

Chapter 3

Stream Discharge

- Introductory Level Volunteer Water Quality Monitoring Training Notebook -

What is Discharge (Flow)?

Discharge, also called flow, is the amount of water that flows past a given point in a given amount of time. This is the product of the cross-sectional area multiplied by the velocity. The rate of discharge is expressed as cubic feet per second (“cfs” or “ft³/sec”).

Discharge Affects the Water Quality of a Stream in a Number of Ways:

Concentrations of Pollutants and Natural Substances – In larger volumes of faster-moving water, a pollutant will be more diluted and flushed out more quickly than an equal amount of pollutant in a smaller volume of slower-moving water.

Oxygen and Temperature – Higher volumes of faster-moving water churn atmospheric oxygen into the water, resulting in higher dissolved oxygen. Smaller volumes of slower-moving water can heat up dramatically in the summer sun. Remember that hot water holds less dissolved oxygen than cold water.

Physical Features – Stream discharge interacts with the gradient and substrate of a stream to influence the types of habitats present, the shape of the channel, and the composition of the stream bottom.

Transport of Sediment and Debris – A larger volume of fast-moving water carries more sediment and larger debris than a small volume of slow-moving water. High volume discharges have greater erosional energy, while smaller and slower discharges allow sediment to settle out and be deposited. These alternating erosional and depositional cycles determine stream channel shape and sinuosity (i.e., how much the stream channel curves back and forth).

Plants and Animals Present – Discharge affects the chemical and physical nature of streams and thus determines what can live there. Fish like salmonids (trout and salmon) and

pollution-sensitive macroinvertebrates require high concentrations of dissolved oxygen, low water temperatures, and gravel substrates for egg laying. Fish, such as carp and catfish, and pollution-tolerant macroinvertebrates can survive in warmer water and softer substrates.

Biological Cues – Specific flow volumes and velocities contribute to a group of cues that combine to trigger spawning in many species of aquatic life.

Minimum Instream Flow – These are requirements for streams subject to withdrawals of water for domestic water use, hydropower generation, and irrigation. Withdrawals may leave little water for fish and other aquatic life at crucial stages of their lives. Minimum instream flows can be established to maintain fish populations and to balance competing out-of-stream uses.

Discharge impacts everything from the concentration of substances dissolved in the water to the distribution of habitats and organisms throughout the stream!

Factors Affecting the Volume of Flow

Precipitation is the primary factor because it usually provides the greatest percent of water for streams. After a rainstorm, stream flow follows a predictable pattern where it rises and then falls in the hours and days following the storm.

Base Flow is the sustained portion of stream discharge that is drawn from natural storage sources such as groundwater and not affected by human activity or regulation.

Vegetation along the banks and within the floodplain absorbs water then releases it to the air through evapotranspiration while deep roots increase the water storage capacity of soil. In these ways, vegetation will influence the volume of water reaching the water table and stream, and water availability year round.

Shallow Groundwater, Springs, Lakes, Adjacent Wetlands, and Tributaries may contribute portions of the total flow in a stream and can be crucial during dry times.

Factors Affecting the Velocity of Flow

Gradient is a key factor. The steeper the gradient (or slope), the faster the water flows. The gradient of a stream is expressed as the vertical drop of a stream over a fixed distance, like 1 foot per mile. On a topographical map, contour lines crossing the stream indicate elevation change. The map scale establishes distance.

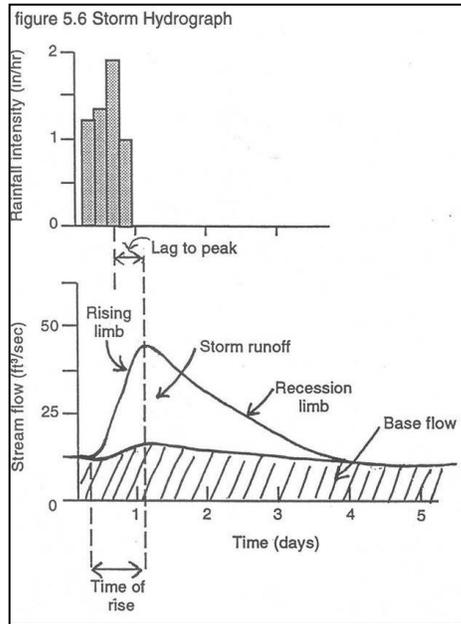
Resistance is another key factor. Resistance, also referred to as roughness, is determined by the nature of the substrate, channel shape, instream vegetation and the presence of woody debris such as logs and root wads. The unevenness of streambed material and vegetation contributes resistance to stream flow and slows the water velocity by causing friction.

Human Activities That Affect Flow

Land-Use – When vegetated areas and wetlands are converted to bare soil and/or impervious surfaces the volume and velocity of runoff increases dramatically during storm events. Impervious surfaces include any surface that impedes the infiltration of water, such as streets, parking lots or rooftops. Therefore, during wet periods, a loss of vegetation and wetlands result in an excess volume of water runoff that moves at a higher velocity, and are referred to as “flashy streams.” In dry times, however, the opposite problem occurs. Without natural vegetation or wetlands, much of the water storage capacity of a watershed is lost. Stream flow may be severely reduced or even non-existent.

Channelization – The straightening of a channel and removal of woody debris and other large objects increases the velocity of flow by increasing the gradient within that reach. This can vastly increase erosion within the stream, and can increase flooding downstream from the channelized area. However, streams naturally meander and if left alone, will slowly regain sinuosity.

Dams – Dams change the flow of water by slowing or detaining it. The rate at which hydroelectric dams release water fluctuates greatly in both timing and volume causing large variances in stream flows. This can dramatically alter the physical and chemical conditions in streams, both upstream and downstream of the dam.



What is a Storm Hydrograph?

After a rainstorm, stream flow follows a predictable pattern in which it rises sharply in response to the storm and then falls, usually more gradually, in the hours or days following the storm. Additionally, discharge varies naturally with the seasons. Higher flows occur in the winter and spring, while lower flows usually occur in summer and early fall. A **storm hydrograph** is a plot or graph of this flow over time. Time is on the X axis (the horizontal axis) and is usually in hours, days, or months. Discharge is on the Y axis (the vertical axis) in cubic feet per second

(ft³/sec). A hydrograph plots the rainfall and stream's response for the time that elapses during and just following a storm. Usually the highest flow resulting from a storm does not happen at the same time as the highest rainfall intensity of the storm. The hydrograph shows a **lag period** between the time the storm reaches its high intensity and the time the stream reaches its peak flow – the stream takes a little time to “catch-up” with the rainfall.

A hydrograph also illustrates the level of **base flow**. Base flow is shown on the hydrograph as the shaded area. The amount of **runoff** that occurs after a storm is the total amount of flow resulting from a storm minus the base flow. Runoff is indicated on the graph by the area that is under the curve and above the shaded base flow area. **Knowing how much rain has fallen in your watershed the week before you sampled is important.**

In a watershed where much of the vegetation has been converted to streets and parking lots, the **time of rise** will be shorter. At the same time, the **rising limb** will rise faster and to a higher level as more water enters the stream, because the rain falls on impervious surfaces. The water is not allowed to “soak in,” and the result is an increase in surface runoff entering the stream more quickly. These streams have a shorter **lag to peak** because there is less resistance. The **recession limb** will also drop faster if resistance within the stream channel is reduced artificially, like when a stream is channelized. Finally, the

base flow level will be lower because the decrease in vegetation decreases the soil's water storage capacity.

While flow changes over a period of a few hours in response to rainstorms, it also varies seasonally. Seasonal variation in precipitation changes the timing and quantity of runoff to streams. Usually streams have predictable periods of maximum and minimum flows that coincide with wet and dry seasons.

Range of Flows (cfs) on Selected Streams

(Source: USGS, 2013)

| | |
|-----------------------------------|--------------------|
| Elk Fork of Salt (Madison, MO) | 0.01– 24,100 |
| Little Piney (Newburg, MO) | 24 – 13,400 |
| Gasconade (Rich Fountain, MO) | 277 – 111,000 |
| Missouri River (Hermann, MO) | 6,210 – 739,000 |
| Mississippi River (St. Louis, MO) | 27,800 – 1,050,000 |

USGS Gaging Stations

Before you start, check to see if your stream has an official “gaging” station maintained by the U.S. Geological Survey. If they do, you can use their “real-time” flow measurements instead of having to measure it yourself. There are four pages at the end of this chapter taken from the PowerPoint presentation used to teach this chapter. These pages provide information on the USGS website where you can access gaging station information. The web address, as well as mailing address and phone number, are also listed in the Appendix of this notebook. If you want to provide us with the stream discharge information from the USGS instead of measuring it yourself, you can do so in one of two ways. One way is to simply go to the USGS website [the day you intend to do your stream monitoring](#) and print the pages that show these four pieces of information:

- The date you monitored
- The gaging station number and name
- The stream discharge that day (as indicated in the example on page 11).

On the computer screen it will look like one long page, but when you print the page, it will probably be at least two pages. You can submit the pages along with your *Site Selection and/or Macroinvertebrate Data Sheets*.

Or, if you don't want to print and send the pages, you can write this information under "Comments" on the *Macroinvertebrate Data Sheet*:

- Date
- Number and name of the gaging station (e.g., "USGS 07065200 Jacks Fork near Mountain View, MO")
- The stream discharge in cubic feet per second (e.g., "225 ft³/sec").

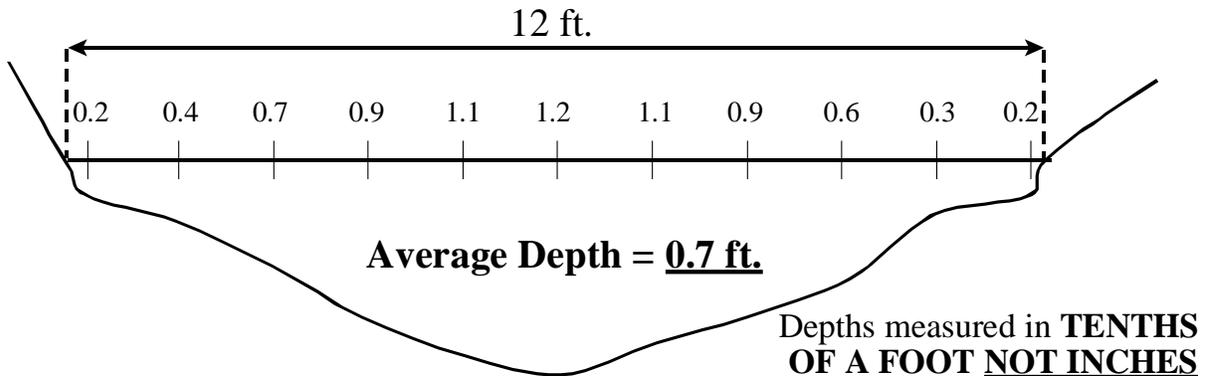
How to Measure Discharge

If you are not lucky enough to have a gaging station nearby, here's one way to measure flow yourself. Select a stream section that is relatively straight, free of large objects such as logs or boulders, with a noticeable current and with a depth as uniform as possible. See Data Sheet on page 9-10 for an example.

1. Determine the stream cross sectional area

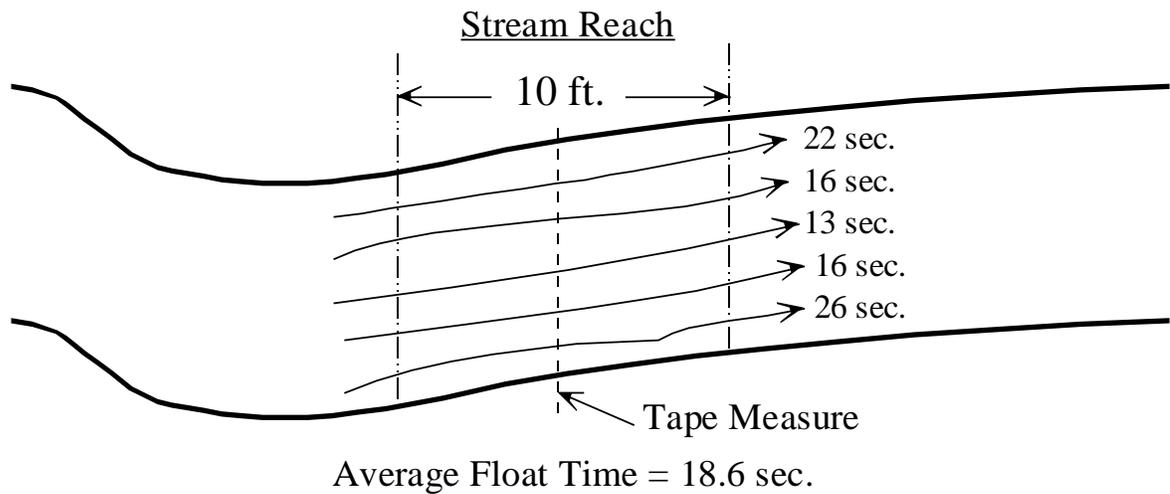
- Stretch a tape measure (provided by the Program) marked in tenths of a foot, not inches, across the stream. The "0" point should be anchored at the wetted edge of the stream. The opposite end of the tape measure should be anchored so that it is taut and perpendicular to the flow. Measure the width of the stream from wetted perimeter to wetted perimeter in tenths of a foot and record the width on the *Stream Discharge Data Sheet*.
- With the tape measure still attached to the stream banks, measure the stream depth at intervals across the stream. Record this information on the first page of your *Stream Discharge Data Sheet*. **For streams less than 20 feet wide, measure the depth every foot. For streams greater than 20 feet wide, measure the depth every two feet. Remember that the depth must be measured in feet and tenths of a foot (e.g., 0.5 ft., 1.5 ft.) and NOT in inches (e.g., 6 inches, 1 ft. 6 inches).**

$$\text{Cross-Sectional Area} = 0.7 \times 12 = 8.4 \text{ ft.}^2$$



2. Determining the Average Surface Velocity for the stream

- Pick several points at intervals across the stream approximately equal distance apart for velocity measurements. **For streams less than ten feet wide, take three measurements. For streams greater than ten feet wide, conduct no fewer than four velocity measurements.** Once you have determined the number of velocity float trials you need, measure the water's surface velocity in the following manner:
 - I. Select two points approximately equal distance upstream and downstream from the tape measure you have stretched across the stream; five feet above and five feet below the tape measure works well for most Missouri streams. However, this will be dependent on the swiftness of the stream. In faster water, you may want this distance to be greater, while shorter in slower water.
 - II. Determine the distance between these two points and record this value (in feet) on the *Stream Discharge Worksheet*.
 - III. Drop a mutually-buoyant practice wiffle golf ball (provided by program) above the upstream point and record the time it takes to float to the downstream point (in seconds). Record each float time on the *Stream Discharge Data Sheet*.



This technique will be demonstrated in the field during the training class. Also, complete instructions are printed on the *Stream Discharge Data Sheet* itself, which serves as a handy reference when you are out sampling. As an example, we've included a completed form at the end of this chapter.

Materials Needed to Measure Stream Discharge

1. 100-foot tape measure, marked in **tenths of a foot** (provided by program)
2. A mutually-buoyant float - for example, a practice, wiffle golf ball (provided by program)
3. Two sticks or metal pins (provided by volunteer)
4. Stick with depths marked in **tenths of a foot** (provided by volunteer)
5. Stopwatch or watch with a second hand (provided by volunteer)
6. 10-foot-long rope (provided by volunteer)

STREAM DISCHARGE DATA SHEET

Please check the box next to the "Site #" if this is a new site and please be sure to attach a map. (PLEASE PRINT)

Site # 1 Stream Maries River County Osage
 Site Location Upstream 100 meters from Rt. Y bridge
 Date 8/13/09 Time (military time) 0915 Rainfall (inches in last 7 days) .25 Water Temp. (°C) 18
 Trained Data Submitter (responsible volunteer) Priscilla Stotts Stream Team Number 2383
 Trained Participants Suzy Higgins, Kat Lackman

Instructions for Calculation of Stream Discharge (Flow)

Select a section of stream that is relatively straight, free from large objects such as logs or large boulders, with a noticeable current, and with a depth as uniform as possible. Stretch the tape measure provided by the program across the stream. The "0" point should be anchored at the wetted edge of the stream. The end of the tape measure should be anchored at the opposite end so that it is taut and even with the other wetted edge.

12

Stream Width
(Feet)

Step 1: Determine stream cross-sectional area. The first step in determining cross-sectional area is to measure and calculate the average stream depth. In the table below, record the depth measurements at one-foot intervals along the tape measure you have stretched across the stream. The depth must be measured in **tenths of a foot** (e.g. 1.7 feet equals one foot and seven tenths). **DO NOT MEASURE DEPTH IN INCHES.**

| Record Depth at 1-Foot Intervals | | | | | |
|----------------------------------|---------------|-----------------|---------------|-----------------|---------------|
| Interval Number | Depth in Feet | Interval Number | Depth in Feet | Interval Number | Depth in Feet |
| 1 | 0.2 | 11 | 0.2 | 21 | |
| 2 | 0.3 | 12 | | 22 | |
| 3 | 0.7 | 13 | | 23 | |
| 4 | 0.6 | 14 | | 24 | |
| 5 | 0.9 | 15 | | 25 | |
| 6 | 1.1 | 16 | | 26 | |
| 7 | 1.1 | 17 | | 27 | |
| 8 | 1.2 | 18 | | 28 | |
| 9 | 0.9 | 19 | | 29 | |
| 10 | 0.4 | 20 | | 30 | |
| Sum | 7.4 | Sum | 0.2 | Sum | |

The average depth is calculated by dividing the sum of the depth measurements by the number of intervals at which measurements were taken.

$$\begin{array}{ccc}
 \boxed{7.6} & \div & \boxed{11} = \boxed{.07} \\
 \text{Sum of Depths} & & \text{Number of} \\
 \text{(Feet)} & & \text{Intervals} \\
 & & \text{Average Depth} \\
 & & \text{(Feet)}
 \end{array}$$

The final step in calculating the cross-sectional area is to multiply the average depth (in feet) by the stream width (in feet) at the point where the tape measure is stretched across the stream.

$$\begin{array}{ccc}
 \boxed{.07} & \times & \boxed{12} = \boxed{8.4} \\
 \text{Average Depths} & & \text{Stream Width} \\
 \text{(Feet)} & & \text{(Feet)} \\
 & & \text{Cross Sectional} \\
 & & \text{Area (Feet)}^2
 \end{array}$$

Step 2: Determine the average velocity for the stream. For a stream less than ten feet in width, select three points in the stream approximately equal distances apart for velocity measurements. For streams greater than ten feet in width, no fewer than four velocity measurements should be taken at approximately equal distances across the stream. For example, if the stream were eight feet wide, then velocity measurements would be taken at approximately two foot intervals across the stream in order to derive three measurements. If the stream were sixteen feet across, then velocity measurements would be taken at approximately three foot intervals across the stream in order to derive four measurements. This method of measuring the stream velocity will insure that velocity measurements are recorded for the slow and fast portions of the stream.

Once you have determined the number of velocity float trials you need to complete, measure the water's surface velocity in the following manner. Select two points located equal distance upstream and downstream from the tape measure you have stretched across the stream. Determine the distance between these two points and record this value (in feet) in the **Distance Box** on the back of this page. Count the number of seconds it takes a mutually buoyant object (such as a wiffle practice golf ball) to float this distance. Record this time (in seconds) in the table on the back of this page for each float trial you complete



| Velocity Float Trials | |
|-----------------------|----------------|
| Trial Number | Time (Seconds) |
| 1 | 22 |
| 2 | 16 |
| 3 | 13 |
| 4 | 16 |
| 5 | 22 |
| 6 | |
| 7 | |
| 8 | |
| 9 | |
| 10 | |
| Sum | 89 |

Distance Box

Distance Floated (in Feet)

The next step in calculating the surface velocity is to determine the average float time. Average float time is equal to the sum of the float times (in seconds) divided by the number of float trials.

$$\frac{\text{Sum of Float Times (Seconds)}}{\text{Number of Trials}} = \text{Average Float Time (Seconds)}$$

÷ =

The final step is to divide the distance floated (from the **Distance Box** at top) by the average float time.

$$\frac{\text{Distance Floated (Feet)}}{\text{Average Float Time (Seconds)}} = \text{Average Surface Velocity (Feet per Second)}$$

÷ =

Water in the stream does not all travel at the same speed. Water near the bottom travels slower than water at the surface because of friction (or drag) on the stream bottom. When calculating stream discharge, the water's velocity for the entire depth (surface to bottom) needs to be determined. Therefore, you must multiply the average **surface** velocity (from above) by a correction factor to make it represent the water velocity of the **entire stream depth**.

Choose the correction factor that best describes the bottom of your stream and multiply it by the average surface velocity to calculate the corrected average stream velocity.

Stream Bottom Type: Rough, loose rocks or coarse gravel: **correction value = 0.8**
 Smooth, mud, sand, or hard pan rock: **correction value = 0.9**

$$\text{Correction Value} \times \text{Average Surface Velocity (Feet per Second)} = \text{Corrected Average Stream Velocity (Feet per Second)}$$

× =

Step 3: Calculate the stream discharge. Multiply the cross-sectional area (Feet)² from **Step 1** by the corrected average stream velocity (Feet/Second) from **Step 2**.

$$\text{Cross-Sectional Area (Feet)}^2 \times \text{Corrected Average Stream Velocity (Feet per Second)} = \text{Stream Discharge (Feet)}^3 \text{ per Second or Cubic Feet per Second (CFS)}$$

× =

Comments (mention any changes from your usual readings) _____

Fish Present (Please Mark) Yes or No

PLEASE KEEP A COPY AND SEND ORIGINAL DATA TO: Stream Team Coordinator
 Water Protection Program
 Department of Natural Resources
 PO Box 176
 Jefferson City, MO 65102-0176

