Teacher's Guide

Comparison of Different Methods for Determining Stream Flow at a Stream Site

Lesson Description

Streams moving at a high speed can carry larger sizes of sediment and cause extreme erosion, while slow moving streams deposit sediments that can cause excessive build up. Stream flow is an important factor in the stream ecosystem and is responsible for many of the physical characteristics of a stream. Stream flow can also modify the chemical and biological aspects of a stream. Aquatic plants and animals depend upon stream flow to bring vital food and nutrients from upstream, or remove wastes downstream. For this reason, stream flow must be carefully monitored at regular intervals. There are several ways to measure the stream flow, but which way is the best? In this lesson, students will measure the stream flow using different methods and will determine the most accurate method for determining discharge, the measure of stream flow.

Stream discharge has two variables: flow velocity and the volume of water in the stream. Both variables are influenced by several environmental factors. The slope of the surrounding terrain, the depth of the stream, the width of the stream, and the roughness of the substrate or stream bottom influence flow velocity. If the surrounding terrain is steep, then rainwater and snowmelt will have less time to soak into the ground, and runoff will be greater. In an area with level terrain such as farmland, the rainwater has plenty of time to soak into the ground, and there is less runoff. The flow velocity will also vary as the width or depth of a stream changes. For instance, if you squeeze a water hose with your hand, the flow velocity of the water increases. This is because you have reduced the area that the water must flow through, while the volume of water passing through the hose remains constant. The same thing happens in a stream when the stream channel changes in its width or depth. The substrate of the stream bottom also affects the flow velocity since water moves faster over a smooth surface than a rough surface. Flow velocity is greater when the stream bottom is comprised of sand and clay and lower when it is cobble, rock, and boulders.

Calculating the discharge of a stream is a challenge due to the difficulty in assessing the fluid dynamics. The flow will be fastest in the middle of the deepest part of the stream and at the middle of the stream depth. If you can imagine the water flowing more slowly in contact with the streambed and shoreline while flowing faster at the surface and flowing fastest at about the middle of the depth of the stream. A flat smooth bottom will promote flow faster than a rocky bottom. An uneven rocky bottom creates turbulence slowing the stream flow.

The volume of water in a stream is affected by the climate of the region. Areas with more rain and snow will have more water draining into surrounding streams and rivers. Seasonal changes affect stream volume as well. In the summer there will be less water in a stream compared to the winter. The numbers of small tributaries that merge into a stream or river contribute more water to the system, increasing the stream volume. Humans are also responsible for altering the volume of water in streams. Water is removed for consumption, industry, and irrigation. Roads and parking lots cover vast areas, preventing rainwater from soaking into the ground. Instead, the water is forced to run off into streams and rivers increasing the rate and volume (discharge) of stream flow.

Science Concepts Introduced

- Scientific inquiry
- Reliability of data.
- Stream flow
- Discharge

Process Skills Emphasized

- Using scientific inquiry.
- Comparing stream flow data.
- Describing percent of error in three methods for determining stream flow.

Technology Used

- Flow meter (flow rate sensor)

MST Standards

- Standard 1 – key ideas 1 and 3.
- Standard 2 - key ideas 1.
- Standard 3 – key idea 5
- Standard 5 - key idea 2 and 3
- Standard 6 – key idea 2
- Standard 7 – key idea 1

Learning Outcomes

Students will be able to:

- Accurately construct a transect (cross sectional area) across a stream
- Measure the velocity of the stream flow using three different methods
- Calculate stream discharge for each of these methods
- Compare the three methods for measuring stream discharge
- Compute the % of error between each of the discharge measurement methods

Time Requirement

4 Class periods or 2 double periods (block)

- o Data collection and analysis
- o Methods comparisons and computation of error

Instructional Strategies

- Communicating and learning through group work
- Using scientific inquiry
- Using basic math.
- Calculating scientific error

Background

- Safety in the stream environment.
- Wearing appropriate water gear
- Knowledge and skill of how to operate the flow meter

Assessment

1. Each of the three groups will submit a written report comparing the three different methods for determining stream discharge which includes:
    - a comparative data table
    - a graphic representation of the results
    - an explanation of the comparative accuracy and reliability of each of the methods based on percent of error computations and student observations
2. The data attained by the three groups will be quantified and compared as a class presentation
3. Teacher overview of each group's performance

A Suggested Rubric:

1. Develop a comparative data table and a graphic representation of the results using algebraic and geometric representations. (40 points)
2. Demonstrate a reasonable skill using the Flow Rate Sensor system. (10 points)
3. Understand and explain the comparative accuracy and reliability of each of the methods based on your percent of error computations and observations of the discharge methods. (30 points)
4. Quantify the data compiled by the three groups and present them to the class. (20 points)

Extensions/Options

- Determine how the varying stream flow affects the stream ecosystem, including: biological, chemical and physical components.
- Compare pre and post precipitation discharge measurement analyses.
- Observe and compare discharge for fast and slow moving sites on the same stream.
- Describe the impact of stream flow variations on a stream ecosystem
- Suggest an alternative method to measure stream flow

Key Terms

Scientific inquiry, percent of error, stream discharge, stream flow, flow velocity, stream transect, stream run, qualitative, quantitative.

Prerequisite Knowledge:

Basic mathematical competency
Experience with inquiry process
Flow meter operation

Equipment Needed

Waders, flow meter equipment (available to Project Watershed participants), 2 pieces of line the width of the stream, 100 ft. tape measure, yardstick, stopwatch, floating object

References

Ely, Eleanor, Volunteer Monitor, Summer 2003, Measuring Stream Flow, How Much and How Fast,
Stream Flow Measurements from Vernier Company
Geology Labs Online: www.flash.calstatela.edu/VirtualRiver
See "Waterwatch Australia" for Background and alternatives http://www.waterwatch.org.au

Handouts For Students

Method 1: Estimation of Discharge
Method 2: Manual Measurement of Discharge
Method 3: Flow Meter Measurement of Discharge

Method 1: Estimation of Discharge

Name of Stream___________________________ Date______________________________

School or Group Name____

Width in feet or meters at selected stream site. _____________________

Estimation of stream flow as high, normal, low or negligible at 5 designated points:

1 ___________ 2 ___________ 3 ___________ 4 ___________ 5 ____________

Estimate the stream flow rate in feet or meters per second.
1 ___________ 2 ___________ 3 ___________ 4 ___________ 5 ____________

Write an assessment of Method 1 for measuring the stream discharge in cubic feet or cubic meters/sec

Method 2: Manual Measurement of Discharge

Name of Stream__________________________ Date_____________________________

School or Group Name____

Discharge = Area X Velocity = Cubic Feet Per Second Or Cubic Meters Per Second.

Stream width __________________

Depths in feet or meters (hint: convert inches or centimeters into feet or meters.)

1 __________ 2 __________ 3 __________ 4 __________ 5 ___________

Average stream depth ________________________

Average Depth X Width = Area of Stream Transect = ___________________ square feet or square meters

Length of stream run _________________________

Float time trials 1 __________ 2 __________ 3 __________ 4 __________ 5 ___________ seconds

Average Velocity = ___________________________ feet or meters per second

Discharge = Area X Average Velocity = ___________Cubic Feet Per Second Or Cubic Meters Per Second.

Multiply the discharge calculation by .9 for a SMOOTH bottom and by .8 for a ROCKY bottom for the corrected measurement.

Corrected Discharge = ___________Cubic Feet Per Second Or Cubic Meters Per Second.

Write an assessment of Method 2 for measuring the stream discharge in cubic feet or cubic meters/sec

Method 3: Flow Meter Measurement of Discharge

Name of Stream___________________________ Date______________________________

School or Group Name____

Discharge = Area X Velocity = Cubic Feet/Meters Per Second Or Cubic Meters Per Second.

Stream width ___________________

Depths in feet or meters (hint: convert inches or centimeters into feet or meters.)

1 ___________ 2 ___________ 3 ___________ 4 ___________ 5 ____________

Average stream depth _________________________

Average Depth X Width = Area of Stream Transect = __________________________ square feet or square meters

Length of stream run __________________________

Velocity measurements with flow rate sensor 1 __________ 2 __________ 3 __________ 4 __________ 5 ___________

Feet Per Second Or Meters Per Second

Average Velocity = ____________________________ feet or meters per second.

Discharge = Area X Average Velocity = ____________Cubic Feet Per Second Or Cubic Meters Per Second.

Write an assessment of Method 3 for measuring the stream discharge in cubic feet or cubic meters/sec

Student's Guide

Comparison of Different Methods for Determining Stream Flow at a Stream Site

Introduction

Streams moving at a high speed can carry larger sizes of sediment and cause extreme erosion, while slow moving streams deposit sediments that can cause excessive build up. Stream flow is an important factor in the stream ecosystem and is responsible for many of the physical characteristics of a stream. Stream flow can also modify the chemical and biological aspects of a stream. Aquatic plants and animals depend upon stream flow to bring vital food and nutrients from upstream, or remove wastes downstream. For this reason, stream flow must be continually and carefully monitored on a regular basis.

Stream flow has two variables: flow velocity and the volume of water in the stream. Both variables are influenced by several environmental factors. The slope of the surrounding terrain, the depth of the stream, the width of the stream, and the roughness of the substrate or stream bottom influences flow velocity. If the surrounding terrain is steep, then rainwater and snowmelt will have less time to soak into the ground, and runoff will be greater. In an area with level terrain, such as farmland, the rainwater has plenty of time to soak into the ground and there is less runoff. The flow velocity will also vary as the width or depth of a stream changes. For instance, if you squeeze a water hose with your hand, the flow velocity of the water increases. This is because you have reduced the area that the water must flow through, while the volume of water passing through the hose remained constant. The same thing happens in a stream when the stream channel changes in its width or depth. The substrate of the stream bottom also affects the flow velocity since water moves faster over a smooth surface than a rough surface. Flow velocity is greater when the stream bottom is comprised of sand and clay and lower when it is cobble, rock, and boulders.

The volume of water in the stream is affected by the climate of the region. Areas with more rain and snow will have more water draining into surrounding streams and rivers. Seasonal changes affect stream volume as well. In the summer there will be less water in the stream compared to the winter. The numbers of tributaries that merge with a stream or river contribute more water to the system, increasing the stream volume. Humans are also responsible for altering the volume of water in streams. Water is removed for consumption, industry, and irrigation. Roads and parking lots cover vast areas, preventing rainwater from soaking into the ground. Instead, the water is forced to run off into surrounding streams and rivers.

You have to realize that it is nearly impossible to measure the actual flow of a stream. Scholars and scientists such as Einstein have thrown their hands in the air in the frustration of trying to calculate an accurate measurement of stream flow. Einstein refused to continue with his work on fluid dynamics of rivers and streams and found the theory of relativity a simpler topic to understand because it was easier to quantify. Please follow the directions in this lesson as carefully as possible, and go with courage where Einstein feared to tread.

Learning Outcomes

Students will be able to:

- Accurately construct a transect (cross sectional area) across a stream
- Measure the velocity of the stream flow using three different methods
- Calculate stream discharge for each of these methods
- Compare the three methods for measuring stream discharge
- Compute the % of error between each of the discharge measurement methods

Skills required

Measuring, timing, observing, calculating, summarizing, comparing, communicating

New Terms

Scientific method, % error, stream discharge, stream flow, riffle, run, transect, velocity, impeller, riser rods

Quest

A heavy rain is causing a stream to rise and threaten the homes and businesses in your community. Since you are a professional hydrologist, you are asked to periodically measure the stream flow to predict if and when the stream overflows its banks and floods the area. What method would you use to accurately measure the ever-increasing stream flow in cubic feet per second?

Materials

Waders, flow meter equipment (available to Project Watershed participants), 2 pieces of line the width of the stream, 100 ft. tape measure, yardstick, stopwatch, floating object, clothespins.

Procedure

CAUTION: Always follow safety precautions when entering the stream. If the water is too deep or swift, select another site. Never venture out into the stream alone without another person available to assist you in case of emergency. When you are unable to see the bottom, wear a safety vest and attach a lifeline (safety rope) to the volunteer. Use a staff to sound the surface in front of you and to maintain balance against the current trying to sweep you downstream.

Background information

How To Select The Site At Or In The Stream

1. Select a site that is a representative part of the stream as a whole. Avoid sites with bends or breaks in the stream caused by rocks or sandbars. Try to choose a site where some flow can be observed with a swift movement similar to that found near a riffle.
2. At this site, you are going to take a cross section of the stream and measure its width and depth. Try to select a cross section that is shallow enough to measure the depth with a yard or meter stick and is easy to cross. Avoid sites where the stream depth is less than 10 cm (4 inches).

How To Measure And Mark The Five Points In The Stream

In each of the three methods, you will measure the width of the stream from shore to shore and stretch a line across the stream and anchor it on each side. Divide that value by six (shore to shore measurement) to obtain five points that will separate the stream into six equal parts. Mark these five points on the line with clothespins or some other easily attachable device. Use these points to estimate/measure the stream velocity for each of the three methods.

Since the performance of the three methods for measuring stream discharge requires 8 students, it is suggested that 3 groups conduct this exercise.

Procedural Steps

Method 1: Estimation of Discharge

1. Using a tape measure, measure and record the width of the stream at a selected site.

2. Two students stretch a line (rope or string) across the measured width of the stream. Divide the width into 6 equal segments. Mark the 5 points where the segments intersect with clothespins or other material.

3. With waders on, walk into the stream, stand at each of the marked points on the line for 30 seconds. Can you feel how fast the water is flowing? Is it flowing at the same rate at each of the 5 points as you walk across the stream?

4. Estimate and record the stream flow at each of the 5 points as high, normal, low or negligible.

5. Estimate and record the stream flow at each of the 5 points in feet or meters per second.

6. How effective is Method 1 for measuring stream discharge? Write your assessment of Method 1.

Method 2: Manual Measurement of Discharge

1. Repeat steps 1 and 2 in Method 1 at the same selected stream site. Record the stream width.

2. At each of the 5 points marked on the line stretched across the stream at the selected site in Method 1, measure the depth of the water at each point with a yardstick or meter stick. Record each depth in feet or meters.

3. Calculate the average depth and multiply this number by the width of the stream. Record this cross-sectional area or transect in square feet or square meters.

4. Two more students stretch another line across the stream 15 to 30 feet (5 to 10 meters) downstream from the transect line. Record this distance as the run for the float trials.

5. The float trials are conducted as follows by four students who manage the trials - Starter, Float Putter, Finish Line Timer and Catcher. The Starter and Float Putter will be positioned at the transect line, and the Finish Line Timer and Catcher(s) will be located at the downstream line.

   When the Finish Line Timer is ready, he/she yells to the Float Putter to throw the selected float into the water. (Important: the float should be thrown upstream of the transect line to allow enough distance and time for the float to surface and be observable to the Starter before it approaches the transect line.)

   Once the float passes the transect line, the Starter calls "Start!", and the Finish Line Timer starts the timer. The finish Line timer stops the timer when the float crosses the downstream line and records the time expended. The Catcher(s) retrieves the float.

   Repeat step 5 five times, compute the average number of seconds for the float trials and record the average.

   Note: different types of floats may be used in this procedure and compared with regard to the time taken from start to finish.

6. Compute the velocity of the float and stream flow. (Divide the run distance by the average time for the float trials.) Record the velocity of the stream flow.

7. Calculate the discharge of the stream.

DISCHARGE = AREA X VELOCITY = CUBIC FEET PER SECOND OR CUBIC METERS PER
SECOND

8. How effective is Method 2 for measuring stream discharge? Write your assessment of Method 2.

Method 3: Flow Meter Measurement of Discharge

1. Repeat steps 1, 2 and 3 in Method 2.

2. Connect the Flow Rate Sensor to the Lab Pro instrument.

   Directions for operating Calculator/LabPro unit:

   1. Press ON button;
   2. Press APPS button;
   3. Select DATAMATE program which then shows CH 1: Flow Rate (Feet/Second);
   4. With impeller in position, select START to begin collecting stream flow data; view velocity in feet/second on screen; press ENTER to collect data at the next impeller position; to turn off unit, select QUIT and press 2ND and then ON.

3. Using the same 5 points on the transect line in Methods 1 and 2, place the Flow Rate Sensor at point 1 near the stream bank. Submerge the impeller of the Flow Rate Sensor at about 40% of the depth (as measured from the surface) at point 1. If point 1 is shallow enough, use the plastic risers included with the Flow rate Sensor to support and protect the impeller on the stream bed. The risers make it easier to keep the impeller in the same spot and oriented in the same direction.

4. Point the impeller of the Flow Rate Sensor upstream and directly into the flow. Turn on the Lab Pro instrument's counter and time the impeller's rotation for 1 minute. After 1 minute, stop the counter and proceed to point 2 on the transect line. (If using a velocity flow graph, compare the number of revolutions per minute with the graph and calculate the flow rate.) Record the flow rate (velocity) for each point on the transect line.

5. Calculate the average velocity for the stream in feet per second or meters per second.

6. Using the transect area previously determined and the average velocity, calculate the stream discharge.

DISCHARGE = AREA X VELOCITY = CUBIC FEET PER SECOND OR CUBIC METERS PER SECOND

7. How effective is Method 3 for measuring stream discharge? Write your assessment of Method

Calculation Of The Percent Of Error

There is no way to know the true (absolute) discharge value. After using each of these methods, we believe that the use of the flow meter will produce the most accurate results. For that reason, the value measured by the flow meter will be used as the **<u>accepted value</u>** in our formula for the percent error. All calculations for percent error will use this procedure.

$$\frac{(\text{Accepted Value}) - (\text{Measured Value})}{\text{Accepted Value}} \times 100 = \%\text{ of Error}$$

Extension/Options

1. Determine the impact of stream flow variations on the stream ecosystem (physical, chemical and biological)
2. Compare the discharge at this site with another nearby site (within fifty meters).
3. Determine if there is any variation in the pre and post discharge of a large rain event.
4. Observe and compare discharge in fast and slow moving parts of the same stream.
5. Suggest an alternative method of measuring stream flow

Assessment

1. Each of the three groups will submit a written report comparing the three different methods for determining stream discharge which includes:

- a comparative data table
- a graphic representation of the results
- an explanation of the comparative accuracy and reliability of each of the methods based on percent of error computations and student observations

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Handout;

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Method 2: Manual Measurement of Discharge
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