Information Paper 4.1: Flow

Intent and Scope

The purpose of this package is to enhance the user's knowledge and ability to make decisions regarding measurement of flow in streams and other open channels. This Information Paper (IP) provides an overview of approaches to measurement and estimation of flow, while focusing on a few methods more commonly used by volunteer monitoring groups. The IP includes tools for selecting appropriate methods in the context of stream characteristics and project objectives. One basic approach, the velocity-area method, is described in detail because it is used by many groups and illustrates basic concepts that underlie many other techniques for monitoring flow. The IP also identifies measures for quality assurance and quality control that should be incorporated into flow monitoring by volunteer programs, and discusses major sources of error. Standard Operating Procedures (SOPs) 4.2.1 and 4.2.2 are two variants of the velocity-area method.

Complete grounding in stream hydrology and flow measurement is beyond the scope of this package, but references are provided for further reading. Estimation of flow from rainfall data and watershed modeling is also outside of the scope. The IP serves as an introduction to this topic and should give volunteer coordinators enough background to have productive discussions with agency partners and professional advisers.

Principles and Applications

Flow is the amount of water that moves past a point in a given period of time. It is a crucial component of a stream ecosystem, intimately connected with a wide range of physical, chemical and biological processes (refer to Flow Fact Sheet). There are many techniques for measuring flow, each with advantages or limitations depending on field conditions and the questions to be answered.

While the principles of flow measurement are relatively simple, they can easily be misapplied through poor site selection or lack of clarity about the goals of sampling. Volunteer self-education is an important goal -- learning about flow is essential to understanding streams and their connection to the watershed. USBR (1997) contains more background on hydrological concepts and detailed descriptions of various flow measurement techniques. Mount (1995) reviews the physical processes affecting river flow, and their interaction with human land use and resource management issues. FISRWG (1998) provides an overview of stream processes and the role of flow analysis in assessments of stream condition.

One-time, instantaneous flow measurements might be used for reconnaissance purposes to determine the general magnitude of flow at a location. They can also be used to check or calibrate other methods of measuring or estimating flow. The rest of this IP focuses mainly on two approaches: direct volumetric measurement and the velocity-area method. A third approach, the use of tracers, is summarized in Appendix A.

Because variation in flow over time is a key characteristic of natural streams, watershed managers often need a detailed record of these changes.   **A continuous series** of instantaneous measurements from one site, generally at specified time intervals, is often used to:

- characterize details of particular events e.g. peaks during storms, often in conjunction with chemical or physical sampling to estimate sediment or pollutant loads
- calculate statistical measures such as monthly or yearly averages, or frequency and duration of particular levels of flow (see FISRWG 1998 and Richter 1999).

Automated instrumentation can produce reliable and precise time history data, but is not always feasible for volunteer groups (see Appendix A). This IP includes a description of a wire-weight gaging system which volunteers can use to take repeated measures on a limited scale.

Visual or qualitative measures are subjective observations that usually relate the discharge to channel features, such as "low flow", "average depth" or "wetted width of streambed". They may be helpful for reconnaissance or when conditions do not permit quantitative measurement. Qualitative flow observations are not covered in this guide, but are included in the companion Folder 5, Visual Assessments. When supported by appropriate training and guidance, they can assist with:

- reconstructing recent events for which no direct observations were made ("did flows reach bankfull during the last storm?").
- interpretation of water quality sampling data ("was the flow and mixing of water likely to make the surface temperature and DO readings representative of deeper pools?").

Method Menu

This section discusses volunteer monitoring options for flow measurement. Table 1 lists some general considerations that affect the choice of method. Consultation with professional hydrologists or agency data users is recommended when flow monitoring is an important aspect of the project. Figure 1 is a decision flow chart to help narrow down the choices among some common methods that can be used for one-time observations.

Figure 1 is primarily oriented to measurements in wadable streams. **Safety is a major consideration** when planning volunteer activities involving wading. Hazardous conditions to watch for include:

- high flows--including the possibility of sudden changes on regulated streams.
- low temperatures--very cold water is dangerous and precautions against wetting and hypothermia should be observed even in warm weather.
- risk of slipping, especially in streams with algae and larger rock substrates.

More detailed notes on specific methods and equipment are in Table 2 and the following text. Once you have identified your likely choices, use the additional information in the text and Appendices to check if your candidate methods are capable of meeting your data quality objectives.

Table 1. Design considerations for selection of flow monitoring method

Study or site characteristic	alternatives	Sampling considerations
Sampling period	Wet weather (storm) flows	Safety; stream may not be wadable Instrumented time history sampling is often required for studies of pollutant or sediment load
	Dry weather (base) flows	Other associated observations may be important for limiting habitat conditions (water quality, pool-riffle-glide ratios, etc.)
Channel bed and sides	Natural materials and sinuosity (bends in the channel)	Irregular channel, care needed in selection of the sampling reach
	Hardened and/or channelized	Often engineered to produce uniform flow; Scouring beneath and behind the structures may "hide" part of the flow
Stream Gradient	High	Irregular channel, hydraulic jumps, boulders and other obstructions
	Low	Very low velocities are often difficult to measure; Channel can back up during higher flows, causing errors because of restricted flow
Overall number of flow observations	Few sites and dates sampled	Repeatability and consistency; Investment in start-up and training vs. value of data
	Repeated observations at a few fixed sites	Automated gages generally most effective, but may not be feasible at a given site.
	Many sites and many observations	Consistency of protocols and SOPs to insure comparable data under a wide range of conditions

Methods described in detail in the Measurement Principles section of this IP include:
- Direct volume measurement, including the subjective "imaginary" variation
- Velocity-area method using either floating objects or a current meter (including "pygmy" type) to determine velocity, and varying numbers of points to determine cross-sectional area. SOPs 4.2.1 and 4.2.2 are provided for these methods.

Methods or variations described more briefly in text or Appendices are:
- Wire weight method (Measurement Principles)
- Calculated estimates of velocity using channel parameters (Appendix A)
- Tracer methods using dye or other substances dissolved in the stream (Appendix A)
- Temporary "aprons", flumes (narrow channels) or weirs (small dams) to channel flow so that it is easier to measure (Appendix B)

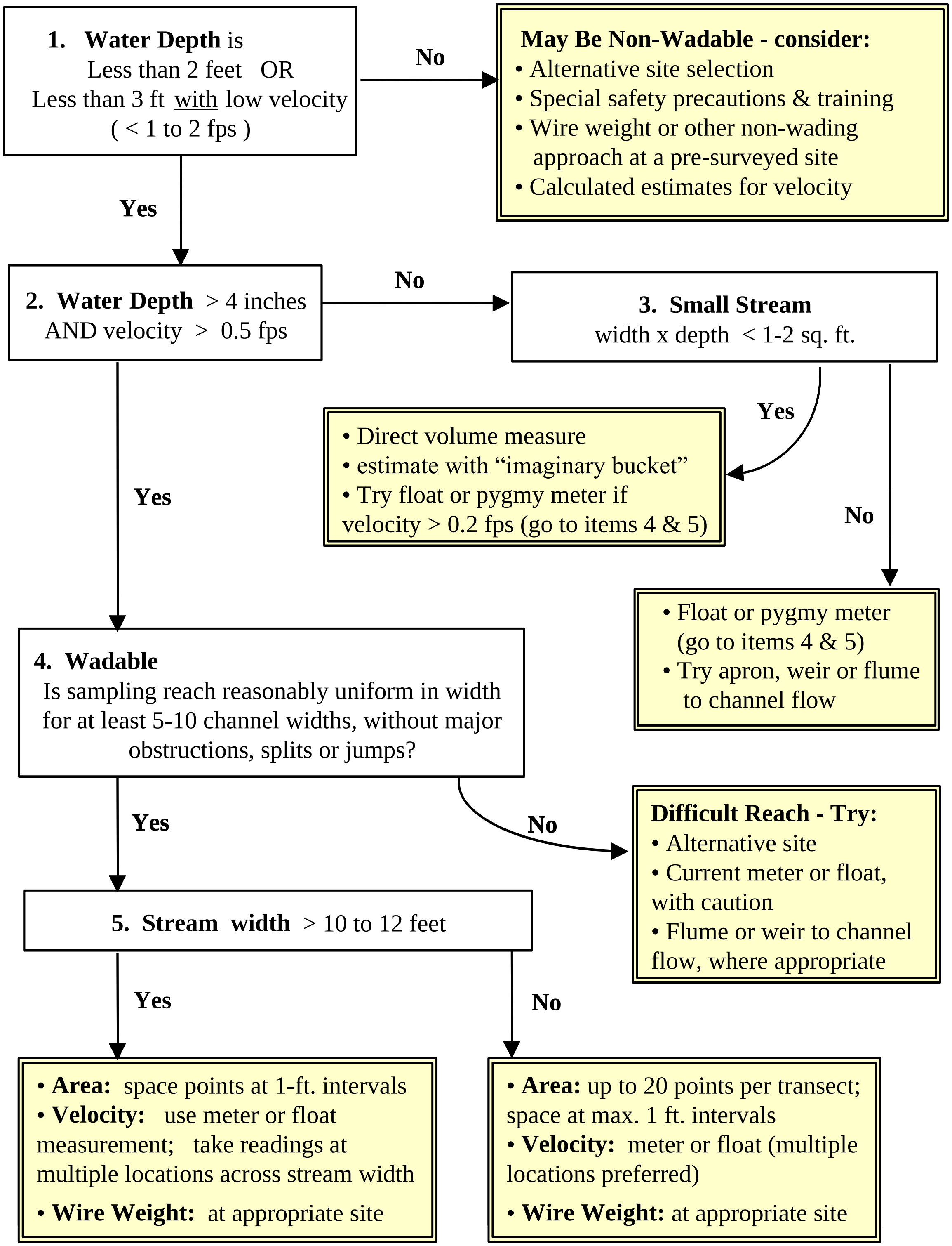

Figure 1. Decision flow chart for selection of flow measurement method

Table 2: Method selection considerations for flow-related measurements

Method (parameter)	Typical Error as +/- percent of parameter value	Equipment cost factor (c)	Labor (time) factor (d)	Professional preparation
Float (velocity)	10 to 25	$	++	training
Bucket meter (velocity)	2 to 5 (a)	$$$ to $$$$	+ (a)(e)	training
Electronic meter (velocity)	2 to 5?	$$$$	+ (e)	training
Yardstick or wading rod at one vertical in stream (stream depth/water level)	up to 5	$ to $$	++ (e)	training
Wire weight gage (water level)	varies (b)	$$	+	set up, training
Fill container (volume per unit time)	10-30	$	+	low
Imaginary container (volume per unit time)	500-1000 or more	none	+	low
Automated flow meter (volume per unit time at preset intervals)	varies with method of calibration (b)	$$$$ risk of loss or vandalism	Very low (maintenance interval ~ 1-2 months)	Set-up, calibration
Apron, flume or weir (accessory for velocity-area or fill container methods)	Used to reduce errors due to channel shape	$-$$	+	depends on primary measurement method

Notes: see Measurement Principles section and Appendix for explanation of methods

a) calibration effort level ++ on each field day
b) range of observation is precalibrated to site, requires professional oversight.
c) cost codes (Fall 2000) $: < $50, $$: $50-$200, $$$: $200-$1000, $$$$: > $1000
d) time factor codes reflect relativ error on meter can increase to 100% with improper calibration or use; e time required for one measurement, including replication where recommended
e) number of readings taken with meter is usually greater than with floats for one discharge measurement

Measurement Principles

There are two main approaches to measuring flow: direct volume measurements and by calculation from separate measurements of velocity and cross-sectional area.

- Direct measure or estimate of volume per unit time

The simplest way to measure the flow through a small opening is to collect the outflow for a given period of time in a container, and measure the volume of water collected in the container during that time. An alternative is to use a stopwatch to measure the time it takes to fill the container. The measurement units normally used are liters per second or gallons per minute (see Appendix D for information on converting units). The container size should be chosen so that it fills in about 15-20 seconds.

This approach works best in small streams, particularly at small waterfalls or chutes where a bucket or beaker can be easily placed. When flow is not concentrated in a way that conveniently fills the bucket, the flow may be temporarily channeled into the bucket in various ways (see Appendix B for more discussion):

- Sandbags
- A flexible plastic or fabric "apron" weighted by stones.
- A portable flume or weir

Advantages of this approach: Low cost; easy to understand; able to measure smaller flows than meters or floats; artificial channelizing offers flexibility.

Limitations: Maximum measurable flow is about 4 liters/second (5 gallon bucket in 5 seconds); usually not feasible in low gradient streams; multiple container sizes may be needed

An imaginary or "virtual" bucket is a subjective variation which can provide a very rough estimate of flow by visualization. It requires no equipment or physical contact with the water, and may be refined with practice and regular self-checking against more precise measurements. Because of its subjectivity, quality assurance measures cannot be consistently applied and error can range up to one or more orders of magnitude (See Table 3).

- Discharge Determination Using the Velocity - Area Approach

Overview

The “velocity-area” method is the most common way to measure discharge because it is applicable to a wide range of flows in both wadable and larger channels. It involves measurement or estimation of two physical attributes at a **transect** or measurement line across the creek perpendicular to the direction of flow. These attributes are average stream velocity and channel cross-sectional area.

To understand the rationale for this method, consider one cubic foot of water (a cube one square foot in area and one foot long). Moving at a velocity of one foot per second, the cube will pass a measuring point in one second with a discharge (area times velocity) of one cubic foot per second (Figure 2). Moving at a velocity of two feet per second, the cube's discharge equals two cubic feet per second, and so on.

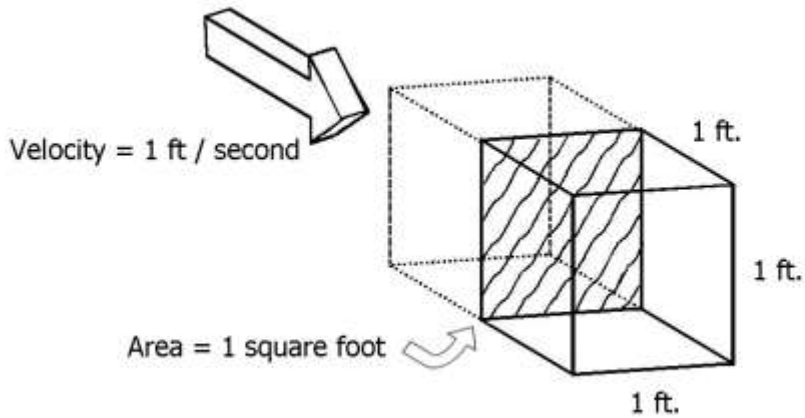

Figure 2. Principles of velocity-area flow measurement

Natural channels are usually larger in cross sectional area than one square foot and they have irregular shapes, but the same principle applies. The average velocity of the water within the channel cross section is multiplied by the cross-sectional area of the channel to determine discharge, typically in cubic feet per second. Symbolically this relationship is represented as

$Q = V*A$ where

Q = discharge (cubic ft/second)
V = average water velocity (ft/second), and
A = channel cross-sectional area (square ft).

The irregular shape of many natural channels (Figure 3) means that depth varies along the measurement transect and that multiple measurements should be made to more closely represent those changes in depth. The varying depths also affect flow velocity. The velocity-area method of calculating discharge therefore incorporates a series of depth and velocity measurements across a channel section.

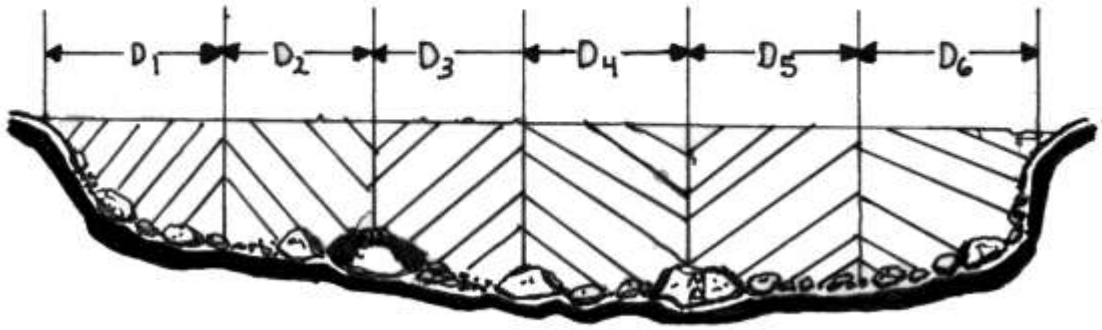

Figure 3: schematic channel cross section with imaginary rectangular "cells"

Most protocols developed for volunteers use the velocity-area method in some form.

Advantages of the velocity-area approach include its widespread use, applicability to a wide range of stream sizes, and its repetition of fairly standardized steps.

Limitations include the inability to safely wade during high flows (which are often of interest), and difficulties taking the velocity measures in very small or very slow streams.

Velocity Measurement

Velocity measurements are usually made by either timing the travel of a floating object or by using an instrument designed to take quantitative measurements of water velocity. There are several different types of such instruments or meters.

Float method of velocity measurement:

The float method is most appropriate for coarse estimates of discharge. It is useful when:

- Conventional flow-measuring equipment is not available
- The velocity is too low or the water too shallow to obtain reliable measurements with a current meter
- Floating ice or other conditions make it difficult or impossible to use a current meter
- Only an estimate of discharge is required

Surface water velocity can be measured by tracking the time required for a floating object to move a known distance. This method is relatively quick and requires minimal equipment:

Recommended equipment for the float method:

- 2 measuring tapes (or marked taglines)
- A timer (stopwatch or digital watch)
- 5-10 floats (orange, orange peel, water-soaked block of wood or other natural material that sinks at least halfway into the water, is visible from shore, and is expendable and non-polluting--not ping-pong balls or plastic jugs. Floats give best results when they move at the same speed as the surface water.)
- Pencils, paper or printed data sheets (waterproof "Rite-in-Rain" preferred)
- Waders
- Calculator (for field calculations to help identify errors on-site)
- Fishing net (to scoop float out of stream)

Procedure: Ideally two taglines (or measuring tapes) are strung at right angles to the flow across the channel at locations marking the beginning and end of the measurement section (Figure 4). If actual lines can't be set, marks on one bank can be identified by pegs, trees or rocks may to define the transects across the stream. The lines should be far enough apart, typically at least two to three channel widths, to allow a travel time for the float of at least 20 seconds.

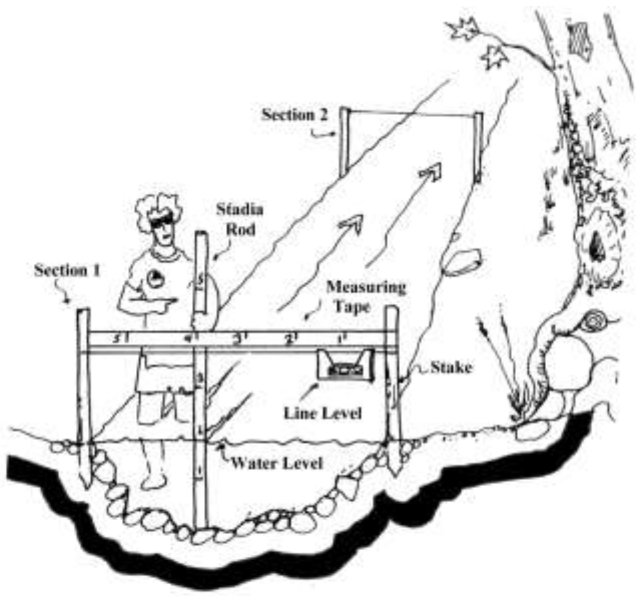

Figure 4. Taglines marking ends of stream segment used for float measurement

A single velocity measurement starts with throwing a float into the channel at a location far enough upstream of the upstream line so that the float is moving in the direction and at the speed of the water when it passes that line. The time taken (measured by the timer) for the float to pass between the upstream and downstream lines is recorded. The process should be repeated more than once and--depending upon the size of the channel--at several subsections at varying distances from the bank by aiming the toss of the float at the center of each subsection.

Float velocity is calculated as the distance between lines divided by the average travel time of the floats between the lines. Note that the float method quantifies only surface velocity; in reality the surface velocity is usually greater than the average velocity of the full vertical depth of flow (Figure 5). Therefore the average *flow* velocity is determined by multiplying the average *float* velocity by an adjustment coefficient, typically assumed to be 0.85. Discharge estimation by the float method, under ideal conditions with repeated measurements, may range from within 10% to 25% of "true" discharge.

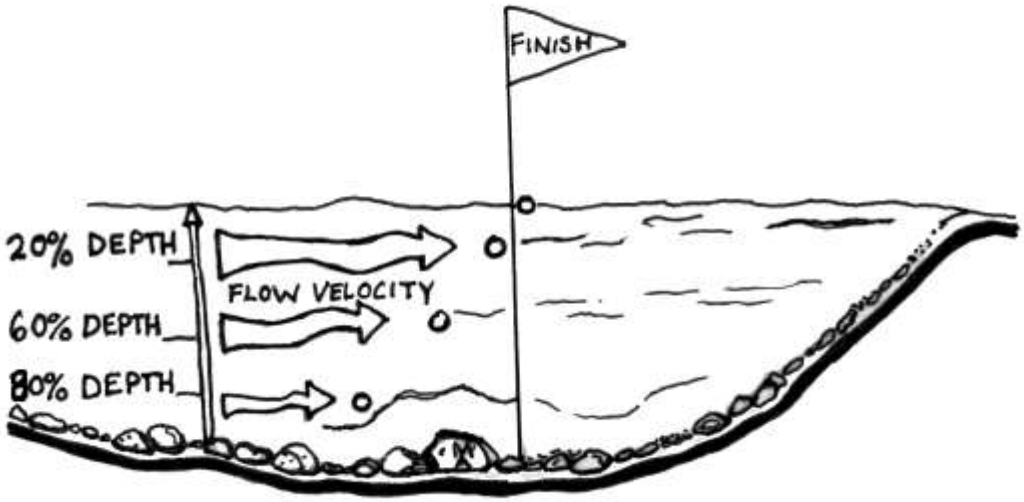

Figure 5. Variation in velocity with depth within stream

Helpful details for improving accuracy, precision and ease of measurement:

- Position observers at both lines, each sighting along their line perpendicular to the flow and announcing the passing of the float.
- Attach a fishing line for the retrieval of floats (or they can be caught in a net).
- Discard any float trials if the float hangs up on boulders or other obstructions in the stream.
- Use the float method on windless days to avoid wind-caused deflection of the floats. Denser floats that ride lower in the water are less readily moved by the wind.

Complications:

- Flow that is not perpendicular to the channel produces errors in velocity determination. Corrections are possible, but form additional sources of error.
- Rocks that project above the water surface and deflect movement of the float cause errors.
- Selection of the value of the adjustment coefficient can be imprecise because its value is a function of the roughness of the channel bed. It's usually possible only to know bed roughness at a coarse level. Lower values (e.g., 0.8) are given for rough beds versus higher values (e.g., 0.9) for smoother, sand/silt beds (Gordon et al 1992), but other references (e.g. USBR 1997) differ in their recommendations for seemingly similar conditions.

Current meter method of velocity measurement

In both the float and current meter methods, discharge is calculated as the product of the average velocity and the cross-sectional channel area at the measurement transect. The float method uses a surface measurement of velocity and a single coefficient to estimate average velocity over the full vertical depth below the float. In contrast, the current meter method applies a more rigorous quantification by directly measuring velocity at one or two locations within the vertical water column that approximate the average flow velocity. In this method, measurements of both velocity and water depth are taken simultaneously as the operator moves across the channel along the transect.

Current meters come in many shapes and sizes. There are two primary types based on different operating principles: a) propeller or cup and b) electromagnetic (see Appendix C for additional details).

Recommended equipment for the current meter method:

- 2 measuring tapes (or marked taglines)
- Current meter (with spare batteries as needed)
- A timer (stopwatch or digital watch if not integrated into the current meter)
- Depth measuring device (top-setting rod)
- Pencils, paper or printed data sheets (waterproof "Rite-in-Rain" preferred)
- Waders

Velocity varies both in the vertical and horizontal directions within a channel. Due to friction, velocities at any vertical line are lowest near the channel bottom and greatest close to the surface (Figure 5). In unobstructed flow conditions the average of two measurements, at 0.2 and 0.8 times the total depth, have been shown to adequately represent the average flow in that vertical (e.g., if depth is 3 feet, the measurements are at 0.6 and 2.4 ft up from the channel bed). Because some instruments (particularly the commonly-used propeller/cup current meters) may be damaged or lose accuracy when positioned close to the bottom, for water depths less than 2.5 ft a single measurement at 0.6 times the total depth, is commonly accepted as representative of average velocity in that vertical.

Wading rods facilitate water depth measurement and function as a mount for a current meter. "Top-setting" and "round" rod types are common. The top-setting rod is usually preferred because it conveniently allows positioning of the meter head at the proper measuring depth. With the top-setting rod the measurer's hands stay dry. The top-setting rod has a base plate about 3 inches in diameter which rests on the channel bed. When the top-setting rod is adjusted to read the depth of the water, the current meter is positioned automatically for a 60% depth reading. Alternatively, the rod also allows ready determination of the 20% and 80% depth readings.

Procedure: To quantify changes in depth and velocity across the channel, depth and velocity measurements are made at multiple points across the channel as follows:

- Stretch a tape or tagline across the channel at the measurement transect.
- Decide the number of points that will be used to represent individual "cells" making up the cross-section. For channels narrower than 10', determine depth and velocity at 1/2' intervals.

For channels over 10', go to 1' (or greater) intervals. Twenty points across wide channels is an adequate number of measurement points. (A smaller number of measurement points may be acceptable for some purposes, as Gordon et al (1992) suggest: "... 20 verticals ... is an excessive number for most surveys for biological purposes ... A practical guideline is to use about one vertical per meter of channel width, with more if the section is irregular and less if it is uniform").

- Calibrate the meter per its instructions.
- Position the wading rod at the first measurement point, and use it to measure both total depth and to set the meter at the correct heights above the channel bed (20%, 60% or 80% of the way up from the bed, depending on overall depth).
- Call out the tape location (distance from bank) of the point, and have the recorder confirm the distance by calling it back.
- Operate the current meter as directed in its instructions, making sure that
  - The wading rod is held vertically with the meter head facing upstream
  - The meter operator's body is kept downstream, off to the side and at least 18 inches from the meter head.
  - Measurement is made for an adequate duration of time (typically between 10 and 60 seconds depending on flow velocity) to sample short-term fluctuations in flow.
- Call out the velocity and measurement depth, and have the recorder confirm the values. If velocities at both 0.8 and 0.2 times the total depth are taken, the recorder calculates the velocity for the vertical as the average of the two readings.
- Move to the next measurement point or vertical and repeat the process.
- After completing a transect of a section, calculate discharge in the field <u>before</u> removing the tape/tagline, and re-measure any verticals that are suspect.

When using a current meter, total discharge is calculated by summing the discharges from the cells represented by individual verticals. The discharge from a cell is the cell area multiplied by the average velocity in the cell. The velocity is either a single measurement (at 60% of the depth), or the mean of measurements at 20% and 80% of depth. At each measurement point, the accompanying cell area is best calculated as the depth at the location times one-half of the difference of the tape positions of the previous and following measurement points (Figure 6):

Area of cell X = $H_X * D_X$

Where H_X = water depth at the midpoint of cell X
D_X = width of the cell, or average distance between depth measurements.

Figure 6 shows an example of a transect with six cells, each having D = 1 foot.
Assuming the H and V measurements as shown for individual cells, the total discharge for the cross section is the sum of the discharges from each individual cell/vertical, or 18.5 cfs:

Cell X	D_X ,feet	H_X ,feet	Area A_X,sq. ft	V_X ,feet/sec	Discharge Q_X,cfs
1	1.0	1.0	1.0	1.5	1.5
2	1.0	1.5	1.5	1.6	2.4
3	1.0	2.0	2.0	1.7	3.4
4	1.0	2.0	2.0	1.8	3.6
5	1.0	2.5	2.5	2.1	5.25
6	1.0	2.0	2.0	1.2	2.4
Totals			11.0		18.55

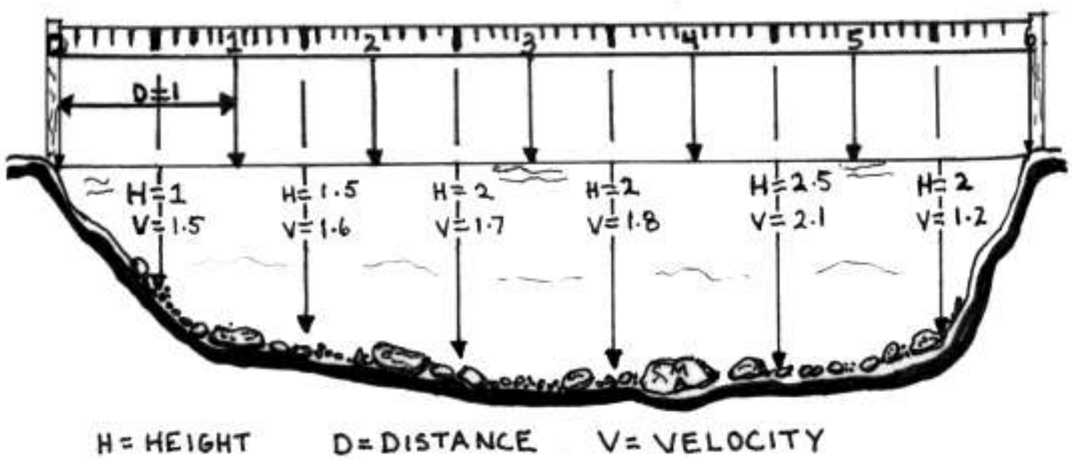

Figure 6: diagram of areas and associated velocity for individual cells

Area Measurement and Calculation of Flow for Float Method

With the float method, any sturdy, waterproof measuring instrument can be used to measure depth. Stadia rods used by professional surveyors come with easy-to-read markings in 0.1 ft. or metric increments. Layout of measurement points and depth readings are performed in the same general manner as described above. Total discharge is calculated by multiplying the combined area of all cells by the average velocity calculated from float trials, and by the adjustment factor. If the average of all float velocity trials is found to be 1.8 ft/second at the transect shown in Figure 6, then total discharge would be estimated as:

$$Q = V*A = 1.8 \text{ ft/sec} * 0.85 * 11.0 \text{ sq. ft.} = 16.8 \text{ cfs.}$$

Note that this is nearly 10% less than the result of the current meter method.

Comparison of Velocity measures: Table 3 summarizes various options for determining velocity at a cross section. Although the current meter method is more complicated and time-consuming than the float method, it more precisely quantifies average stream velocity.

Table 3. Use of Velocity Measurement Methods for Different Stream Conditions

Method	When to use	Number of verticals in transect	Number of points per vertical	Depth of velocity measurement
Current meter A	When H < 2 ½ ft or when measurement must be made quickly	Up to 20	1	0.4*H
Current meter B	Preferable to current meter A method if size of meter allows both measurements (normally when depth > 2 ½ ft)	Up to 20	2	0.2*H and 0.8*H
Float	In swift streams or in high flows where it is difficult or hazardous to lower meter into channel or when meter unavailable	3 or more	1	At water surface

H = the vertical distance between the water surface and the streambed, measured upwards from the streambed (typical with stadia rods and wading rods)

v = velocity at height h within the water column

V = mean velocity in the vertical position, calculated as follows:

Current meter A: $V = v_{0.4H}$

Current meter B: $V = 0.5*(v_{0.2H}+v_{0.8H})$

Float method: $V = k*v_{surface}$
where k depends on channel roughness;
k often taken as 0.85 (see text)

Where to measure

A primary goal when selecting a sampling reach and measurement cross section is finding a location with representative flow, with the following characteristics:

- The water moves uniformly and smoothly in a direction perpendicular to the transect. Backflowing eddies or split streams should be avoided where posible.

- The reach length ideally should extend for at least 5 channel widths above the measurement section and at least 2 channel widths below the measurement section and be straight, with a stable streambed and bank.
- Ideally the channel should be free of scattered boulders, weeds and protruding obstructions, such as logs or bridge piers or abutments, that create turbulence either vertically or horizontally.

For float measurements, a reach with slower velocities and relatively greater depths is often preferred. Normally, a good cross-section location is near the outlet of a pool where velocities don't vary drastically across the channel (USDA 1996; USDI 1992). Meeting the requirements of an ideal cross-section is often much easier said than done, and compromises must frequently be made. Appendix E shows photographs of good sampling locations, but help from a professional is recommended for site selection.

If repeated measurements will be made, the ability to re-locate the cross-section is critical. Permanent **benchmarks**, reference points that spatially locate the cross section on each side of the channel, can include rebar driven into the ground surface, spikes at the base of trees, or marked boulders (Harrelson et al 1994). Landowners or managers should be consulted before selecting and placing permanent benchmarks.

If measurements will be made by wading (e.g., with a current meter), the following rule of thumb is a guide to preserving both safety and good quality results: The product of the stream depth (expressed in feet) times the water velocity (in feet per second) should always be less than 10.

Variations and extensions of the velocity-area method

Other ways to determine velocity

A less common, but simple method for determining surface velocity is callled the "hydraulic jump" method (see Appendix A). Another technique used by engineers involves calculation of velocity from channel slope and an empirical roughness coefficient called Manning's "n" (SCS 1963, FISRWG 1998). This method is usually used in conjunction with automated measurement of water depth (see below) and requires professional help in selecting the location and surveying the stream channel .

Repeated measurements at fixed stations

When a stream's discharge increases, the cross-sectional area at a given transect also increases as the water level, often called "stage" or "gage height", rises. By surveying the shape of the channel during periods of low discharge, hydrologists can calculate the cross-sectional area that goes with any stage. Then flow can be calculated at any time by observing the velocity and stage, without the need for wading.

As the water level changes during and after a storm event, observations are repeated at different stages and discharge is plotted against stage to produce a "rating curve" (Figure 7) that is specific to the site. Because of observation error and natural variation in the system, the curve does not go smoothly through all the data points. As more observations are taken during different storm events, the increased number of points reduces the influence of a few unrepresentative points on the shape of the rating curve. Outliers might be caused by observer error, or by temporary obstructions in the flow such as a debris jam in the reach. The channel should be resurveyed periodically by a professional hydrologist to be sure that no permanent changes have occurred that could affect the cross-sectional area and rating curve.

Once a rating curve is established, it can be used to convert stage measurements to discharge without the need for velocity measurements. Stream gaging stations installed by USGS and other water agencies use a variety of automated instruments to record continual stage observations, thus producing detailed time-series observations of flow (see Appendix A). These continuous reading stations are generally beyond the budget and scope of citizen monitoring groups, although volunteers may be able to assist agency partners with maintenance and checking activities.

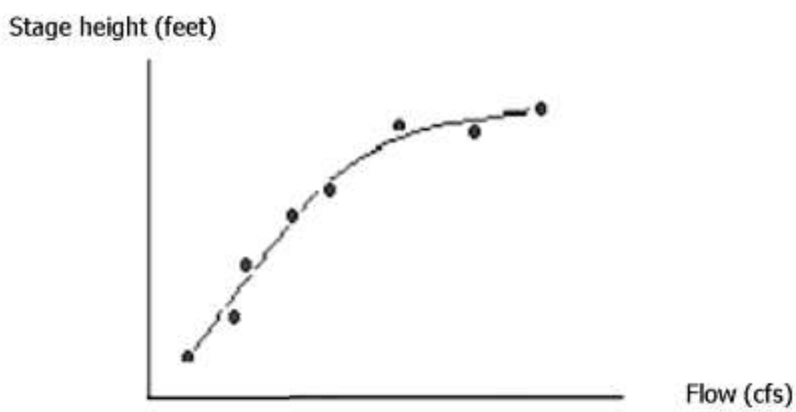

Figure 7: simplified rating curve

Wire-weight gaging at fixed stations

Volunteers can make stage observations from a bridge or other fixed point by lowering a weight suspended from a premeasured length of wire until it touches the surface of the water (Figure 8) . The associated velocity measurements are made using floats thrown from the bridge or bank.

The Sonoma Ecology Center uses this procedure along with rain gauge readings to get a general understanding of how watershed tributaries behave during storm events. A summary of SEC's protocol (based on Napa RCD 1998) follows:

Each volunteer monitors a creek near his or her home. The creek must be monitored from a bridge, over whose side the water surface may be seen clearly. Three on-site measurements are necessary for the calculation of stream discharge: water surface height, average velocity, and the cross-sectional stream bed profile.

The height of the water surface is measured by lowering a weighted wire gauge over the side of the bridge at a pre-determined point which is directly over the deepest part of the stream. The gauge was calibrated at this location and has markers at every foot. The height is then read off the gauge when the weight touches the surface of the water.

Average velocity of the water is measured by timing an orange peel over a measured distance, usually about 30 feet. The peel is tossed in the water upstream of the marked distance, so that it has time to equilibrate with the water velocity before timing begins. During a storm event, the water may be swift and rough enough that an orange peel is difficult to see in the swirling water; in this case a log or other debris floating by is used. The timing is repeated 3 or 4 times to get an average across the stream bed. Average velocity is then calculated by dividing the distance by the average time.

The stream bed profile is surveyed accurately with surveying equipment. It need only be done once, as long as it remains constant throughout the season. It is desirable to re-survey the site at the end of the rainy season to determine if there have been any significant changes.

Volunteers always work in pairs for both safety and quality assurance reasons. New volunteers are given preseason training and then teamed with experienced volunteers.

Advantages: can be used during storm events if volunteers are available; repeated measurements provide additional QA/QC check, can support refinement of rating curve

Limitations: restricted to specific sites with stable observation point on bridge or bank; require professional hydrologists to survey the channel and design the depth gauge; reinforcement and team-building needed to maintain volunteer commitments through the season

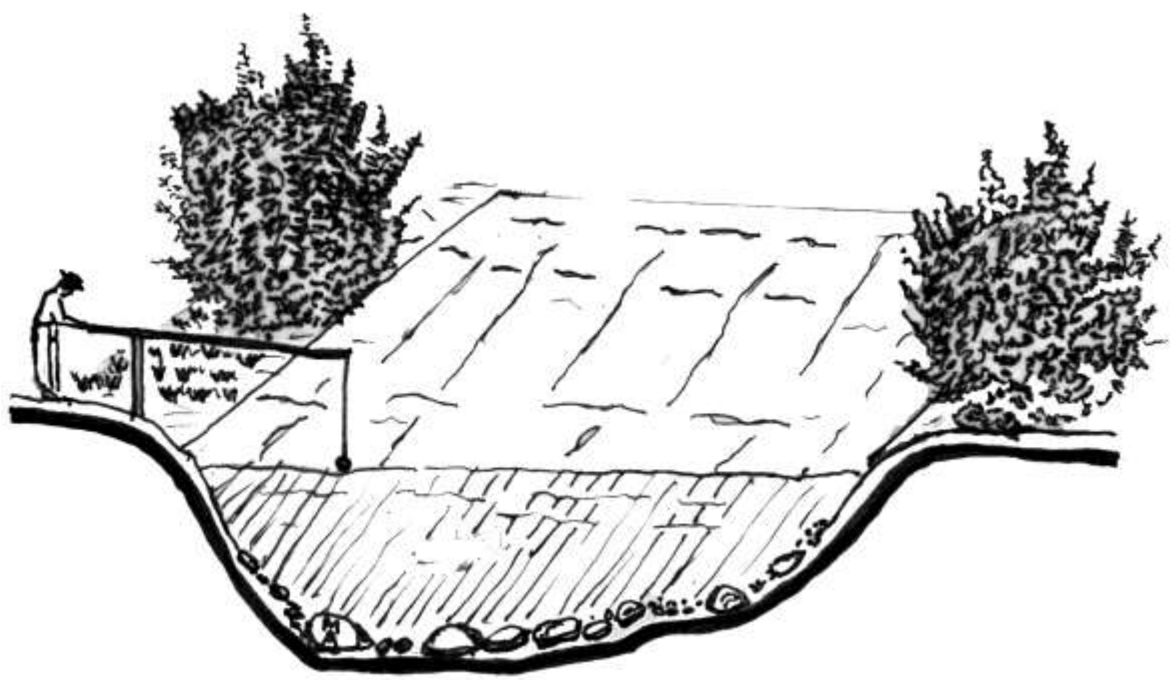

Figure 8 wire weight gaging from fixed vantage point (after Napa RCD, 1998)

Quality Assurance and Quality Control (QA/QC)

Consistent, repeatable measurement of flow begins with application of the general QA/QC principles outlined in Sections 1 and 2 of the Compendium.

Table 4 summarizes some approaches to flow measurement adopted by several volunteer programs or sources. Footnotes to Table 4 list quality assurance measures which these groups incorporated in their protocols. Some practices (Items 1-8) are written into their Standard Operating Procedures (SOPs) and are applied each time flow is measured. Others (a-e) are aspects of project design or are conducted as part of ongoing program support and management. None of the measures is relevant to all of the protocols.

The accompanying SOPs are examples written for volunteer monitors taking individual, one-time measurements of discharge in open channels using the velocity-area approach. Two variations are provided, using different techniques for measuring velocity:

SOP 4.2.1:   velocity-area method using float (written by Malibu Stream Team/Heal The Bay)
SOP 4.2.2:   velocity-area method using current meter (written by Coastal Watershed Council)

Table 4. Representative Flow Measurement Protocols for Volunteer Monitors

Group/Source	Area measurement	Velocity Measure	QA/QC provisions	Comments
Volunteer Methods Manual (USEPA 1997)	3-pt profile	Float	1,2,3,4+,6,7	
Malibu Stream Team	1-ft. interval profile	Float	1,2,3,4,5,6,7 b, d	See SOP 4.2.1
Coastal Watershed Council	min. 20-pt	meter (also float alternative)	1,2,4 (by rod set), 6	See SOP 4.2.2
Sonoma Ecology Center, Napa RCD (1998)	wire weight depth gauge at fixed pt.	float	1 (initial), 2,3,6,7, 8 a, b, e	sites are professionally selected and surveyed, usually beneath a bridge
USFS (Christine Mai)	profile	meter, float/dye and jump	1,3,6,7 a,c,d	also uses direct measures; multiple teams at a one-time large group event provide cross-checks on data

Notes:
(QA/QC) measures for measurement of velocity and area

1. Measurement of cross-section in multiple “cells” across transect
2. Specified reach length and required channel characteristics
3. Average multiple trials for velocity estimates (e.g. float runs or current meter readings)
4. Depth correction factor, (+) when varies with depth and/or bottom roughness
5. Average 2 or more cross-sections
6. Detailed SOP
7. Data sheet provides calculation steps, check for completeness
8. Site-specific custom equipment provides direct reading of depth

QA/QC elements incorporated into volunteer program design:

a) Expert tailoring of site procedures for project-specific DQO's
b) Initial training and periodic refreshers or review
c) Field supervision by professional-level staff
d) Regular cross-checks with different methods and professional-level measurements
e) Well-defined volunteer commitments and backup provisions for monitoring assignments

- Purposes of Collection of Flow Data

Flow measurements can be separated into two primary categories: single and repeated measurements. Each of these two measurement categories typically implies differing monitoring objectives and uses of the resulting data, as well as differing levels of resolution and time requirements for the measurements.

Because of the need for improved measurement precision, float measurements are relatively less useful than methods incorporating current meters or other instrumentation. In channels where water depths are too great for wading, the wire weight gauging technique may be useful.

- Evaluating error sources and attainable data quality

Stream flow and other hydrologic processes can vary drastically in time and space. At a given point in a stream, flow patterns across the channel are affected by boulders, channel irregularities or man-made obstructions. Because flow velocity is typically greatest at the surface of the channel, measurements made at one point (and one depth) in a channel typically do not represent the entire flow at that point across the channel. Natural processes--like groundwater inflow rates, and surface runoff that contribute water to the channel—change in magnitude through time so that flow discharge at one time may not reflect discharges on the previous or following day (or even the previous or following hour).

Errors caused by to instruments and methods of flow measurement combine with the natural causes of flow variability, so that the best professional measurements of natural stream flow will still vary up to +/- 5 percent of actual flow as measured at permanent discharge gages.

Redundancy and **replication** help optimize the attainable data quality through additional observations. If two or more methods of flow measurement can be used, comparison of their results can boost confidence in the reliability of the measurement procedure if the values are similar; this check also raises a yellow flag if the values differ appreciably. Replicated measurements by the same method function similarly, with the added benefit of allowing statistical quantification of measurement error for the chosen method with actual operators. In practice, QA/QC planning often needs to balance allocations of effort between increasing precision and accuracy for individual observations and taking more observations.

- Preparing an Error Budget

Once a sampling design is proposed, keeping error in flow measurement at acceptable levels requires consideration of different sources of error. These can be grouped into two broad categories: administrative and technical. Administrative support provides adequate training and clear description of SOPs so that the chances of error-prone measurement are minimized. When participants thoroughly understand the measurement process and its purpose, it is easier to manage technical issues like selection of the sampling reach and cross-section, and measurement of wetted cross-section and velocity.

The following section reviews the administrative and technical factors that are part of the overall "error budget" in the metered and float-based velocity-area methods. Collecting reliable and reproducible data requires management of all the factors.

Clarity and detail of standard operating procedure

The most precise instrumentation and equipment in the world is useless if the volunteer doesn't know how to use it or is otherwise unfamiliar with basic principles of streamflow measurement. Understandable and concise SOPs are crucial toward achieving the necessary familiarity.
A good SOP document is the cornerstone for attaining good data quality. It should be reviewed by the volunteers before each field day.

Training and supervision

Training and supervision reinforce and support the SOP. If elements of the SOP and training don't match, the volunteer will be uncertain of how to best proceed. Successful training is best given by individuals knowledgeable about both the local conditions and objectives of the monitoring project as well as in general principles of streamflow gaging. Regular checking of actual field practice and periodic refreshment or reinforcement of training are important elements. Supervision tasks also include organizing volunteers' teams and responsibilities to match skills and commitments, as well as offering encouragement and fostering team-building.

Selection of sampling reach and cross section

A primary goal in selection of sampling reach and cross section is to identify a location of representative flow. Backflowing eddies should be avoided and the preferred reach is long and straight, with a stable streambed and bank. Ideally the channel should be free of scattered boulders, weeds and protruding obstructions, such as logs or bridge piers or abutments, that create turbulence or vertical velocity "threads". For float measurements a reach with slower velocities and relatively greater depths is often preferred. Normally, a good cross-section location is near the outlet of a pool where velocities don't vary drastically across the channel. (USDI 1992). Selection of an adequate sampling reach and cross section is often a greater error source than the subsequent measurements of wetted cross section and velocity. Selection help from a professional is recommended.

If repeated measurements will be made, permanent benchmarks should be established as described above in "Where to Measure". Fixed sampling sites should be evaluated regularly for changes in channel or adjacent use that may affect the flow measurements.

Measurement/estimation of wetted cross-section

Several methods of discharge estimation require quantification of the depth of water across the cross-section. For the velocity-area method, errors are minimized by increasing the number of cells in the cross-section. A trade-off is the time taken for the increased measurements. To achieve the most precision, at least 20 depth measurements per cross-section are preferred for most natural stream channels.

Velocity measurement

Choices of method for velocity measurement should be driven by the objective of the monitoring, tempered with availability of measurement equipment. The optimum method for one site may not always be the best for another site. For best results, the measurements should be repeated by different volunteers. This will help reduce errors associated with equipment precision and maintenance, and average out minor inconsistencies among human operators.

Under the best possible conditions, the velocity-area method probably has an error range of +/- 5-10%. Carefully made float measurements under favorable conditions may be accurate to +/- 10%. This error range increases greatly if the selection of the vertical velocity coefficient (typically 0.85) is inappropriate, or if few floats are used in a nonuniform reach.

Error budget table

Table 5 estimates the relative contributions for the five major sources of error given above. Administrative and technical categories are kept separate because without an adequate SOP and training regime, the technical aspects of flow gaging will fail. Volunteer managers, team leaders and technical advisers can use these estimates as a guide for allocating their quality assurance efforts, by asking themselves:

- which error sources are probably contributing the most to the overall error
- which error sources are amenable to changes in procedure
- which changes in procedure are likely to significantly reduce overall effort

Table 5. Relative contributions to error in steamflow measurements

Type of error source	Estimated percentage of total error	Total category percentage
Administrative		100
Standard operating procedure	55	
Training and supervision	45	
Technical		100
Selection of sampling reach and cross-section	50	
Measurement or estimation of wetted cross-section	25	
Velocity measurement	25	

Sources & Resources

This Information Paper was created by Clean Water Team in collaboration with the Flow workgroup of the 2000-2001 Technical Advisory Council on Citizen Monitoring: Mark Abramson, Neil Berg and Arleen Feng.

Additional comments and information were contributed by:
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Maya Conrad (Coastal Watershed Council)
Kathleen Edson (Napa RCD)
Rebecca Lawton (Sonoma Ecology Center)
Christine Mai (USDAFS)
Laurel Marcus (Laurel Marcus and Associates)
Jill Marshall (Urban Creeks Council)
Kristi Pier (Sonoma Ecology Center)

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Appendices-Flow

Appendix A. Other methods of flow measurement

Automated instrumentation

USBR (1997) describes a variety of electronic devices commonly used to monitor water velocity or depth at fixed locations. Velocity meters are very expensive and have limitated application in streams. Water depth gages usually operate either by mechanical floats or sensors in a tube or by sensing changes in pressure at the bottom of the channel. The depth measurements are combined with channel survey information to convert depth values to flow. Data loggers located on the bank can record up to several months of observations and some also support additional sensors for monitoring temperature or other water quality parameters.

The main advantage of automated sampling is the ability to monitor continuously, especially during storms when close time intervals between measurements may be desirable. Agencies involved in watershed management may accept such data more readily than volunteer field observations. Limitations include the initial cost of equipment, the need for a site installation that is reasonably secure from vandalism, and the potentially large size of datasets to manage. Professional assistance is also needed for site selection, surveying the channel, and installation,

Tracers

Tracer methods involve putting a detectable substance in the stream and following its progress downstream. USBR (1997) and Gordon et al (1992) describe procedures for two main options: fluorescent dyes, which are generally used in lieu of floats with the velocity-area method described in the text, and chemicals such as salt. When an appropriate quantity of salt is introduced into the stream, the dilution of the resulting "salt slug" shows as a short pulse of elevated conductivity to an observer monitoring with a conductivity meter some distance downstream. With trial and error the amount of salt can be increased to where the conductivity increase is measurable but not harmful to the stream organisms. Tracers can be used to determine discharge with accuracies that can vary considerably from about +/-1 percent to over 30 percent in open channels (USBR 1997) depending on the equipment used and the care in applying the techniques. Advantages include simplicity and usefulness in small streams or braided channels where floats or meters do not work well. Limitations include the need to adjust salt quantities for individual sites and the calculations required to obtain flow values.

Hydraulic Jump measurement of velocity

When a thin object like a ruler, wading rod or stadia rod is positioned vertically in flowing water, there is a small increase in height of the water where the water hits the rod.   This increase is known as the hydraulic jump. Velocity can be calculated based on the hydraulic jump as

$$V = (2gh)^{1/2}$$

whereV = velocity in feet per second, g = gravity constant of 32 ft per sec^2, and h = hydraulic jump (ft). h is the measured height of the water on the front of the rod as compared to the water surface on the sides of the rod. This measurement should be repeated across the channel.

Appendix B. Artificial channel modifications: flumes and weirs

Changing the configuration of a channel with special devices can facilitate flow measurements, and may justify the expense and effort in some cases:

When the flow through a channel is no more than 2 liter/second, the water can be channeled into a flexible "apron" that discharges into a bucket, and the rate at which the bucket is filled is measured. The challenges of this procedure are to get all the water in the channel to flow into the apron, and to have a sufficient "step" under the apron discharge that would accommodate a bucket (another option is to use a flatter tray and transfer the water into a bucket later, for volume measurement). Cloths, clay, or other materials can temporarily seal cracks; use of Plumber's Putty to create a spout in "waterfalls" has also been reported.

In higher gradient streams, a small weir or barrier can be used to channel flow into a container. A notched weir may also be used as a calibrated structure to relate water-level (i.e., head) to flow (i.e., discharge) in an open channel. A Parshall measuring flume is another commercially available device that can be used to measure flows when the depths are shallow and velocities low. The following description of a flume and its operational theory is from the ISCO Open-Channel Flow Measurement Handbook (1989): "A flume is a specially shaped open channel flow section that restricts the channel area and/or changes the channel slope, resulting in an increased velocity and a change in the level of the liquid flowing through the flume." Modified Parshall flumes are recommended because of simplicity, relatively light weight, and ease of installation. The flume is installed by placing it in a hole dug in the channel and by filling in around it to prevent any water from bypassing it and leveling it with a carpenter's level. Discharge is determined by staff gage readings and a flume rating table.

Appendix C. Current meters

There are a wide variety of current meters or gages for various applications ranging from pipes to large rivers (see USBR 1997 for overview and examples). Two types of portable meters are commonly used in stream monitoring: propeller/cup and electromagnetic.

Propeller/cup or "bucket" gages work somewhat like wind gages, where water passing a vane causes the vane to rotate. Velocity is calculated as a function of the rate of rotation. The rapidity of cup rotation is counted either by some type of recording device or by listening to clicks (representing each revolution) in a headphone. Counts are made over a time interval, which is measured with a timer. These meters traditionally come with a rating curve or table relating rotation speed (clicks) to flow velocity.

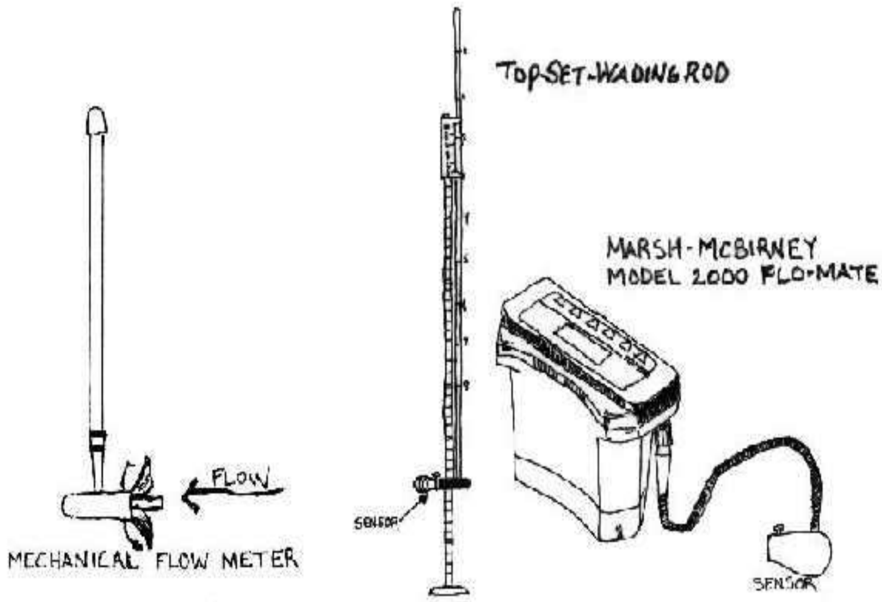


Figure A-1. Examples of portable velocity meters

An example is the Price Pygmy Current Meter, primarily used for discharge measurements in shallow streams (less than 1-foot depths). It is similar in construction to the larger Price AA meter in that both types contain a cup-type bucket wheel that is mounted on a vertical shaft. However, the Pygmy meter is two-fifths the size of the Price AA meter and has no tail piece. The rotational speed of the Price Pygmy meter bucket wheel is more than twice that of the Price AA meter and limits its use to velocities of 0.20 to 4 fps or less, versus about 0.5 to 10 fps or more for the Price AA.

Propeller/cup meters require great care in handling, storage and maintenance to avoid damaging parts. Other disadvantages include vulnerability to clogging by algae or debris and difficulty listening to clicks in noisy streams. Some modern versions of propeller/cup gages have direct readout displays.

Electromagnetic gages are based on the principle that water moving through a magnetic field will induce a voltage that varies with the rate of water movement. These meters provide a direct reading of velocity. They are durable and benefit from having no moving parts that could get tangled in clumps of vegetation. Although more costly than propeller/cup meters, electromagnetic gages require less day-to-day maintenance. They cannot be used near metallic objects or in water with very low conductivity. This meter does not produce good results in water less than 0.2 feet deep or in very low velocities.

Appendix D. Unit conversions

one cubic foot =	7.48052	gallons =		28.32	liters
one gallon =	0.1337	cu. ft.			
one gallon =	3.785	liters =		0.00379	cubic meters
one liter =	0.2649	gallons		0.03531	cu. ft
one liter/sec =	15.86	gallons/min	=	0.03531	cubic feet/sec. (cfs)
one cfs =	448.8	gallons/min	=	28.32	liters/sec
			=	0.02832	cubic meters/sec
one foot/sec =	0.3048	meters/sec			

Appendix E. Photographs

Tagline across a stream transect

Setting the stadia rod for a depth reading

4.2.1 Stream Flow Using Float to Measure Velocity

Adapted from *Streamkeeper's Field Guide* (Murdoch, Cheo, and O'Laughin1996, p. 108) by Abramson M., Padick C., Takata-Schuemen E., and Taylor G. for The Malibu Creek Watershed Stream Team Field Guide.

Stream flow is measured by calculating the volume of water that passes a particular point in a stream within a specified amount of time. To calculate flow you must know two things: how much water a section of stream holds (volume), and how fast that water is moving (velocity). Stream flow can be determined by measuring the velocity of water and the cross sectional area of the stream. The formula to use when calculating stream flow is:

stream flow = velocity x cross sectional area

To measure velocity a float (orange peel) will be used to determine how fast the water is flowing. To calculate the cross sectional area of the stream, a stadia rod will be used to measure water depth at 1-foot intervals across the width of the stream (Figure 5-3).

Procedures for determining stream flow:

Pick a 20-foot long section of the stream that is straight and of uniform width. Water should be flowing evenly within this section without turbulence, obstacles or other disturbances. This section of the stream should be shallow enough for you to safely wade across and conduct the stream flow test.

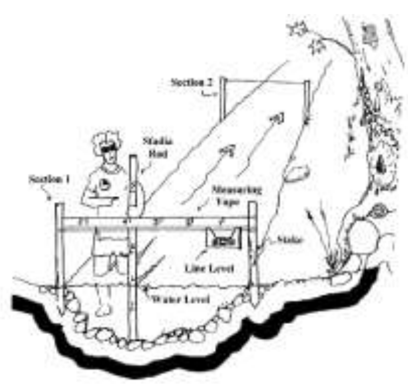
1. To measure the cross sectional area of a stream, place a stake at the wetted edge on each streambank.

2. Tie a string line to both stakes running across the stream, use the line level in the field kit to insure the string line is level.

3. Attach the loose end of the tape measure to one of the stakes using the spring clamp in the field kit, while one of your teammates holds the other end of the tape measure on the opposite streambank. The tape measure should be placed directly beside the level string line.
   Note: This location will be the starting line for the stream flow velocity trials.

4. Have one person take the stadia rod to measure the depth of the water at 1-foot intervals across the stream use the tape measure to establish these points. Always stand downstream of the tape line and stadia rod.

5. Continue to measure at 1-foot intervals until you reach the edge of the water on the opposite side of the stream bank. Call out the depth measurements at every 1-foot interval so it can be recorded on the Stream Flow Field Sheet. Please read the section on How to Read the Stadia Rod.



6. Add up the depths on the Stream Flow Field Sheet. This is the cross sectional area for that section of the stream.

Note: Leave the string line attached to the stakes running across the stream. You will use this as a marker for the velocity measurement.

7. Repeat this procedure 20 feet downstream from where the first cross section was measured. This is where the finishing line for your stream flow velocity trials will take place. Compute the cross sectional area for this section and record this on the Stream Flow Field Sheet.

8. Add the two cross sectional area figures together and divide by two to get an average cross sectional area. Record this information on the Stream Flow Field Sheet.

Now you are ready for the velocity float trial part of the stream flow test.

1. Measure the length of the stream where the velocity float trials are to be conducted and record this information on the Stream Flow Field Sheet. This distance should be 20 feet, from starting line to finish line.

2. One team member stands in the stream at the starting line with an orange peel. Another team member stands downstream at the finish line waiting to retrieve the orange peel as it crosses the finish line. A third team member is standing on the bank next to the finish line with a stopwatch and clipboard.

The team member at the starting line drops an orange peel and as it passes the starting line, yells, “go”. The person on the bank starts the stopwatch. When the orange peel passes the finish line the watch is stopped, the orange peel retrieved, and the time recorded on the Stream Flow Field Sheet.

4. Repeat this test five times moving from the left to the right side of the stream along the starting line. Doing this will give you a more representative depiction of stream flow along that section of the stream. Record the results on the Stream Flow Field Sheet each time.

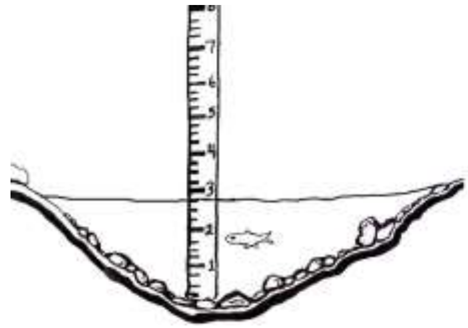
5. Add up the times for each of the velocity float trials and divide by the number of trials (5) to get an average velocity time. Record the results on the Stream Flow Field Sheet.

6. Use the Stream Flow Field Sheet to calculate surface velocity. Divide distance (20 feet) by average velocity time to get average surface velocity in feet per second. Next, multiply this result by the velocity correction factor of 0.8 to get average corrected velocity. The velocity correction factor has been added to adjust for the fact that water velocity at the surface is faster than water velocity closer to the bottom of a stream. Use this factor to get a more accurate stream flow calculation.

7. Finally, calculate stream flow by multiplying average correction velocity by average cross sectional area. Your result will in CFS (cubic feet per second). Record this number on the Stream Flow Field Sheet.

Reading the Stadia Rod

Hold the stadia rod plumb (straight up and down) and on the stream bottom. You are taking measurements at every foot along the horizontal tape measure that is stretched across the stream. The team is measuring at the four-foot mark on the tape measure. The stadia rod touches the top of the stream water at the two-foot mark. Record 2 foot on the Stream Flow Field Sheet in the box directly along side of the 4 foot horizontal box.



Field Sheets:

Record the results on the Stream Flow Field Sheet. A sample of the Stream Flow Field Sheet is provided on the following pages (Figure _).

4.2.2 Stream Flow Using Meters to Measure Velocity

Coastal Watershed Council has written two forms of this SOP, depending on the type of current meter used.

Background Information

During the dry season, substantial streamflow is essential for fish rearing and passage. Basically, the more water within the channel, the more biological habitat available. Streamflow monitoring allows us to:

1) Determine baseline flow
2) Better understand local geology
3) Determine whether or not streamflow is sufficient for fish
4) Analyze legal water diversions that may affect surface flow or subsurface flow
5) Determine whether illegal water diversions are present or are impacting flow

Monitoring streamflow during the dry season is a safe and relatively simple parameter for volunteer groups. The streamflow data can be extremely useful to water districts, the California Department of Fish and Game, fisheries biologists, and hydrologists.

Low flow monitoring generally means that streamflow levels are 10 cubic feet per second (cfs) or less. For this document, the low flow monitoring protocols will focus on surveying in areas with stream depths less than 2 feet. Although there are other streamflow monitoring techniques, we will only discuss the Six-tenth Monitoring Method because it is the appropriate method for stream depths less than 2 feet. The six-tenthsMethod refers to where the reading is taken in the water column; six tenths from the surface, or four-tenths from the stream bottom.

Generally, streamflow monitoring occurs during the summer and early fall when water levels are lowest. It should be noted that "Low Flow Monitoring" should be conducted when the water levels are low enough to ensure not only accurate data, but more importantly, volunteer safety during monitoring. Abandon streamflow monitoring during stormy/rainy periods or when water levels exceed 2 feet.

Several meters are available for use and can be obtained through scientific supply companies. A popular, relatively inexpensive (~$1000.00) yet accurate meter available is the bucket wheel or "pygmy meter." Although this device provides accurate data, it requires a good deal of maintenance and can be more difficult for volunteers to use. Another type of meter that is easier for volunteer to use but more expensive (~$2000.00-$3000.00) and not necessarily more accurate is the current meter. Current meters allow easier data collection and some also come with data loggers so that data can be quickly downloaded directly onto your computer.

Important Resources and References: USBR 1997, Harrelson et. al. 1994.
For historical information or assistance, contact your local California Department of Fish and Game fisheries biologist, water districts, and/or State Water Resources Control Board. Contacting a local hydrologist can also be extremely useful.

4.2.2 a 0.6 Foot Streamflow Protocol - Current Meter

For use with a Marsh McBirney Portable Current Analog or Digital Meter (model 201) and a 4' topsetting wading rod.

Equipment Needed:

4' top setting rod	100' tape measure that reads in tenths
flow meter	data sheets
thermometer	2-3 people
watch w/second hand	flathead screwdriver
"D" size batteries	rubber boots or hip waders (if available)

Number of Volunteers Needed:

1) Top-setting rodperson
2) Timer
3) Data recorder

1) **Choose a point on the creek** that is:

- wadable (less than 2 feet);
- lacks obstructions (such as logs, rocks, human structures or anything else that significantly affects the creek flow) within 15 feet up- or downstream of the site;
- at least 10 feet in width (if this isn't possible, take more readings);
- has a depth greater than 0.2 feet

2) Carefully **attach the flow meter to the topsetting rod**. Loosen the screw on the end of the meter and fit it onto the base of the rod. The meter should fit flush with the rod. Tighten the screw.

3) **Extend the tape measure across the section of creek to be measured. Make sure you use the side of the tape that measures feet in tenths, not inches**. The tape must be held in place firmly during all measurements and not moved. Measure the total width of the creek. If the creek width is 20' or greater, take measurements at 1' intervals. If the creek is less than 20' wide, take measurements at 0.5' increments. Make sure to take at least 20 measurements.

4) **Calibrate the meter** by turning it from "Off" to "Cal. The meter needle should hit the black "Cal" box. If it does not, insert new 6 "D" batteries by unscrewing the back plate of the meter with a flathead screwdriver.

After calibrating, **switch the setting to "2.5" to read streamflow measurements**. “2.5” refers to 2.5 feet per second, indicating that you are estimating the flow within that range. If the meter is maxed out when you set it to the 2.5 setting you will have to change the setting to the 5 or 10 feet per second scale, depending on the streamflow. Read all measurements from the appropriate setting. The **Time Con. should be set at "2."**

5) Place the top-setting rod in the water so that the meter bulb faces upstream. Make sure the rod sits flat, stands upright, and there are no rocks, sticks, etc. obstructing the meter bulb. Hold the cord straight up from the meter bulb so that there is no slack in the cord.

6) Begin on the right bank (when facing downstream) of the creek and measure across to the left bank. You may be unable to obtain a reading at depths <0.2'.
At least 20 readings must be taken.

To set the top setting rod, visually measure the depth of the creek using the graduation lines on the hexagonal rod. One line = 0.1', Two lines = 0.5', Three lines = 1.0'.

Once you've determined the depth, set the rod to the 6/10 reading. To do this, press the trigger (see diagram) to slide the smaller rod up or down. This will change the setting within the "vernier" located at the top of the rod. The smaller rod has graduations marked in feet starting with "0" for depths less than 1 foot. For example, if the creek depth at a certain point is 1 foot, move the rod so that the 1 foot graduation lines up with the "0" on the vernier. If the creek depth is 1.4 feet, raise the rod to the 1 foot graduation and align it with the "4" on the vernier.

To measure the stream flow, have one person holding the rod. **This person should stand downstream and to the side of the top-setting rod**. Once the rod is set for the proper depth, let the flow meter **equilibrate for 20 seconds** in the creek. After 20 seconds, average the meter reading **for 40 seconds** and record on the data sheet provided. The data recorder should repeat the information back to the rod person to ensure correct data recording.

Repeat this process for all points.

4.2.2 b 0.6 Foot Streamflow Protocol - Bucket Wheel Meter

For use with a Scientific Instruments "mini" current meter (model 1205) and a topsetting wading rod.

Equipment Needed:

4' top setting rod	100' tape measure that reads in tenths
flow meter	data sheets
headphones	calculator
thermometer	2-3 people
watch w/second hand	flathead screwdriver
"D" size batteries	rubber boots or hip waders (if available)

Number of Volunteers Needed:

1) Top-setting rodperson and "click" counter
2) Timer
3) Data recorder

1) Choose a point on the creek that is:

- wadable (less than 2 feet);
- lacks obstructions (such as logs, rocks, human structures or anything else that significantly affects the creek flow) within 15 feet up- or downstream of the site;
- at least 10 feet in width (if this isn't possible, take more readings)

2) Carefully attach the flow meter to the topsetting rod. Loosen the screw on the end of the meter and fit it onto the base of the rod. The meter should fit flush with the rod. Tighten the screw.

Attach the connecting wire from the top setting rod onto the meter by loosening the screw above the bucket wheel. Slide the connecting wire into the base of this screw and tighten.

Plug the headphones into the connection at the top of the top setting rod.
The meter is now ready to collect readings.

3) Extend the tape measure across the section of creek to be measured**. Make sure you use the side of the tape that measures feet in tenths not inches**. The tape must be held in place firmly during all measurements and not moved. Measure the total width of the creek. If the creek width is 20' or greater, take measurements at 1' intervals. If the creek is less than 20' wide, take measurements at 0.5' increments.

4) Begin on the right bank of the creek and measure across to the left bank (right and left banks when facing downstream). You may be unable to obtain a reading at depths <0.4'.
At least 20 readings should be taken.

To set the top setting rod, visually measure the depth of the creek using the graduation lines on the hexagonal rod. One line = 0.1', Two lines = 0.5', Three lines = 1.0'.

Once you've determined the depth, set the rod to the 6/10 reading. To do this, press the trigger on top of the rod to slide the smaller rod up or down. This will change the setting within the "vernier" located at the top of the rod. The smaller rod has graduations marked in feet starting with "0" for depths less than 1 foot. For example, if the creek depth at a certain point is 1 foot, move the rod so that the 1 foot graduation lines up with the "0" on the vernier. If the creek depth is 1.4 feet, raise the rod to the 1 foot graduation and align it with the "4" on the vernier.

5) To measure the stream flow, have one person holding the rod and wearing the headphones. Once the rod is set for the proper depth, let the flow meter calibrate for 20 seconds in the creek. After 20 seconds, count the number of "clicks" or revolutions (these will sound like static blips in the headphones) **for 40 seconds** in the headphones and record on the data sheet provided. You can determine the velocity by consulting a rating table for your meter that determines velocity (one should be provided in your meter's manual).

Repeat this process for all points.