the navigation reference data types in the same graph per transect.
 - 5) The ship track time series shows the ship track for each of the navigation reference data types in the same graph per transect.
 - 6) In the Selected Reference panel, the reference navigation data type used for computing discharge can be changed. Refer back to the summary table to see how a change affects the calculated discharge.
 - 7) The Composite Tracks feature can automatically substitute one of the other valid navigation references for the selected navigation reference, if the selected navigation reference is invalid.
 - a) Composite tracks default to off.
- h. Depth Filters/Draft
- 1) Here data from each beam can be reviewed and the combined cross-sectional value.
 - 2) QRev defaults to using inverse depth weighting to compute the mean depth when the 4 slant beams are used.
 - 3) The filter type can be changed to eliminate erroneous spikes. Note this will change the discharge value.
- i. WT Filters
- 1) Here raw and processed water track data can be reviewed and adjusted.
 - 2) Note that the error and vertical velocity filters do not always perform well on data from ADCPs with auto adaptive modes (the RiverPro being one such model) due to the change in error velocity distribution for the different modes.
 - a) If this button is yellow or red try turning error and vertical velocity filters off. Note the change in total discharge.
- j. Extrapolation
- 1) Default edge extrapolation settings are determined automatically from algorithms created for the Extrap program.
 - 2) The data panel displays average normalized depths for segments of the channel, with each segment equating to 5 percent of the total discharge.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 3) The Profile Panel is the primary panel in this window.
 - a) Gray Dots represent raw data, normalized discharge or velocity (depending on which is selected) in each depth cell for all transects selected in the Fit panel.
 - b) Green circles represent the top cell for each ensemble, the cell at the water's surface.
 - c) The Red/Black Squares are median points for the raw data in each segment. They are color coded:
 - (1) Red: contains less values in the segment than the threshold requires, and is not used in the computation of extrapolation.
 - (2) Black: Median values of the composite of all the transects in the measurements.
 - d) The horizontal Red/Black lines (Whiskers) on either side of each median value extend to the 25th and 75th percentile of all the data in that segment (i.e. 50% of the raw data will fall inside the whiskers).
 - e) The center line, going through the median squares is the extrapolation line, which is also color coded:
 - (1) Magenta: transects collected while crossing the channel from left bank to right bank (facing upstream).
 - (2) Blue: transects collected while crossing the channel from right bank to left bank (facing upstream).
 - (3) Black: is a composite of all the transects.
 - f) The fit panel allows a separate fit edge for each transect.
 - (1) Leave "Fit" set to "Automatic" for default algorithms to be used (recommended default setting).
 - (2) Change "Fit" to "Manual" to change the extrapolation method at the Top and Bottom of the graph to different fit options – Power, Constant, or 3-Point (Top) or Power or No-Slip (Bottom).
 - (a) Set the Exponent value incrementally for Power or No-Slip extrapolations. The graph will update as the exponent is changed.
 - (3) Note that discharge values will change as extrapolation fits are adjusted.
- k. Edges
 - 1) This window displays the edge settings for computing the left and right edge discharges and displays graphs for evaluation.



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

- 2) The Edges button will be yellow if any of the extrapolated edge discharge contributes >5% of the total measured discharge for the transect.
 - a) Uncertainty in the total estimated discharge increases with increased contribution of edge discharge to the total estimate.
 - b) Check the “Left Distance (m)” and “Right Distance (m)” values to ensure the left and right edge distances were entered correctly.
 - (1) These values are directly correlated to the percentage of total discharge contributed by the edges.
 - (2) To edit an edge distance click on the “Left/Right Distance (m)” value you wish to edit. The new value can be applied to a singular transect or all transects in the measurement.
 - c) If edge distances are correct but edge discharge remains >5% of the total measured discharge, not much else can be done during post-processing other than re-measuring additional transects during which you begin and end the measurement closer to the edge of water.

7. Save the file and exit Q-Rev.

SOP O Post-Field Sampling Tasks: River Sites using the Piloted Boat Method

Once field verification of the measurement file is complete, all instrumentation be cleaned following standard operating procedures for cleaning field equipment used in aquatic systems. Batteries for the ADCP shall be charged or replaced as needed.

O.1 Document Incomplete Sampling Within a Site

Discharge sampling is scheduled to occur at the prescribed sampling location according to the frequency and timing described in **Section 4**. Ideally, sampling will occur at this sampling location for the lifetime of the Observatory (core sites) or the duration of the site’s affiliation with the NEON project (relocatable sites). However, sampling may be shifted from one location to another when sampling is compromised. In general, a sampling location is compromised when sampling becomes so limited that data quality is significantly reduced.

There are two main pathways by which sampling can be compromised. First, sampling locations can become inappropriately suited to answer meaningful biological questions – e.g., stream morphology changes in such a way that discharge measurement quality is reduced. Second, sampling locations may be located in areas that are logistically impossible to sample on a schedule that that is biologically meaningful.

For the river discharge sampling program, a given discharge transect must be sampled during 100% of the bouts expected for the site (See **Appendix E.1** for the number of expected bouts and site-specific



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

documentation) over a one-year period. Transects that cannot be sampled on this schedule should be considered compromised.

If sampling at a given transect is not possible during a given bout a trouble ticket should be submitted by Field Science staff.

To document a missed discharge bout:

1. Create an incident with the following naming convention to document the missed sampling: 'AOS/TOS Sampling Incomplete: MOD – [Root Cause Description]'
 - a. Example: 'TOS Sampling Incomplete: CDW – Could not access plot due to permanently closed road'

Staff scientists review incident tickets periodically to determine whether a sampling location is compromised.

SOP P Data Entry and Verification: River Sites Using the Piloted Boat Method

Raw ADCP discharge measurement files (i.e. files that have been evaluated in WinRiver II and Q-Rev but not post-processed by Science) are stored on an online file storage page and post-processed by Science. Complete the following steps to upload discharge measurement files.

8. In the office (or location with internet connection), store the measurement file on the cloud-based Box.com folder.
 - a. Navigate to the main Box.com folder where raw ADCP files are stored.
 - 1) "NEON ADCP Discharge Measurement Files" <https://app.box.com/folder/48084982589>
 - 2) "Raw_Data"
 - b. Navigate to the applicable Domain folder for raw files.
 - 1) Ex: "Domain_03_Raw_Files"
 - c. Navigate to the appropriate site folder.
 - 1) Ex: "FLNT"
 - d. Navigate to the appropriate calendar year.
 - e. Create a new folder that is unique to your discharge measurement.
 - 1) Click the "New" dropdown and select "Folder".
 - 2) Ensure that the folder name is in a standardized format.
 - a) Ex: "SITE_YYYYMMDD" (FLNT_20180317)
 - f. Move all of the measurement files into this folder.



<i>Title:</i> AOS Protocol and Procedure: Stream Discharge		<i>Date:</i> 06/19/2020
<i>NEON Doc. #:</i> NEON.DOC.001085	<i>Author:</i> N. Harrison	<i>Revision:</i> G

- 1) This includes .MMT, .PDO files, and _GPS.TXT file (StreamPro only) - everything that was saved on the laptop/USB.
 - 2) If any other relevant materials correspond to the discharge measurement (i.e. pictures, screen shots, etc.) create a sub-folder here where they can be stored.
 - 3) In addition to .PDO and _GPS.TXT files (of which there will be many depending on the number of transects measured), include only one (1) .MMT file (from WinRiver II) and one (1) .XML file in the sub-folder.
- g. Once the all data is available on the Box folder, Science will assume it is ready for post-processing.



APPENDIX D REMINDERS

ARC-Boat Tiller Repair:

The ARC-Boat tiller may become disconnected from the rudder shaft during transport or use, resulting in the inability to steer the ARC-Boat. A disconnected tiller can be easily repaired in the field with the proper tools (**Figure 76**). Repairing a broken tiller may involve a third party, such as the manufacturer or a machine shop.

Symptoms of ARC-Boat tiller failure:

- Clicking noise emanates from the ARC-Boat at higher speeds.
- Loss of rudder control.
- Inability to accurately steer boat in a given direction.
- ARC-Boat moves in circles when the throttle is applied.

To repair a disconnected ARC-Boat tiller:

- Remove the rear hatch plate on the ARC-Boat (**A**).
- Locate the tiller arm.
 - Note whether it is broken or disconnected from the rudder shaft (**B**).
 - If the tiller is broken the discharge measurement cannot be conducted and a more extensive repair is likely needed. Contact Science immediately.
 - If the tiller is disconnected from the rudder shaft use the following steps to re-connect the tiller to the rudder shaft.
- Remove the stainless steel connecting piece using a 5/32 Allen wrench (**C**).
- Reconnect the tiller arm to the stainless steel connecting piece.
- Carefully reconnect tiller arm to rudder shaft.
 - Ensure that the rudders are at exactly 90 degrees to the rear hull and the rudder shafts are at a 45 degree angle (**D, E**).
- Contact Science and/or the manufacturer (HR Wallingford) with any ARC-Boat repair questions.

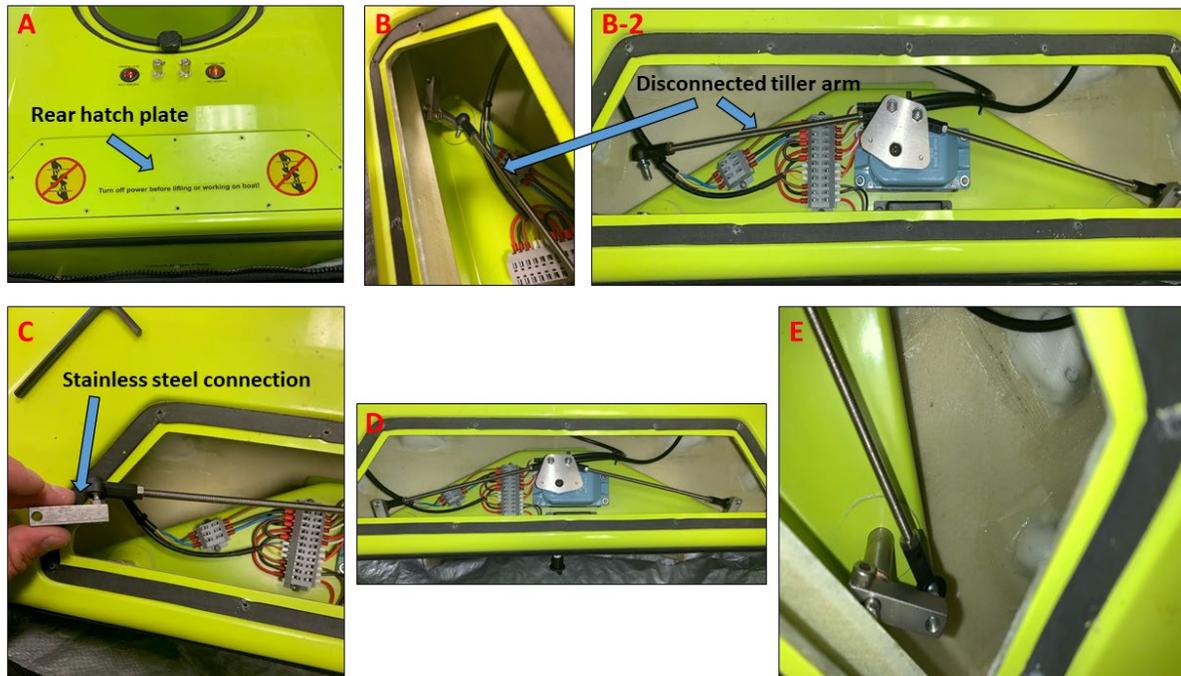


Figure 77. Repairing a disconnected tiller on the ARC-Boat.

Viewing the laptop screen in bright and direct sunlight:

Computer screens can be difficult to read in direct sunlight. Mouse cursor and screen contrast settings can be configured in Windows settings that make the laptop screen easier to read/navigate, increase the size of the mouse cursor, and provide a high contrast display.

1. Configure mouse cursor size
 - a. Hit the "Windows" key on the laptop keyboard.
 - 1) Located on the bottom left of the keyboard between "Ctrl" and "Alt" keys.
 - b. Type "Mouse settings" and click the first result "Mouse settings".
 - c. Click "Adjust Mouse & cursor size" to increase the size of the cursor.
 - d. Adjust the cursor size to something reasonable for easy viewing in the field.
2. Increasing Screen Contrast
 - a. Hit the "Windows" key on the laptop keyboard.
 - 1) Located on the bottom left of the keyboard between "Ctrl" and "Alt" keys.
 - b. Type "Contrast".
 - c. Select "Turn high contrast on or off" to turn on high contrast and choose screen color themes that are easier to read.



- 1) Hotkey option: Left Alt + Left Shift + Print Screen (PrtSC).

Rating Curve supplementary information:

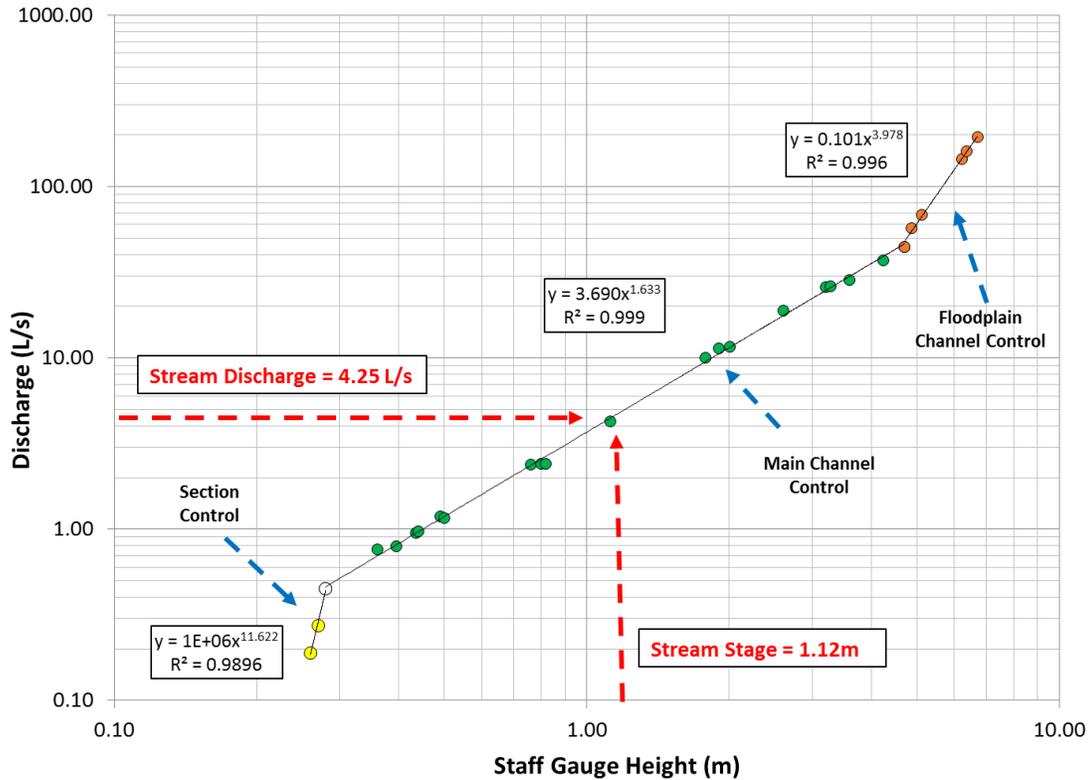


Figure 78. Example of stage-discharge rating curve. Circles indicate discharge measurements collected across a wide range of gauge heights. Rating equations for each of the three distinct segments are shown representing low, medium, and high flow regimes. In this example, a section control governs the stage-discharge relationship during the low-flow regime and the main channel control becomes de-activated at higher stages when as the streamflow tops the banks. Once flow exceeds the channel capacity the stage-discharge relationship is governed by floodplain channel control.

Breaks in the slope of the rating curve are often associated with one control becoming submerged and another becoming activated. Three types of controls are common in natural streams, each of which depend on streamflow and channel conditions (Braca 2008).

1. Section Controls: a natural downstream feature such as a riffle, rock ledge, sand bar, or severe channel restriction that tends to control the low-flow regime. As gauge height increases with higher streamflow the section control becomes submerged in such a way that it no longer controls the relation between gauge height and discharge.



2. Channel Controls: a combination of downstream features throughout the reach such as channel size, shape, curvature, slope and roughness. The length of channel controls can be extremely variable. Channel controls typically govern stage-discharge relations during periods of higher streamflow.
3. Combination of Section and Channel Controls: at some stages, the stage-discharge relation may be governed by a combination of section and channel controls. This usually occurs during a short range in stage between section-controlled and channel-controlled segments of the rating curve, or the transition zone. Channels with unstable controls tend to exhibit section/channel combinations.

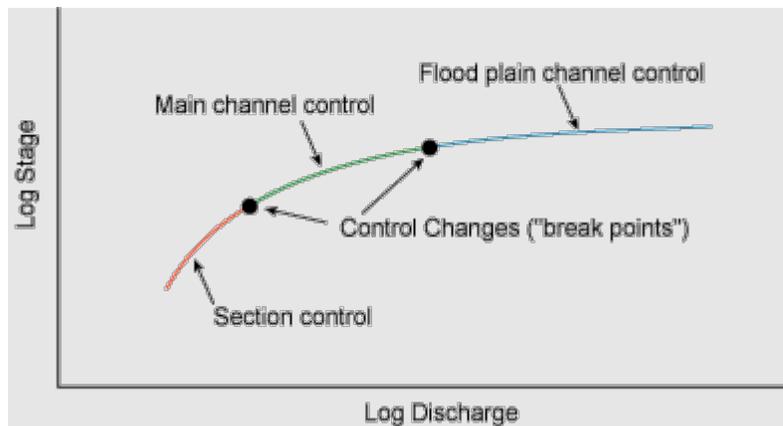


Figure 79. Schematic representation of control range in a rating curve. (Illustration: Braca 2008).



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

APPENDIX E SITE-SPECIFIC INFORMATION

E.1 Estimated Dates for Onset and Cessation of Sampling

Each domain has site-specific guidelines for timing of sample collection, which can be found in Domain Specific Sampling Designs (**Table 10**). The dates in the Sampling Design documents are estimated from historical hydrologic data. Dates presented are only a guide, and are derived according to the logic presented in **Section 4.2**. Because individual years may vary widely from the average dates provided below, it is essential that domain staff monitor real-time conditions to determine when to start (and stop) sampling per environmental conditions, as described in **Section 4** of this protocol.

Table 10. Site-specific bout number, start dates, end dates and additional site-specific sampling guidance.

Domain Number	Req. # of Annual Bouts per Site pre-Rating Curve Development	Document Number	Document Name
01	24	NEON.DOC.003600	Aquatic Site Sampling Design – NEON Domain 01
02	24	NEON.DOC.003601	Aquatic Site Sampling Design – NEON Domain 02
03	12	NEON.DOC.003602	Aquatic Site Sampling Design – NEON Domain 03
04	24	NEON.DOC.003603	Aquatic Site Sampling Design – NEON Domain 04
05	NA	NEON.DOC.003604	Aquatic Site Sampling Design – NEON Domain 05
06	24	NEON.DOC.003605	Aquatic Site Sampling Design – NEON Domain 06
07	24	NEON.DOC.003606	Aquatic Site Sampling Design – NEON Domain 07
08	12 (TOMB, BLWA) 24 (MAYF)	NEON.DOC.003607	Aquatic Site Sampling Design – NEON Domain 08
09	NA	NEON.DOC.003608	Aquatic Site Sampling Design – NEON Domain 09
10	24	NEON.DOC.003609	Aquatic Site Sampling Design – NEON Domain 10
11	24	NEON.DOC.003610	Aquatic Site Sampling Design – NEON Domain 11
12	24	NEON.DOC.003611	Aquatic Site Sampling Design – NEON Domain 12
13	24	NEON.DOC.003612	Aquatic Site Sampling Design – NEON Domain 13
14	24	NEON.DOC.003613	Aquatic Site Sampling Design – NEON Domain 14



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

Domain Number	Req. # of Annual Bouts per Site pre-Rating Curve Development	Document Number	Document Name
15	24	NEON.DOC.003614	Aquatic Site Sampling Design – NEON Domain 15
16	24	NEON.DOC.003615	Aquatic Site Sampling Design – NEON Domain 16
17	24	NEON.DOC.003616	Aquatic Site Sampling Design – NEON Domain 17
18	24 (OKSR)	NEON.DOC.003617	Aquatic Site Sampling Design – NEON Domain 18
19	24	NEON.DOC.003618	Aquatic Site Sampling Design – NEON Domain 19

E.2 ADCP Maximum Depth Measurement Thresholds per Site

The maximum measurement depth of StreamPro (used at wadable stream sites) and RiverPro (used at river sites) is 2.00 meters though specific units have been upgraded to increase the maximum depth profiling to 6.00 meters at the following sites

Domain Number	Site Name(s)	ADCP Model	Maximum Depth Measurement (m)
01	HOPB	StreamPro	2.00
02	POSE, LEWI	StreamPro	2.00
03	FLNT	RiverPro	25.00
04	CUPE, GUIL	StreamPro	6.00
06	KING, MCDI	StreamPro	6.00
07	LECO	StreamPro	2.00
08	MAYF, TOMB, BLWA	RiverPro	25.00
10/13	COMO, WLOU, ARIK	StreamPro	2.00
11	PRIN, BLUE	StreamPro	6.00
12	BLDE	StreamPro	2.00
14	SYCA	StreamPro	6.00
15	REDB	StreamPro	2.00
16	MART, MCRA	StreamPro	2.00
17	TECR, BIGC	StreamPro	2.00
18/19	CARI, OKSR, TOOK-IN, TOOK-OUT	StreamPro	2.00



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

APPENDIX F 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 11. Equipment list for measuring discharge at wadable stream sites using the Flowmeter Method.

Item No.	Exact Brand?	Description	Purpose	Quantity
Hach	Y	Velocity flow meter	Measures stream velocity	1
Fondriest Environmental, Inc.	Y	Top setting wading rod	Houses flowmeter and measures depth	1
	N	Meter tape (minimum length must be greater than the wetted width of the channel)	Delineates the discharge transect	1
	N	Stakes	Anchoring survey tape	2
	N	Clamps	Attaches and secures meter tape to stakes	2
	N	5 Gallon Bucket	Flowmeter calibration	1
	N	Waders (per person)	Safe wading	1
	N	Personal Flotation Device (at sites where required)	Safe wading	1
	NA	Discharge protocol	Used as a reference during discharge measurement	
	N	Hand tools (flathead screw driver, etc.)	Assist in attaching the flowmeter to the wading rod	1



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

Table 12. Equipment list for measuring discharge at wadable stream sites using the ADCP Method.

Item No.	Exact Brand?	Description	Purpose	Quantity
	N	Fully charged laptop with Bluetooth capability and necessary software installed (WinRiver II, Q-Rev, ParaniWin)	Interfaces with ADCP and GPS	1
Teledyne	Y	StreamPro ADCP with 8 charged AA batteries	Measures discharge	1
SX Blue	Y	SX Blue II GPS antenna	Provides GPS data during discharge measurement	1
Teledyne	Y	Trimaran float and all associated components to mount ADCP and GPS units	Houses ADCP and GPS	1
Sena	Y	Parani SD1000U Bluetooth transmitter	Transmits ADCP and GPS data from instruments to laptop via Bluetooth connection	3
Teledyne	N	Temporary High Line – all components (tripod, winch post, pulley post, Guideline rope, guideline support, guy wire + earth anchor, guy wire driving rod)	Mechanical assembly used to deploy the trimaran float across the stream channel	1
	N	Control rope (minimum length is twice the wetted width of the stream + additional length to accommodate the distance to the point of operation on the near bank and tie off on the far bank, strong climbing rope is recommended)	Long length of rope used to pull the trimaran float back and forth across channel	1
	N	Trimaran rope (required length is dependent on surface velocity during the measurement, maximum length not likely to exceed	Short length of rope that connects and orients the trimaran float to the Guideline rope	1



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

Item No.	Exact Brand?	Description	Purpose	Quantity
		~1.5m, strong climbing rope is recommended)		
	N	Locking carabiner	Connects the trimaran float to the Trimaran rope	3
	N	Small hammer or mallet	Drives the guy wire earth anchor into the substrate to support High Line assembly	1
	N	Thermometer (reads in C)	Measures water temperature	1
	N	Anemometer (reads in kmh)	Measures wind speed	1
	N	Laser rangefinder	Measures edge distances	1
	N	Meter tape or metric ruler	Measures ADCP depth and edge distances	1
	N	Flagging	Marks start and end transect points	1
	N	Sharpie	Marks flagging	1
	N	Laptop cover or umbrella	Protects laptop in wet weather	1
	N	Lazy Susan (contains no magnetic parts)	Rotates trimaran float during pre-measurement QAQC, reduces compass calibration error	1
	N	Laptop shade	Shades computer screen so it can be easily read in bright weather	1
	N	USB flash drive	Backs up measurement files	1
	NA	Discharge protocol and laminated TRDI protocol cards	Used as a reference during discharge measurement	1
	NA	All necessary safety and PPO	Safety	NA



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

Table 13. Equipment list for measuring discharge at river sites using the Remote Controlled Boat Method.

Item No.	Exact Brand?	Description	Purpose	Quantity
	N	Fully charged laptop with Bluetooth capability and necessary software installed (WinRiver II, Q-Rev, ParaniWin)	Interfaces with ADCP and GPS	1
Teledyne	Y	RiverPro ADCP	Measures discharge	1
	N	Charged RiverPro ADCP 12V batteries	Powers the ADCP	2
H.R. Wallingford	Y	ARC-Boat	Deploys ADCP	1
H.R. Wallingford	Y	RiverPro ADCP Adapter for ARC-Boat (with charged 12V battery inside) and GPS mount	Houses ADCP in ARC-Boat, provides ADCP power and Bluetooth communications	1
H.R. Wallingford	Y	Charged ARC-Boat Batteries (10Nimh)	Powers the ARC-Boat	4
H.R. Wallingford	Y	Charger for ARC-Boat batteries	Charges ARC-Boat batteries	1
H.R. Wallingford	Y	Charged ARC-Boat Remote Control (Futaba 2.4GHz) w/neckstrap and charged battery pack	Controls the ARC-Boat	1
H.R. Wallingford	Y	Spare ARC-Boat Remote Control battery pack	Powers the ARC-Boat remote controller	1
H.R. Wallingford	Y	ARC-Boat spare parts kit with Allen wrench	ARC-Boat maintenance	1



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

Item No.	Exact Brand?	Description	Purpose	Quantity
Sena	Y	Parani SD1000U Bluetooth transmitter	Transmits ADCP and GPS data from instruments to laptop via Bluetooth connection	2
Subsea	Y	Hemisphere GNSS V102 GPS antenna	Provides GPS referencing for ADCP	1
	N	Thermometer (reads in C)	Measures water temperature	1
	N	Anemometer (reads in kmh)	Measures wind speed	1
	N	Laser rangefinder	Measures edge distances	1
	N	Meter tape or metric ruler	Measures ADCP depth and edge distances	1
	N	Flagging	Marks starting and ending transect points	1
	N	Sharpie	Marks flagging	1
	N	Anchored floats (non-magnetic)	Marks transect start and end points	2
	N	Laptop cover or umbrella	Protects laptop in wet weather	1
	N	Lazy Susan (contains no magnetic parts)	Rotates trimaran float during pre-measurement QAQC, reduces compass calibration error	1
	N	Laptop shade	Shades computer screen so it can be easily read in bright weather	1
	N	USB flash drive	Backs up measurement files	1



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

Item No.	Exact Brand?	Description	Purpose	Quantity
	NA	Discharge protocol and laminated TRDI protocol cards	Used as a reference during discharge measurement	1
	NA	All necessary safety and PPO	Safety	NA

Table 14. Equipment list for measuring discharge at river sites using the Piloted Boat Method.

Item No.	Exact Brand?	Description	Purpose	Quantity
	N	Fully charged laptop with Bluetooth capability and necessary software installed (WinRiver II, Q-Rev, ParaniWin)	Interfaces with ADCP and GPS	1
Teledyne	Y	RiverPro ADCP	Measures discharge	1
	N	Charged RiverPro ADCP 12V batteries	Powers the ADCP	2
ECO-05389	Y	ADCP mount (all components listed in ECO-05389) + Allen wrench	Deploys ADCP over the side of the piloted boat	1
	N	Thermometer (reads in C)	Measures water temperature	1
	N	Anemometer (reads in kmh)	Measures wind speed	1
	N	Laser rangefinder	Measures edge distances	1
	N	Meter tape or metric ruler	Measures ADCP depth and edge distances	1



Title: AOS Protocol and Procedure: Stream Discharge		Date: 06/19/2020
NEON Doc. #: NEON.DOC.001085	Author: N. Harrison	Revision: G

Item No.	Exact Brand?	Description	Purpose	Quantity
	N	Flagging	Marks starting and ending transect points	1
	N	Sharpie	Marks flagging	1
	N	Anchored floats (non-magnetic)	Marks transect start and end points	2
	N	Laptop cover or umbrella	Protects laptop in wet weather	1
	N	Lazy Susan (contains no magnetic parts)	Rotates trimaran float during pre-measurement QAQC, reduces compass calibration error	1
	N	Laptop shade	Shades computer screen so it can be easily read in bright weather	1
	N	USB flash drive	Backs up measurement files	1
	NA	Discharge protocol and laminated TRDI protocol cards	Used as a reference during discharge measurement	1
	NA	All necessary safety and PPO	Safety	NA