

Washington State Department of Ecology

Environmental Assessment Program

Water Quality Studies Unit

Standard Operating Procedure for Estimating Streamflow

Version 1.0

Author - Lawrence Sullivan, Water Quality Studies Unit

Date -

Reviewer – Karol Erickson, Water Quality Studies Unit Supervisor

Date -

QA Approval - William R. Kammin, Ecology Quality Assurance Officer

Date -

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*Although Ecology follows the SOP in most instances, there may be instances in which Ecology uses an alternative methodology, procedure, or process.*



## Environmental Assessment Program

### Standard Operating Procedure for Estimating Streamflow

#### **1.0 Purpose and Scope**

- 1.1. This document is the Environmental Assessment Program (EAP), Water Quality Studies Unit Standard Operating Procedure (SOP) for Estimating Streamflow.

#### **2.0 Applicability**

- 2.1. This document should be used for all streamflow measurements.

#### **3.0 Definitions**

- 3.1 Fixed Point Averaging (FPA) - An average of velocities over a fixed period of time.
- 3.2 Reference Point (RP) - A fixed point or datum on the bridge or other structure from which a measurement can be made to the surface of the water under all flow conditions.
- 3.3 Staff Gage - A graduated measuring device securely fixed to a permanent structure in the streambed from which river stage height can be read directly to the 100th of a foot.

#### **4.0 Personnel Qualifications/Responsibilities**

- 4.1. Trained in safety procedures for work in streams.

#### **5.0 Equipment, Reagents, and Supplies**

- 5.1. Flow/current meter
- 5.2. Wading Rod
- 5.3. Field notebook
- 5.4. Measuring Tape (100 ft or long enough to span the width of the stream)
- 5.5. 2 Stakes
- 5.6. Life Vest
- 5.7. Chest Waders
- 5.8. Staff gage (if used) and equipment for installation

## **6.0 Summary of Procedure**

### **6.1 Measuring Depth and Velocity of a Stream Cross Section**

#### **6.1.1 Selecting a Representative Cross Section to Measure Discharge**

6.1.1.1. The selection of a suitable stream cross section for measuring discharge is very important and cannot be over emphasized. Site selection is, in most cases, the most important factor in developing accurate flow information. The limitations of a poor cross section can not be overcome by the ability of the individual taking the measurement. Use the following criteria for deciding which cross section to use:

6.1.1.1.1. The stream reach should be relatively straight and uniform for a long enough distance to provide uniform flow through the measuring section (preferably 200-300 feet upstream and downstream of the measurement site). The site should be free from excessive turbulence.

6.1.1.1.2. The stream channel should be free from vegetative growth and be relatively stable (free from major seasonal scouring or deposition of bed material).

6.1.1.1.3. The stream bed should be relatively uniform with only minor irregularities (no large cobble or boulders).

6.1.1.1.4. During low flow conditions (typically August-October), the stream channel should be confined to a single course.

6.1.1.1.5. The stream bank should be stable and able to contain the maximum stream discharge (floods).

6.1.1.2. If these criteria are met, the cross section should be relatively stable under most conditions and the streamflow should be uniformly distributed across the cross section. It is, however, unrealistic to assume all stream cross sections will meet all of these criteria. Therefore, complete and accurate field notes describing the cross section and noting the exceptions to these criteria are vital when determining the relative accuracy of the discharge measurement.

#### **6.1.2 Site preparation**

6.1.2. 1. Ideally, the cross section to be measured will meet all of the selection criteria, however, some will not. If the cross section selected is compromised by excessive aquatic plants, the presence of woody debris, or has minor irregularities in the stream bed (rocks and manageable boulders), an attempt should be made to minimize their impact on flow measurements. This may require physical removal of interference and minor alterations of the streambed. After the cross section has been cleared, inspect the stream banks to ensure they are confining enough to provide a distinct edge. If the streambed has a gentle sloping bank, use rocks or other available material to make a defined stream edge. Care should be taken to ensure that minimal water bypasses these structures. Do not change the section after starting a measurement. Modifying the cross section after velocity measurements have begun may alter the flow characteristics and therefore the accuracy of your measurement.

- 6.1.3 Dividing the stream channel into segments
  - 6.1.3.1. Approximate stream discharge by multiplying the average velocity by the cross sectional area of the stream. Because most stream velocity and bottom contours vary as you proceed across the stream channel, the cross section is divided into manageable segments.
  - 6.1.3.2. Stretch a measuring tape (tagline) across the stream perpendicular to the cross section to be measured.
  - 6.1.3.3. Anchor the tape to the surrounding vegetation/debris or to stakes driven in for attachment points.
  - 6.1.3.4. Note width of the stream channel and divide into conveniently measurable segments. The total number of segments should be large enough to ensure no more than 10% of the total flow is contained in any one segment (preferably 5%). For example, if the stream is relatively uniform with a width of 12 feet, the distance between segment of one or 0.5 foot would be adequate. If, however, the flow is unequally distributed, measuring points should be closer together where velocity or bottom irregularities are the greatest. In this case the distance would be one foot for uniform segments and 0.5 foot near the area of greatest variability.
- 6.1.4 Measuring stream velocity of the stream segments
  - 6.1.4.1. Stream velocities not only vary horizontally as one proceeds across the stream cross section, but vertically as well. Currently two methods are used to address vertical variability within a segment, one applies with stream depths less than 2.0 feet and the other for streams over 2.0 feet. For stream segments under 2.0 feet in depth, the velocity is measured at sixth-tenths of the depth (six-tenths method). For streams with depths greater than 2.0 feet, the velocity is measured at two-tenth and eight-tenths of the depth and the results are averaged (two-tenths/eight-tenths method).
- 6.1.5 Measuring Water Depths and Velocities
  - 6.1.5.1 Measuring Water Depths and Velocities by Wading
    - 6.1.5.1.1. Record site information in the field notes.
    - 6.1.5.1.2. Measure and record stage gage readings or tape down (if available).
    - 6.1.5.1.3. Select a suitable stream cross section for measurement.
    - 6.1.5.1.4. Determine which safety requirements are warranted based on in-stream conditions. Do not proceed if the conditions are not deemed safe by the field crew.
    - 6.1.5.1.5. Prepare cross section by removing debris, rocks and confining stream edges.
    - 6.1.5.1.6. Stretch measuring tape across the stream channel perpendicular to streamflow and note total stream width.
    - 6.1.5.1.7. Divide stream width into segments (15-25) with no more than 10 percent (preferably 5%) in any one.

- 6.1.5.1.8. Turn current meter on and make sure settings are correct (See Appendix A for current meter instructions).
- 6.1.5.1.9. Measure the depth of the first segment by reading the water level on the wading rod.
- 6.1.5.1.10. Adjust the wading rod to the proper depth.
- 6.1.5.1.11. For < 2.0 feet total depth, use the scale on the wading rod to place the meter sensor at 6 tenths depth.
- 6.1.5.1.12. For > 2.0 feet total depth (if vertical stratification is abnormal), adjust the wading rod so that the meter sensor is at half the total depth for the 8 tenths depth and double the total depth for 2 tenths depth.
- 6.1.5.1.13. Record the velocity in the proper column in field notes.
- 6.1.5.1.14. Proceed across the stream, repeating steps 9-13 at each segment.
- 6.1.5.1.15. Measure and record the stage height (if available).

## 6.1.5.2 Measuring Water Depths and Velocities from a Bridge

- 6.1.5.2.1. Refer to the Stream Hydrology Unit's SOP for Measuring Discharge from a Bridge.

## 6.1.5.3 Measuring Water Depths and Velocities from a Boat.

- 6.1.5.3.1. Refer to the Stream Hydrology Unit's SOP for Measuring Discharge from a Boat.

## 6.1.6 Calculating Stream Discharge

- 6.1.6.1. Calculate discharge as a summation of discharge in partial areas. Compute discharge in a partial area using the equation:

$$q_x = v_x d_x (b_{x+1} - b_{x-1}) / 2$$

where:  $b_{(x+1)}$  = distance from the initial point to the preceding point (feet)  
 $b_{(x-1)}$  = distance from the initial point to the following point (feet)  
 $d_x$  = mean depth of partial area  $x$   
 $v_x$  = average velocity in partial area  $x$   
 $q_x$  = discharge in partial area  $x$  (cfs)

## 6.2 Float Method to Estimate Velocity

- 6.2.1. When usual flow measurement methods cannot be used (e.g., during extremely high flows, or when equipment is not available), a floating object can be used to estimate velocity. The object can be an orange, a plastic sample bottle partially filled with water, or other semi-buoyant object.
- 6.2.2. Locate a straight stretch of stream.
- 6.2.3. Select two cross-sections within the stretch, measure (or estimate) their cross-section area and distance between them. Sites should be far enough apart that float movement between sites exceeds 20 seconds.

6.2.4. Release the float at the upstream site and record the time it takes to reach the downstream site. Repeat twice and average the three measurements. To increase accuracy, release the float at different places across the width of the stream.

6.2.5. Calculate the velocity as distance traveled divided by average travel time.

6.2.6. Calculate the adjusted (true mid-depth) mean velocity of the water by multiplying the surface velocity by 0.85.

6.2.7. Calculate discharge by multiplying velocity by the average cross-sectional area.

### 6.3 Measuring Flow from Pipes

#### 6.3.1 Volumetric Measurements

6.3.1.1. In this method, discharge is calculated by observing the time required to fill a container of a known volume. A limiting factor of this technique is that it can only be used with small discharges (i.e., where all of the flow can be caught in one container). This technique can also be used to estimate discharge over a weir or at any place where flow is concentrated into a narrow stream.

6.3.1.2. Place bucket or other container below the discharge.

6.3.1.3. Time how long it takes to fill the container. Repeat three times (or more if there are large differences between results).

6.3.1.4. Calculate discharge as the volume of the container divided by the average time to fill it.

#### 6.3.2 Discharge of a Jet of Water

6.3.2.1. This technique can be used on any discharge regardless of size. The limitations are that the pipe must be horizontal and it must be running completely full.

6.3.2.2. Measure or estimate the diameter of the pipe.

6.3.2.3. Measure the distance from the end of the pipe to the spot where the stream of water hits the ground (“x”).

6.3.2.4. Measure the vertical distance from (“x”) to the midpoint of the pipe orifice (“y”).

6.3.2.5. Calculate the velocity as:  $V = 4.01(x)/\sqrt{y}$

6.3.2.6. Calculate the area (“A”) of the pipe as:  $A = \Pi r^2$

6.3.2.7. Calculate the volume by multiplying the area by velocity. Units of measurement must be the same.

## 6.4 Use of Staff Gage for Estimating Flow

- 6.4.1. A staff gaging station may be set up at a sample site (preferably at the mouth of the watershed). The purpose of a staff gaging station is to develop a relationship between stream height (stage) and flow. Once this relationship is established, stream discharge may be estimated based on gage heights. Where the flows fluctuate greatly, it may be necessary to set staff gages in series to accommodate a variety of stream levels.
- 6.4.2. Site Selection
  - 6.4.2.1. The stream course should be relatively straight and free flowing for 200-300 feet upstream and downstream of the measurement site. The site, however, should be free from excessive turbulence.
  - 6.4.2.2. The stream channel should be free from vegetative growth and be relatively stable (free from major seasonal scouring or deposition of bed material).
  - 6.4.2.3. The stream bed should be relatively uniform with only minor irregularities (no large cobble or boulders).
  - 6.4.2.4. During low flow conditions, the stream channel should be confined to a single course.
  - 6.4.2.5. The stream bank should be stable and able to contain the maximum stream discharge (floods).
  - 6.4.2.6. Gaging stations should be located a sufficient distance upstream of tributaries and tidal action to prevent the distortion of stage/discharge measurements.
  - 6.4.2.7. All discharge stages should be measurable somewhere within the reach (it is not necessary to measure low and high flows in exactly the same place).
- 6.4.3. Staff Gage Installation
  - 6.4.3.1. Attach staff gage vertically on a permanent structure (concrete piling, revetment, etc.) or install in the stream by driving an appropriate post into the substrate and then attaching staff gage to the post.
  - 6.4.3.2. Set the zero point of the staff gage below the lowest level of possible streamflow to prevent negative values of the gage height.
  - 6.4.3.3. Establish a datum point on the gage, and make two or three reference marks at the same level on nearby permanent features. (Use a point on the gage that is above the highest expected gage height to prevent flow-related erosion of the marks.) The datum may also be referenced to an official surveyor's benchmark. Establishing reference elevations allows data to be recovered if the staff gage is destroyed.

#### 6.4.4. Reference Point Measurement

6.4.4.1. The distance from a reference point (RP) to the water surface is measured with a weighted fiberglass measuring tape. The weighted tape is lowered to the water surface just to the point where the wake from the water passing by the weight forms a slight distinctive "V" shape. The distance from the RP to the water surface is recorded to the nearest 100th of a foot.

6.4.4.2. Establish a RP on the bridge by locating or creating a permanent mark near the center of the stream.

6.4.4.3. Find the RP mark on the bridge.

6.4.4.4. Lower the weighted tape until it just touches the water (a distinctive "V" should appear downstream of the weight). Raise the weight to make sure you are just touching the water.

6.4.4.5. Read the tape at the edge of the RP to the hundredth of a foot.

6.4.4.6. Record the time, RP measurement, and the correction factor for the tape (written on the side of the tape) in the field notes.

#### 6.4.5. Establish a Rating Curve

6.4.5.1. Take streamflow measurements over a wide range of gage heights and/or RP measurements. It is very important that measurements are not just made in average flow conditions, but also at high and low flows to develop a rating curve for a wide range of flow conditions. Make sure to note the gage height/RP measurement before and after the flow measurement.

6.4.5.2. Develop a rating curve using regression analysis of instantaneous flow measurement and stage height. Rating curves should be based on sufficient number of measurements to allow a smooth curve to be drawn through the points (usually 8 to 10 measurements).

6.4.5.3. Periodically check the discharge curve, especially after high flows, to ensure the stream bed has been unaltered by sediment deposition or erosion, and that a reasonably accurate rating curve still exists.

### **7.0 Records Management**

(Not Applicable)

### **8.0 Quality Control and Quality Assurance Section**

8.1. QA/QC procedures will be addressed thoroughly on a project-by-project basis in the Quality Assurance Project Plan (QAPP) for the project.

## **9.0 Safety**

- 9.1. Wading streams is one of the most dangerous activities undertaken by field staff especially during higher flows. Two people are required at all times when streams are to be waded. Life jackets are to be worn if there is any chance of being pushed downstream or being submerged after falling into the water. Life jackets should also be worn when new sites are being established and when stream conditions to be encountered are unknown.
- 9.2. If there is any chance of the streamflow being strong enough to potentially cause injury (by being swept downstream into rocks or other dangerous settings, drowning, hypothermia, etc.), do not consider taking a flow cross section. If a safety harness or safety rope is warranted, do not take velocity measurements (request SHU unit assistance). When in doubt, err on the side of safety.
- 9.3. For further field health and safety measures refer to the: [Environmental Assessment Program \(EAP\) Safety Manual](#)

## **10.0 References**

- 10.1. Model 2000 Portable Flowmeter Instruction Manual. 1990. Marsh-McBirney, Inc. Frederick, MD. [www.marsh-mcBirney.com](http://www.marsh-mcBirney.com)
- 10.2. Model 201 Portable Flowmeter Instruction Manual. Marsh-McBirney, Inc. Frederick, MD. [www.marsh-mcBirney.com](http://www.marsh-mcBirney.com)
- 10.3. Model 2100 Instruction Manual. Swoffer Instruments, Inc. Seattle, WA. [www.swoffer.com](http://www.swoffer.com)
- 10.4. Rantz, S.E., et al. Measurement and Computation of Stream Flow. U.S. Geological Survey, Water Supply Paper 2175. <http://pubs.usgs.gov/wsp/wsp2175/>
- 10.5. SOP for Measuring Discharge from a Bridge
- 10.6. SOP for Measuring Discharge from a Boat

## Appendix A: Current Meter Instructions

### 1.0 Current Meter Instructions

#### 1.1 Marsh-McBirney Model 2000

The Marsh-McBirney 2000 consists of a transducer probe cable, and a signal processor. The Marsh-McBirney wading rod has an adapter capable of holding the transducer probe.

Marsh-McBirney model 2000 current meters should be zeroed periodically to ensure accurate measurements. The meters should be zeroed at least once a week during use; however, it is preferable that they are zeroed at the beginning and end of each day of use. They should also be sent to the factory for calibration at least once a year. First clean the sensor because a thin film of oil on the electrodes can cause noisy readings. Then place the sensor in a five gallon plastic bucket of water. Keep it at least three inches away from the sides and bottom of the bucket. To make sure the water is not moving, wait 10 or 15 minutes after you have positioned the sensor before taking any zero readings. Use a filter value of 5 seconds. Zero stability is  $\pm 0.05$  ft/sec.

#### Marsh-McBirney Model 2000 Zero Adjust

- Position the sensor as described in the zero check procedure.
- To initiate the zero start sequence, press the **STO** and **RCL** keys at the same time. You will see the number 3 on the display.
- Decrement to zero with the 6 key.
- The number 32 will be displayed.
- The unit will decrement itself to zero and turn off. The unit is now zeroed.

#### Measuring Velocity

- Attach transducer to the probe to wading rod.
- Turn the meter on.
- Set selector to desired measuring unit (e.g., FT/S). You can toggle between M/S and FT/S by pressing the **On** and **Off** keys simultaneously. Set the meter to Fixed Point averaging (FPA) and set the interval between 20 and 40 seconds. Press the  $\uparrow$  and  $\downarrow$  keys simultaneously to alternate between the FPA and rC displays. The display will show the letters FPA when you first switch to the FPA display. Except for the first period, the display is updated at the end of each averaging period. For example, if the FPA is set to 10 seconds, the display is updated once every ten seconds. The FPA display will have a horizontal time bar under the velocity output. The time bar provides an indication as to the amount of time left until the display is updated. The FPA time is specified in seconds. The  $\uparrow$  key increments time and the  $\downarrow$  key decrements time. The display will show the FPA length in seconds. After you have reached the desired setting, wait and the display will automatically switch to velocity.

- Place the probe in the stream with the round end of the sensor facing into the stream.
- The wading rod should be set to the appropriate depth (see Measuring Stream Velocity-Section 6.4).
- Wait for the appropriate time delay and then record the stream velocity.

## 1.2 Marsh-McBirney Model 201

The Marsh-McBirney 201 consists of a transducer probe cable, and a signal processor. The Marsh-McBirney wading rod has an adapter capable of holding the transducer probe.

### Measuring Velocity

- Attach transducer to the probe to wading rod.
- Set selector switch to **Cal** and the time constant switch to **2**. After approximately 10 seconds, the readout should be on or between 9.8 and 10.2. If not, change the batteries and recheck.
- Set selector to desired measuring unit (e.g., FT/SEC).
- Set time constant switch. The purpose of the time constant is to help stabilize flow readings. This produces a delay between when the unit is first turned on and the time the first full scale reading is reached. This delay can be calculated as seconds by multiplying the switch setting by five. Start with the smallest time constant 2 (10 second delay). If after the calculated time delay the output has not stabilized, move to the next highest number.
- Place the probe in the stream with the round end of the sensor facing into the stream.
- The wading rod should be set to the appropriate depth (see Measuring Stream Velocity-Section 6.5).
- Wait for the appropriate time delay and then+ record the stream velocity.

## 1.3 Swoffer Model 2100

The Swoffer is composed of a rotor assembly, sensor body, and cable which are attached to a wading rod (assembly is called the Sensor Wand), an indicator panel then attaches to the Sensor Wand to form the whole unit.

### Measuring Velocity

- Turn knob on Swoffer meter to **Calibration**. It should read 185-186. If it is does not, change the nine-volt battery. Record the Calibration # in the proper space in the field notes. Install the propeller on the wading rod and tighten the Allen screw.
- Turn the knob on the Swoffer meter to **Ave. Velocity**.
- Press the **start** button on the Swoffer meter.

- Place the propeller in the stream with the propeller facing into the streamflow.
- Record the velocity in the proper column in the field notes.

Upon completion of the flow measurement, turn the knob on the Swoffer meter to **Calibration** and record the number in the proper space in the field notes.