Discharge Measurement Standard Operating Procedure

Water Quality Control Division • Watershed Section

1.0 Introduction

Discharge or flow measurements are an integral facet of a monitoring and assessment program and are essential for pollutant loading calculations, dilution factors, and discharge rates.

This Standard Operating Procedure (SOP) will address the standardized, instantaneous measurement of flow in open channel waters in Colorado. Open channels are natural and man-made structures though which water flows with a free surface. Examples of such structures include streams, rivers, ditches, canals, and water conveyance flumes. For purposes of this procedure, open channel will simply be referred to as streams.

This procedure will further focus on the pairing of a Marsh-McBirney Model 2000 Flo-Mate portable flowmeter and a USGS[1] top setting wading rod.

2.0 Equipment

The following equipment and supplies will be necessary to measure flow.

- Marsh-McBirney Model 2000 Flo-Mate portable flowmeter with (2) D-cell batteries, sensor cable, and shoulder strap.
- USGS top setting wading rod
- Measuring tape – steel tape and 100-200 ft. length recommended
- 9" galvanized metal stakes or nails
- Clipboard
- Pencil(s)
- Discharge Summary field sheet(s)

2.1 Marsh-McBirney Model 2000 Flo-Mate

The Flo-Mate is a portable flowmeter designed for use in both the field and the laboratory. The unit uses an electromagnetic sensor to measure the velocity in a conductive liquid, such as water. The velocity is in one direction and displayed on the digital display of the Flo-Mate as feet per second (ft/s) or meters per second (m/s).

Figure 1. Flo-Mate Flowmeter

2.2 USGS Top Setting Wading Rod

The top setting wading rod is a model specifically developed to simplify the task of the sampler to gauge flow in small streams or rivers that are wadeable. This ensures the stable placement of the rod on the stream bed and allows the depth of the stream to be measured.

[1] USGS – United States Geological Survey

The wading rods owned and operated by the Water Quality Control Division (division) are graduated to 0.1 feet. Each single mark represents 0.1 foot, each double mark represents 0.5 foot, and each triple mark represents 1.0 foot. See Figure 2.

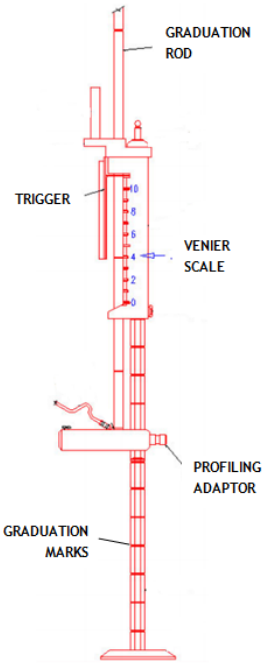

Figure 2. USGS Top Setting Wading Rod Components

3.0 Flow Measurement Procedure

The procedures in this section describe the process for determining flow in a stream by measuring a cross-sectional area using the wading rod and tape line (tape measure) and measuring velocity using the Marsh-McBirney Model 2000 Flo-Mate portable flowmeter.

All length measurements are in feet.

Equipment Connection

- Connect the Flo-Mate sensor cable to the profiling adaptor at the base of the wading rod. See Figure 3. Tighten the screw to secure the sensor to the adaptor.

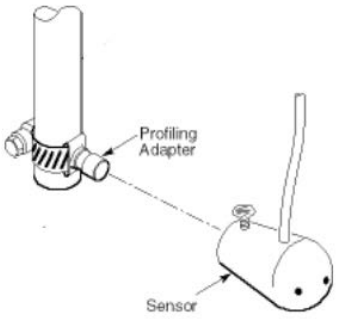

Figure 3. Illustration of Sensor Mount

- Turn on the Flo-Mate unit by pressing the "ON/C" button. Allow the display output sequence to run until the velocity output display is shown.

- If necessary, set the units of measurement to **ft/s** by pressing down on the "ON/C" and "OFF" buttons simultaneously to cycle between available units. The unit of measurement will be displayed on the output display screen as "FT/S".

- The fluid dynamics around the sensor electrodes may cause the readings to fluctuate. To stabilize the readings, the output to the display may be dampened by Fixed Point Averaging (FTA). Fixed point averaging is an average of velocities over a fixed period of time. Press the up ↑ and down ↓ arrow keys simultaneously to alternate between the FPA and other displays.

  The display will show the letters "FPA" when you first switch to the FPA display. If the FPA is set to 10 seconds, then the display updates once every 10 seconds. To get more stabilized readings then decrease the FPA display refresh rate – which will result in less frequent but more stabilized readings.

Selection of Measurement Location

- Identify a measurement cross-section transect in a straight run or calm riffle where flow is laminar and generally free from large cobble, emergent or submergent aquatic vegetation, and protruding obstructions. Do not place a cross-section through a pool.

  Additional Tips:

  - Use a channel width that is as free from flow disturbances as possible, such as instream or bank obstructions (i.e. log fall and boulders).
  - Avoid areas with contributing or outgoing side streams.
  - Avoid cross-sections with eddies, vortices, backflow or swirls.

  The sampler may adjust the channel by removing cobbles that interrupt flow or to temporarily make the channel deep enough to measure.

Setting the Tape Line

- Stretch the tape measure across the stream and secure each end using metal stakes or nails driven into the bank.

- Ensure the tape is perpendicular to the flow to be measured and is not angled along the flow.

- Ensure the tape is taut, level and is at least one foot above the waterline so the tape does not touch the water. If necessary, move the tape ends to higher ground on each bank.

Establish Wetted Width

- Measure the stream's wetted width across the cross-section transect. Record the wetted width on the Discharge Summary field sheet.

- Divide this width by a minimum of 10 sections to establish distance between measurements points along the cross-section transect. The distance from one point to the next is typically referred to as a "window" or segment. Take no less than 10 measurements per transect. If the channel width is extensive it is recommended to increase the number of measurement points beyond 10 so the segments are made smaller.

  Example: If the wetted width is 20 feet and the minimum of 10 segments is selected, then the distance between segments is 2 feet.

Velocity and Depth Measurements

- Begin on the stream bank where the tape starts at zero feet. This can be left or right bank. Record the starting bank (left bank=LB or right bank=RB) on Discharge Summary field sheet.

- Standing downstream of the tape line, place the base of the wading rod at the waterline with the torpedo end of the sensor pointing in the upstream direction. The only measurement here will be the distance from the initial point (i.e. the zero mark on the tape) to this first measurement point. The width, depth, and velocity for this point will be documented as zeroes. See Figure 4.

Location (Initial & end pts)	Distance from initial pt	Width (ft)	Depth (ft)	Velocity (ft/s)	Area (ft^2)	Q (ft^3/s)
LB	5 ft.	0	0	0		

Figure 4. Example of First Waterline Measurement

- Move the wading rod to the next point along the tape line. Place the base of the wading rod flush to the stream bed.

- Note the depth at this point by observing the graduation marks on the bottom half (or depth gauge) of the wading rod. Each single mark represents 0.1 foot, each double mark represents 0.5 foot, and each triple mark represents 1.0 foot. Record the depth on the Discharge Summary field sheet. See Figure 5.

- The top setting wading rod automatically places the sensor at 60% of the depth from the surface. This is the standard velocity measurement for depths of 2.5 ft. or less.

  To re-position the sensor at 60% depth, depress the trigger near the top of the unit and slide the suspension (sliding) rod until the graduation mark on the sliding rod is in line with the graduation mark for the recorded depth on the vernier scale. See Figure 2.

  Where the depth is greater than 2.5 ft., a velocity measurement must be taken at 80% and 20% from the surface and averaged for that segment of the transect. This is done by adjusting the graduation rod to **double** the depth reading for the 80% velocity reading and by **halving** the depth reading for the 20% reading. If necessary, record both velocity readings side by side in the space provided on the Discharge Summary field sheet.

Example: 0.4 / 0.37

- Allow the velocity readout on the Flo-Mate to cycle through 1-2 FPA periods, lasting approximately 10 seconds each, in order to arrive at a stabilized reading. See the *Equipment Connection* section.

- Record the distance from initial, the width from the first point to the second point, and the velocity (or average velocity). See Figure 5.

Location (Initial & end pts)	Distance from initial pt	Width (ft)	Depth (ft)	Velocity (ft/s)	Area (ft^2)	Q (ft^3/s)
LB	5 ft.	0	0	0		
	7 ft.	2	0.6	0.47		

Figure 5. Example of Second Point Measurement

- Continue the procedure at the remaining points along the tape line. Take the last velocity measurement as close to the opposite bank waterline as possible.

- At the last measurement point, which will be the last row of measurements on the Discharge Summary field sheet, enter the tape line measurements (distance from initial and width) but enter depth as zero and velocity as zero. Note the opposite bank on the Discharge Summary field sheet as LB or RB. See Figure 6.

Location (Initial & end pts)	Distance from initial pt	Width (ft)	Depth (ft)	Velocity (ft/s)	Area (ft^2)	Q (ft^3/s)
LB	5 ft.	0	0	0		
	7 ft.	2	0.6	0.47		
	9 ft	2	0.8	0.5		
	11 ft	2	0.8	0.68		
	13 ft	2	0.9	0.26		
	15 ft	2	1.3	1.3		
	17 ft	2	1.2	1.5		
	19 ft	2	1.2	1.4		
	21 ft	2	0.7	0.9		
	23 ft	2	0.7	0.4		
RB	25 ft	2	0	0		

Figure 6. Example of All Measurements

- Remove both stakes and reel in the tape line.

4.0 Discharge Calculations

Follow the steps below to calculate the total flow for a cross-section. See Figure 7.

- Calculate the area (ft^2) of each segment (row): $W * D = A^x$
- Calculate the flow (ft^3/s) of each segment: $A^x * V^{(avg)} = Q^x$
- Sum the flow of the segments for the total flow (ft^3/s): $Q^1 + Q^2 + Q^3 + \ldots + Q^x = Q_{tot}$

W = measured width of segment; D = measured depth of segment; A = calculated area of segment; V = measured velocity of segment; and Q = calculated flow of segment

Location (Initial & end pts)	Distance from initial pt	Width (ft)	Depth (ft)	Velocity (ft/s)	Area (ft^2)	Q (ft^3/s)
LB	5 ft.	0	0	0	0	0
	7 ft.	2	0.6	0.47	1.2	0.564
	9 ft	2	0.8	0.5	1.6	0.8
	11 ft	2	0.8	0.68	1.6	1.088
	13 ft	2	0.9	0.26	1.8	0.468
	15 ft	2	1.3	1.3	2.6	3.38
	17 ft	2	1.2	1.5	2.4	3.6
	19 ft	2	1.2	1.4	2.4	3.36
	21 ft	2	0.7	0.9	1.4	1.26
	23 ft	2	0.7	0.4	1.4	0.56
RB	25 ft	2	0	0	0	0
Totals						15.08

Figure 7. Calculating Total Flow

You may also reference a similar USGS procedure at the following webpage:

http://water.usgs.gov/edu/streamflow2.html

5.0 Document Version

2.0_120716

6.0 Approval Signatures

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12/7/2016

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