EPA/XXX/X-XX/XXX
April 2001

ENVIRONMENTAL MONITORING AND ASSESSMENT PROGRAM-SURFACE WATERS:

WESTERN PILOT STUDY
FIELD OPERATIONS MANUAL FOR WADEABLE STREAMS

Edited by

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SECTION 6
STREAM DISCHARGE

by
Philip R. Kaufmann[1]

Stream discharge is equal to the product of the mean current velocity and vertical cross sectional area of flowing water. Discharge measurements are critical for assessing trends in streamwater acidity and other characteristics that are very sensitive to streamflow differences. Discharge should be measured at a suitable location within the sample reach that is as close as possible to the location where chemical samples are collected (typically the X-site; see Section 5), so that these data correspond.

Discharge is usually determined after collecting water chemistry samples. Although discharge is part of the physical habitat indicator (Section 7), it is presented as a separate section because the "biomorphs" measure it while the "geomorphs" conduct the other habitat characterization procedures (see Section 2).

No single method for measuring discharge is applicable to all types of stream channels. The preferred procedure for obtaining discharge data is based on "velocity-area" methods (e.g., Rantz and others, 1982; Linsley et al., 1982). For streams that are too small or too shallow to use the equipment required for the velocity-area procedure, two alternative procedures are presented. One procedure is based on timing the filling of a volume of water in a calibrated bucket. The second procedure is based on timing the movement of a neutrally buoyant object (e.g., an orange or a small rubber ball) through a measured length of the channel, after measuring one or more cross-sectional depth profiles within that length.

The procedures and activities presented here for the EMAP-WP are unchanged from those previously published for EMAP-SW (Kaufmann, 1998). Beginning in 2001, the

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field data forms have been modified to allow field crews to record a calculated value for discharge, and to record data for more than 20 intervals (using an additional form).

6.1 VELOCITY-AREA PROCEDURE

Because velocity and depth typically vary greatly across a stream, accuracy in field measurements is achieved by measuring the mean velocity and flow cross-sectional area of many increments across a channel (Figure 6-1). Each increment gives a subtotal of the stream discharge, and the whole is calculated as the sum of these parts. Discharge measurements are made **at only one carefully chosen channel cross section within the sampling reach**. It is important to choose a channel cross section that is as much like a canal as possible. A glide area with a "U" shaped channel cross section that is free of obstructions provides the best conditions for measuring discharge by the velocity-area method. You may remove rocks and other obstructions to improve the cross-section before any measurements are made. However, because removing obstacles from one part of a cross-section affects adjacent water velocities, you must not change the cross-section once you commence collecting the set of velocity and depth measurements.

The procedure for obtaining depth and velocity measurements is outlined in Table 6-1. Record the data from each measurement on the Stream Discharge Form as shown in Figure 6-2. To reduce redundancy and to conserve space, Figure 6-2 shows measurement data recorded for all procedures. In the field, data will be recorded using only one of the available procedures.

6.2 TIMED FILLING PROCEDURE

In channels too "small" for the velocity-area method, discharge can sometimes be determined directly by measuring the time it takes to fill a container of known volume. “Small” is defined as a channel so shallow that the current velocity probe cannot be placed in the water, or where the channel is broken up and irregular due to rocks and debris, and a suitable cross-section for using the velocity area procedure is not available. This can be an extremely precise and accurate method, but requires a natural or constructed spillway of free-falling water. If obtaining data by this procedure will result in a lot of channel disturbance or stir up a lot of sediment, wait until after all biological and chemical measurements and sampling activities have been completed.

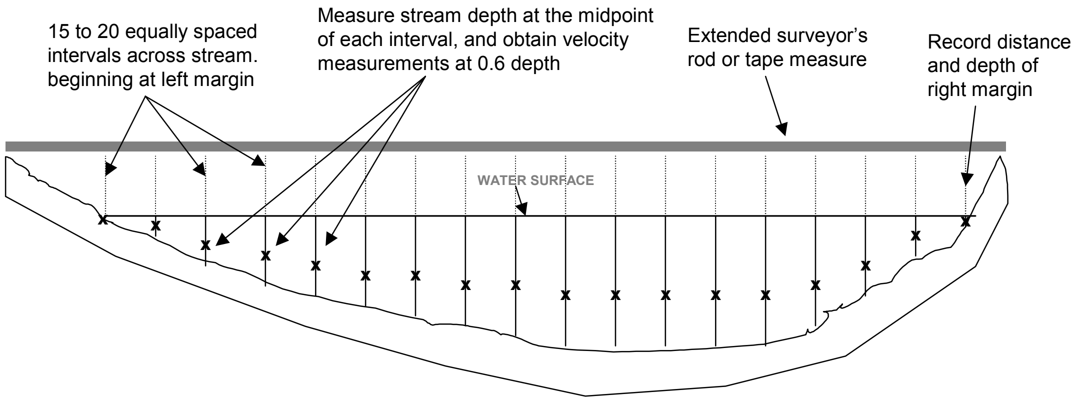

Figure 6-1. Layout of channel cross-section for obtaining discharge data by the velocity-area procedure.

Choose a cross-section of the stream that contains one or more natural spillways or plunges that collectively include the entire stream flow. A temporary spillway can also be constructed using a portable V-notch weir, plastic sheeting, or other materials that are available onsite. Choose a location within the sampling reach that is narrow and easy to block when using a portable weir. Position the weir in the channel so that the entire flow of the stream is completely rerouted through its notch (Figure 6-3). Impound the flow with the weir, making sure that water is not flowing beneath or around the side of the weir. Use mud or stones and plastic sheeting to get a good waterproof seal. The notch must be high enough to create a small spillway as water flows over its sharp crest.

TABLE 6-1. VELOCITY-AREA PROCEDURE FOR DETERMINING STREAM DISCHARGE

1. Locate a cross-section of the stream channel for discharge determination that has most of the following qualities (based on Rantz and others, 1982):

   - Segment of stream above and below cross-section is straight
   - Depths mostly greater than 15 centimeters, and velocities mostly greater than 0.15 meters/second. Do not measure discharge in a pool.
   - "U" shaped, with a uniform streambed free of large boulders, woody debris or brush, and dense aquatic vegetation.
   - Flow is relatively uniform, with no eddies, backwaters, or excessive turbulence.

2. Lay the surveyor's rod (or stretch a meter tape) across the stream perpendicular to its flow, with the "zero" end of the rod or tape on the left bank, as viewed when looking downstream. Leave the tape tightly suspended across the stream, approximately one foot above water level.

3. Attach the velocity meter probe to the calibrated wading rod. Check to ensure the meter is functioning properly and the correct calibration value is displayed. Calibrate (or check the calibration) the velocity meter and probe as directed in the meter's operating manual. Place an "X" in the "VELOCITY AREA" box in the "STREAM DISCHARGE" section of the Field Measurement Form.

4. Divide the total wetted stream width into 15 to 20 equal-sized intervals. To determine interval width, divide the width by 20 and round up to a convenient number. Intervals should not be less than 10 cm wide, even if this results in less than 15 intervals. The first interval is located at the left margin of the stream (left when looking downstream), and the last interval is located at the right margin of the stream (right when looking downstream).

5. Stand downstream of the rod or tape and to the side of the first interval point (closest to the left bank if looking downstream).

6. Place the wading rod in the stream at the interval point and adjust the probe or propeller so that it is at the water surface. Record the distance from the left bank (in centimeters) and the depth indicated on the wading rod (in centimeters) on the Field Measurement Form.

   Note for the first interval, distance equals 0 cm, and in many cases depth may also equal 0 cm. For the last interval, distance will equal the wetted width (in cm) and depth may again equal 0 cm.

7. Stand downstream of the probe or propeller to avoid disrupting the stream flow. Adjust the position of the probe on the wading rod so it is at 0.6 of the measured depth below the surface of the water. Face the probe upstream at a right angle to the cross-section, even if local flow eddies hit at oblique angles to the cross-section.

(continued)

TABLE 6-1 (continued)

8. Wait 20 seconds to allow the meter to equilibrate, then measure the velocity. Record the value on the Field Measurement Form. Note for the first interval, velocity may equal 0 m/s because depth will equal 0 cm.

   - For the electromagnetic current meter (e.g., Marsh-McBirney), use the lowest time constant scale setting on the meter that provides stable readings.
   - For the impeller-type meter (e.g., Swoffer 2100), set the control knob at the mid-position of "DISPLAY AVERAGING". Press "RESET" then "START" and proceed with the measurements.

9. Move to the next interval point and repeat Steps 6 through 8. Continue until depth and velocity measurements have been recorded for all intervals. Note for the last interval (right margin), depth and velocity values may equal 0.

10. At the last interval (right margin), record a “Z” flag on the field form to denote the last interval sampled

STREAM DISCHARGE FORM

Reviewed by (Initials): [initials]

SITE ID: WXXP99-9999 DATE: 07/01/2001

☐ Velocity Area

Distance Units ☐ ft ☒ cm | Depth Units ☐ ft ☒ cm | Velocity Units ☐ ft/s XX.X ☒ m/s X.XX

(Final measurement should be left bank.)

	Dist. from Bank (cm)	Depth	Velocity	Flag
1	0	0	0	F1
2	10	6	0.30	
3	20	6	0.59	
4	30	12	0.37	
5	40	15	0.34	
6	50	15	0.34	
7	60	24	0.43	
8	70	27	0.37	
9	80	40	0.43	
10	90	40	0.37	
11	100	46	0.30	
12	110	37	0.27	
13	120	30	0.27	
14	130	24	0.30	
15	140	15	0.30	
16	150	0	0	Z
17				
18				
19				
20				

☐ Timed Filling

Repeat	Volume (L)	Time (s)	Flag
1	4.0	10.5	F1
2	4.0	11.2	
3	4.0	10.8	
4	4.0	11.0	
5	4.0	10.7	

☐ Neutral Bouyant Object

	Float 1	Float 2	Float 3
Float Dist. ☐ ft ☒ m	5	5	5
Float Time (s)	10	10	9
Flag	F1		

Cross Sections on Float Reach

	Upper Section	Middle Section	Lower Section
Width ☐ ft ☒ m	2.5	1.8	1.5
Depth 1 (cm)	10	5	12
Depth 2 (cm)	9	15	20
Depth 3 (cm)	9	20	15
Depth 4 (cm)	8	7	6
Depth 5 (cm)	5	2	5

If discharge is determined directly in field, record value here: Q = 0.12 ☐ cfs ☒ m³/s

Flag	Comments
F1	MEASUREMENTS FOR ALL 4 DISCHARGE PROCEDURES ARE SHOWN
Z	LAST INTERVAL MEASURED

Flag Codes: K = No measurement or observation made; U = Suspect measurement or observation; Q = Unacceptable QC check associated with measurement; Z = Last station measured (if not Station 20); F1, F2, etc. = Miscellaneous flags assigned by each field crew. Explain all flags in comments section.

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03/26/2001 2001 Stream Discharge

Figure 6-2. Stream Discharge Form, showing data recorded for all discharge measurement procedures.

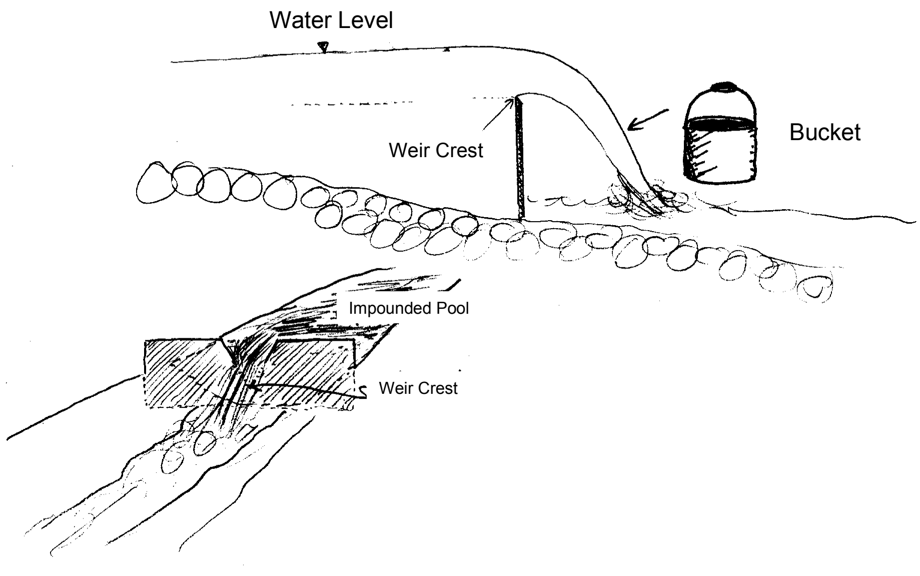

Figure 6-3. Use of a portable weir in conjunction with a calibrated bucket to obtain an estimate of stream discharge.

The timed filling procedure is presented in Table 6-2. Make sure that the entire flow of the spillway is going into the bucket. Record the time it takes to fill a measured volume on the Discharge Measurement Form as shown in Figure 6-2. Repeat the procedure 5 times. If the cross-section contains multiple spillways, you will need to do separate determinations for each spillway. If so, clearly indicate which time and volume data replicates should be averaged together for each spillway; use additional field measurement forms if necessary.

TABLE 6-2. TIMED FILLING PROCEDURE FOR DETERMINING STREAM DISCHARGE

NOTE: If measuring discharge by this procedure will result in significant channel disturbance or will stir up sediment, delay determining discharge until all biological and chemical measurement and sampling activities have been completed.

1. Choose a cross-section that contains one or more natural spillways or plunges, or construct a temporary one using on-site materials, or install a portable weir using a plastic sheet and on-site materials.

2. Place an “X” in the “TIMED FILLING” box in the stream discharge section of the Field Measurement Form.

3. Position a calibrated bucket or other container beneath the spillway to capture the entire flow. Use a stopwatch to determine the time required to collect a known volume of water. Record the volume collected (in liters) and the time required (in seconds) on the Field Measurement Form.

4. Repeat Step 3 a total of 5 times for each spillway that occurs in the cross section. If there is more than one spillway in a cross-section, you must use the timed-filling approach on all of them. Additional spillways may require additional data forms

6.3 NEUTRALLY-BUOYANT OBJECT PROCEDURE

In very small, shallow streams with no waterfalls, where the standard velocity-area or timed-filling methods cannot be applied, the neutrally buoyant object method may be the only way to obtain an estimate of discharge. The required pieces of information are the mean flow velocity in the channel and the cross-sectional area of the flow. The mean velocity is estimated by measuring the time it takes for a neutrally buoyant object to flow through a measured length of the channel. The channel cross-sectional area is determined from a series of depth measurements along one or more channel cross-sections. Since the discharge is the product of mean velocity and channel cross-sectional area, this method is conceptually very similar to the standard velocity-area method.

The neutrally buoyant object procedure is described in Table 6-3. Examples of suitable objects include oranges, small sponge rubber balls, or small sticks. The object must float, but very low in the water. It should also be small enough that it does not “run aground” or drag bottom. Choose a stream segment that is roughly uniform in cross-section, and that is long enough to require 10 to 30 seconds for an object to float through it. Select one to three cross-sections to represent the channel dimensions within the segment, depending on the variability of width and/or depth. Determine the stream depth at 5 equally spaced points at each cross-section. Three separate times, measure the time required for the object to pass through the segment that includes all of the selected cross-sections. Record data on the Field Measurement Form as shown in Figure 6-2.

6.4 EQUIPMENT AND SUPPLIES

Figure 6-4 shows the list of equipment and supplies necessary to measure stream discharge. This checklist is similar to the checklist presented in Appendix A, which is used at the base location (Section 3) to ensure that all of the required equipment is brought to the stream. Use this checklist to ensure that equipment and supplies are organized and available at the stream site in order to conduct the activities efficiently.

TABLE 6-3. NEUTRALLY BUOYANT OBJECT PROCEDURE FOR DETERMINING STREAM DISCHARGE

1. Place an “X” in the “NEUTRALLY BUOYANT OBJECT” box on the Field Measurement Form.

2. Select a segment of the sampling reach that is deep enough to float the object freely, and long enough that it will take between 10 and 30 seconds for the object to travel. Record the length of the segment in the “FLOAT DISTANCE” field of the Field Measurement Form.

3. If the channel width and/or depth change substantially within the segment, measure widths and depths at three cross-sections, one near the upstream end of the segment, a second near the middle of the segment, and a third near the downstream end of the segment.

   If there is little change in channel width and/or depth, obtain depths from a single “typical” cross-section within the segment.

4. At each cross section, measure the wetted width (m) using a surveyor’s rod or tape measure, and record on the Field Measurement Form. Measure the stream depth using a wading rod or meter stick at points approximately equal to the following proportions of the total width: 0.1, 0.3, 0.5, 0.7, and 0.9. Record the depths (not the distances) in centimeters on the Field Measurement Form.

5. Repeat Step 4 for the remaining cross-sections.

6. Use a stopwatch to determine the time required for the object to travel through the segment. Record the time in the “FLOAT TIME” field of the Field Measurement Form.

7. Repeat Step 6 two more times. The float distance may differ somewhat for the three trials

EQUIPMENT AND SUPPLIES FOR STREAM DISCHARGE

QTY.	ITEM	
1	Surveyor's telescoping leveling rod	
1	50-m fiberglass measuring tape and reel	
1	Current velocity meter, probe, and operating manual	
1	Top-set wading rod (metric scale) for use with current velocity meter	
1	Portable Weir with 60° "V" notch (optional)	
1	Plastic sheeting to use with weir	
1	Plastic bucket (or similar container) with volume graduations	
1	Stopwatch	
1	Neutrally buoyant object (e.g., orange, small rubber ball, stick)	
1	Covered clipboard	
	Soft (#2) lead pencils	
	Field Measurement Forms (1 per stream plus extras if needed for timed filling procedure)	
1 copy	Field operations and methods manual	
1 set	Laminated sheets of procedure tables and/or quick reference guides for stream discharge	

Figure 6-4. Equipment and supply checklist for stream discharge.

6.5 LITERATURE CITED

Kaufmann, P.R. 1998. Stream Discharge. pp. 67-76 **IN**: J.M. Lazorchak, D.J. Klemm, and D.V. Peck (Eds.). *Environmental Monitoring and Assessment Program-Surface Waters: Field Operations and Methods for Measuring the Ecological Condition of Wadeable Streams*. EPA/620/R-94/004F. U.S. Environmental Protection Agency, Washington, D.C.

Linsley, R.K., M.A. Kohler, and J.L.H. Paulhus. 1982. *Hydrology for Engineers*. McGraw-Hill Book Co. New York.

Rantz, S.E. and others. 1982. *Measurement and Computation of Streamflow: Volume 1. Measurement of Stage and Discharge.* U.S. Geological Survey Water-Supply Paper 2175.

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