

**FIELD EXERCISE IN STREAM GAGING  
MEMORIAL PARK, NUTLEY**

**General Instructions:**

- 1) Welcome to the CE 320A Field Exercise at Memorial Park. Please remember that **SAFETY IS THE MOST IMPORTANT TASK OF THIS EXERCISE**. Please handle all equipment carefully and use caution when making flow measurement in or adjacent to the streams. The stream banks and beds can be slippery! Please ask any questions that you may have at any time and report any unsafe conditions.
- 2) Please listen carefully to all directions given by the instructor and the teaching assistant before and during the exercise. Please respect other visitors to the park.
- 3) Due to equipment limitations, some activities you will do with you regular Lab Group, while others we will do by combining groups. The distribution of activities is given below.
- 4) Please exercise care in using the field equipment since it is expensive and is difficult to replace.

**Stream Gaging Instructions:**

- 1) Make a sketch of the assigned section of the park showing the water courses and the direction of flow. Label all main features, e.g., bridges, weirs. (INDIVIDUAL)
- 2) Measure the discharge of the two streams entering the park from the south. Make these measurements from Bridge 1 and Bridge 2. Make sure to develop a cross section of the channel sections, and measure the velocity at reasonable intervals. Use at least two methods for determining flow velocity at each vertical section, e.g. sin tenths. (THIS EXERCISE WILL BE PERFORMED BY PAIRING TWO GROUPS).
- 3) Measure the discharge over the two broad-crested weirs that flow from Fountain Pond. Designate these on your map as Weir 1 and Weir 2. Use your folding ruler for the measurements, and apply the equations in the attached handout. (THIS EXERCISE WILL BE PERFORMED BY YOUR STANDARD LAB GROUP).
- 4) Measure the discharge in the Main Stream Channel at the north end of the park. Make sure to develop a cross section of the channel section, and measure the velocity at reasonable intervals. Use at least two methods for determining flow velocity at each vertical section, e.g. sin tenths. (THIS EXERCISE WILL BE PERFORMED BY FULL CLASS GROUP).

**To Be Handed In By Each Individual:**

- 1) Labeled sketch of the water courses showing measured discharges.
- 2) Channel cross sections
- 3) Supporting data and discharge calculations
- 4) Apply the continuity principle to your results. Offer explanations for discrepancies, if any.

# Lab Exercise 12

## Stream Gaging

### Objectives:

- To demonstrate the analysis techniques used to for measuring open channel flow.
- To directly measure the discharge of an actual stream in the field using a *current meter*.
- To directly measure stream discharge using a *broad-crested weir*.

### Background:

Many streams are too large to build control structures such as weirs to measure discharge. In these situations a technique known as *stream gaging* is used to determine discharge. The basic idea is discharge equals the product of the water velocity and the cross-sectional area of the stream, i.e., the principle of continuity. This is accomplished by establishing a *gaging station* along the water course, which can be either temporary or permanent. After a large number of discharge measurements have been made for different water levels, a *stream rating curve* is established that relates stream depth to stream discharge. The U.S. Geological Survey maintains about 7000 stream gaging stations in the United States. Other federal agencies and some state agencies also operate a limited number of stations.

*Current meters* are the most common the most common measuring devices for large streams and rivers. A current meter is a device that is lowered into the water to measure velocity at a particular point in the stream. In order to gage the stream it is necessary to make current meter measurements at multiple locations within the cross section. Current meter measurements are made using the following techniques:

- Wading measurement
- Cableway measurement
- Bridge measurement
- Boat measurement
- Measurement through ice cover.

In streams as in pipe flow, the velocity past any cross-section has a parabolic distribution and varies from point to point as shown in Fig. 11.1. The question then becomes: where should velocity be measured to obtain an average? The answer is that one of the following three approaches are commonly used:

- USGS “six tenths” method, which maintains that the average velocity occurs at or close to  $0.6D$  as measured from the surface.
- Averaging the velocity at depths  $0.2D$  and  $0.8D$  along any vertical section to obtain average velocity.
- Integrating the velocity over the entire depth range at a particular section.

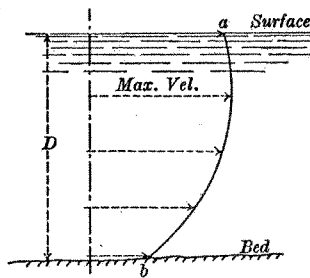
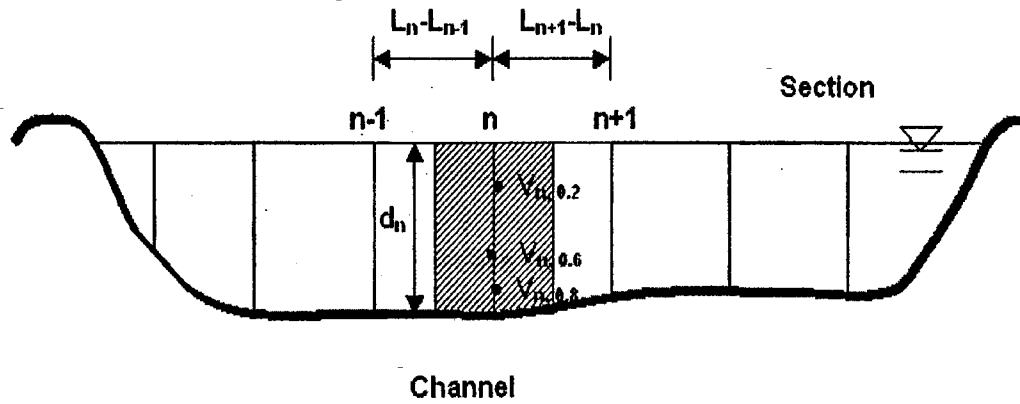


Fig. 11.1 – Velocity Distribution in an Open Channel

Formulas for computing discharge:



0.6 Method:

$$Q_{channel} = \sum q_n = \sum \left[ V_{n,0.6} \left( \frac{L_{n+1} - L_{n-1}}{2} \right) d_n \right]$$

0.2-0.8 method:

$$Q_{channel} = \sum q_n = \sum \left[ \frac{V_{n,0.2} + V_{n,0.8}}{2} \left( \frac{L_{n+1} - L_{n-1}}{2} \right) d_n \right]$$

Integrated velocity method:

$$Q_{channel} = \sum q_n = \sum \left[ V_{n,INT} \left( \frac{L_{n+1} - L_{n-1}}{2} \right) d_n \right]$$

Where:  $L_{n+1}$ ,  $L_n$ ,  $L_{n-1}$  = distances in feet from the initial point, for any three consecutive verticals.

$d_n$  = water depth in feet at vertical  $L_n$ .

$V_{n,0.6}$  = velocities in feet per second at 0.6 of the water depth, respectively, at vertical  $L_n$ .

$V_{n,0.2}$ ,  $V_{n,0.8}$  = velocities in feet per second at 0.2 and 0.8 of the water depth, respectively, at vertical  $L_n$ .

$V_{n,INT}$  = velocities in feet per second calculated by integrated velocity method, respectively, at vertical  $L_n$ .

$q_n$  = discharge in cubic feet per second through section of average depth  $d_n$ .

## GLOBAL FLOW PROBE

### Instructions

- 1) Make sure the prop turns freely
- 2) Point the probe directly into the flow with the arrow on the bottom of the probe pointing downstream.
- 3) Press the right button until the "V" for velocity appears. The top number is the instantaneous velocity to the nearest 0.1 ft/sec. Push the left button to toggle between maximum ("mx") and average ("av") velocity which reads out to the nearest 0.01 ft/sec.
- 4) Put the probe at your measurement point. Push both the right and left buttons simultaneously and release the rezero and start the averaging. Hold in the flow for several seconds until you have a steady average velocity and then remove the probe. The average velocity will freeze once the prop stops turning.
- 5) Measure and calculate the cross-sectional area of your flow stream in square feet. The average velocity in feet/second times the area in square feet = flow in cubic feet per second (cfs).

### *Flow Measurement*

The average velocity in the flow stream times the cross-sectional area is equal to the flow ( $Q=V \times A$ ). The cross-sectional area is measured by manually measuring the depth of flow at several points across the flow and constructing a picture of the cross section. This is most easily done using graph paper with a scale of 1" per square. Once the picture is completed, counting the number of squares gives the cross section in square feet. The cross-section in square feet times the average velocity in feet per second gives the flow in cubic feet per second (cfs). If you are working in round pipes, you need only to measure the depth of water and use the enclosed tables to determine the cross-sectional area.

**The Flow Probe is used to measure the average water velocity. Naturally flowing water varies in velocity for two reasons:**

- 1) The velocities vary across the cross-section. In general, the velocities are greater in the center of the flow and lesser near the bottom and sides of the channel.
- 2) The water surges in velocity with time. In a smooth running stream the velocity at a specific point can easily vary 1-2 feet per second over the period of a minute. This pulsating or surging of flow should be averaged to get a good average flow reading.

**The Flow Probe can be used in three ways to determine average velocity in a stream.**

- 1) *For small streams and pipes*, the probe can be moved slowly and smoothly throughout the flow. The goal is to move the probe smoothly and evenly back and forth from top to bottom so that the probe stays on each point in the flow for the same amount of time. Keep moving the probe for 20 – 40 seconds to get a good average value which accounts for surging. (Move the probe as if you were spray painting and attempting to get an even coat of paint over the entire surface.)

- 2) *For true Velocity Averaging*, the Flow Probe uses true velocity averaging. When, the Readout is zeroed by pushing both buttons or when the probe is inserted into flowing water, a running average is started. As long as the probe remains in the flow, the averaging continues. One reading is taken per second, and a continuous average is displayed. For example after 10 seconds the 10 readings are added and then divided by 10 and this average is displayed. Once the average reading becomes steady, the true average velocity has been obtained. When you pull the probe from the water, this average value is frozen on the display until reset.
- 3) *For larger streams and rivers* where you can't easily move the Probe throughout the flow from one location, divide the stream into subsections 2-3 feet in width (Do this on the graph paper flow profile). Run a measuring tape across the stream to determine distance from the shore. At the center of each subsection, run a vertical velocity profile: Zero the averaging function and move the Probe vertically from the surface to the bottom slowly and smoothly. Move the probe up and down for 20-40 seconds to obtain a good average. The Average Velocity times the Area of the subsection is the Flow for the subsection. Then add all the subsection flows to obtain the Total Stream Flow.

#### **OPERATION:**

The Flow Probe is set up and calibrated at the factory. You may want to set your clock if you want to use the time of day function. Otherwise nothing needs to be done except to change your batteries. Normal battery life is 1 year.

The Flow probe computer has a simple 2- button operation. The Right button changes between Function and the Left button picks the Option. Push both buttons for 1 second zeros the displayed value. With a little practice, one or both buttons can be pushed with the thumb of the hand holding the top of the probe.

Push the Right button to scroll through the functions:

*Velocity:* "V" is instantaneous velocity to nearest 0.5 feet per second.

Push Left button to scroll between "AV" (average velocity) and "MX" (maximum velocity).

Push both buttons to zero the displayed values ("RMS" is not activated at this time).

"D" *Function:* Not used for this application.

*Stop Watch/Clock Function:* The top number is the stop watch (Push Left button to start and stop function. Push both buttons to zero). The bottom number is the time of day.

## Broad-Crested Weirs

A weir approximately rectangular in cross section is termed a broad-crested weir. Unless otherwise noted, it will be assumed to have vertical faces, a plane level crest, and sharp right-angled corners. Figure 5.6 represents a broad-crested weir of breadth  $b$ . The head  $H$  should be measured at least  $2.5H$  upstream from the weir. Because of the sharp upstream edge, contraction of the nappe occurs. Surface contraction begins at a point slightly upstream from the weir.

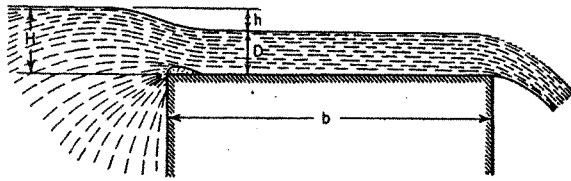


FIGURE 5.6 Broad-crested weir.

The discharge over broad-crested weirs is usually expressed by the equation

$$Q = CLH^{3/2} \quad (5.10)$$

Experiments on broad-crested weirs have been performed by Blackwell, Bazin, Woodburn, the U.S. Deep Waterways Board, and the U.S. Geological Survey. These experiments cover a wide range of conditions as to the head, breadth, and height of the weir. Considerable discrepancy exists in the results of the different experiments, especially for heads below 15 cm. For heads from 15 to about 45 cm the coefficient becomes more uniform, and for heads from 45 cm to the point at which the nappe becomes detached from the crest, the coefficient as given by the different experiments is nearly constant and equals approximately 1.45. When the head reaches one to two times the breadth of the weir, the nappe becomes detached and the weir becomes essentially sharp-crested. The effect on discharge of the roughness of the crest can be computed by applying the principles of flow in open channels.

In order to put the results of the various experiments in a form convenient for use, Table 5.1 has been prepared by graphically interpolating the results of all experiments, giving more weight to those of the U.S. Geological Survey. This table should give values of  $C$  within the limits of accuracy of the original experiments.

The effect of rounding the upstream corner of a broad-crested weir is to increase the discharge for a given head. Table 5.2 lists experiments on this type of weir. The effect of rounding the upstream corner on a radius of 10 cm is to increase the coefficient  $C$  by approximately 9 percent. Coefficients by Woodburn<sup>19</sup> for flat weirs with rounded upstream corners and gently sloping crests are given in Table 5.3a.

Blackwell experimented with three weirs 90 cm broad, having a slightly inclined crest. Inclining the crest appears to increase the coefficient of discharge slightly. The results of these experiments are rather inconsistent, especially for low heads. Table 5.3b has been compiled from Blackwell's experiments. Sloping the top of a broad-crested weir makes it similar to a triangular weir with the upstream face vertical. The coefficients given in Tables 5.4 and 5.5 will therefore be helpful in selecting coefficients for broad-crested weirs with sloping crests.

If the upstream corner of a weir is so rounded as to prevent contraction entirely, and if the slope of the crest is as great as the loss of head due to friction, flow occurs at critical depth, and discharge is given by the rational formula

TABLE 5.1 Values of  $C$  in Formula  $Q = CLH^{3/2}$  for Broad-Crested Weirs

Measured head, m	Breadth of crest of weir, m										
	0.15	0.20	0.30	0.45	0.60	0.75	0.90	1.20	1.50	3.00	4.50

TABLE 5.2 Values of  $C$  in Formula  $Q = CLH^{3/2}$  for Models of Broad-Crested Weirs with Rounded Upstream Corner

Experimenter	Radius of curve, m	Breadth of weir, m	Height of weir, m	Head $H$ , m										
				0.10	0.20	0.30	0.45	0.60	0.75	0.90	1.20	1.50		
	0.10	0.80	0.75	1.62	1.64	1.66	1.68							
	0.10	2.00	0.75	1.49	1.56	1.60	1.61							
	0.10	0.80	1.40		1.53	1.56	1.61	1.66	1.70	1.75	1.85	1.93		
	0.10	2.00	1.40			1.56	1.56	1.56	1.56	1.56	1.56	1.55		