Washington State Department of Ecology

Environmental Assessment Program

Standard Operating Procedure for Measuring Stream Discharge from a Bridge

Version 2.1

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SOP Revision History

Revision Date	Rev Person	Summary of changes	Sections	Reviser(s)
03/30/2016		Grammatical changes	All	Jim Shedd
03/30/2016		Grammatical changes	All	Mike Anderson

Environmental Assessment Program

Standard Operating Procedure for Measuring Stream Discharge from a Bridge

1.0 Purpose and Scope

1.1 This document is the Environmental Assessment Program (EAP) Freshwater Monitoring Unit (FMU) Standard Operating Procedure (SOP) for measuring discharge of a stream from a bridge.

2.0 Applicability

2.1 Field staff follow this SOP when measuring discharge from any bridge. It includes the approved methods for assembling bridge equipment, setting up a work zone and conducting an accurate and safe discharge measurement.

3.0 Definitions

3.1 HYDSTRA- Data processing software used by FMU

3.2 Current meter – A measuring device that is used to measure velocity at a given point in a stream

4.0 Personnel Qualifications/Responsibilities

4.1 This work requires a minimum of two technicians to safely perform.

4.2 Training in the use of discharge measurement equipment and hardware is required as well as experience, training and knowledge of stream flow measurement procedures.

4.3 Staff performing bridge measurements are properly trained in safety protocols for working in and around wadeable streams, on bridges, roadways, floating structures and open water. Personnel must also possess and properly employ the approved safety gear for each specific environment.

5.0 Equipment, Reagents, and Supplies

5.1 Approved personal floatation devices, waders, and foul weather gear
5.2 Field log notebook with “Write in the rain” field forms
5.3 Laminated bridge measurement depth conversion sheets
5.4 300 ft. transect tape with tenths of a foot demarcation
5.5 Tool box with listed tools present (appendix A)
5.6 Replacement parts for hardware
5.7 Bridge board or crane with meter attachments
5.8 Approved current meter (Hydrological Services, Swoffer, etc.)
5.9 Type A or Type B Sounding Reel

5.10 Sounding weights (30, 50, 75 or 100 lb.), weight hanger and securing pin
5.11 Approved traffic signs, road cones, and reflective apparel
5.12 Two spare 9 volt batteries (for mechanical velocity indicators)
5.13 Keys to access station house for data collection platforms (if needed)

6.0 Summary of Procedure

6.1 Field Trip Preparation

6.1.1 Prepare a field/float plan found on the EAP SharePoint site.

6.1.2 Before packing the bridge measurement equipment check the station discharge at the sites you anticipate visiting. Determine the appropriate bridge equipment, current meter, and sounding weights needed to perform an accurate and safe discharge measurement. Bridge board equipment is part of the standard kit for FMU vehicles and is permanently stored in each flow support vehicle. Bridge cranes are quite cumbersome and are stored separately. If using a Stream-Pro™, Rio-Grande™ Acoustic Doppler Current Profiler (ADCP), or mechanical current meters, please refer to their specific SOP for operation techniques and deployment methods (Shedd et al., 2013; Holt, 2009; Myers et al., 2015).

6.2 Bridge Measurement Equipment: Purpose and Function

Bridge board: A bridge board is a light duty, compact instrument used for measuring flow from a bridge. Bridge boards consist of a sheave mounted at the end of a plank or arm that the cable from a reel passes over. The other end of the board houses the A-type reel and the mount for the T-bar, which the operator will stand upon to balance the unit. A rubber tired bridge board roller mounts in the middle of the board to roll it along bridge railings for ease of use.

6.2.1 *Bridge crane*: Bridge cranes are a rolling framework specifically designed to run on the narrow walkways and curbs of bridges and allow the operator to roll the unit back and forth to position it. Cranes are usually constructed of aluminum and hinged to fold up or down to avoid obstacles. Cast iron counterweights are positioned on cranes to offset and balance the sounding weights. Bridge cranes require Type B or larger sounding reels.

6.2.2 Bridge measurements require specialized equipment to accurately sound depth, maintain a well-defined cross section, and safely measure discharge while working near a roadway. Mechanical and electromagnetic velocimeters are typically suspended from the bridge using a bridge board or a bridge crane. With acoustic instrumentation, the unit is attached to a raft and towed with a rope or cable from the bridge (Shedd et. al, 2013).

6.2.3 The primary difference between a wading measurement and a bridge crane/board measurement is the equipment used to position the flow measuring sensor in the cross section. The current meter attaches to a sounding reel cable (type A or B reels) and suspends above a sounding weight (Columbus or C-type weights) via sounding weight hangers and a hanger pin. The size of the sounding weight used depends on two factors: the highest water speed and greatest depth of current. Determine the optimal weight by multiplying the estimated velocity in feet per second by the depth of water in feet. The calculated product provides an approximation of the size of the sounding weight for the measurement conditions. Be sure to note the length of the hanger (0.6 ft. for FMU applications) in order to determine the distance the meter sits above the bottom.

6.2.4 The sounding weight/current meter assembly is raised and lowered using a type A or type B USGS sounding reel which is mounted to a bridge board or portable bridge crane. If the determined weight of the sounding weight is 50 pounds or less, a bridge board is adequate to conduct the measurement. If the required weight is greater than 50 pounds, use the bridge crane. The use of a bridge board with weights greater than 50 pounds will cause an unsafe and unstable platform for measuring and may result in injury or loss of equipment. A crane may be used in place of a bridge board when using sounding weights less than 50 pounds.

6.2.5 Sounding reels are composed of a thin cable (size dependent on reel type) wound around a winch drum with a geared crank or a mechanical clutch to raise and lower the equipment. A computing depth indicator is integrated into the unit for measuring depth.

6.3 Preparing the Work Zone

6.3.1 Upon arrival at the bridge station, assess the work zone and set up proper traffic signs and work zone boundaries as needed. Refer to the EAP Safety Manual, the Flagger Certification Handbook and the Manual of Uniform Traffic Control Devices (MUTCD) for determining type of work zone, proper work zone preparation, and operation. Plan for work zone preparation before departure to ensure proper equipment is at hand and all safety contingencies are considered.

6.3.2 Record station information, including date and time of measurement in a field notebook and/or log sheet. Extend the 300ft. measuring tape as needed to include the entire stream cross section and both edges. Secure the measuring tape to the bridge railing or on the bridge deck in a manner that ensures it will remain in place through the entire measurement. It is standard practice to start the tape from the right side of the channel looking downstream. Note the tape reading at an easily identifiable point on the bridge (such as a tapedown reference mark) so that the tape can be reset in the event it moves. Record the edge information on the log sheet as specified in the Measuring and Calculating Discharge SOP (Shedd, 2014).

6.3.3 *Bridge Board Assembly***:** The bridge board assembles easily.

6.3.3.1 First, undo the bolt that fastens the hand crank to the reel and flip the handle around from its storage position to its working position (Fig.1).

Fig. 1. Bridge board assembly

6.3.3.2 Reattach the bolt to fasten it to the reel.

6.3.3.3 Next, slide the T-bar into the receiver behind the sounding reel, adjusting it to the proper height to level the instrument and clear the railing of the bridge.

6.3.3.4 Place the bridge board wheeled car under the board so that it can balance on the railing and keep the sheave far enough out over the edge of the bridge to clear all parts of the bridge below the railing.

6.3.3.5 Tighten the fastening plate on the car so it is firmly attached to the bridge board.

6.3.3.6 Pay out some of the sounding reel cable to attach the sounding weight, current meter, hanger and pin to the cable. See Mechanical Velocity Indicators SOP (Holt, 2013) for specific velocity indicators assembly instructions.

6.3.3.7 Reel in any slack in the cable and lift the meter assembly over the side of the bridge. Be careful not to damage the current meter. The bridge board is now ready for use.

6.3.4 *Bridge Crane Assembly*: Most of the bridge crane is already assembled. Attach the arm assembly to the base unit via the bolts/wingnuts. Carefully unfold the arm assembly and attach the sounding reel via wingnuts to the anchoring platform located opposite of the arm (Fig. 2). Carefully place the counterweights in the weight slot on the base unit. Let out some of the sounding reel cable to be able to attach the sounding weight, current meter, hanger and pin to the cable.
Run the cable over the sheave at the end of the arm and lower the assembly over the side of the bridge. The bridge crane is now ready for use.

Fig 2. Bridge Crane assembly

6.4 Operation of the Bridge Equipment

6.4.1 Check the instrument by comparing it against another velocity indicator. Currently, the FMU standard equipment for this comparison is the Son Tek ® Flow tracker Acoustic Doppler Velocimeter ® (ADV). Refer to the chosen instrument SOP for further quality control information and procedures. After comparison, reassemble the measuring equipment on the reel. Set up your cross section and divide the stream into appropriate segments as described in the Measuring and Calculating Discharge SOP (Shedd, 2014). If finished assembling the bridge instrumentation proceed with flow measurements.

6.4.2 Position the bridge measuring equipment at the first station nearest the right edge of water (REW). Lower the sounding assembly slowly down to the water surface until the tail fin of the Columbus weight just touches the water surface. Zero the computing depth indicator on the sounding reel (appendix B) and carefully lower the sounding weight to the stream bottom. Reel in any slack in the cable until the sounding weight is just barely touching the bottom. Record the depth on the measurement note sheet.

6.4.3 Determine a depth to set the sounding weight in order to accurately attain $2/10^{th}$, $6/10^{th}$ or $8/10^{th}$ depth intervals for the current meter. Calculate these depths mathematically, or use the computing depth indicator (appendix B), or use the pre-calculated depth conversion sheets (appendix C). For depths less than 2.5 feet use the $6/10^{th}$ depth correction sheets. For depths greater than 2.5 feet use the $8/10^{th}$ depth and $2/10^{th}$ depth correction sheets. Make sure that a logarithmic relationship exists vertically in the water column. A non-logarithmic relationship exists when the two tenths velocity is less than the eight tenths velocity or the two tenths velocity is greater than two times the eight tenths velocity. If non-logarithmic condition exists measure an additional velocity at six-tenths depth. To calculate the velocity compute the average the of eight-tenths and two-tenths velocities against the six-tenth velocity measurement. (Shedd, 2014).

6.4.4 To mathematically determine corrected depths for measurement, first determine the total depth at the station. Next multiply that value by 0.8 and add 0.6 to the product for a corrected $8/10^{th}$ value. Use the same method for determining $2/10^{th}$ depths, but multiply the depth by 0.2 instead of 0.8. After repositioning the equipment at the corrected depth sample the velocity.

6.4.5 Set the chosen current meter to sample as described in the appropriate SOP for the instrument. Sample at the corrected depths and record the data to the flow measurement log sheet. Repeat for each measurement point in the cross section.

6.4.6 In some instances when measuring from a bridge, the entire stream channel is at an oblique angle to the cross section defined by the bridge. In these cases, when using mechanical equipment, multiply the raw average velocity of the measurement by the cosine of the angle between flow current direction and the cross section. In other measurement situations multiple oblique flow angles are encountered through a cross-section, which will require angle corrections at individual measurement location (Shedd, 2014). The discharge measurement forms have a built in calculator on the back section of the form to determine the cosine of oblique flow angles. Use of this correction calculator is presented in Appendix E. Do not measure from a curved bridge causing a curved cross section when using mechanical bridge measurement equipment.

6.4.5 Remain aware at all times of surrounding elements while measuring streamflow from bridges. Remember, the work described in this document is conducted from a roadway over open water. Avoid putting yourself and others in unsafe or hazardous situations. Look out for possible floating debris or boat traffic that may not see sounding cables and could collide with them causing injury or damage. Always prepare to quickly raise instrumentation in order to avoid collisions. If necessary, flag the sounding cable with orange tape or floating buoys to warn boaters of the location of the cable.

6.4.6 After completion of the flow measurement, clean up the work zone. Pick up signs, cones, and safety equipment. Disassemble the measurement equipment, and return everything to the vehicle prior to departure.

7.0 Records Management

7.1 Processed measurement files are saved to windows file system folders for archival purposes. These processed files are then uploaded to the Hydstra© data management system for evaluation.

7.2 Field log sheets are stored in the central filing locations at Ecology headquarters and regional offices.

7.3 Quality checked and reviewed report storage are the responsibility of the lead investigator in charge of the stations where the data was collected.

7.4 Records of all peer reviewed discharge measurements are found on the FMU shared server as well as with the principal investigator. After completion and review, the raw field forms are filed in a central location at headquarters and regional offices.

8.0 Quality Control and Quality Assurance

8.1 A pre-measurement side by side comparison with a Sontek ® Flow Tracker ADV ® is necessary for determining current meter accuracy.

8.2 One of the most important parameters in assuring statistically relevant, accurate data collection with stream flow measuring devices is consistent maintenance and calibration of all measuring components. The ability to identify a drifting or worn out fan, failing batteries and worn cables is very necessary for collecting accurate data.

8.3 Assessment of sampling location and cross section characteristics are very important factors in determining quality of data. The description and quality of these parameters are determined via professional rating as described in the Standard Operating Procedure for Measuring and Calculating Discharge (Shedd, 2014).

8.4 Upon completion of the flow measurement and data entry/assessment, turn in the measurement notes and data collected to the principal investigator.

9.0 Safety

9.1 All field staff must understand and comply with the Environmental Assessment Program (EAP) safety manual (2015).

9.2 All field staff must also possess the proper, up to date safety equipment approved by the EAP safety officer and understand its complete operation and maintenance.

10.0 References

10.1 Environmental Assessment Program, 2015. Environmental Assessment Program Safety Manual.

10.2 Myers, Jason. 2015. Standard Operating Procedure for Stream Hydrology Site Visits. Environmental Assessment Program, Washington State Department of Ecology. Document available at: www.ecy.wa.gov/programs/eap/quality.html

10.3 Rantz, S. E., et al., 1982. "Measurement and computation of streamflow." *U.S.Geological Survey Water-Supply Paper No. 2175*, Vol. 1, Reston, Va.

10.4 Shedd, James R. 2014. Standard Operating Procedure for Measuring and Calculating Discharge. Environmental Assessment Program, Washington State Department of Ecology. Document available at: www.ecy.wa.gov/programs/eap/quality.html

10.5 Holt, Zackary B. 2013. Standard Operating Procedure for Operation of Mechanical Velocity Indicators. Environmental Assessment Program, Washington State Department of Ecology. Document available at: www.ecy.wa.gov/programs/eap/quality.html

Appendix A

Vehicle and Equipment Checklist

Standard Vehicle Equipment:

This equipment should be present anytime the vehicle is used.

- Cell Phone and Charger

Vehicle Folder containing

- Mileage Logs
- Emergency Information
- Fuel Card
- Maps

Safety Equipment

- First Aid Kit
- MUTCD compliant Safety Vests (2)
- CG Approved PFD (1 per person)
- PFD CO_2 Refill
- Road Cones
- Signs
- Hard Hats (2)
- Orange Strobe

Tools / Other

- Mechanic's Toolbox
- Shovel
- Loppers/Clippers/Machete
- Tire Chains
- 2- 150 ft. Ropes
- Spare Key
- Jack, jack handle, adequate spare
- Flashlight
- Lighter
- Electrical Tool Box
- Pens
- Pencils
- Note Paper
- Flagging Tape
- Orange Spray Paint
- Spare Bucket

Standard Flow Gear

Flow Box:

- Weighted Tape for Tape Down
- Tag Line
- 300 ft. Transect Tape
- Line Clamps
- Swoffer Kit w/ Cables and Fans
- Swoffer Meter
- Bridge Depth Sounding Correction Sheets (2/10, 6/10, 8/10's)
- Survey Pins and Hammer
- Flow Tracker
- Wading rod
- Laser Level
- Stadia Rod
- Thermistor
- Spare Batteries for All Devices
- Battery Chargers
- Discharge Measurement Sheets

Station Visit

- Station Visit Data Flash Card
- Multi-meter
- Logger Menu Flow Chart
- Desiccant
- Station Key
- USGS key
- Other Keys as needed
- Appropriate DCP Batteries

ADCP Gear

- ADCP Unit
- PDA (CHECK BATTERY STATUS)
- SD card for PDA
- Tow Ropes and Carabiners
- ADCP Data Sheet

Bridge Gear (If Needed)

- Lead Flow Weights, all sizes
- Bridge Board
- T-bar
- Reel w/ Swoffer Cable

3-Wheel Crane

- Reel
- Crane Assembly

4-Wheel Crane

- HS Meter Box
- Props
- Meter Body w/Fiber-Fin
- Cleaning Soln.
- Lubricant
- Reel
- Crane Assembly/Boom
- Counterweights
- Wheel Chocks

Personal Equipment

- Water
- Food
- Dry Clothes
- Rain Gear
- Sunscreen
- Gloves
- Waders/Hip Boots
- Up to Date Ratings Sheets
- Maps/Station Directions
- Notebook w/ Extra Data Sheets

Decontamination Equipment

- To Be Determined
-

Appendix B

Technical note for operation of the Rickly™ Computing Depth Indicator (CDI)
April, 2009
Freshwater Monitoring Unit

A- Dial Adjustment reel
B- Tens of feet counter
C- Per foot counter with tenths demarcation
D- 8 tenths adjustment scale.

- The dial adjustment reel is for zeroing or adjusting surface/bottom depths as well as identifying 8/10th depth conversions
- The computing depth indicator (CDI) on the reel has a main dial graduated in feet and tenths of a foot. The numbered inner dial shows total depth while the spiraled inner dial shows 8/10th depth.

To zero: After positioning the Columbus weight at the water surface, pull outward on the dial adjustment reel to disengage the gearing inside that connects to the sounding reel drum. Spin the dial adjustment reel until you have reached the Φ symbol on the tens of feet counter. This is just past the number zero on the dial and represents actual zero for surface depth.

The spiraled scale in the middle is useful to determine 8/10th depth. Remember, the distance from the meter assembly to the bottom of the Columbus weight to correct for the actual distance from the bottom. With the current mechanical velocity indicators and the sounding weight hangers the FMU uses this distance is 0.6 tenths of a foot. Measure accordingly if using different hangers or velocity indicators.

To determine 8/10th depth using the spiraled inner dial: Determine the depth at the measurement location. For example suppose the measured depth is 8 feet. Locate the 8 foot mark on the spiraled inner dial and reel in the cable such that the needle aligns over the numeral 8 on the spiraled inner dial. (See below). When you have lined the needle up over the 8 on the spiraled dial the tip of the needle now points at a different value in the outer (per-foot) dial (for the 8 ft. measurement the value indicated is 6.4). Add the additional 0.6 for the Columbus weight to this and you have determined the actual 8/10th depth where the meter will measure the velocity.

Appendix C

Depth from 0.25 foot to 3.0 feet using the 6\10ths method

Depth	6/10ths		Depth	6/10ths
0.25	bottom		1.70	1.62
0.30	bottom		1.75	1.65
0.35	bottom		1.80	1.68
0.40	bottom		1.85	1.71
0.45	bottom		1.90	1.74
0.50	bottom		1.95	1.77
0.55	bottom		2.00	1.80
0.60	bottom		2.05	1.83
0.65	bottom		2.10	1.86
0.70	bottom		2.15	1.89
0.75	bottom		2.20	1.92
0.80	bottom		2.25	1.95
0.85	bottom		2.30	1.98
0.90	bottom		2.35	2.01
0.95	bottom		2.40	2.04
1.00	bottom		2.45	2.07
1.05	bottom		2.50	2.10
1.10	bottom		2.55	2.13
1.15	bottom		2.60	2.16
1.20	bottom		2.65	2.19
1.25	bottom		2.70	2.22
1.30	bottom		2.75	2.25
1.35	bottom		2.80	2.28
1.40	bottom		2.85	2.31
1.45	bottom		2.90	2.34
1.50	1.50		2.95	2.37
1.55	1.53		3.00	2.40
1.60	1.55			
1.65	1.59			

Depths > 2.5 feet using the 8\10ths and 2\10ths method

Depth	8\10	2\10		Depth	8\10	2\10
5.50	5.00	1.70		7.00	6.20	2.00
5.55	5.04	1.71		7.05	6.24	2.01
5.60	5.08	1.72		7.10	6.28	2.02
5.65	5.12	1.73		7.15	6.32	2.03
5.70	5.16	1.74		7.20	6.36	2.04
5.75	5.20	1.75		7.25	6.40	2.05
5.80	5.24	1.76		7.30	6.44	2.06
5.85	5.28	1.77		7.35	6.48	2.07
5.90	5.32	1.78		7.40	6.52	2.08
5.95	5.36	1.79		7.45	6.56	2.09
6.00	5.40	1.80		7.50	6.60	2.10
6.05	5.44	1.81		7.55	6.64	2.11
6.10	5.48	1.82		7.60	6.68	2.12
6.15	5.52	1.83		7.65	6.72	2.13
6.20	5.56	1.84		7.70	6.76	2,14
6.25	5.60	1.85		7.75	6.80	2.15
6.30	5.64	1.86		7.80	6.84	2.16
6.35	5.68	1.87		7.85	6.88	2.17
6.40	5.72	1.88		7.90	6.92	2.18
6.45	5.76	1.89		7.95	6.96	2.19
6.50	5.80	1.90		8.00	7.00	2.20
6.55	5.84	1.91		8.05	7.04	2.21
6.60	5.88	1.92		8.10	7.08	2.22
6.65	5.92	1.93		8.15	7.12	2.23
6.70	5.96	1.94		8.20	7.16	2.24
6.75	6.00	1.95		8.25	7.20	2.25
6.80	6.04	1.96		8.30	7.24	2.26
6.85	6.08	1.97		8.35	7.28	2.27
6.90	6.12	1.98		8.40	7.32	2.28
6.95	6.16	1.99		8.45	7.36	2.29

Depths > 2.5 feet using the 8\10ths and 2\10ths method

Depth	8\10	2\10		Depth	8\10	2\10
2.50	bottom	1.10		4.00	3.80	1.40
2.55	bottom	1.11		4.05	3.84	1.41
2.60	bottom	1.12		4.10	3.88	1.42
2.65	bottom	1.13		4.15	3.92	1.43
2.70	bottom	1.14		4.20	3.96	1.44
2.75	bottom	1.15		4.25	4.00	1.45
2.80	bottom	1.16		4.30	4.04	1.46
2.85	bottom	1.17		4.35	4.08	1.47
2.90	bottom	1.18		4.40	4.12	1.48
2.95	bottom	1.19		4.45	4.16	1.49
3.00	3.00	1.20		4.50	4.20	1.50
3.05	3.04	1.21		4.55	4.24	1.51
3.10	3.08	1.22		4.60	4.28	1.52
3.15	3.12	1.23		4.65	4.32	1.53
3.20	3.16	1.24		4.70	4.36	1.54
3.25	3.20	1.25		4.75	4.40	1.55
3.30	3.24	1.26		4.80	4.44	1.56
3.35	3.28	1.27		4.85	4.48	1.57
3.40	3.32	1.28		4.90	4.52	1.58
3.45	3.36	1.29		4.95	4.56	1.59
3.50	3.40	1.30		5.00	4.60	1.60
3.55	3.44	1.31		5.05	4.64	1.61
3.60	3.48	1.32		5.10	4.68	1.62
3.65	3.52	1.33		5.15	4.72	1.63
3.70	3.56	1.34		5.20	4.76	1.64
3.75	3.60	1.35		5.25	4.80	1.65
3.80	3.64	1.36		5.30	4.84	1.66
3.85	3.68	1.37		5.35	4.88	1.67
3.90	3.72	1.38		5.40	4.92	1.68
3.95	3.76	1.39		5.45	4.96	1.69

Depths > 2.5 feet using the 8\10ths and 2\10ths method

Depth	8\10	2\10		Depth	8\10	2\10
8.50	7.40	2.30		10.35	8.84	2.66
8.55	7.44	2.31		10.40	8.88	2.67
8.60	7.48	2.32		10.45	8.92	2.68
8.65	7.52	2.33		10.50	8.96	2.69
8.70	7.56	2.34		10.55	9.00	2.70
8.75	7.60	2.35		10.60	9.04	2.71
8.80	7.64	2.36		10.65	9.08	2.72
8.85	7.68	2.37		10.70	9.12	2.73
8.90	7.72	2.38		10.75	9.16	2.74
8.95	7.76	2.39		10.80	9.20	2.75
9.00	7.80	2.40		10.85	9.24	2.76
9.05	7.84	2.41		10.90	9.28	2.77
9.15	7.88	2.42		10.95	9.32	2.78
9.20	7.92	2.43		11.00	9.36	2.79
9.25	7.96	2.44		11.05	9.40	2.80
9.30	8.00	2.45		11.10	9.44	2.81
9.35	8.04	2.46		11.15	9.48	2.82
9.40	8.08	2.47		11.20	9.52	2.83
9.45	8.12	2.48		11.25	9.56	2.84
9.50	8.16	2.49		11.30	9.60	2.85
9.55	8.20	2.50		11.35	9.64	2.86
9.60	8.24	2.51		11.40	9.68	2.87
9.65	8.28	2.52		11.45	9.72	2.88
9.70	8.32	2.53		11.50	9.76	2.89
9.75	8.36	2.54		11.55	9.80	2.90
9.80	8.40	2.55		11.60	9.84	2.91
9.85	8.44	2.56		11.65	9.88	2.92
9.90	8.48	2.57		11.70	9.92	2.93
9.95	8.52	2.58		11.75	9.96	2.94
10.00	8.56	2.59		11.80	10.00	2.95
10.05	8.60	2.60		11.85	10.04	2.96
10.10	8.64	2.61		11.90	10.08	2.97
10.15	8.68	2.62		11.95	10.12	2.98
10.20	8.72	2.63		12.00	10.16	2.99
10.25	8.76	2.64		12.05	10.20	3.00
10.30	8.80	2.65		12.10	10.24	3.01

Depths > 2.5 feet using the 8\10ths and 2\10ths method

Depth	8\10	2\10		Depth	8\10	2\10
19.25	15.96	4.44		21.00	17.36	4.79
19.30	16.00	4.45		21.05	17.40	4.80
19.35	16.04	4.46		21.10	17.44	4.81
19.40	16.08	4.47		21.15	17.48	4.82
19.45	16.12	4.48		21.20	17.52	4.83
19.50	16.16	4.49		21.25	17.56	4.84
19.55	16.20	4.50		21.30	17.60	4.85
19.60	16.24	4.51		21.35	17.64	4.86
19.65	16.28	4.52		21.40	17.68	4.87
19.70	16.32	4.53		21.45	17.72	4.88
19.75	16.36	4.54		21.50	17.76	4.89
19.80	16.40	4.55		21.55	17.80	4.90
19.85	16.44	4.56		21.60	17.84	4.91
19.90	16.48	4.57		21.65	17.88	4.92
19.95	16.52	4.58		21.70	17.92	4.93
20.00	16.56	4.59		21.75	17.96	4.94
20.05	16.60	4.60		21.80	18.00	4.95
20.10	16.64	4.61		21.85	18.04	4.96
20.15	16.68	4.62		21.90	18.08	4.97
20.20	16.72	4.63		21.95	18.12	4.98
20.25	16.76	4.64		22.00	18.16	4.99
20.30	16.80	4.65		22.05	18.20	5.00
20.35	16.84	4.66		22.10	18.24	5.01
20.40	16.88	4.67		22.15	18.28	5.02
20.45	16.92	4.68		22.20	18.32	5.03
20.50	16.96	4.69		22.25	18.36	5.04
20.55	17.00	4.70		22.30	18.40	5.05
20.60	17.04	4.71		22.35	18.44	5.06
20.65	17.08	4.72		22.40	18.48	5.07
20.70	17.12	4.73		22.45	18.52	5.08
20.75	17.16	4.74		22.50	18.56	5.09
20.80	17.20	4.75		22.55	18.60	5.10
20.85	17.24	4.76		22.60	18.64	5.11
20.90	17.28	4.77		22.65	18.68	5.12
20.95	17.32	4.78		22.70	18.72	5.13

Depths > 2.5 feet using the 8\10ths and 2\10ths method

Depth	8\10	2\10		Depth	8\10	2\10
12.15	10.28	3.02		13.95	11.72	3.38
12.20	10.32	3.03		14.00	11.76	3.39
12.25	13.36	3.04		14.05	11.80	3.40
12.30	10.40	3.05		14.10	11.84	3.41
12.35	10.44	3.06		14.15	11.88	3.42
12.40	10.48	3.07		14.20	11.92	3.43
12.45	10.52	3.08		14.25	11.96	3.44
12.50	10.56	3.09		14.30	12.00	3.45
12.55	10.60	3.10		14.35	12.04	3.46
12.60	10.64	3.11		14.40	12.08	3.47
12.65	10.68	3.12		14.45	12.12	3.48
12.70	10.72	3.13		14.50	12.16	3.49
12.75	10.76	3.14		14.55	12.20	3.50
12.80	10.80	3.15		14.60	12.24	3.51
12.85	10.84	3.16		14.65	12.28	3.52
12.90	10.88	3.17		14.70	12.32	3.53
12.95	10.92	3.18		14.75	12.36	3.54
13.00	10.96	3.19		14.80	12.40	3.55
13.05	11.00	3.20		14.85	12.44	3.56
13.10	11.04	3.21		14.90	12.48	3.57
13.15	11.08	3.22		14.95	12.52	3.58
13.20	11.12	3.23		15.00	12.56	3.59
13.25	11.16	3.24		15.05	12.60	3.60
13.30	11.20	3.25		15.10	12.64	3.61
13.35	11.24	3.26		15.15	12.68	3.62
13.40	11.28	3.27		15.20	12.72	3.63
13.45	11.32	3.28		15.25	12.76	3.64
13.50	11.36	3.29		15.30	12.80	3.65
13.55	11.40	3.30		15.35	12.84	3.66
13.60	11.44	3.31		15.40	12.88	3.67
13.65	11.48	3.32		15.45	12.92	3.68
13.70	11.52	3.33		15.50	12.96	3.69
13.75	11.56	3.34		15.55	13.00	3.70
13.80	11.60	3.35		15.60	13.04	3.71
13.85	11.64	3.36		15.65	13.08	3.72
13.90	11.68	3.37		15.70	13.12	3.73

Depths > 2.5 feet using the 8\10ths and 2\10ths method

Depth	8\10	2\10	Depth	8\10	2\10
15.75	13.16	3.74	17.50	14.56	4.09
15.80	13.20	3.75	17.55	14.60	4.10
15.85	13.24	3.76	17.60	14.64	4.11
15.90	13.28	3.77	17.65	14.68	4.12
15.95	13.32	3.78	17.70	14.72	4.13
16.00	13.36	3.79	17.75	14.76	4.14
16.05	13.40	3.80	17.80	14.80	4.15
16.10	13.44	3.81	17.85	14.84	4.16
16.15	13.48	3.82	17.90	14.88	4.17
16.20	13.52	3.83	17.95	14.92	4.18
16.25	13.56	3.84	18.00	14.96	4.19
16.30	13.60	3.85	18.05	15.00	4.20
16.35	13.64	3.86	18.10	15.04	4.21
16.40	13.68	3.87	18.15	15.08	4.22
16.45	13.72	3.88	18.20	15.12	4.23
16.50	13.76	3.89	18.25	15.16	4.24
16.55	13.80	3.90	18.30	15.20	4.25
16.60	13.84	3.91	18.35	15.24	4.26
16.65	13.88	3.92	18.40	15.28	4.27
16.70	13.92	3.93	18.45	15.32	4.28
16.75	13.96	3.94	18.50	15.36	4.29
16.80	14.00	3.95	18.55	15.40	4.30
16.85	14.04	3.96	18.60	15.44	4.31
16.90	14.08	3.97	18.65	15.48	4.32
16.95	14.12	3.98	18.70	15.52	4.33
17.00	14.16	3.99	18.75	15.56	4.34
17.05	14.20	4.00	18.80	15.60	4.35
17.10	14.24	4.01	18.85	15.64	4.36
17.15	14.28	4.02	18.90	15.68	4.37
17.20	14.32	4.03	18.95	15.72	4.38
17.25	14.36	4.04	19.00	15.76	4.39
17.30	14.40	4.05	19.05	15.80	4.40
17.35	14.44	4.06	19.10	15.84	4.41
17.40	14.48	4.07	19.15	15.88	4.42
17.45	14.52	4.08	19.20	15.92	4.43

Depths > 2.5 feet using the 8\10ths and 2\10ths method

Depth	8\10	2\10	Depth	8\10	2\10
22.75	18.76	5.14	24.45	20.12	5.48
22.80	18.80	5.15	24.50	20.16	5.49
22.85	18.84	5.16	24.55	20.20	5.50
22.90	18.88	5.17	24.60	20.24	5.51
22.95	18.92	5.18	24.65	20.28	5.52
23.00	18.96	5.19	24.70	20.32	5.53
23.05	19.00	5.20	24.75	20.36	5.54
23.10	19.04	5.21	24.80	20.40	5.55
23.15	19.08	5.22	24.85	20.44	5.56
23.20	19.12	5.23	24.90	20.48	5.57
23.25	19.16	5.24	24.95	20.52	5.58
23.30	19.20	5.25	25.00	20.56	5.59
23.35	19.24	5.26	25.05	20.60	5.60
23.40	19.28	5.27	25.10	20.64	5.61
23.45	19.32	5.28	25.15	20.68	5.62
23.50	19.36	5.29	25.20	20.72	5.63
23.55	19.40	5.30	25.25	20.76	5.64
23.60	19.44	5.31	25.30	20.80	5.65
23.65	19.48	5.32	25.35	20.84	5.66
23.70	19.52	5.33	25.40	20.88	5.67
23.75	19.56	5.34	25.45	20.92	5.68
23.80	19.60	5.35	25.50	20.96	5.69
23.85	19.64	5.36	25.55	21.00	5.70
23.90	19.68	5.37	25.60	21.04	5.71
23.95	19.72	5.38	25.65	21.08	5.72
24.00	19.76	5.39	25.70	21.12	5.73
24.05	19.80	5.40	25.75	21.16	5.74
24.10	19.84	5.41	25.80	21.20	5.75
24.15	19.88	5.42	25.85	21.24	5.76
24.20	19.92	5.43	25.90	21.28	5.77
24.25	19.96	5.44	25.95	21.32	5.78
24.30	20.00	5.45	26.00	21.36	5.79
24.35	20.04	5.46	26.05	21.40	5.80
24.40	20.08	5.47	26.10	21.44	5.81

Appendix D

PRE/POST FIELD EXCURSION CHECKLIST

Before embarking in the field all FMU staff must:

1. Arrange for lodging (if necessary)
2. Update outlook calendar indicating basin location and duration of trip
3. Prepare current rating curve sheets for basin
4. Notify basin contacts (if necessary)
5. Prepare field/float plan form with emergency contact information for specific trip location and duration
6. Be sure to check van packing lists and pre trip vehicle inspection before embarking from the Operations Center

Pre-Trip Vehicle Inspection:

1. Inspect tires for wear/damage on both sides of sidewall. Be sure to check tire pressure as well
2. Check fluid levels (oil, transmission, windshield washer, radiator) before embarking in order to minimize possible breakdowns
3. Make sure that the vehicle safety equipment is packed and that a spare tire, jack and lug wrench are in the van <u>and in working order</u>
4. If any of these listed items are not in satisfactory working order please notify Sarah Barrie or Oliver Brock as soon as possible. Do not embark with a vehicle that is in need of service or may be damaged

Upon return from the field:

End of Day-

If staying at a hotel; notify your contact person each evening that you are finished with field sampling so they do not initiate the rescue protocol. If your trip is only a day trip refer to end of trip protocol.

End of trip-

- Fill vehicle with fuel before returning to the Operations Center
- Upon return to the Operations Center, please unload your gear and measuring equipment
- Don't forget to download Flow-Tracker files to your laptop
- Unload spent batteries and carefully refill them with DI water if needed
- Place spent batteries on appropriate chargers after servicing them
- Load spent desiccant (packs or loose crystals) into appropriate drying ovens and check to be sure that the oven temperatures are set at the pre-determined levels correctly
- Hang any wet ropes in their designated locations to dry
- Store ADCP's in their designated locations, tethered to the wall to prevent falling over
- Clean the interior of the van (if needed) Wash vehicle if possible

Close field/float plan and notify contact person that you are done.

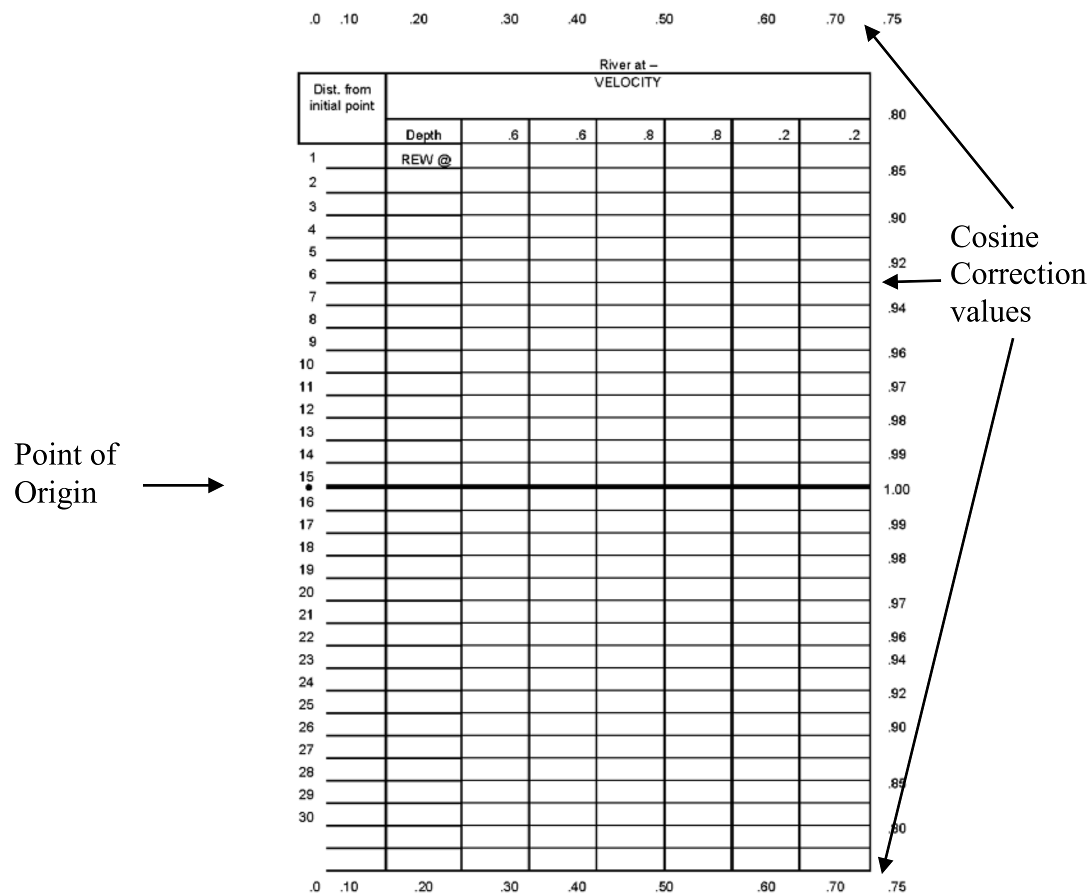
Appendix E

Technical Note for Operation of the Horizontal Angle Calculator

September 2009

Foreword.

When measuring discharge in a stream with flow oblique to the cross section, the velocity of the current normal or perpendicular to the cross section must be determined to calculate discharge correctly. To accomplish this, a horizontal angle calculator has been included on the back side of the field note sheet in order to determine the correction factor needed to compensate for the angle.



How to use the calculator.

The point of origin signified by the dot on the left side of the back of measurement note sheet, opposite of the thick black line extending across the sheet acts as a type of hinge or pivot point in which to move and orient the sheet to accurately determine the cosine value. Place the point of origin at the edge of the bridge (railing or guardrail) and pivot it to sit parallel to the orientation of flow (or your measuring instrument if at the water surface). Placing a finger on the point of origin rotate the note sheets right edge to sit parallel to flow and instrument. Looking directly down over the sheet you will notice “the tag line or bridge rail will intersect the value of cosine α on the top, bottom or right edge of the note sheet” (Rantz,et.al, 1982). Use this value to correct the velocity measurement taken at this location. The correction is as follows:

V*Cos α = (corrected velocity)

Where:
V – measured velocity
Cos α – cosine of the angle determined