Water Science School

How Streamflow is Measured

How can one tell how much water is flowing in a river? Can we simply measure how high the water has risen/fallen? The height of the surface of the water is called the stream stage or gage height. However, the USGS has more accurate ways of determining how much water is flowing in a river. Read on to learn more.

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Introduction to USGS Streamgaging

The U.S. Geological Survey (USGS) started its first streamgage in 1889 on the Rio Grande River in New Mexico to help determine if there was adequate water for irrigation purposes to encourage new development and western expansion. The USGS operates over 8,200 continuous-record streamgages that provide streamflow information for a wide variety of uses including flood prediction, water management and allocation, engineering design, research, operation of locks and dams, and recreational safety and enjoyment.

How Streamflow is Measured

As you're enjoying yourself sitting on the peaceful bank of a local river, one question you may ask yourself is "How much water is flowing in this river?" You've come to the right place for an answer. The USGS has been measuring streamflow on thousands of rivers and streams for many decades and by reading this set of Web pages you can find out how the whole streamflow-measurement process works.

Often during a large rainstorm you can hear an announcement on the radio like "Peachtree Creek is expected to crest later today at 14.5 feet." The 14.5 feet the announcer is referring to is the stream stage. Stream stage is important in that it can be used (after a complex process described below) to compute streamflow, or how much water is flowing in the stream at any instant.

Stream stage (also called stage or gage height) is the height of the water surface, in feet, above an established altitude where the stage is zero. The zero level is arbitrary, but is often close to the streambed. You can get an idea of what stream stage is by looking at a **picture of a common staff gage**, which is used to make a visual reading of stream stage. The gage is marked in 1/100th and 1/10th foot intervals.

Streamgaging generally involves 3 steps:

1. Measuring stream stage—obtaining a continuous record of stage—the height of the water surface at a location along a stream or river
2. The discharge measurement—obtaining periodic measurements of discharge (the quantity of water passing a location along a stream)
3. The stage-discharge relation—defining the natural but often changing relation between the stage and discharge; using the stage-discharge relation to convert the continuously measured stage into estimates of streamflow or discharge

Measuring stream stage

Most U.S. Geological Survey (USGS) streamgages measure stage and consist of a structure in which instruments used to measure, store, and transmit the stream-stage information are housed. Stage, sometimes called gage height, can be measured using a variety of methods. One common approach is with a stilling well in the river bank or attached to a bridge pier. Water from the river enters and leaves the stilling well through underwater pipes allowing the water surface in the stilling well to be at the same elevation as the water surface in the river. The stage is then measured inside the stilling well using a float or a pressure, optic, or acoustic sensor. The measured stage value is stored in an electronic data recorder on a regular interval, usually every 15 minutes.

At some streamgage sites, a stilling well is not feasible or is not cost effective to install. As an alternative, stage can be determined by measuring the pressure required to maintain a small flow of gas through a tube and bubbled out at a fixed location under water in the stream. The measured pressure is directly related to the height of water over the tube outlet in the stream. As the depth of water above the tube outlet increases, more pressure is required to push the gas bubbles through the tube.

Streamgages operated by the USGS provide stage measurements that are accurate to the nearest 0.01 foot or 0.2 percent of stage, whichever is greater. Stage at a streamgage must be measured with respect to a constant reference elevation, known as a datum. Sometimes streamgage structures are damaged by floods or can settle over time. To maintain accuracy, and to ensure that stage is being measured above a constant reference elevation, the elevations of streamgage structures, and the associated stage measurement, are routinely surveyed relative to permanent elevation benchmarks near the streamgage.

Although stage is valuable information for some purposes, most users of streamgage data are interested in streamflow or discharge—the amount of water flowing in the stream or river, commonly expressed in cubic feet per second or gallons per day. However, it is not practical for a streamgage to continuously measure discharge. Fortunately, there is a strong relation between river stage and discharge and, as a result, a continuous record of river discharge can be determined from the continuous record of stage. Determining discharge from stage requires defining the stage-discharge relationship by measuring discharge at a wide range of river stages.

The discharge measurement

Discharge is the volume of water moving down a stream or river per unit of time, commonly expressed in cubic feet per second or gallons per day. In general, river discharge is computed by multiplying the area of water in a channel cross section by the average velocity of the water in that cross section:

discharge = area x velocity

The USGS uses numerous methods and types of equipment to measure velocity and cross-sectional area, including the following current meter and Acoustic Doppler Current Profiler.

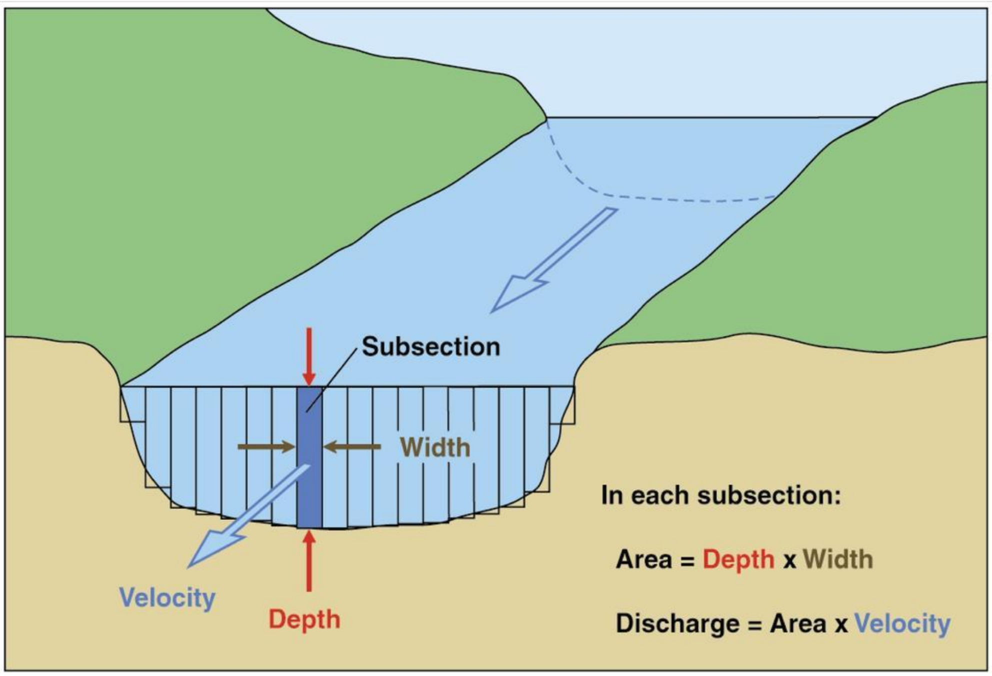

Diagram of Channel Cross Section With Subsections.

The most common method used by the USGS for measuring velocity is with a current meter. However, a variety of advanced equipment can also be used to sense stage and measure streamflow. In the simplest method, a current meter turns with the flow of the river or stream. The current meter is used to measure water velocity at predetermined points (subsections) along a marked line, suspended cableway, or bridge across a river or stream. The depth of the water is also measured at each point. These velocity and depth measurements are used to compute the total volume of water flowing past the line during a specific interval of time. Usually a river or stream will be measured at 25 to 30 regularly spaced locations across the river or stream.

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Current Meter

One method that has been used for decades by the USGS for measuring discharge is the mechanical current-meter method. In this method, the stream channel cross section is divided into numerous vertical subsections. In each subsection, the area is obtained by measuring the width and depth of the subsection, and the water velocity is determined using a current meter. The discharge in each subsection is computed by multiplying the subsection area by the measured velocity. The total discharge is then computed by summing the discharge of each subsection.

Numerous types of equipment and methods are used by USGS personnel to make current-meter measurements because of the wide range of stream conditions throughout the United States. Subsection width is generally measured using a cable, steel tape, or similar piece of equipment. Subsection depth is measured using a wading rod, if conditions permit, or by suspending a sounding weight from a calibrated cable and reel system off a bridge, cableway, or boat or through a hole drilled in ice.

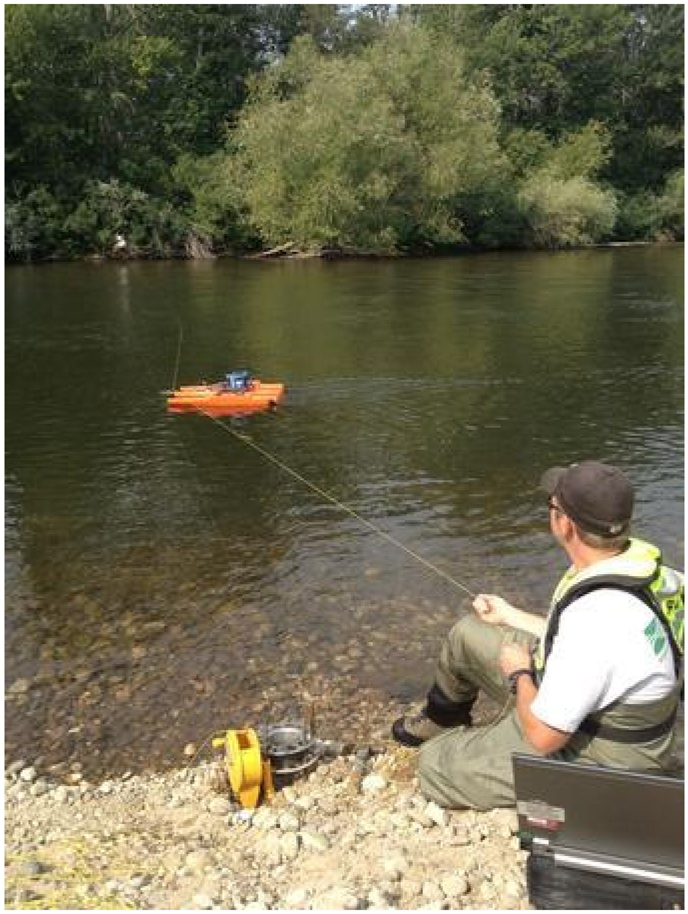
Developed in the early 1900s and modified many times prior to 1930. Purchased from the W. & L. E. Gurley Company, Troy, New York.
Object ID: USGS-000458

Credit: Justin Bongard, U.S. Geological Survey. Public domain.

The velocity of the streamflow can be measured using a current meter. The most common current meter used by the USGS is the Price AA current meter. The Price AA current meter has a wheel of six metal cups that revolve around a vertical axis. An electronic signal is transmitted by the meter on each revolution allowing the revolutions to be counted and timed. Because the rate at which the cups revolve is directly related to the velocity of the water, the timed revolutions are used to determine the water velocity. The Price AA meter is designed to be attached to a wading rod for measuring in shallow waters or to be mounted just above a weight suspended from a cable and reel system for measuring in fast or deep water. In shallow water, the Pygmy Price current meter can be used. It is a two-fifths scale version of the Price AA meter and is designed to be attached to a wading rod. A third mechanical current meter, also a variation of the Price AA current meter, is used for measuring water velocity beneath ice. Its dimensions allow it to fit easily through a small hole in the ice, and it has a polymer rotor wheel that hinders the adherence of ice and slush.

Acoustic Doppler Current Profiler

In recent years, advances in technology have allowed the USGS to make discharge measurements by use of an Acoustic Doppler Current Profiler (ADCP). An ADCP uses the principles of the Doppler Effect to measure the velocity of water. The Doppler Effect is the phenomenon we experience when passed by a car or train that is sounding its horn. As the car or train passes, the sound of the horn seems to drop in frequency.



U.S. Geological Survey hydrologic technicians use an acoustic Doppler current profiler to measure streamflow on the Boise River in Boise's Veterans Memorial Park as part of a study of phosphorus mass balance.

Credit: Tim Merrick, USGS. Public domain

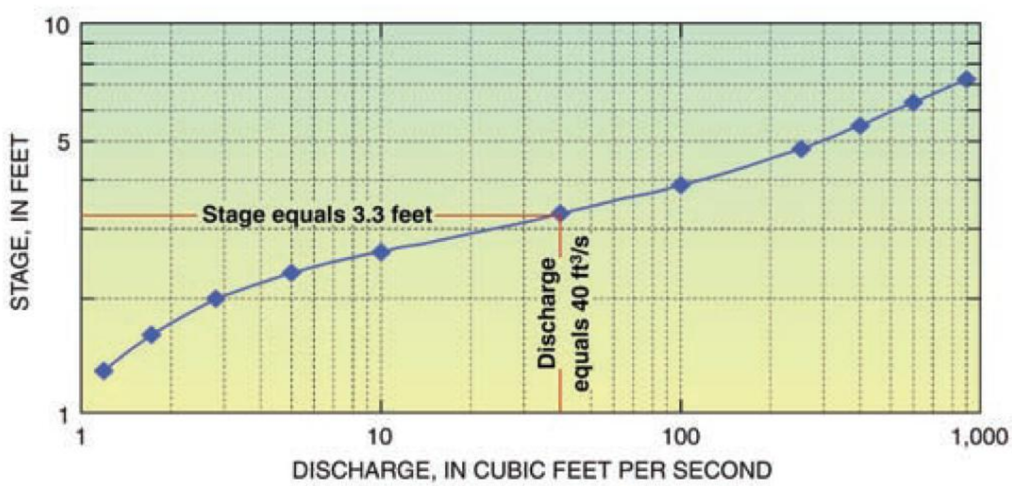
The ADCP uses the Doppler Effect to determine water velocity by sending a sound pulse into the water and measuring the change in frequency of that sound pulse reflected back to the ADCP by sediment or other particulates being transported in the water. The change in frequency, or Doppler Shift, that is measured by the ADCP is translated into water velocity. The sound is transmitted into the water from a transducer to the bottom of the river and receives return signals throughout the entire depth. The ADCP also uses acoustics to measure water depth by measuring the travel time of a pulse of sound to reach the river bottom at back to the ADCP.

To make a discharge measurement, the ADCP is mounted onto a boat or into a small watercraft (diagram above) with its acoustic beams directed into the water from the water surface. The ADCP is then guided across the surface of the river to obtain measurements of velocity and depth across the channel. The river-bottom tracking capability of the ADCP acoustic beams or a Global Positioning System (GPS) is used to track the progress of the ADCP across the channel and provide channel-width measurements. Using the depth and width measurements for calculating the area and the velocity measurements, the discharge is computed by the ADCP using discharge = area x velocity, similar to the conventional current-meter method. Acoustic velocity meters have also been developed for making wading measurements (picture to the left).

The ADCP has proven to be beneficial to streamgaging in several ways. The use of ADCPs has reduced the time it takes to make a discharge measurement. The ADCP allows discharge measurements to be made in some flooding conditions that were not previously possible. Lastly, the ADCP provides a detailed profile of water velocity and direction for the majority of a cross section instead of just at point locations with a mechanical current meter; this improves the discharge measurement accuracy.

The stage-discharge relation

Streamgages continuously measure stage, as stated in the "Measuring Stage"" section. This continuous record of stage is translated to river discharge by applying the stage-discharge relation (also called rating). Stage-discharge relations are developed for streamgages by physically measuring the flow of the river with a mechanical current meter or ADCP at a wide range of stages; for each measurement of discharge there is a corresponding measurement of stage. The USGS makes discharge measurements at most streamgages every 6 to 8 weeks, ensuring that the range of stage and flows at the streamgage are measured regularly. Special effort is made to measure extremely high and low stages and flows because these measurements occur less frequently. The stage-discharge relation depends upon the shape, size, slope, and roughness of the channel at the streamgage and is different for every streamgage.



USGS Stage-Discharge Relation Example.

The continuous record of stage is converted to streamflow by applying a mathematical rating curve. A rating curve (fig. 3) is a graphic representation of the relation between stage and streamflow for a given river or stream. USGS computers use these site-specific rating curves to convert the water-level data into information about the flow of the river.

The development of an accurate stage-discharge relation requires numerous discharge measurements at all ranges of stage and streamflow. In addition, these relations must be continually checked against on-going discharge measurements because stream channels are constantly changing. Changes in stream channels are often caused by erosion or deposition of streambed materials, seasonal vegetation growth, debris, or ice. New discharge measurements plotted on an existing stage-discharge relation graph would show this, and the rating could be adjusted to allow the correct discharge to be estimated for the measured stage.

Converting stage information to streamflow information

Most USGS streamgages transmit stage data by satellite to USGS computers where the stage data are used to estimate streamflow using the developed stage-discharge relation (rating). The stage information is routinely reviewed and checked to ensure that the calculated discharge is accurate. In addition, the USGS has quality-control processes in place to ensure the streamflow information being reported across the country has comparable quality and is obtained and analyzed using consistent methods.

Most of the stage and streamflow information produced by the USGS is available online in near real time through the **National Water Information System (NWIS) Web**. In addition to real-time streamgage data, the NWIS Web site also provides access to daily discharges and annual maximum discharges for the period of record for all active and discontinued streamgages operated by the USGS.

Streamflow summary

Streamgaging involves obtaining a continuous record of stage, making periodic discharge measurements, establishing and maintaining a relation between the stage and discharge, and applying the stage-discharge relation to the stage record to obtain a continuous record of discharge. The USGS has provided the Nation with consistent, reliable streamflow information for over 115 years. USGS streamflow information is critical for supporting water management, hazard management, environmental research, and infrastructure design.

Sources and more information*:*

- Discharge Measurements at Gaging Stations, USGS Techniques and Methods 3-A8 (PDF)

Below are other science topics associated with measuring streamflow.

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Streamgaging Basics

A streamgage is a structure installed beside a stream or river that contains equipment that measures and records the water level (called gage height or stage) of the stream. Streamflow (also called discharge) is computed from measured water levels using a site-specific relation (called a stage-discharge rating curve) developed from onsite water level and streamflow measurements made by USGS...

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A Day in the Life of a USGS Water Scientist

If you have to spend time in other people's shoes before judging them, you'd have to do a lot more than walk a mile to understand a USGS water scientist. For example, if you were Hydrologic Technician, or "Hydrotech," John Jastram, you would be perched 40 feet above a river as you made water-quality measurements from a swaying cable car. And if you were Hydrotech Karl Dydak, you would actually...

Contacts: Ask USGS